Cyfoeth Naturiol Cymru
Natural Resources Wales

A winter census (2020/21) of cormorant and goosander in Wales

Report No: 592

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Mae sylw yn cael ei roi i effeithiau ysglyfaethu gan adar pysgysol fel rhan o waith cadwraeth a chynnal a chadw pysgodfeydd dŵr croyw yn sgil pryderon sydd wedi codi ynghylch dirywiad ym mhoblogaethau salmonidau (eog yr Iwerydd, *Salmo salar*, a brithyll y môr, *Salmo trutta*) yng Nghymru.. Gwnaeth CNC gontractio Ymddiriedolaeth Adareg Prydain i gyflawni arolwg ac amcangyfrifon o boblogaeth y fulfran, *Phalacrocorax carbo carbo* (“y fulfran”), a'r hwyaden ddanheddog, *Mergus merganser*, fu'n gaeafu ar hyd deg afon salmonidau mudol pwysig yng Nghymru. Bydd yr amcangyfrifon poblogaethau o ganlyniad yn hybu’r gwaith o fodelu demograffeg poblogaethau'r fulfran a'r hwyaden ddanheddog er mwyn asesu effeithiau dulliau rheolaeth drwyddedig ar boblogaethau o adar sy’n gaeafu, y bwriedir iddynt gefnogi mesurau cadwraeth salmonidau ac atal difrod difrifol i bysgodfeydd dŵr llonydd fel rhan o bolisi adar pysgysol ehangach i Gymru.

Yn 2020, gwnaeth Ymddiriedolaeth Adareg Prydain ailymweld â’r dulliau a ddatblygwyd yn Taylor a Noble (2017), a’u harfarnu, gan eu datblygu'n gynllun arolwg cytunedig ar gyfer poblogaethau’r fulfran a’r hwyaden ddanheddog yn ystod y gaeaf ar draws yr un ar ddeg afon salmonidau pwysicaf (afon Gwy, afon Wysg, afon Dyfrdwy, afon Teifi, afon Tywi, afon Conwy, afon Dyfi, afon Clwyd, afon Mawddach, afon Cleddau Ddu ac afon Cleddau Wen) yng Nghymru. Roedd cynllun yr arolwg yn arolwg prif sianel 100% a gynhaliwyd yn ddilyniannol i fyny'r afon o’r pwynt cyfeirnod aberol tuag at darddiad yr afon (ym mis Rhagfyr); wedi'i ddilyn gan arolwg ailadroddol 50% systematig o'r brif sianel ynghyd ag arolwg o sampl 33% haenedig o ddyfrffyrdd is-afonol ym mis Ionawr a mis Chwefror. Fel rhan o’r sampl is-afonol, detholwyd yn systematig pob trydedd dyfrffordd fechan (>1km o hyd) sy'n llifo i'r brif sianel, ynghyd â phob trydedd segment o 10km o hyd o sianel barhaus hiraf pob prif isafon i'r brif afon. Er gwaethaf heriau logisteg yn sgil pandemig COVID-19, cynhaliwyd arolygon fel y cynlluniwyd drwy gydol mis Rhagfyr, mis Ionawr a mis Chwefror 2020/2021. Perfformiodd y fethodoleg maes yn dda, er gwaethaf y tywydd gaeafol (eira a llifogydd).

Cafodd cyfanswm o 956km o afonydd eu harolygu ym mis Rhagfyr (103 o rannau arolwg ar draws y deg afon), oddeutu 500km yn yr arolygon ailadroddol, ac oddeutu 900km o isafonydd ym mis Ionawr a mis Chwefror (50 a 114 o rannau yn ôl eu trefn). Ar gyfartaledd cafodd 92% o'r cyfanswm o 2,482km yr oedd modd ei arolygu ar draws y deg afon ei gwmpasu (y lleiaf oedd 83% ar gyfer afon Conwy, a’r mwyaf oedd 98% ar gyfer afon Gwy). Roedd ardaloedd na chafodd eu harolygu yn gyfuniad o leoedd y gwrthododd tirfeddianwyr roi mynediad iddynt, topograffeg anffafriol, llystyfiant nad oedd modd mynd trwyddo, a mannau â llifogydd difrifol.

Arsylwyd ar gyfanswm o 564 o fulfrain a 522 o hwyaid danheddog gyda meintiau grŵp bach ar gyfartaledd ar gyfer y ddwy rywogaeth ac ychydig yn fwy ar gyfer y mulfrain (1.7 ar gyfartaledd, uchafswm o 20 o adar) na’r hwyaid danheddog (1.3 ar gyfartaledd, uchafswm o 6 aderyn). Arsylwyd ar 81% o fulfrain a 78% o hwyaid danheddog fel adar unigol. Roedd dwyseddau adar yn gyson â rhagfynegiadau ystadegol, sef yn fwy tuag at ben isaf y dalgylch a'r aber.

Cyfrifwyd amcangyfrifon o’r poblogaethau ar gyfer y mulfrain a’r hwyaid danheddog yn yr afonydd a arolygwyd (y brif sianel a’r isafonydd) a dyfroedd llonydd; y cawsant eu modelu o ddata WeBS hanesyddol ar gyfer aberoedd a'u hallosod o fodelau afonydd i afonydd nad oeddent wedi’u harolygu ac amcangyfrif cenedlaethol i Gymru. **Amcangyfrifwyd bod**

2,894 o fulfrain (adar bridio Cymreig wedi'u hategu gan adar o'r cyfandir yn gaeafu) a 1,460 o hwyaid danheddog yn gaeafu yng Nghymru.

Roedd dosbarthiadau gofodol y ddwy rywogaeth yn wahanol iawn, gydag ychydig dros 50% o fulfrain yn gaeafu mewn aberoedd (wedi'u monitro'n flynyddol drwy arolwg gwirfoddolwyr WeBS), a dim ond 6% a welwyd ar ddyfroedd llonydd. Ar gyfer hwyaid danheddog roedd llai na 4% yn aberol a gwelwyd 28% ar ddyfroedd llonydd.

Executive summary

With concerns raised over declining populations of salmonids (Atlantic salmon *Salmo salar* and sea trout *Salmo trutta*) in Wales, the impacts of predation by fish-eating birds are being considered in the conservation and maintenance of freshwater fisheries. NRW contracted BTO to deliver a survey and population estimates of great cormorant *Phalacrocorax carbo carbo* ("cormorant") and goosander *Mergus merganser* wintering in ten principal migratory salmonid rivers of Wales. The resulting population estimates will aid the demographic modelling of great cormorant and goosander populations for the assessment of impacts of licensed control on wintering bird populations, intended to support salmonid conservation and prevent serious damage to stillwater fisheries as part of a wider fish-eating bird policy for Wales.

In 2020 BTO revisited and appraised the methods developed in Taylor and Noble (2017) developing them into an agreed survey design for winter cormorant and goosander populations across the ten principal salmonid rivers (Wye, Usk, Dee, Teifi, Tywi, Conwy, Dyfi, Clwyd, Mawddach and east and west Cleddau) of Wales. The survey design was a 100% main-channel survey proceeding sequentially upstream from the estuary reference point towards the river source (in December); followed by a systematic 50% repeat survey of the main channel plus survey of a stratified 33% sample of tributary waterways in January and February. The tributary sample systematically selected every third small (>1km long) waterway flowing into the main channel, plus every third 10km segment of the longest continuous channel of each major tributary to the main river. Despite logistical challenges presented by the Covid pandemic, surveys were carried out as planned through December, January and February 2020/2021. Field methodology performed well, despite winter weather (snow and flooding).

In total 956km of rivers were surveyed in December (103 survey sections across the ten rivers), c. 500km in the repeat surveys and c.900km of tributaries in January and February (50 and 114 sections respectively). On average 92% of the 2,482km of total surveyable length across the ten rivers was covered (min. 83% Conwy, max. 98% Wye). Un-surveyed areas were a combination of access refusal by landowners, topography, impassable vegetation and severe flooding.

A total of 564 cormorants and 522 goosanders were observed with average group sizes small for both species and slightly larger for cormorant (average 1.7, max 20 birds) than goosander (average 1.3, max 6 birds). 81% of cormorants and 78% of goosander were observed as single birds. Bird densities followed statistical predictions, being greater towards the lower end of the catchment and estuary.

Population estimates were calculated for cormorant and goosander in the surveyed rivers (main-channel and tributaries) and stillwaters; modelled from historic WeBS data for estuaries and extrapolated from river models to un-surveyed rivers and a national estimate for Wales. **Welsh wintering estimates were 2,894 cormorants (Welsh breeding birds supplemented by continental wintering birds) and 1,460 goosanders.**

The spatial distributions of the two species were very different, with just over 50% of wintering cormorant in estuaries (monitored annually through the WeBS volunteer survey) and only 6% found on stillwaters. For goosander less than 4% were estuarine and 28% found on stillwaters.

1. Introduction

There have been large increases in breeding populations of Great cormorant *Phalacrocorax carbo carbo* ("cormorant") across Europe over the past 40–50 years (Van Erden *et al*., 2012, Bregnballe *et al*., 2014). This increase has been mirrored in the UK (Chamberlain *et al.,* 2013), with birds also making increased use of inland fishery sites at which to feed and breed (Newson *et al*., 2013). Goosanders *Mergus merganser* have also increased in numbers across the UK in recent decades and have spread to many parts of the country (Musgrove *et al.,* 2013). Both species are widely distributed in Wales and, as elsewhere in the UK, this has resulted in widespread conflicts with fishery interests. Principal concerns in Wales have centred on the potential impact of these fish-eating birds on river catchments supporting populations of salmonid species, mainly Atlantic salmon *Salmo salar* ("salmon") and sea trout *Salmo trutta*. However, concerns have also been raised about the potential impact of the birds on other riverine fish stocks and on stillwater fisheries, both stocked and 'natural', that all support important fisheries.

Atlantic salmon and many sea trout populations have been in decline for many years and the majority of stocks are currently classified as either 'at risk' or 'probably at risk' (Cefas, Environment Agency and Natural Resources Wales, 2020). Both fish species are now considered to be endangered and of high conservation concern and are fully protected by law. Salmon are Annex II species under the EU Habitats Directive, supporting classification of six rivers in Wales as Special Areas of Conservation (SAC). Salmon numbers have declined significantly in 23 principal salmon and 33 main sea trout rivers across Wales over the last 3 decades and stocks are now all classified as at "At risk" or "Probably at Risk". Such chronic declines, coupled with a Ministerial request, led Natural Resources Wales (NRW) to develop a Plan of Action for salmon and sea trout ("the PoA") in Wales (NRW, 2020). This plan, launched in April 2020, outlines ongoing and new actions for the remediation of adverse pressures on salmon and sea trout in Wales. Here, the overall objective for migratory salmon and sea trout stocks in Wales is: "*To protect, through the application of best-practice science and management, the sustainability of our natural resource of wild salmon and sea trout stocks in Wales."* NRW is committed to addressing pressures on wild salmonid populations including through catch control regulations, habitat restoration, a renewed focus on water quality management, and a review of predation.

The Wildlife and Countryside Act 1981, as amended ("the Act") provides the legal framework in Wales for the protection of wild birds, their eggs and nests. The Act also establishes the framework under which NRW may issue licences allowing the killing or taking of wild birds.

There has been significant growth in the numbers of managed stillwater fisheries in Wales over the past two decades. Most of these are small, often less than two acres, and contain valuable stocks of carp and some other coarse fish species. These fisheries are vulnerable to predation by cormorants, causing sometimes significant economic harm through lost fishing business.

The potential impacts of piscivorous birds (referred to as "fish-eating birds") on wild and stocked fisheries have been the focus of many scientific studies in the UK and elsewhere within Europe. These studies suggest that, at a site level, fish-eating birds can take large numbers of fish from natural and inland stocked fisheries. In Wales, the highest levels of

concern have been raised for wintering cormorant and goosander in catchments where salmon parr and smolts are taken, and at stocked and natural stillwater fisheries.

The impacts of fish-eating birds on salmonid populations and game fisheries in the UK has been considered as part of extensive reviews in Scotland (Harris *et al*., 2008 and Humphreys *et al*., 2016) and England (Defra 2013) and also, for cormorants, across Europe (Carss *et al.,* 2012, Marzano and Carss, 2012). In Scotland, the review presented the evidence for population-level and economic impacts on Scottish salmon fisheries by fish-eating birds, Defra reviewed the existing fish-eating bird's policy in England, and in Wales in the absence of a fish-eating bird's policy an NRW-led advocacy paper recommended a group be established to develop such a policy.

All wild birds in Wales have legal protection. Natural Resources Wales (NRW) has a number of powers under which we can authorise others to kill or take particular species of wild birds, eggs and nests for certain purposes, for example in order to prevent serious damage to crops, livestock or fisheries, to protect public health or safety or to conserve other species of wildlife. NRW is responsible for assessing and issuing licences to authorise legal control of fish-eating birds (cormorant and goosander) over the winter and early spring period for the purpose of preventing serious damage to fisheries and for the conservation of flora and fauna, in this case principally salmon and sea trout. In balancing these responsibilities, NRW seek to work towards the restoration and protection of a healthy and balanced biodiversity in Welsh aquatic ecosystems, extending to populations of both fish and birds. NRW have also recognised the need to protect populations of fish species other than migratory salmonids, including non-migratory brown trout in rivers and lakes, and other fish species in stillwaters.

This focus, together with concerns of Welsh Government, the fishing sector and some freshwater conservation bodies about to the impact of predation by fish-eating birds on wild and stocked fisheries, led NRW's Board to endorse the establishment of an NRW led Fish-eating Birds Advisory Group (the Advisory Group) to assess the position in Wales and advise on the suite of actions required. To meet this challenge NRW's Board endorsed the establishment of an NRW-led fish-eating birds Advisory Group to assess the position in Wales and advise on potential actions required. In January 2020, the NRW Board asked for a comprehensive wide review of its approach to the permissions it gives for the shooting and trapping of wild birds. The policy development to address the impacts of predation by fish-eating birds on Welsh fisheries falls within this review.

NRW has identified ten principal migratory salmonid rivers in Wales (Wye, Usk, Tywi, Cleddaus, Teifi, Dyfi, Mawddach, Conwy, Clwyd and Dee). This includes four rivers (Wye, Usk, Teifi, and the Dee with Bala Lake) designated as Special Areas of Conservation (SAC) with Atlantic salmon among the primary reasons for site selection. For each of these ten catchments, a robust population estimate of non-breeding (wintering) cormorant and goosander was required.

Cormorant and goosander wintering in Wales are considered to be primarily estuarine in distribution, and in England winter populations are modelled using Wetland Bird Survey (WeBS) data. A previous NRW survey (Taylor and Noble, 2017) reviewed the survey datasets available for use in population estimation and modelling in Wales prior to surveying the lower River Dee, finding that many of the BTO's core surveys are designed for monitoring breeding populations of wild birds, and therefore take place at inappropriate

times of year for assessing numbers of wintering piscivores. Only two core datasets relevant to wintering riverine birds are available; the highly structured and coordinated WeBS, and the unstructured BirdTrack database.

The Wetland Bird Survey monitors non-breeding waterbirds in the UK. The principal aims of WeBS are to identify population sizes, determine trends in numbers and distribution, and identify important sites for waterbirds. Continuing a tradition begun in 1947, around 3,000 volunteer counters participate in synchronised monthly counts at wetlands of all habitat types, mainly during the winter period. These WeBS Core Counts are supplemented by occasional WeBS Low Tide Counts undertaken on estuaries, with the aim of identifying key feeding areas. BirdTrack is organised by the BTO for the partnership including BTO, RSPB, BirdWatch Ireland, the Scottish Ornithologists' Club (SOC) and the Welsh Ornithological Society (WOS), that looks at migration movements and distributions of birds throughout Britain and Ireland. BirdTrack provides facilities for observers to store and manage their own personal records as well as using these to support species conservation at local, regional, national and international scales. The scheme is year-round, and ongoing, and anyone with an interest in birds can contribute. Important results produced by BirdTrack include mapping migration (arrivals and departures) timings and monitoring scarce birds. BirdTrack provides little data for wintering Cormorant or Goosander and is not thought to be representative of the true populations or distributions of these birds.

Several species characteristics and data gaps in our understanding of the population and distribution of wintering cormorant and goosander were highlighted by the expert panel reviewing survey methodology for NRW (Taylor *et al*., 2022). First, these two species are highly mobile, both in response to disturbance (observer, targeted or stochastic events) and both diurnally and seasonally. It is not possible to survey an entire river channel or catchment simultaneously, and the mobility of piscivorous birds in winter means that there is unavoidable potential for double- or under-counting individuals. The influence of this characteristic on population estimates can be reduced with an informed analytical and survey design approach, including repeat survey and density modelling.

Secondly, the 2017 survey highlighted both a spatial bias in wintering bird distributions, and the number of birds using the river above the upper limit of WeBS survey. In the Dee survey, 95% of the bird records were from near-estuary lower reaches of the river but above the WeBS limit. This is in agreement with the known ecology of the two focal species but introduces a significant potential source of statistical error unless taken into account in survey design. The true relative distribution (between main-channel, tributary and stillwaters) of these two species in winter is poorly understood and likely to differ between the two species. The Dee survey did not include stillwaters or tributaries to the main river channel, but the report highlighted a general paucity of data on wintering piscivore distribution outside the WeBS network which is primarily estuarine. NRW’s interest in catchment and national population estimates requires up-scaling from linear river channel survey to area-based survey, with survey effort appropriately designed and distributed to take into account differences in spatial behaviour between cormorant and goosander.

Finally, in order to support NRW’s future demographic modelling work, it is likely that recording behaviour (foraging, roosting etc) and for goosander at least, sex ratios, may be critically important. Populations in winter are supplemented to a greater or lesser extent by

continental wintering birds, and the complex moult-migration of goosander may have a considerable impact on predation pressure as the main conflict with salmonid conservation.

Wintering population estimates and trends are derived from WeBS trends (Frost *et al.,* 2016) alongside the winter BirdAtlas series (Balmer *et al*., 2013 and APEP4 (Woodward *et al*., 2020). From these reports, the Welsh population is derived using the ratio of Welsh to non-Welsh Atlas records (records and occupied squares) to produce high-level estimates.

For cormorant, the British estimated breeding population is 8,200 and the wintering population 62,000; in 2011 Wales held approximately 8.6% of the total UK wintering numbers and 9.1% of the UK spatial distribution of cormorant producing a winter estimate of **5,332 - 5,642** birds. However, population trends differ between Wales and other parts of the UK, as does the extent of lethal control and the ratio of resident coastal-breeding *carbo* to migratory and inland-breeding *sinensis* birds. Breeding populations in Wales are fluctuating but broadly stable with declining productivity and there are few inland sinensis colonies; demographic modelling will need to be based on a much more nuanced understanding of breeding and wintering numbers than provided by estuarine WeBS data alone.

Goosander population estimates have similarly been derived from WeBS and Atlas datasets. APEP4 estimates the UK/GB breeding population at 4,800 birds and the wintering population at 14,500. Welsh records represented 8.7-10.5% of these, with an increasing trend in Wales contrasting with a declining trend at UK scale. The complex moult-migration and suspected breeding isolation of UK breeders may in future change their conservation status; with the British-breeding population moving closer to a status more comparable to outlying populations currently treated as discrete, namely the Iceland, Central west Europe and Balkans populations. The Welsh population estimate for this species is therefore **1,261-1,522** birds, but this estimate does not take into account the impact of differential population trends in England and Wales since the last Atlas in 2011.

This report seeks to determine population estimates and trends for wintering cormorant and goosander and national and/or catchment scale. This work will deliver the survey designed by BTO under contract to NRW (Taylor *et al*., 2022) and calculate estimates of known precision for both these species with 95% confidence intervals. These estimates will be used in future to develop catchment-specific non-breeding cormorant and goosander models for the assessment of the consequences of different levels of licensed control on wintering cormorant and goosander populations as an aid to salmonid conservation action and to prevent serious damage to stillwater fisheries in Wales.

2. Methods

2.1. Approach

Appraisal of the Taylor and Noble method

An internal team of senior BTO staff with relevant species and survey-design experience appraised the Taylor and Noble (2017) method for surveying riverine wintering cormorant and goosander on inland waterways. The team considered its appropriateness for census of fish-eating birds at the catchment scale and its ability to provide data underpinning precise river and catchment population estimates.

Census design

A BTO led scientific review team consisting of senior and experienced BTO staff developed and documented a robust census and survey design for undertaking riverine wintering cormorant and goosander surveys for each of the ten principal salmonid rivers and their catchments (Table 1, see page 15 and Figure 1, see page 16) in Wales. This survey design included the following specific steps required by NRW:

a. A method and supporting documentation for the requirement to survey additional areas to the main river channel (Figure 1) in each catchment. Additional (i.e. tributary) sampling was considered necessary by NRW, and the sampling effort required was estimated using a modelling approach based on winter distribution data. Two options for sampling effort (i.e. how many tributaries and survey length) were provided to NRW, with their estimated ability to generate a precise population estimate of cormorant and goosander at the catchment scale.

b. A breakdown of suitability, logistical and any other considerations relevant to each survey option (i.e. river survey only; river survey plus additional sampling e.g. of tributaries) referencing their ability to provide sufficiently robust data for the determination of population estimates. Population estimates are required to be precise and suitable to inform future population modelling work.

c. A costed delivery schedule based on the detailed survey methods developed above, for delivering catchment surveys in winter 2020-21 for each of the ten salmonid rivers (Table 1). Costs were presented separately for each river and both survey methods and included:

    i) main-channel census method

    ii) main channel-plus-stratified-sample method

BTO developed and costed a survey method and plan for surveying the ten principal salmonid catchments (Taylor *et al*., 2022). The BTO review team also developed and shared with NRW a working method for surveying wintering cormorant and goosander at stillwater fisheries, appropriate for a range of waterbody sizes; this survey was delivered by NRW.

i) Main channel survey

It was agreed that the Taylor and Noble (2017) survey method was an appropriate approach for surveying each river survey unit, which was a single 10km stretch of waterway surveyed by one surveyor in a day from one bank, walking upstream and mapping all encounters of the target species including recording sex (goosander) and standardised behaviour categories (both species). This survey unit and field method was considered to provide appropriate underlying data for population estimation.

Full details of the statistical analysis are presented in Taylor *et al*. (2022). The final recommended survey design for the main river channel was a single complete (100% coverage) survey in December 2020, followed by resurvey of 50% of these survey sections through January and February 2021 (in random order). Here, it was accepted that 50% resurvey significantly improves confidence in the population estimates.

ii) Tributary survey

Tributaries to each surveyed river main channel were numbered at their entry point to the main river channel, starting at the downriver and upstream georeference provided by NRW. Tributaries (including the main channels of major tributaries) were selected systematically to cover the geographic catchment and assigned to survey segments such that 33% of tributary watercourse to the assigned river main-channel was surveyed once during January and February 2021.

The field method for tributary survey was similar to that for the main channel, except that additional logistical and sampling considerations applied. 10km river-length survey units were identified and mapped before the start of the fieldwork period. Surveyors walked one bank of the river channel, recording all observations of the target species (cormorant, *Phalacrocorax carbo carbo / sinensis* and goosander) either on the river, on riverbanks or visible (e.g. flying over). Behaviour of all individuals will be recorded, along with sex (goosander).

If any section of the river was not accessible, e.g. for reasons of topology, refused access permissions, surveyor safety etc. it was recorded as ‘not surveyed’. Each observation was mapped onto OS map sheets and the data later transferred to a GIS in ArcMap. Quality control was provided by surveyors additionally recording the locations and numbers of the two target species on a separate datasheet as well as marking them on an OS map.

iii) Stillwaters survey

Stillwater surveys were based on complete counts of each single waterbody, using the same behaviour and sex recording as for the river surveys. Specific methods for stillwaters (as different from the river surveys) were applied as follows:

- Counts were synchronised with WeBS, ideally counted on the same day (weather permitting), and repeated on the same schedule as WeBS counts, in order to compensate for the expected variability in birds’ use of stillwaters.
- In order to understand diurnal patterns of the birds’ use of stillwaters, each survey day would need to include three separate counts, a) at or just after first light (within the hour after nominal sunrise); b) noon (within one hour either side of 12.00) and c)

dusk (within the hour before nominal sunset). However, due to Covid restrictions, two visits were made, these were noon and dusk counts.
- Multiple waterbodies in a complex (such as separate ponds in a stillwater fishery) were counted and recorded separately.
- Intentional disturbance activities (e.g. scaring or lethal control under licence) occurring on the same day or in the previous 24hrs were recorded.

Preliminary analysis of data from the Wetland Bird Survey (WeBS) suggested that cormorant and goosander are seldom recorded on bodies of water smaller than 1 ha, and these small waterbodies were therefore excluded from sample selection.

For very large stillwaters such as reservoirs and natural lakes, visual sectors were established as for WeBS stillwaters counts. Where WeBS sectors are already set up by counters in the BTO network, it was advantageous to use the same sectors and record birds in each sector; this method was used for Llyn Tegid. Here, sectors were set using visible landmarks and repeatable vantage points were recorded such that the sector boundaries could be mapped.

Full details of the underpinning statistical design, appraisal and modelling approaches for all surveys can be found in Taylor *et al*. (2022).

2.2. Survey commissioning and delivery

Rivers Survey timeline

A full description of the survey design and the underpinning population modelling approach can be found in BTO's report to NRW (2020/21 winter census of cormorant and goosander in Wales: design and analytical approach, (Taylor *et. al*., 2022)). In order to deliver population estimates by the end of March 2021, and to ensure the survey delivered a true reflection of winter cormorant and goosander populations (i.e. before the birds begin pre-breeding distributional change), surveys were planned to take place throughout December 2020 and January 2021, and pre-season work including surveyor recruitment, production of river and catchment GIS, field map production etc. through October and November 2020.

The full main-channel survey was delivered first and completed in December 2020. This was planned to highlight any change in bird distributions between December 2020 and January 2021, to allow the statistical team to assess in-season spatial distribution change in these potentially highly mobile birds. The main-channel full survey proceeded sequentially upstream from the reference point nearest the estuary towards the river source. Resurvey sections of the main channel were selected systematically (alternate sections) unless access permissions made an alternative section more appropriate: these were surveyed in random order alongside the wider catchment (tributary) samples in January and February 2021.

A strategic plan for the surveys was designed to provide information on population size, distribution and, to a certain extent, seasonal change in cormorant and goosander. Broadly, fieldwork fell into two distinct phases:

a. The first (complete) survey of all 10 main river channels was performed during December 2020. Riverine sectors were surveyed in random order.
b. A systematic 50% repeat survey of the main channels (i.e. every second 10km survey segment) plus survey of 33% of tributary waterways, were undertaken concurrently through January and February 2021.

Similarly, the sampling strategy for the tributary waterways was as follows:

a. Systematic sample (every third waterway) of small (>1km long, most are <10km long) tributary waterways flowing into the main river channel. Survey the whole length of the longest (main) channel of each selected waterway.

b. Systematic sample (every third 10km segment) of the longest continuous channel of every major tributary to the main river.

Key logistical considerations for rivers survey

The field survey activity was designed to be undertaken continuously through December 2020 to February 2021. All survey activity took place in a potentially challenging working environment, including specific risks associated with winter fieldwork in general, but also Covid guidelines and restrictions, and Avian Influenza guidelines. These were reflected in an expanded Risk Assessment and also, in our approach to staffing. We identified the following strategic risks to the fieldwork:

a) National or local travel restrictions under Welsh Government Covid announcements
b) Welsh Government guidelines on minimising travel across Wales and between local authority areas
c) Risk of individual fieldworkers either becoming ill or having to self-isolate
d) Risks associated with Avian Influenza controls or outbreaks

BTO's approach to mitigating these risks was discussed with NRW and finalised as follows:

- To deliver the survey using only contracted BTO staff and employees. Travel for work that cannot be done at home was not legally prevented in Wales under any of the different regulations through 2020 and 2021. BTO provided field staff with written confirmation that they were employed to perform field surveys by BTO, and which were carried during surveying or travel to survey areas.

- To employ a larger than usual number of field staff. A larger number of part-time staff gave BTO more flexibility to cope with temporary restrictions or individual illness in the field team. The staff team was nine people, three existing BTO staff (two fulltime plus one part-time) and six fieldworkers on part-time contracts.

- To employ surveyor's resident across Wales. The field team were distributed in the right areas of Wales such that they are surveying near to their home areas. In addition, the two BTO staff members working full-time on the survey did not share accommodation with each other.

- To assess and mitigate individual infection or transmission risk. BTO's Risk Assessment for individual fieldworkers includes careful guidance on minimising

COVID (and Avian Influenza) risks. Fieldworkers discussed this guidance in detail and signed the completed assessments before fieldwork started; and the Field Coordinator maintained contact with the field team throughout the work to keep oversight of any additional issues arising.

Welsh Government guidelines changed several times through the field survey period of this project. However, the guidance for travelling within and into Wales for work permitted this professional BTO survey work. The relevant text was ***"Where necessary travelling to a workplace in Wales is a reasonable excuse to enter Wales under the rules, including travelling from a tier three area. Similarly, the rules allow people living in Wales to travel to anywhere in England for work purposes where this is necessary, and they cannot work from home."*** BTO senior staff monitored these changes in Welsh Government guidance relating to travel and outdoor work in Wales throughout the survey period.

Deliverables

BTO provided copies of the digitised river and tributary maps in two groups:

a. Shapefiles of the main waterways (river channels, major and minor tributaries) for each catchment being surveyed. These were ready to provide to NRW at the progress meeting in December 2020
b. Maps of the survey segments including the tributary waterways and segments surveyed. These were provided as a data adjunct to this report.

Survey access and permissions

NRW were responsible for communicating and agreeing access for BTO surveyors. This was the responsibility of NRW's rivers staff who communicated with Afonydd Cymru under contract. NRW shared relevant contact information with BTO and also agreed the wording of a letter of identification and introduction to the work to be carried at all times by fieldworkers performing surveys.

Survey communications plan

There is considerable public interest in fish-eating birds and the questions of conservation, management and conflict arising in the freshwater environment. It was agreed that any major communications (media articles etc) should be reviewed by NRW, and a description and narrative approach prepared and agreed with NRW for use in newsletters and fieldworker paperwork.

2.3. Analytical approach

River Population modelling

Statistical modelling methods follow those presented in Taylor *et al*. (2022). Predictive count models for both species used a Generalised Linear Mixed Model (GLMM) with a Bayesian framework, run in the R package, and derived from the field survey datasets. Models were fitted with a Poisson error distribution. Each model was fitted with four Markov-Chain Monte Carlo (MCMC) chains, a method that draws samples where the next sample is dependent on the existing sample, called a Markov Chain. Each MCMC chain

had 2,000 iterations (i.e. 1,000 post-warmup samples) unless more were required to achieve satisfactory convergence (this was only the case when modelling estuarine and stillwater populations; see below). The model fixed effects are river segment position (a multiple of 10km distance from the geo-referenced near-estuary start point of the river main channel), log-transformed segment length, and survey sample category (main, tributary, tributary type), with segment position nested within the river as a random effect. For channel categories, tributaries were categorised into major and minor groups. Tributary segment positions were labelled as the segment position of the main channel into which they flow.

River segment density modelling

Posterior distributions at river- and national-scales were generated by summing estimates at segment-scale. Mean and 95% confidence intervals were calculated from each posterior distribution. For main channels, sections were 10km long and numbered sequentially from the mouth (i.e. section 1 contains the first 10km upstream from the mouth). For tributaries, sections were numbered according to the main channel section with which they form a confluence. Tributary sections were modelled according to their actual length (which varied between 0.2–10 km). For each river section, a population estimate is given, which is the mean of a posterior sample of 4,000 draws predicted by the fitted model. The 95% confidence interval for the total population estimate were calculated by adding together the lower confidence intervals and upper confidence intervals respectively for each river (i.e. the 100^{th} and 3900^{th} largest draws in each river). The resulting population estimates for main-channel and tributary birds are presented separately and summed to give the riverine population for that river (major and minor tributary estimates are combined).

Currently, the overall Wales predictions are derived from Welsh River datasets alone, including both the surveyed Principal Salmonid rivers and the unsurveyed rivers listed in the Welsh river dataset. For the unsurveyed rivers, estimated populations assume similar bird distributions to the surveyed rivers (i.e. application of the same model) and are applied to the main channel only.

Stillwaters population modelling

Statistical modelling of data from stillwater surveys proceeded as described above, using GLMMs with Bayesian framework and Poisson error distribution. The methodology differed slightly between species, due to differences in our expectations for how each species would utilize stillwaters that were borne out in preliminary examination of behavioural observations recorded during surveys. For cormorant (which are expected to visit stillwaters primarily in order to forage), we fitted models to the full dataset, with stillwater area (in hectares) and time of day (noon or dusk) as fixed effects and catchment and survey round (December or January) as random effects. Goosander may visit stillwaters in order to roost as well as fish, such that individuals counted on stillwaters during the noon/ dusk surveys might later be present on river channels during river channel surveys, and therefore potentially be double-counted. For this species we fitted models to data from the noon surveys only, with stillwater area as the sole fixed effect. MCMC chains were allowed to iterate 5,000 times (2,500 post-warmup samples) for cormorant, and 8,000 times (4,000 post-warmup samples) for goosander, to ensure convergence.

Population estimation from models also proceeded as for the river estimates above. Populations were estimated for all 263 stillwaters over 1 ha in size within the catchments of

the ten principal salmonid rivers and summed to give a national-scale estimate of the population of birds ***using stillwaters for fishing***. For both species, estimates were made for the noon survey time (i.e. for cormorant, estimates were made at the “noon” level of the “time of day” factor), since this was most likely to coincide with the river surveys.

Estuarine population modelling

Estuarine population models were based on data from WeBS. Data were obtained from the nine WeBS sites that collectively encompass the estuarine sections of the ten principal salmonid rivers (Wye, Usk, Tywi, Cleddaus, Teifi, Dyfi, Mawddach, Conwy, Clwyd and Dee (including Llyn Tegid) see Table 1). Some WeBS sectors were excluded, firstly in order to avoid double-counting of sections of river that were surveyed both by WeBS and during river channel surveys; and secondly to include only the sectors of the Severn Estuary site that corresponded to estuarine portions of the Usk and Wye catchments. However, we note that WeBS coverage within the Teifi estuary is very limited, whereas the Carmarthen Bay WeBS site used to model the Tywi estuary also includes the estuarine sectors of the Gwendraeth and Taff rivers.

Owing to the Covid pandemic, volunteer surveys were suspended for much of the 2020-21 winter season and WeBS coverage was consequently poor. We therefore estimated populations for each estuary during December 2020–January 2021 based on historic data and climatic variables. We fitted GLMMs to WeBS sector- and count-resolution data with Bayesian framework (5,000 iterations) and Poisson error distribution (as above), with year (as a linear trend), abundance in the previous year (to offset potential density-dependent effects), and continental temperature as fixed effects; and (WeBS) site as a random effect. Continental temperature was modelled to estimate the effect of additional birds migrating from northern Europe and Scandinavia during colder winters. For each species, we selected four locations in continental Europe where birds ringed or recovered in the UK during winter had previously/subsequently been ringed or recovered. We extracted monthly mean temperatures in December for each location from the E-OBS dataset, fitting the average across the four locations for each species to data from years up to 2019, and using temperature from December 2020 to predict abundance during our survey period (January temperature was not used in models because temperature data for January 2021 was not yet available at the time of analysis).

Population estimation from the models again proceeded as above. Populations in December 2020 were estimated for all included WeBS sectors across the nine sites and summed to give a national-scale estimate of the population of birds using estuarine sections of the ten principal salmonid rivers. Populations of cormorant and goosander occupying non-river locations (i.e. estuaries and stillwaters) during the survey period were added to the national population estimate for riverine birds to yield a total national population estimate.

3. Results

3.1. Survey delivery

River surveys, as planned, started on 1st December 2020, and the main-channel first (full) survey was completed as planned by 1st January 2021. Surveyors moved on to the main-channel repeat surveys and tributary surveys as planned in early January 2021, and these were completed by 26th February 2021.

December 2020 surveys - Surveyors encountered some sections where access permissions were not in place, and these were reported to NRW and to the organisation responsible for obtaining and communicating access permissions for the survey. Few landowners refused permission once the survey was explained to them. Additional problems were encountered as a result of the very heavy rainfall and consequent flooding through late December. The field methodology generally performed well. In some sectors, significant flooding required fieldworkers to alter their planned survey route and we discussed alternative approaches with them. In a very small number of cases flooding very significantly affected survey effort, and we have noted the affected sectors and % coverage or confidence in coverage for the target species or planned to revisit the sector as a whole during the resurveys in January and February 2021. Surveyors reported that access in some cases was physically difficult (topography, vegetation including wetlands and bog areas) and the small number of inaccessible areas was mapped.

Digitising the main channel survey – Field staff returned survey maps and datasheets for this first survey of the main channel to BTO Cymru by the New Year, ready for scanning and digitising this first set of goosander and cormorant records in preparation for coverage, population and spatial analysis.

January and February 2021 surveys - Through January and February 50% of the main channels were resurveyed and the stratified sample of tributary sections. Resurvey and tributary sections were selected and allocated to fieldworkers during November and early December 2020, and survey materials (field maps etc) prepared and sent out to all the field staff in mid-December. As for the survey of main channels in December, and in line with our policy on keeping travel to a minimum during the pandemic, fieldworkers were allocated tributary sample sectors as close as possible to their homes. The same nine fieldworkers carried out the survey work in January and February, and mostly covered the same river catchments they surveyed in December.

As outlined in the survey design (Taylor *et. al.,* 2022), tributary sections were stratified by connectivity (major and minor tributaries), with a larger sample of major tributary sectors but a statistically significant sample of minor tributaries. The locations of these survey sites were shared with Afonydd Cymru (on 7th December 2020) to provide them with sufficient time to contact landowners along these river stretches; with the intention of reducing or mitigating any communications or (generally minor) landowner issues such as were experienced during the survey of the main channels in December 2020. Whilst most interactions with landowners were positive once it was explained to them what the fieldworkers were doing, a small number were less positive resulting in fieldworkers being challenged and, in some cases, denied access. In other cases, fieldworkers had to abandon a survey and return another day whilst access permission was sought.

Survey effort - Across all the field team, BTO surveyors worked 289 field days in three months of the survey (including some contingency used during the poor weather in December 2020 and snow in January 2021). In total there were 103 survey sections in the December main-channel survey, covering 956km of the 10 rivers geo-referenced* by NRW. 50 sections (c. 500km) main-channel sectors were resurveyed in January and February 2021, along with 114 tributary sections (c. 900km).

3.2. Survey coverage

Across the main-channel survey, main-channel resurvey and tributary samples for the ten rivers, survey planning identified 2,482km of river to be visited. Coverage averaged 92%, with the unsurveyed areas a combination of access refusal by landowners, topography and vegetation (e.g. dense wetlands, blanket bog) or severe flooding. Some sections flooded in December were covered as an additional sector during the resurvey period in January and February. Surveyed river sections and the sections we were unable to survey are mapped in Figure 1.

Table 1. Survey coverage by river for the ten principal salmonid rivers surveyed in winter 2020-21.

River	Start point	End point	Survey length (km)	% surveyed
Clwyd	SJ0314052980	SJ0076079340	155.7	97.2
Conwy	SH7815045790	SH7893072280	144.2	82.9
Dee	SJ0314052980	SJ3126569487	376.4	90.1
Dyfi	SH8690022450	SN6941097890	141.1	97.1
E Cleddau	SN1667029730	SN0483013840	77.7	92.3
W Cleddau	SM8433030430	SM9548415421	95.5	79.6
Mawddach	SH8137031210	SH7108019020	68.1	90.3
Teifi	SN7901063610	SN1899045430	324.4	83.0
Tywi	SN8064060920	SN4043019320	215.9	93.6
Usk	SN8074026130	ST3133788434	288.1	94.8
Wye	SN8069085630	ST5386096520	594.6	98.2
			2481.8	**92.1**

Figure 1. Map of survey coverage (river segments in blue) and unsurveyed planned segments (red) across the ten salmonid rivers in Wales. Segments were unsurveyed due to access issues (topography, vegetation, permission, safety) or flooding.

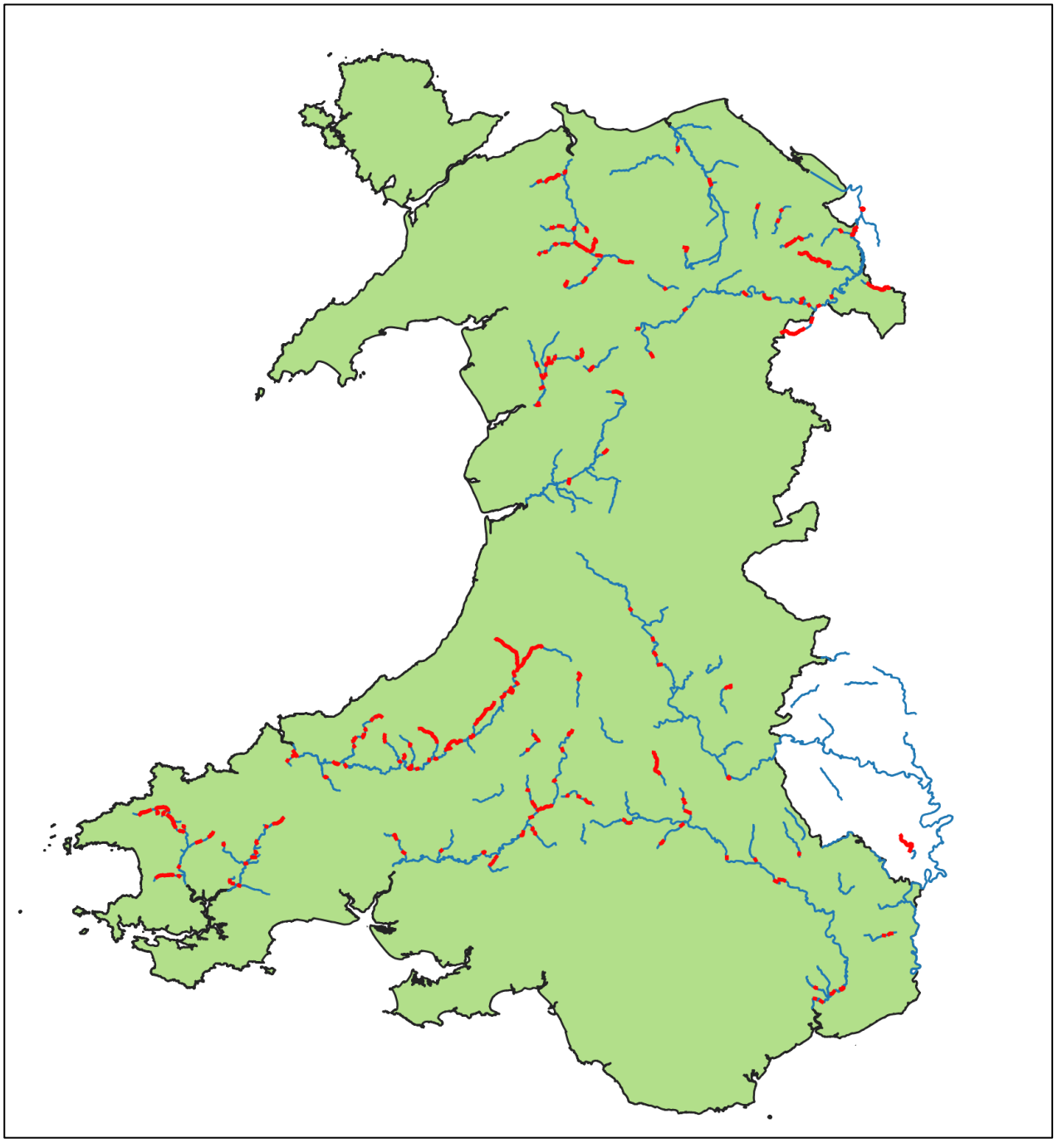
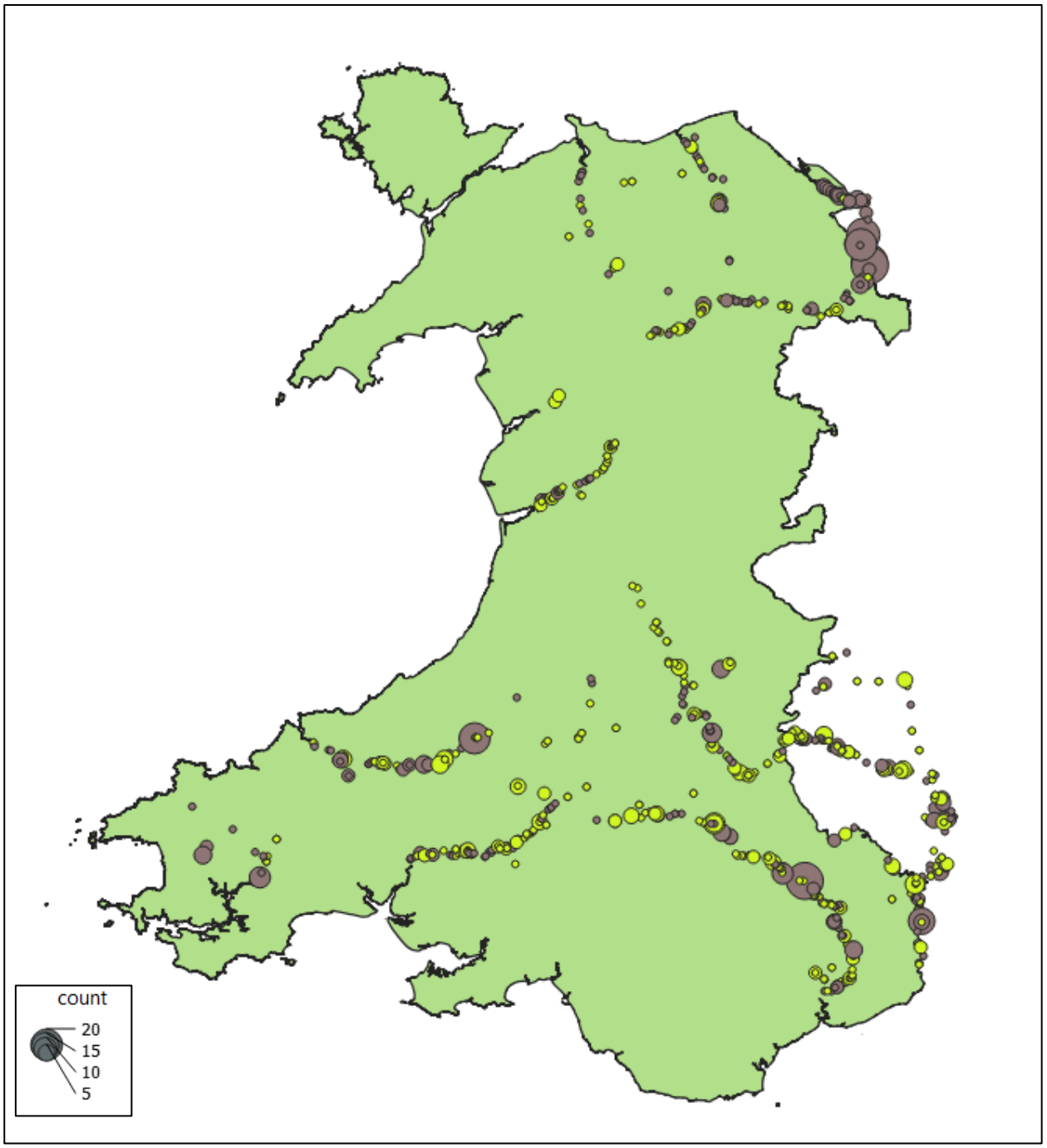


Figure 2. Map of **cormorant** (grey circle) and **goosander** (yellow circle) records across the ten surveyed Principal Salmonid Rivers of Wales.



3.3. Raw observation data

A total of 564 cormorant and 522 goosander observations were recorded during the survey (Table 2). Average group sizes for both species were small, but slightly larger for cormorant (average 1.7 birds, maximum 20) than for goosander (average 1.3 birds, maximum 6). The majority (81% of cormorant and 78% of goosander) of both species were recorded as single birds.

Survey data are provided as an adjunct to this report in GIS and Excel format.

Birds were distributed towards the estuary and lower in the catchments. Numbers observed in the tributaries were very much lower than in the main channel, and surveyors commented on the low numbers of birds seen, particularly higher in the tributaries. Tables 3 and 4 present raw observations by river and survey segment for the two species in the main channel and tributary sample surveys. We note that observations of a mobile and disturbance-sensitive species should be considered an underestimate of the population providing the raw data from which modelled population estimates are derived.

Bird distribution and group numbers are also presented as a map in Figure 2.

Table 2. Cormorant and **goosander** observed in surveyed sections of the ten principal salmonid rivers in winter 2020-21. Observations are assumed to be an underestimate of the population but are presented as the raw data from which modelled population estimates are derived. Note that data include observations from both the first and repeat surveys so some individuals will likely have been double-counted.

River	Cormorant observed	%	Goosander observed	%
Clwyd	19	3.4	9	1.7
Conwy	11	2.0	8	1.5
Dee	186	33.0	75	14.4
Dyfi	15	2.7	34	6.5
E Cleddau	13	2.3	8	1.5
Mawddach	9	1.6	0	0.0
Teifi	0	0.0	4	0.8
Tywi	49	8.7	41	7.9
Usk	36	6.4	55	10.5
W Cleddau	101	17.9	113	21.6
Wye	125	22.2	175	33.5
Grand Total	**564**		**522**	

Table 3. Individual records of **cormorant** and **goosander** in each 10km distance band of main channel from the river's mouth. N.B. data includes both survey rounds, so some individuals likely to have been counted twice.

Species	River	Distance from sea (10km segments):																						
		10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230
Cormorant	**Total**	110	53	78	73	36	36	51	15	23	6	19	6	14	17	4	1	2	10	7	2	1		
	Clwyd	6	3	9		1																		
	Conwy	6	2		3																			
	Dee	43	12	35	48	9	7	3	3	2	1	10	5	4	4									
	Dyfi	10	5																					
	E Cleddau	13																						
	W Cleddau	8		1																				
	Mawddach																							
	Teifi	4	2	9	6	6	2	19		1														
	Tywi	12	2	7	5	5	5																	
	Usk	4	2	10	8	9	21	18	6	16	4	2		1										
	Wye	4	25	7	3	6	1	11	6	4	1	7	1	9	13	4	1	2	10	7	2	1		
Goosander	**Total**	47	40	67	33	50	12	36	14	45	3	42	16	28	12	16	5	14	6	7	3	16	7	3
	Clwyd	4	2	2							1													
	Conwy	3	1		4																			
	Dee	2			9	2		5	8	13	1	7	9	15	4									
	Dyfi	13	4	17																				
	E Cleddau	5	3																					
	W Cleddau																							
	Mawddach	4																						
	Teifi	2	7	11	3	13	1	4																
	Tywi	6	11	4	11	10	6	2		5														
	Usk	5	9	17	3	14	4	20	5	19		13	4											
	Wye	3	3	16	3	11	1	5	1	8	1	22	3	13	8	16	5	14	6	7	3	16	7	3

Table 4. Individual records of **cormorant** and **goosander** in each 10km distance band of tributaries from the river's mouth.

Species	River	Distance from sea (10km segments):																					
		20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230
Cormorant	**Total**	6	9	2	3	1	3				1			2			1	3		3	1		4
	Clwyd	2	1	2		1																	
	Conwy																						
	Dee													1									
	Dyfi																						
	E Cleddau	3																					
	W Cleddau		1																				
	Mawddach																						
	Teifi		7																				
	Tywi																						
	Usk	1																					
	Wye				3		3				1			1			1	3		3	1		4
Goosander	**Total**	9	8	25	14		10	2			4	6		1	4	4	2	2			2	2	8
	Clwyd			5	2																		
	Conwy		2		2																		
	Dee			18																			
	Dyfi		2																				
	E Cleddau																						
	W Cleddau																						
	Mawddach																						
	Teifi		2																				
	Tywi		2		6		7	2															
	Usk	9									2	2											
	Wye			2	4		3				2	4		1	4	4	2	2			2	2	8

3.4. Modelled population estimates

River population estimates

Modelled population estimates for the surveyed rivers are presented in Table 5. Estimates are separated into main-channel and tributary birds, which are summed to give the riverine population for that river. Modelled estimates for unsurveyed rivers are given (Table 6).

Table 5. Modelled population estimates and lower (-) and upper (+) confidence intervals (CI) for **cormorant** and **goosander** in the ten principal salmonid rivers surveyed in winter 2020-21. Estimates are separated into main-channel and tributary records.

River	Sample	Cormorant	(– CI)	(+ CI)	Goosander	(– CI)	(+ CI)
Clwyd	Main	25	15	37	10	4	17
	Tributary	10	4	17	13	6	21
		35	***19***	***54***	***23***	***10***	***38***
Conwy	Main	11.6	5	20	8.53	3	15
	Tributary	3.51	0	8	6.71	2	13
		15	***5***	***28***	***15***	***5***	***28***
Dee	Main	194.96	163	230	71.38	54	91
	Tributary	46.48	31	63	56.33	40	74
		241	***194***	***293***	***128***	***94***	***165***
Dyfi	Main	15.2	7	25	22.72	13	33
	Tributary	3.77	1	8	23.85	14	35
		19	***8***	***33***	***47***	***27***	***68***
W Cleddau	Main	26.89	0	114	12.9	0	33
	Tributary	4.7	0	21	6.49	0	18
		32	***0***	***135***	***19***	***0***	***51***
E Cleddau	Main	23.68	0	97	10.81	0	27
	Tributary	5.47	0	24	5.45	0	15
		29	***0***	***121***	***16***	***0***	***42***
Mawddach	Main	0.46	0	3	2.69	0	7
	Tributary	0.1	0	1	1.57	0	5
		1	***0***	***4***	***4***	***0***	***12***
Teifi	Main	58.12	42	76	29.86	19	42
	Tributary	11.77	5	20	18.56	10	28
		70	***47***	***96***	***48***	***29***	***70***
Tywi	Main	37.22	24	52	48.12	33	65
	Tributary	10.8	4	18.03	40.21	26	56
		48	***28***	***70.03***	***88***	***59***	***121***
Usk	Main	109.75	86	135	92.78	72	115
	Tributary	22.81	13	35	56.92	41	75
		133	***99***	***170***	***150***	***113***	***190***
Wye	Main	147.39	120	175	145.91	120	174
	Tributary	38.3	25	53	116.22	91	143
		186	***145***	***228***	***262***	***211***	***317***

Table 6. Modelled population estimates and lower (-) and upper (+) confidence intervals (CI) for **cormorant** and **goosander** in other major rivers of Wales. These rivers were not surveyed, and population estimates are predicted based on modelled bird distributions in the surveyed rivers only.

River	Cormorant	(– CI)	(+ CI)	Goosander	(– CI)	(+ CI)
Aber	5	0	23	2	0	7
Aeron	15	0	65	8	0	21
Afan	12	0	52	6	0	15
Arth	8	0	36	4	0	11
Artro	6	0	28	3	0	9
Braint Nor	5	0	26	3	0	9
Braint Sou	5	0	23	2	0	8
Cadoxton	7	0	30	3	0	8
Cefni	7	0	31	3	0	9
Ce.g.in	6	0	24	2	0	7
Clarach	8	0	31	3	0	9
Cledan	6	0	23	2	0	7
Crigyll	8	0	34	4	0	10
Daron	4	0	15	1	0	5
Dwyfor	11	0	45	5	0	13
Dysynni	11	0	49	5	0	14
Ffraw	5	0	22	2	0	7
Glaslyn	13	0	54	6	0	16
Gwyrfai	8	0	36	4	0	11
Lliedi	6	0	26	3	0	8
Loughor	10	0	46	5	0	15
N Gwendrae	10	0	46	5	0	14
Nedd	14	0	61	7	0	21
Nyfer	10	0	44	5	0	13
Ogmore	10	0	47	5	0	15
Ogwen	11	0	45	5	0	13
Rheidol	13	0	55	7	0	19
Rhyd-hir	8	0	34	4	0	11
Rhymney	18	0	78	11	0	30
S Gwendrae	11	0	50	6	0	16
Seiont	6	0	29	3	0	10
Soch	11	0	45	5	0	13
Taf	19	0	84	10	0	25
Taff	22	0	93	12	0	32
Tawe	19	0	80	10	0	27
Thaw	13	0	55	6	0	15
Wyre	10	0	44	5	0	13
Ysgethin	6	0	26	3	0	8
Ystwyth	19	0	81	10	0	25
	398			***192***		

Modelled national population estimates, plus confidence intervals, for cormorant and goosander extrapolated from surveyed catchments and other major Welsh catchments that were unsurveyed is tabulated (Table 7).

Table 7. Modelled national population estimate for **cormorant** and **goosande**r using Welsh rivers in winter. The population estimate is extrapolated from surveyed, unsurveyed rivers and their catchments but excludes estuarine and non-estuarine (marine) birds monitored under WeBS and NEWS surveys.

Species	Population estimate	(– CI)	(+ CI)
Cormorant	1207	1035	1420
Goosander	991	894	1097

Estuarine population estimates

Estuarine populations of cormorant and goosander are predicted as WeBS counts for December / January for each of the ten Principal Salmonid River estuary systems (Tables 8 and 9). Note that these WeBS sites represent (in some cases) larger estuary systems than a single river: for example, in the case of the Wye, the estimate presented is for the Severn estuary. These estuaries are therefore considered representative of the majority of estuarine wintering cormorant and goosander (but see discussion for important considerations in scaling-up or extrapolating winter populations outside these estuaries across Wales).

Table 8. Modelled population estimates and lower (-) and upper (+) confidence intervals (CI) for **cormorant** and **goosander** in the estuaries of the ten principal salmonid rivers surveyed in winter 2020–21.

Estuary	Salmonid river(s)	Cormorant	(– CI)	(+ CI)	Goosander	(– CI)	(+ CI)
Carmarthen Bay	Tywi	253	105	420	4	0	26
Cleddau	W & E Cleddau	77	19	153	1	0	19
Clwyd	Clwyd	73	41	108	7	0	20
Conwy	Conwy	63	13	130	3	0	26
Dee	Dee	728	518	961	3	0	18
Dyfi	Dyfi	74	32	125	5	0	24
Mawddach	Mawddach	43	15	75	6	0	20
Severn	Usk, Wye	170	86	269	12	0	42
Teifi	Teifi	22	10	37	12	4	26
		1503			***53***		

Table 9. Modelled population estimate and lower (-) and upper (+) confidence intervals (CI) for **cormorant** and **goosander** using estuaries of the ten principal salmonid rivers surveyed in winter 2020–21. The population estimate is additional to the estimate for riverine birds (Table 7) but excludes non-estuarine (marine) birds monitored under NEWS surveys.

Species	Population estimate	(– CI)	(+ CI)
Cormorant	1503	1410	1598
Goosander	53	36	73

Stillwaters population estimates

In total, NRW staff surveyed 72 stillwaters for cormorant and goosander, waterbodies ranging in area from 1–422 ha. A list of stillwaters surveyed by NRW staff is presented in Appendix 1. Surveys were conducted following the methodology of Taylor *et al*. (2022), with surveys synchronous with (planned) WeBS dates for the winter; and each surveyed once in December 2020 and once in January 2021. Repeat surveys in January were conducted at the same times of day as in December for each waterbody. All stillwaters were surveyed at noon, and the majority were additionally surveyed at either dawn or dusk (in a few cases, both). Llyn Tegid was surveyed in the same way using WeBS Survey vantage points by BTO survey staff advised by the local WeBS volunteer.

The population estimate presented in Table 10 represents the number of individual birds to be added to the national population estimates derived from river, tributary and estuarine models for calculating Welsh national wintering estimates for Cormorant and Goosander.

Table 10. Modelled population estimate and lower (-) and upper (+) confidence intervals (CI) for **cormorant** and **goosander** using stillwaters within the catchments of the ten principal salmonid rivers surveyed in winter 2020–21. The population estimate is additional to the estimate for riverine birds (Table 7).

Species	Population estimate	(– CI)	(+ CI)
Cormorant	184	135	241
Goosander	416	293	580

3.5. Welsh national wintering population estimates

The overall population estimates for Welsh wintering cormorant and goosander are the sum, for each species, of modelled estimates for the surveyed rivers with their tributaries, estuaries and stillwaters; plus, the sum of the extrapolated populations for the remaining major rivers of Wales (Table 11). These represent the sum of values from Tables 7, 9 and 10, but it should be noted that there will likely be additional non-estuarine and other coastal birds and these totals should be considered conservative estimates for the Welsh wintering population.

Table 11. Modelled population estimate and lower (-) and upper (+) confidence intervals (CI) for **cormorant** and **goosander** within the catchments of the ten principal salmonid rivers surveyed in winter 2020–21).

Species	Population estimate		(– CI)	(+ CI)
Cormorant	Rivers	1207	1035	1420
	Estuaries	1503	1410	1598
	Stillwaters	184	135	241
		2894		
Goosander	Rivers	991	894	1097
	Estuaries	53	36	73
	Stillwaters	416	293	580
		1460		

For cormorant, estuarine birds (i.e. those monitored by WeBS surveys) represent 52% of the wintering population in Wales, while a further 42% were found in the rivers above the upper limit of WeBS counts, and only 6% of the total estimate added by surveying stillwaters. For goosander the proportions were very different, with the majority (68%) of birds found on rivers and a further 28% added from the stillwaters survey. Estuarine (WeBS counted) birds represented less than 4% of the winter population estimate.

Modelled species distributions

These model outputs can be presented as distribution densities (birds expected in each 10km survey sector) and are summarised in Table 12 (cormorant) and Table 13 (goosander).

Table 12. Modelled distribution of **cormorant** in the ten principal salmonid rivers. For main channels, sections are 10km long and numbered sequentially from the mouth (i.e. section 1 contains the first 10km upstream from the mouth). For tributaries, sections are numbered according to the main channel section with which they form a confluence. Tributary sections were modelled using their actual length (which varied between 0.2–10 km).

Channel	River	Section																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Main channel	**Total**	28–174	18–141	14–108	12–70	9–59	6–52	5–44	3–40	3–36	2–35	2–29	1–25	0–20	0–12	0–11	0–8	0–7	0–6	0–6	0–6	0–6	0–5	0–5	0–4	0–3
	Clwyd	5.4	3.8	2.7	1.9	1.4	0.6																			
	Conwy	3.0	1.9	1.2	0.8	0.3																				
	Dee	25.5	20.5	16.5	13.3	10.6	8.5	6.9	5.5	4.4	3.6	2.8	2.3	1.9	1.3	1.2	0.2									
	Dyfi	6.0	1.8	0.5	0.2	0.0																				
	E Cleddau	7.1	4.8	2.3																						
	Mawddach	0.2	0.0	0.0																						
	Teifi	6.3	5.4	4.7	4.0	3.5	3.0	2.5	2.2	1.9	1.6	1.4	0.9													
	Tywi	6.2	4.7	3.6	2.7	2.1	1.6	1.3	0.6	0.3	0.5															
	Usk	6.6	6.5	6.3	6.2	6.0	5.9	5.8	5.5	5.5	5.4	5.3	3.7	3.0												
	W Cleddau	7.2	4.9	3.9	0.5																					
	Wye	7.3	6.9	6.5	6.2	5.8	5.5	5.2	4.9	4.5	4.3	4.1	3.8	3.6	3.4	3.2	3.1	2.8	2.7	2.5	2.3	2.2	2.1	2.0	1.2	0.7
Major tributary	**Total**	0–25	0–13	0–17	0–11	0–8	0–9	0–7	0–7	0–5	0–7	0–5	0–4	0–3	0–3	0–2	0–2	0–1	0–1	0–1	0–1	0–1	0–1	0–1	0–1	
	Clwyd	0.5	0.2	0.2	0.2																					
	Conwy	0.2	0.0	0.1	0.0																					
	Dee	1.9	0.7	1.0	0.7	0.7	0.7	0.5	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1										
	Dyfi	0.4	0.1	0.0	0.0																					
	E Cleddau	0.4	0.2	0.2																						
	Mawddach	0.0	0.0																							
	Teifi	0.4	0.3	0.4	0.2	0.3	0.1	0.2	0.1	0.2	0.1	0.1														
	Tywi	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.1															
	Usk	0.3		0.3	0.4		0.4	0.3	0.3	0.5	0.3	0.4	0.3													
	W Cleddau	0.5	0.3	0.3																						
	Wye	0.7		0.6	0.4	0.4	0.5	0.1	0.1		0.4	0.2	0.2	0.4	0.3	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	

Channel	River	Section																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Minor tributary	**Total**	0–10	0–9	0–8	0–6	0–5	0–5	0–3	0–3	0–2	0–3	0–3	0–2	0–2	0–1	0–1	0–1	0–1	0–1	0–1	0–1	0–1	0–1	0–0	0–1	0–0
	Clwyd	0.1	0.0	0.0	0.0	0.0	0.0																			
	Conwy	0.0	0.0	0.0	0.0	0.0																				
	Dee	0.5	0.3	0.1	0.2		0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0										
	Dyfi	0.1	0.0	0.0	0.0	0.0																				
	E Cleddau	0.1	0.1	0.1																						
	Mawddach	0.0	0.0	0.0																						
	Teifi	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0													
	Tywi	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0															
	Usk	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1												
	W Cleddau	0.0	0.1	0.0																						
	Wye	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0

Table 13. Modelled distribution of **goosander** in the ten principal salmonid rivers. For main channels, sections are 10km long and numbered sequentially from the mouth (i.e. section 1 contains the first 10km upstream from the mouth). For tributaries, sections are numbered according to the main channel section with which they form a confluence. Tributary sections were modelled using their actual length (which varied between 0.2–10 km. Per-river estimates are not given for minor tributaries because the population estimate for Goosander on minor tributaries was zero).

Channel	River	Section																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Main channel	**Total**	5–84	3–75	3–64	1–51	2–45	2–36	2–36	2–32	2–30	2–32	2–26	2–25	2–22	1–15	2–17	1–11	1–8	1–8	1–8	1–9	1–8	1–8	1–9	0–6	0–5
	Clwyd	2.2	1.5	1.0	0.7	0.4	0.2																			
	Conwy	1.3	1.2	1.2	1.2	0.6																				
	Dee	2.2	2.3	2.5	2.5	2.7	2.8	2.9	3.1	3.1	3.4	3.5	3.6	3.8	3.4	4.2	0.9									
	Dyfi	4.8	3.6	2.7	2.0	1.1																				
	E Cleddau	2.9	2.5	1.3																						
	Mawddach	1.0	0.5	0.1																						
	Teifi	4.0	3.2	2.6	2.1	1.7	1.3	1.1	0.9	0.7	0.6	0.4	0.3													
	Tywi	4.7	4.4	4.0	3.7	3.5	3.2	3.0	1.7	1.0	2.0															
	Usk	5.5	5.5	5.3	5.2	5.0	5.0	4.9	4.7	4.6	4.5	4.4	3.1	2.6												
	W Cleddau	2.9	2.5	2.2	0.4																					
	Wye	3.8	3.8	3.9	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.0	4.0	3.9	4.0	4.0	4.1	4.0	4.1	4.1	4.1	4.1	2.6	1.6
Major tributaries	**Total**	0–36	0–20	0–27	0–21	0–11	0–15	0–14	0–11	0–9	0–14	0–11	0–10	0–8	0–6	0–6	0–4	0–3	0–4	0–4	0–3	0–3	0–4	0–3	0–4	
	Clwyd	0.8	0.3	0.3	0.3																					
	Conwy	0.3	0.1	0.3	0.3																					
	Dee	0.7	0.3	0.6	0.6	0.7	0.9	0.8	0.7	0.6	0.9	0.8	0.8	0.9	0.6	0.9										
	Dyfi	1.1	0.8	0.5	0.5																					
	E Cleddau	0.7	0.4	0.6																						
	Mawddach	0.3	0.1																							
	Teifi	1.1	0.6	0.8	0.4	0.6	0.2	0.3	0.1	0.3	0.1	0.1														
	Tywi	1.4	1.1	0.9	1.2	0.8	1.0	0.7	0.6	0.4	0.9															
	Usk	1.0		0.9	1.4		1.3	1.1	1.0	1.5	1.0	1.2	1.1													
	W Cleddau	0.8	0.6	0.7																						
	Wye	1.3		1.4	1.1	1.0	1.3	0.3	0.4		1.5	0.8	0.9	1.6	1.4	1.0	1.2	0.6	1.4	1.1	1.0	0.9	1.5	0.9	1.3	

4. Discussion

Difference between survey records and modelled populations

The high mobility and low density of these two species in winter (as expected from their ecology), combined with a history of active human intervention (scaring, shooting), means that survey observations should be expected to represent an underestimate of the real population. Birds were observed to respond to the presence of observers by moving (flying up- or down-river) and if actively fishing, a walking survey carries a small risk of missing submerged birds in deeper water. Obvious instances of likely double-counting (groups of birds observed after flushing on a successive river reach) were removed from the model dataset before analysis.

Summing survey observations also carries a significant risk of over-estimation, since groups of birds may be observed (and counted) on successive river reaches or successive days. The main-channel repeat survey data was used to test assumptions about relative density as a function of distance from the river mouth, and also to provide an additional test of predicted density based on the December survey: model assumptions were found to be reliable and to agree with the findings of Taylor and Noble (2017). In addition, the modelled distribution predictions made using the December survey agreed with observed densities recorded during the repeat surveys of the main-channels in January and February, indicating that survey timing was appropriate, and the birds had not begun either international migrations or dispersal upriver before the end of the field survey.

Spatial distribution

In the Dee survey (Taylor and Noble, 2017) 95% of the bird records were from near-estuary lower reaches of the river. This view supports known ecological behaviour of the two focal species (*pers comm*. BTO expert panel). Similarly, in the present survey, bird densities were much higher in the main channel than in the tributaries, and the majority of records were within 50km of the estuary spatial reference (start point of the river survey). One implication of this observed estuarine distribution bias might be that future resurvey effort could be focused on the 50km of river main-channel starting at the upper limit of estuarine WeBS counts, rather than covering a greater extent of the main channel and tributaries. It would be possible to model the proportion of the riverine wintering population expected to be surveyed using such an informed spatial targeting approach, which could reduce the costs of resurvey potentially quite significantly.

The population modelling output for tributaries takes these lower densities and extrapolates from the surveyed tributary sections to the entire catchment based on available river GIS data, producing a whole-catchment estimate that assumes all tributaries are equally attractive to birds (relative to their length and distance from the sea and the main river channel). It may be possible in future to use this modelling approach to reduce the survey effort required for monitoring change (for example as a consequence of changed management practices), assuming that relative densities do not also change over time or as a response to changes in fish availability. However, this assumption requires caution, since both cormorant and goosander are generalist predators and overall conservation status, and fish availability will likely change over time and differ between rivers and tributaries. An additional complication is the availability of attractive resources in the form of stocked stillwaters. In particular, the stillwater analysis highlighted the importance of this resource for goosander.

Modelling WeBS data for the winter of 2020-21

In a normal year, estuarine data for cormorant and goosander would be available as an output of the WeBS Survey, coordinated by BTO and performed by a network of volunteers. WeBS might also have provided a comparator dataset for some of the stillwaters surveyed by NRW and BTO staff. However, volunteer surveys were suspended in Wales for most of the winter and WeBS coverage was therefore rather poor.

Summary information in the form of annual and monthly peak counts and long-term trends are available for the estuaries of all ten rivers surveyed, although several of the WeBS sites actually combine the estuaries of more than a single river. These long-term historic and standardised datasets provide an opportunity to consider the proportion of wintering birds likely to be continental migrants (by comparing mid-winter and late-winter numbers) but also to predict more complete WeBS count data from historic trends. An additional variable is continental winter temperature, which is thought (at least in extreme winters) to drive a greater migration of continental birds to British coastlines. This effect is different in cormorant and goosander. Here, goosander in Wales is considered to be mostly sedentary, performing local seasonal breeding dispersal inland combined with moult-migration (particularly in males), but not being supplemented by continental wintering birds which are thought to be more numerous in English and Scottish estuaries. Whereas Welsh breeding cormorant are predominantly coastal-breeding *carbo* birds, strongly supplemented in winter by estuarine continental *sinensis* (the two are not easily distinguished in the field). Without improved understanding of spatial movement and population turnover in Welsh wintering birds (for example through colour-marking or tagging studies) it is very difficult to calculate the proportion of the wintering flock that represents Welsh breeding birds; and the breeding population in Wales is thought to be either stable or gradually declining even in the absence of additional control activities.

Predicted (modelled) WeBS counts for the major estuaries were calculated for both cormorant and goosander in December and January 2020-21. The confidence interval for the cormorant estuarine population estimate was 1500 birds ±6%, representing just over half of the total Welsh wintering population estimate and highlighting the importance of WeBS surveys in cormorant monitoring. For goosander, estuarine birds represented a very small proportion (~4%) of the total population estimate, and the confidence interval was consequently rather large (±30%). WeBS alone is therefore unlikely to provide the best tool for monitoring changes in goosander populations over time.

Differences in the use of stillwaters between cormorant and goosander

There were important differences in stillwater use between cormorant and goosander, and these have notable implications in understanding both populations and stillwater predation risk. However, it is important to consider the assumptions and decisions made in analysing the stillwaters data before discussing data gaps.

Cormorant are considered to roost predominantly in trees (at least in winter) rather than on waterbodies. Birds counted during stillwater surveys were recorded on water (behaviour unknown) as well as actively fishing; but since any cormorant using water is most likely to be on a foraging visit than performing non-foraging activities (as their plumage is not waterproof) most records were considered to be foraging birds and all records included in the population models. It was assumed that all cormorants were considered to be additional to birds counted on rivers.

In contrast, goosander may roost on water. The primary consideration for this species was to avoid double-counting, for instance birds counted on a stillwater at dawn or dusk that commute to nearby river reaches and are there counted by the river survey team. Birds recorded on stillwaters during the noon survey period were considered least likely to be double-counted on rivers, since river surveyors would be active through noon but less likely to be counting at dawn or dusk (for safety and logistical reasons). Goosander numbers are therefore a conservative addition to the overall population estimate.

It is interesting therefore to see the very different proportions of the modelled goosander and cormorant populations associated with stillwaters. For cormorant, the all-records approach only added 6% (184 birds) to the overall population estimate, while for goosander the conservative approach still produced 416 birds or 28% of the winter population. The impacts of these birds on fish populations (a complex function of fish species and size/age class selection, availability and vulnerability, timing and many other factors) is also likely to differ through the year, depending on fish demography (i.e. the selection of fish in density-dependent or density-independent age classes) and, fundamentally, the accuracy or otherwise of our assumptions about birds' behaviour around stillwaters and rivers. Avian predation pressure on stillwaters is also much more easily managed than in rivers, so the importance of stillwaters as a resource for piscivorous birds is very likely to change over time and differ between managed and unmanaged sites. There is an urgent need to better understand both cormorant and goosanders' use of stillwaters relative to rivers, their spatial behaviour around and between these different resources and their response to activities intended to reduce local predation pressure. Spatial studies involving colour marking and/or tracking work would be a very informative approach to understanding these issues in future.

Extrapolation to all-Wales estimates

Only ten rivers were surveyed; representing 20% of the rivers listed in the Welsh Rivers spatial dataset on Lle (www.lle.gov.wales). Extrapolation from this survey to all-Wales therefore requires a set of critical assumptions – essentially, that bird distributions in 39 un-surveyed rivers have similar distributions and densities to the ten surveyed principal rivers. However, the ten rivers surveyed were selected because they are conservation critical, i.e. Principal Salmonid Rivers, where Wales' salmon and trout populations are found. However, such rivers might be expected to be subject to effective and long-term conservation efforts such as bird management activities (shooting, scaring, refugia) or the provision of improved resources to fish. Interventions might include bank structure, water quality improvements, removal of barriers to fish movement (hard landscaping including dams and weirs) and more limited abstraction. Better conditions for fish, whether salmonids or other freshwater species, might be expected to improve the availability and quality of all fish species as well as larger invertebrates (a critical resource for young goosander) making them attractive to generalist piscivores and biasing both fish and predator distributions. Alternatively, both cormorant and goosander are generalist predators rather than salmonid specialists, and in winter cormorant at least are primarily marine or near-estuary. Bird densities in un-surveyed rivers relative to the surveyed rivers may instead be a reflection of overall fish availability, including all the coarse fish species, marine species (particularly flatfish in the case of cormorant) and eels as well as migrating salmonids.

Testing the assumption that bird densities in the un-surveyed rivers are similar to the surveyed rivers is required for extrapolation to national estimates but requires some further supporting information. It would be appropriate in future to revisit the bird survey data for these ten surveyed rivers in light of any and all available fish data for these and the un-surveyed rivers. More refined cormorant and goosander winter population modelling might then include predicted densities based on fish availability or (in the absence of fish data) other potential predictors of prey availability such as water quality, river structures or bank vegetation; and even fish behavioural metrics such as migration or spawning locations. The vulnerability of fish populations to predation, and the impact of that predation on fish population trends, is a complex combination of factors including not only predator numbers but also the availability of alternative prey species, the timing of demographic events (breeding, migration) in both species, the specific factors driving population change (breeding success, recruitment, migratory survival, annual survival) and the impacts of anthropogenic change and abiotic factors on these variables. The freshwater and marine environments are affected independently by human behaviour and climate change, and both have impacts on both birds and fish.

Comparison with previous population estimates

The country-level population estimates combining river, stillwater and estuary birds may be compared with previous population estimates generated from independent datasets (APEP4 estimates from Atlas and trends data, Woodward *et al*. 2020).

For cormorant, APEP4 and Atlas proportional methods predict a Welsh wintering population of 5,332 - 5,642 birds, while the present method produces a total estimate for rivers, stillwaters and estuaries combined of 2,894 birds. There are several potential sources for this difference, which can be summarised as follows:

- Differential cormorant trends in UK/GB and Wales, reducing accuracy of the Atlas proportional estimate method. Cormorant trends in England broadly reflect the UK/GB trend, with increasing populations that have recently become less positive (possibly in response to increased lethal control in England). Welsh breeding cormorants, the majority of which are coastal-breeding *carbo*, have declining productivity and a stable population: wintering populations are therefore likely to be more sensitive to continental population trends (recovering from historic controls) and unstable weather patterns (cold winters) than to UK trends.

- Datasets used for these calculations are designed more appropriately for area-survey (tetrads) than linear features (waterways) and may also be vulnerable to double- or under-counting due to the birds' response to observers and previous experience of intentional disturbance or control activities. Disturbance considerations also apply to the rivers survey method used by BTO, which would tend to slightly reduce the resulting population estimates.

- Atlas data are now ten years old. Differential trends in Wales, England and GB will by now have changed the proportion of the GB populations associated with England and Wales.

- Modelling and extrapolation assumptions. If un-surveyed rivers support higher densities of cormorant than the Principal Salmonid Rivers surveyed, or if a much greater proportion of cormorant are outside the major estuaries modelled here, the

national estimate produced would be smaller than the APEP estimate which is based on a large spatial scale of survey (Atlas coverage is not limited to defined rivers and catchments).

For goosander, APEP4 and Atlas proportional methods predict a Welsh wintering population of 1,261-1,522 birds, while the present method produces a total estimate for rivers, stillwaters and estuaries combined of 1,460 birds. This close agreement between the estimates implies that the modelling assumptions made are broadly appropriate, at least in providing estimates consistent with a larger (although less focused) survey method.

Further analysis / future recommendations

Some data gaps were identified, and assumptions made during the survey design, analysis of survey data and consideration of results, and these are summarised below:

Predator population is not necessarily an accurate reflection of predation risk or impact.

Both cormorant and goosander are generalist predators, at population level thought to take any species of an appropriate size based on availability (although individuals may specialise). Declining fish diversity combined with the focused conservation of a single species or guild (salmonids) may increase the vulnerability of that species or guild to predation by allowing the availability of alternatives to decline.

Fish availability and river condition might underpin better bird population estimates for un-surveyed rivers.

In extrapolating from surveyed to un-surveyed rivers, modelling bird density based on a more sensitive suite of metrics including prey availability and/or river condition might yield better bird population estimates, particularly for cormorant. The assumption is currently that all rivers are equally attractive and provide comparable resources to piscivores, but this assumption may be weak given the importance of the ten surveyed rivers in conservation terms.

Predation pressure will differ between the winter season and other times of the year (e.g. the bird breeding season or the smolt-run).

Bird distributions and densities would be expected to change markedly, since cormorant are predominantly coastal breeders with an extended and colonial breeding season, while goosander breed high in the catchments and in a shorter period and are markedly restricted to rivers as the chicks and females are flightless through June and July and the males absent. Fish vulnerability and the age classes targeted by birds will also change as the season progresses. For the purpose of demographic modelling, these changes need to be informed by additional survey effort particularly during the breeding season.

Birds' movements are relatively poorly understood.

Cormorant and goosander are highly mobile and responsive species but their use of different water resources (rivers and stillwaters), seasonal in-country movements and responses to disturbance of various sorts are poorly understood. Critical questions exist

around how and under what circumstances the birds use stillwaters, how they respond to disturbance events of different types, intensities and durations, and how their spatial behaviour changes annually and seasonally. Well-designed colour marking and/or tagging studies could provide very valuable information to inform not only population modelling but also management activities.

5. References

Balmer, D., Gillings, S., Caffrey, B., Swann, B., Downie, I. and Fuller, R. 2013. *Bird Atlas 2007-11: The Breeding and Wintering Birds of Britain and Ireland*. British Trust for Ornithology. ISBN: 978-1908581280, 720pp.

Bregnballe, T., Lynch, J., Parz-Gollner, R., Marion, L., Volponi, S., Paquet, J.-Y., Carss, D.N. and van Eerden, M.R. (eds.) 2014. Breeding numbers of Great Cormorants Phalacrocorax carbo in the Western Palearctic, 2012-2013. IUCN-Wetlands International Cormorant Research Group Report. Aarhus University, DCE – Danish Centre for Environment and Energy.

Carss, D.N., Parz-Gollner, R. and Trauttmansdorff, J. 2012. *The INTERCAFE Field Manual: research methods for cormorants, fishes, and the interactions between them.* INTERCAFE COST Action 635 Final Report II (ISBN 978-1-906698-08-9)

Cefas, Environment Agency and Natural Resources Wales. 2019. Salmon stocks and fisheries in England and Wales, 2019 - Preliminary assessment prepared for ICES, March 2020, 90pp. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/907284/SalmonReport-2019-summary.pdf

Chamberlain D.E, Austin G.E. Green R.E, Hulme M.F. and Burton N.H.K. 2013. Improved estimates of population trends of Great Cormorants Phalacrocorax carbo in England and Wales for effective management of a protected species at the centre of a human–wildlife conflict. Bird Study Vol. 60, Iss. 3, 2013

Defra. 2013. Evidence summary. Review of fish-eating bird's policy.

Frost, T.M., Austin, G.E., Calbrade, N.A., Holt, C.A., Mellan, H.J., Hearn, R.D., Stroud D.A., Wotton S.R. and Balmer D.E. 2016. Waterbirds in the UK 2014/15: The Wetland Bird Survey. BTO, RSPB and JNCC, in association with WWT. British Trust for Ornithology, Thetford.

Harris, C. M., Calladine, J., Wernham, C. W. and Park, K. J. 2008. Impacts of piscivorous birds on salmonid populations and game fisheries in Scotland: a review. Wildlife Biology, 14(4), 395-411.

Humphreys, E.M., Gillings, S., Musgrove, A., Austin, G., Marchant, J. and Calladine, J. 2016. An update of the review on the impacts of piscivorous birds on salmonid populations and game fisheries in Scotland. Scottish Natural Heritage Commissioned Report No. 884

Marzano, M. and Carss, D.N. 2012. Essential social, cultural and le.g.al perspectives on cormorant-fisheries conflicts. INTERCAFE COST Action 635 Final Report IV (ISBN 978-1-906698-11-9)

Musgrove, A.J., Aebischer, N.J., Eaton, M.A., Hearn, R.D., Newson, S.E., Noble, D.G., Parsons, M., Risely, K. & Stroud, D.A. 2013. Population estimates of birds in Great Britain and the United Kingdom. British Birds 106: 64-100.

Newson, S.E., Marchant, J., Sellers, R., Ekins, G., Hearn, R., and Burton, N. 2013. Colonisation and range expansion of inland-breeding Cormorants in England. British Birds, 106, 737-743.

NRW. 2020. A plan of action for salmon and sea trout in Wales – tackling the 'salmonid emergency'

Taylor, R. and Noble, D. 2017. Population estimates of non-breeding cormorant and goosander on the River Dee. Unpublished NRW Report.

Taylor, R. C., Austin, G., Boersch-Supan, P., Bowgen, K., Burton, N., Calladine, J., Noble, D., Robinson, R. 2022. Design of a 2020/21 winter census of cormorant and goosander in Wales: design and analytical approach. NRW Evidence Report Series (No. 598).

van Eerden, M.R., van Rijn, S., Volponi, S., Paquet, J-Y. & Carss, D.N. 2012. Cormorants and the European environment: exploring cormorant status and distribution on a continental scale. INTERCAFE COST Action 635 Final Report I. NERC/Centre for Ecology & Hydrology on behalf of COST, pp126.

Woodward, I., Aebischer, N., Burnell, D., Eaton, M., Frost, T., Hall, C., Stroud, D.A. and Noble, D. 2020. Population estimates of birds in Great Britain and the United Kingdom. British Birds 113: 69–104.

Appendix 1. List of stillwaters surveyed

Catchment	Name	Area. ha	E	N	OS
Clwyd	Marine Pond, Rhyl	12.70	299900	380400	SH999804
	Brickfields Pond	3.59	301277	380347	SJ012803
Conwy	Llyn Crafnant	24.53	274926	361054	SH749610
	Llyn Geirionydd	24.88	276325	360904	SH763609
	Llynnau Mymbyr	33.22	270808	357397	SH708573
	Llyn Elsi	10.50	278293	355226	SH782552
	Llyn Dulyn	13.74	270057	366556	SH700665
	Llyn Eigiau	49.75	272039	364991	SH720649
	Llyn Cowlyd	107.52	272802	362435	SH728624
	Ffynnon Lugwy	16.29	269250	362734	SH692627
	Llyn Conwy	38.79	277997	346224	SH779462
	Llyn Coedty	6.47	275463	366635	SH754666
	Llyn Goddionduon	5.66	275343	358613	SH753586
	Llyn y Cwrt - PRoW	5.16	290725	351269	SH907512
	Graig Fawr	6.61	270154	365674	SH701656
	Llyn Pen-y-Gwryd	7.11	266178	355808	SH661558
Dee	Llyn Celyn	330.86	285913	340422	SH859404
	Llyn Te.g.id	421.72	290869	333460	SH908334
	Llyn Arenig Fach	12.00	282767	341726	SH827417
	Llyn Arenig Fawr	35.19	284683	338039	SH846380
	Bottom Reservoir	1.61	327251	345383	SJ272453
	Top Reservoir	2.88	326741	345305	SJ267453
	Llyn Maes y Clawdd	1.37	297357	337739	SH973377
	Wynnstay Lake	3.66	330776	342865	SJ307428
Dyfi	Glaslyn	22.07	282611	294047	SN826940
	Llyn Craig Y Pistyll	10.20	272169	285822	SN721858
	Llyn Glanmerin	2.99	275564	299060	SN755990
	Lyn Barfog	1.38	265289	298760	SN652987
	Llyn Dwfn	1.20	273906	292611	SN739926
	Llyn Conach	7.20	275564	299060	SN755990
E Cleddau	Llys-y-fran Reservoir	76.06	203642	225073	SN036250
	Rosebush Reservoir	12.57	206251	229553	SN062295
W Cleddau	Heathfield Gravel Pits SM923311	5.75	192300	231100	SM923311
Mawddach	Llynnau Cre.g.ennen	10.51	266074	314373	SH660143
	Llyn Cynwch	9.48	273743	320764	SH737207
	Llyn Gwernan	4.63	270466	316033	SH704160
	Llynnau Cre.g.ennen	6.27	266058	314122	SH660144
	Llyn Tan-y-graig Reservoir	1.07	271184	320066	SH711200
Teifi	Llyn Berwyn	12.83	274303	256900	SN743568
	Lyn Teifi	17.82	278393	267536	SN783675
	Llyn E.g.nant	11.74	279347	267190	SN793671
	Llyn Pencarre.g.	8.65	253715	245624	SN537456
	Llyn y Gwaith	5.00	267155	250651	SN671506
	Llyn Hir	4.87	279013	267598	SN790675

Catchment	Name	Area. ha	E	N	OS
	Reservoir next to Lyn Teifi	2.55	277915	267721	SN779677
	Llyn Gorlau	3.29	278751	266972	SN787669
Teifi	Llyn Bach	2.16	278996	266844	SN789668
Tywi	Llyn Brianne	206.85	280128	250225	SN801502
	Llyn y Fan Fawr	10.53	283090	221695	SN830216
	Dinefwr Pools	1.19	260548	222068	SN605220
	Llyn Du (Tywi Forest)	2.50	276900	261200	SN769612
	Tywi Forest (east of Llyn Du)	1.50	275388	261329	SN753613
	Bishop's Pool	3.50	244568	220978	SN445209
Usk	Llande.g.fedd Reservoir	173.92	332911	199646	ST329996
	Usk Reservoir	116.89	282179	228550	SN821285
	Cray Reservoir	39.99	288266	221535	SN882215
	Talybont Reservoir	123.27	310000	219000	SO100190
	Ynys-y-Fro Reservoir	3.68	328123	189094	ST281890
	Ynys-y-Fro Reservoir (upper)	6.11	328436	189011	ST284890
	Liswerry Pond	1.40	334087	187647	ST340876
	Woodstock Pool, Brynglas (next Morgans Pool, 693)	1.30	329972	190017	ST299900
	Morgans Pool, Brynglas (next Woodstock Pool, 765)	3.16	329838	189835	ST298898
	Pant-yr-eos Reservoir	6.30	325630	191562	ST256915
	Trede.g.ar Lake	4.60	328915	185536	ST289855
Wye	Llyn Syfadden	123.09	313273	226491	SO132264
	Cronfa Ddwr Craig Goch	88.88	289656	269776	SN896697
	Cronfa Ddwr Penygarre.g.	48.73	290273	267682	SN902676
	Cronfa Ddwr Claerwen	268.12	285101	265071	SN851650
	Cronfa Ddwr Garre.g.-Du	83.48	291131	265064	SN911650
	Caban-Coch Reservoir (lower)	115.32	291712	263434	SN917634
	Dolymynach Reservoir	10.83	290596	261639	SN905616
	Llan Bwch-llyn Lake	10.01	311913	246334	SO119463
	Llyn Fyrddon Fawr	14.00	280015	270741	SN800707
	Llyn Gynon	25.76	279953	264653	SN799646
	Llandrindod Lake	6.13	311824	247581	SO118475
	St Pierre Lake	4.35	351261	190517	ST512905
	Marsh's Pool	5.50	292700	281100	SN927811
	Llyn Alarch	1.00	302688	250629	SO026506

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