Cyfoeth Naturiol Cymru
Natural Resources Wales

# 2020/21 winter census of cormorant and goosander in Wales: design and analytical approach

Report No: 598

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# Contents

# Crynodeb Gweithredol

Mae effeithiau posib adar sy'n bwyta pysgod, ar bysgodfeydd gwyllt a physgodfeydd wedi'u stocio wedi cael cryn sylw gan lawer o astudiaethau gwyddonol yn y DU ac mewn mannau eraill yn Ewrop. Mae'r astudiaethau hyn yn awgrymu, ar lefel safleoedd, y gall adar sy'n bwyta pysgod fel mulfrain *Phalacrocorax carbo* a hwyaid danheddog *Mergus merganser* gymryd nifer fawr o bysgod o bysgodfeydd naturiol a mewndirol.

Mae ar CNC angen dull cyfrif cadarn sy'n addas i'r diben er mwyn pennu amcangyfrifon o boblogaethau mulfrain a hwyaid danheddog sy'n gaeafu yng Nghymru. Bydd amcangyfrifon o'r fath yn helpu gwaith modelu demograffig i asesu effeithiau mesurau rheoli trwyddedig ar boblogaethau mulfrain a hwyaid danheddog sy'n gaeafu, gyda'r nod o gefnogi gwaith i warchod salmonidau ac atal difrod difrifol i bysgodfeydd dŵr llonydd. Mae CNC wedi nodi deg prif afon yng Nghymru o ran salmonidau mudol, lle mae angen cyfrif niferoedd mulfrain a hwyaid danheddog (Gwy, Wysg, Tywi, Cleddau Ddu a Chleddau Wen, Teifi, Dyfi, Mawddach, Conwy, Clwyd a Dyfrdwy). Mae hyn yn cynnwys pedair afon (Gwy, Wysg, Teifi, a Dyfrdwy gyda Llyn Tegid) a ddynodwyd yn Ardaloedd Cadwraeth Arbennig (ACA) lle roedd eogiaid ymhlith y prif resymau dros ddewis y safleoedd.

Mae'r adroddiad hwn yn cyflwyno pedwar opsiwn i CNC eu hystyried o ran dyluniad y cyfrifiad, sef:

i) Prif sianel yr afon.
ii) Prif sianel yr afon + ailarolygu 50%.
iii) Prif sianel yr afon + ailarolygu 50% + arolygu 25% o isafonydd y dalgylch.
iv) Prif sianel yr afon + ailarolygu 50% + arolygu 33% o isafonydd y dalgylch.

Cyfrifwyd costau'r opsiynau ac fe'u cyflwynwyd i CNC i'w hystyried. Ni ddatgelir y rhain yn yr adroddiad hwn.

# Executive summary

The potential impacts of 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 such as great cormorant *Phalacrocorax carbo carbo* ("cormorant") and goosander *Mergus merganser* can take large numbers of fish from natural and inland stocked fisheries.

NRW require a robust and fit for purpose census method to determine wintering population estimates of cormorant and goosander for Wales. Such population estimates will aid demographic modelling to assess the impacts of licensed control on wintering cormorant and goosander populations, intended to support salmonid conservation and prevent serious damage to stillwater fisheries. NRW has identified ten principal migratory salmonid rivers in Wales that require a census of cormorant and goosander (Wye, Usk, Tywi, Cleddaus' (eastern and western), 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.

This report presents four census design options for NRW to consider, these are:

v) Main river channel.
vi) Main river channel +50% resurvey.
vii) Main river channel +50% resurvey +25% survey of catchment tributaries.
viii) Main river channel +50% resurvey +33% survey of catchment tributaries.

Option costings were calculated and presented to NRW for consideration. These are not disclosed in this report.

# 1. Introduction

Atlantic salmon (*Salmo salar*) and many sea trout (*Salmo trutta*) populations have been in decline for many years, and both are now considered to be endangered fish species of high conservation concern. Both species are fully protected by law and Atlantic salmon (‘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 three 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.

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 (‘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 great cormorant (*Phalacrocorax carbo*) (‘cormorant’) and goosander (*Mergus merganser*) 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 & 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 advocacy paper was recommended to develop such a policy.

All wild birds in Wales have legal protection. NRW has a number of powers under which to 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. As the licensing authority, NRW assess and issue licences to shoot a limited number 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. 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 (NRW, 2020). 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 Advisory Group to assess the position in Wales and advise on the suite of actions required. To meet this challenge, in July 2018 NRW established a Fish-eating Birds Advisory Group ('the Advisory Group') consisting of a multi-disciplinary team from NRW and external interest groups.

NRW has identified ten principal migratory salmonid rivers in Wales (Wye, Usk, Tywi, Cleddaus' (eastern and western), 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. Fish stocks in each of these rivers have declined significantly and are below safe biological limits and potentially at risk from predation by fish-eating birds as a factor limiting populations or suppressing stock recovery.

To inform the work of the Advisory Group, a robust Wales population estimate of non-breeding (wintering) cormorant and goosander was sought. Specifically, this work:

- Appraises whether the Taylor and Noble (2017) method is appropriate to survey wintering cormorant and goosander across ten principal rivers in Wales.

- Develops a robust, fit for purpose census design to undertake winter cormorant and goosander surveys across the ten principal salmonid rivers/catchments in Wales and includes an appraisal of whether a randomised sampling of tributaries is required to establish precise population estimates at the catchment scale.

- Provides 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.

- Provides costings for catchment surveys in winter 2020-21 for each of the ten salmonid rivers. Cost were presented to NRW for each river and survey methods (e.g. main-channel census method main channel-plus-stratified-sample method), these are not presented in this report.

- Develops a working method for surveying wintering cormorant and goosander at stillwater fisheries for a range of waterbody sizes.

# 2. Method

### 2.1 Appraisal of Taylor and Noble (2017) survey method

An expert team of senior BTO Conservation Science 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 Taylor and Noble method was for a survey of cormorant and goosander on the main River Dee channel from the estuary to Llyn Tegid (Bala Lake) and is summarised below:

- The River Dee cormorant and goosander survey was completed in 15 person-days over an eight-day period beginning 24th January 2017.
- Coverage of the lower river was considered the highest priority for wintering birds.
- Two experienced BTO fieldworkers surveyed the main channel of the Dee River (plus the parallel reach of the Llangollen canal) starting from the upper limit of the Dee Estuary WeBS area at 3°2’52.7”W 53°13’18.7”N, and travelling upstream to Pont Mwnwgl-y-llyn at the eastern end of Llyn Tegid, 3°35’34.8”W 52°54’9.7”N.
- Complete coverage of the survey area and concentration of effort into a short period was a planned strategy to minimise double-counting.
- Surveyors walked one bank of the river channel, recording all observations of the target species (cormorant, *P. carbo carbo* / *P. carbo* sinensis and goosander) either on the river, riverbanks or visible (e.g. flying over).
- Behaviour was noted, as was sex (goosander). If a section of the river was not accessible for reasons of refused or absent 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.

The BTO expert team considered its appropriateness for catchment surveys and its ability to provide data underpinning precise river and catchment population estimates for Wales. BTO addressed this task by:

Appraising the method applied by Taylor and Noble (2017) for a multi-river census of cormorant and goosander. Here, this survey method in terms of its appropriateness was examined for:

i) Surveying the entire length of each of the ten principal salmon rivers in Wales (see Appendix 1: App. 1. Figure 1, and App. 1. Table 1).

ii) Calculating and up-scaling a population census of the main river channel to provide a robust full-catchment wintering population estimate for the two species, with 95% confidence intervals.

**2.2 Census design**

Developing a cormorant and goosander census design of ten catchments in Wales involved:

- Developing a method and supporting documentation for any requirement to survey additional areas to the main river channel in each catchment. If additional (e.g. tributary) sampling is considered necessary, provide an indication of sampling effort required (i.e. how many tributaries and survey length) to generate a precise population estimate of cormorant and goosander at the catchment scale.

- Providing 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 were required to be precise to inform future population modelling work.

- Provide options and costings for delivering catchment census in winter 2020-21 for each of the ten salmonid rivers. Costs were determined separately for i) main-channel census method, main river channel plus repeat census and ii) main channel-plus-stratified-sample method. All costs were presented to NRW and are not included in this report.

*Statistical methods used in assessing options for survey design*

Assuming the 2017 River Dee survey data is representative of main-channel goosander and cormorant wintering distributions in Wales, BTO's Ecological Statistician and Research Ecologists addressed four specific questions:

a) What are the implications (in terms of statistical confidence in the resulting population estimate) of surveying 10km river survey units either i) in random order or ii) systematic geographic sequence (i.e. upstream from estuary to source)?

b) Is there any statistical benefit to in-season repeat samples in the main-channel survey, and if so, what are the benefits of different amounts of resurvey effort in terms of statistical confidence in the population estimate?

c) What information can be extracted from the BTO Winter Atlas datasets to assess the importance of surveying more than the main river channel, with the ultimate aim of robustly assessing goosander and cormorant populations at catchment and (potentially) Wales national spatial scales?

d) Are there any useful conclusions at this stage about the consequences of different-sized confidence intervals around the resulting population estimates, in terms of modelling population response to future licensed control activities?

To determine required survey effort, the BTO reviewed the GIS data available for Welsh rivers and catchments, and the spatial data and map provided by NRW so as to understand the GIS resources available for survey planning, and to provide information on the extent of tributary waterways in each of the ten catchments.

### 2.3 Stillwaters survey design

An expert review panel (see authors list), supplemented by BTO's WeBS National Organiser considered appropriate methods for surveying stillwaters by NRW staff. Here, the panel discussed the strategic and policy importance of natural and manmade stillwaters, and their potential impact on fish-eating bird populations as potential resources and refugia. The review panel also discussed what is known about stillwaters selection by cormorant and goosander, and how this might best be addressed in designing a survey method. It was determined the likely uses of stillwater survey data included some or all of the following:

i) Understanding and modelling the distribution of fish-eating birds away from the main river channels in winter.
ii) Understanding and modelling diurnal and spatial behaviour including flocking and roosting behaviour in winter.
iii) Modelling relative densities in catchments where river and tributary sampling is not undertaken, for robust national population estimation.
iv) Improving understanding of the resource selection and foraging behaviour of fish-eating birds.
v) Improving understanding of birds' responses to disturbance including control activities during the river surveys.

The review panel noted that expert opinion suggests cormorant and goosander travel between water resources differently, with cormorant likely to fly directly from site to site 'across country' and goosander more likely to follow watercourses. If true, this behavioural difference may have an impact on how the two species perceive water resource connectivity. The panel also noted that birds' use of stillwaters may be more complex and diurnally structured than their use of flowing water, and the stillwater survey method needs to take this into account.

# 3. Results

### 3.1 Appraisal of Taylor and Noble (2017) survey method

The Taylor and Noble survey method (Taylor and Noble, 2017) after review by an expert panel of BTO senior Conservation Scientists was accepted as appropriate for linear survey of waterways and as an appropriate compromise for surveying large-bodied and potentially highly mobile species such as cormorant and goosander. The panel noted the following specific points:

a. **Mobility of the target species.** 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 on population estimates can be reduced with an informed analytical and survey design approach.

b. **Spatial bias in wintering bird distributions** in the River Dee survey, 95% of the bird records were from near-estuary lower reaches of the river. This is in agreement with the known ecology of cormorant and goosander but introduces a significant potential source of statistical error unless taken into account in survey design.

c. **Unknown relative distribution (between main-channel, tributary and stillwaters) in winter.** The River Dee survey did not include stillwaters or tributaries to the main river channel. Taylor and Noble (2017) highlighted a general paucity of data on wintering fish-eating birds' interest in catchment and national population estimates will require up-scaling from linear river channel survey to area-based survey, with survey effort appropriately designed to take into account differences in movement behaviour between cormorant and goosander.

d. **Behaviour and sex recording may be important in later modelling work.** The additional information provided by recording sex ratios (goosander) and behaviour (activity and flight direction) may be important in understanding wider considerations relevant to the species' ecology, conflict with salmonid conservation, and the robustness of the population estimates.

The Taylor and Noble (2017) survey method was also accepted as an appropriate approach for surveying each 10km river survey unit by one surveyor in a day from one bank, walking upstream and mapping all encounters of the target species including recording sex ratio (goosander) and standardised behaviour recording (both species). Surveyors on the lower River Dee in winter 2017 could survey just over 10km of river per day. This survey unit and field method was considered to provide appropriate underlying data for population estimation.

The review panel agreed that further investigation was required to consider the impacts of mobility, spatial bias and unknown distribution bias on both the statistical approach and confidence in the resulting population estimates, particularly given the ultimate purpose of this survey in underpinning population and species control modelling and monitoring. Specific pilot analyses were designed to inform overall survey design and sampling strategy. The panel recognised that the mapped River Dee survey data (Taylor and Noble, 2017) provide an appropriate sample dataset for investigating distribution and statistical power in river surveys for goosander and cormorant, and the Winter Atlas (Balmer *et al.,* 2013) tetrad counts and interpolated density model outputs might provide independent information about catchment distribution in the two species. The panel recognised that the ultimate aim of the survey work is the provision of bird data to underpin population modelling, and therefore the implications of survey design and effort decisions on statistical confidence in population estimates for river, catchment and country need to be considered carefully and taken into account.

**Census design**

*Statistical methods used in assessing options for survey design*

Full details of the statistical analysis are presented in Appendix 2. In summary, the mapped observations of cormorant and goosander from the River Dee survey (Taylor and Noble, 2017) were assigned to 10km stretches of main river channel (surveyor-day units) and the river population modelled using a Poisson Generalised Linear Model (GLM). In the absence of pilot data, bird distribution in tributaries was assumed to be similar to distribution in the main channel.

In order to understand the potential impacts of expected uncertainty in the population estimates, we calculated the confidence interval around the ‘true’ proportion of the population that would be removed for a given nominal level of control. Given the lack of data on the proportion of birds of either species found in tributaries (and stillwaters) vs. the main-channel survey, the results should be interpreted as ‘best-case’ and ‘worst-case’ scenarios until adequate data are available.

### 3.2 Method and supporting documentation for tributary survey

*Winter Atlas data as a proxy for tributary pilot data*

BTO Atlas datasets are designed to deliver comprehensive long-term data on changes in bird density and spatial range across the UK and Ireland. Data collection is based on structured survey of 2x2km squares (tetrads) and analysis may be based on tetrad or hectad (10x10km) data. This data collection represents an effective compromise for most species but is not targeted specifically for birds using linear features such as waterways. The BTO did not undertake a full analysis of the waterway’s datasets (WeBS, WBBS) or the unstructured datasets (BirdTrack), this was out of scope of this work, although these datasets will be required for any future population modelling work.

Given this caveat, a first approximation was made of the relative distribution of cormorant and goosander between main-channel and tributary areas of river catchments by extracting Winter Atlas data and identifying a) tetrads and b) hectads that contain part of the main channel of an identified river. It was noted that many main-channel squares contain significant amounts of tributary waterways. The data are presented in maps in Appendix 3. The coastal bias of both cormorant and goosander records is as expected from the species' ecology (Taylor and Noble, 2017) but inland records are not strongly biased towards tetrads including main-channel rivers. This supports the importance of improving understanding of winter inland distributions through new systematic survey.

*Notes on survey method selection*

***Pilot data for tributaries -*** No pilot data for Welsh rivers of sufficient resolution to predict the exact proportion of the wintering population of cormorant or goosander is available. Licence applications analysed in the River Dee survey (Taylor and Noble, 2017) suggested significantly more birds were recorded by licence applicant in the river catchment than was surveyed by BTO surveyors. Extracts from Breeding Bird Atlas data (see Appendix 3 App. 3 Figure 2 for cormorant and App. 3 Figure 3 for goosander) suggest that both cormorant and goosander are found more widely in surveyed tetrads than would be expected if they were restricted to the lower main river channels.

*Field method statement for tributary survey*

Tributaries to each surveyed river main channel will be numbered at their entry point to the main river channel, starting at the downriver georeference provided by NRW and ending at the upstream georeference provided by NRW. Tributaries (including the main channels of major tributaries) will be selected systematically to cover the geographic catchment and assigned to survey segments such that 25% or 33% of tributary watercourse to the assigned main river channel is surveyed once.

The field method for tributary survey would be similar to that for the main channel, except that additional logistical and sampling considerations would apply. 10km river-length survey units would be identified and mapped before the start of the fieldwork period. Surveyors would walk one bank of the river channel, recording all observations of cormorant and goosander either on the river, on riverbanks or visible (e.g. flying over). Behaviour of all individuals will be recorded, along with sex (in the case of goosander). If a section of the river is not accessible, e.g. for reasons of topology, refused access permissions, surveyor safety etc. it will be recorded as 'not surveyed'. Each observation will be mapped onto OS map sheets and the data later transferred to a GIS in ArcMap.

It is possible that taking a partial approach, i.e. surveying only the main channel (with resurvey) of some rivers, and performing a full survey including tributary coverage in others might provide some gains in terms of estimate confidence for all catchments. Without at least some tributary survey the assumptions underlying scaling-up from river channel to immediate catchments and thence to management catchment, region or country will lead to significant uncertainty in population estimates and an increased urgency for further surveys in the future.

### 3.3 Survey suitability, logistical and analytical comparisons

*Considerations on choosing overall survey design*

***Dee survey as pilot data –*** The River Dee survey data from 2017 represent the only available winter riverine georeferenced dataset available for Wales, that is suitable for modelling survey design and the statistical implications of estimate error in this way. It is worth noting, however, that the georeferenced data in that survey agree with expert understanding of winter piscivore distributions on rivers across the UK. Cormorant form larger aggregations and are more numerous than the less numerous, less aggregated Goosander, but the distributions of both are notably biased towards the lower reaches of the surveyed river, closer to the estuary. It is therefore likely to be a reasonably representative distribution dataset for the purposes of winter survey design.

***Benefits of increased survey effort -*** Modelling using the Dee survey data suggested that there would be potentially very significant consequences (in terms of uncertainty around population estimates) to either a main-channel survey with no resurvey, or no tributary survey; and the increased error in population estimates will be propagated into any later population and control modelling work.

***Main-channel resurvey design -*** The modelling work included an assessment of sampling design in comparing systematic vs. random resampling of the main channel survey segments. Random sampling produces very similar errors around the population estimate for all sampling rates until they narrow significantly at 100% full repeat survey. For systematic sampling approaches (e.g. sampling every fourth, third or second segment along the entire length of the main channel) errors decrease progressively as the proportion of segments resurveyed increases. At 50% resurvey the 95% confidence intervals are similar to those 100% resurvey and further improvements are only seen in the coefficient of variation declining from ~7.3 to ~6.5% for cormorant and ~11.4% to ~10% for goosander (see Appendix 2: App. 2 Figure 1 for cormorant and App. 2 Figure 2 for goosander).

The implications of different survey designs have been presented in more detail in Table 1 and summarises the (modelled) implications in terms of error in the population estimates provided at main-channel and sub-catchment scales. It includes the implications of those errors as they are likely to propagate into uncertainty in the proportion of the actual populations of the two bird species controlled under a theoretical 30% licensed control scenario.

***Relative distributions of birds between main channels and tributaries*** - The modelled outcomes for main river channels and tributaries can be interpreted as 'best-case' and 'worst-case' scenarios for the impacts of the relative distribution of goosander and cormorant through catchments in winter, and for the implications of that distribution on survey outcomes and analysed population estimates. In the best-case scenario, survey finds all the birds on the main river channel during a survey including a high rate of in-season repeat survey. The distribution and analysis as the tightest errors in this modelling exercise (±6.5% for cormorant and ±10% for goosander), propagating into errors of around ±10% in licensed control scenarios. In the 'worst-case' scenario, survey finds wintering distributions for both species that are very strongly biased towards tributaries, so that population estimates suffer from the wider estimate errors in the tributary modelling exercise (±20-30%) which propagates into very significant uncertainty in the actual proportion of the population represented by a set licensed control limit. Under this scenario, an uncertain population estimate used to set a 30%-of-population control limit might actually lead to anything from 15% to 75% of the population being controlled.

**Table 1.** Summary of estimated error in population estimates, and propagated error on true control impacts (at 30% licensed control) for goosander and cormorant under different survey design options.

| Species | Survey target | Survey effort | Population estimate error | Propagated control error (30% control) |
|---|---|---|---|---|
| *Cormorant* | Main-channel | Single survey | 9.5% | ±15% |
| *Goosander* | Main-channel | Single survey | 14.5% | ±20% |
| *Cormorant* | Main-channel | 100% resurvey | 6.5% | ±5% |
| *Goosander* | Main-channel | 100% resurvey | 10% | ±10% |
| *Cormorant* | Main-channel | 50% resurvey | 7.5% | ±10% |
| *Goosander* | Main-channel | 50% resurvey | 12% | ±15% |
| *Cormorant* | Tributaries | 33% surveyed | 20% | -5%, <+15% |
| *Goosander* | Tributaries | 33% surveyed | 25% | -5%, <+30% |
| *Cormorant* | Tributaries | 25% surveyed | 25% | -10%, +15% |
| *Goosander* | Tributaries | 25% surveyed | 30% | -10%, +30% |
| *Cormorant* | Tributaries | 20% surveyed | 30% | -15%, +45% |
| *Goosander* | Tributaries | 20% surveyed | 35% | -15%, +40% |

These propagated errors would also have an impact on the required interval between this baseline survey and subsequent resurvey. As uncertainty increases, the importance of resurvey in ground-truthing and monitoring the consequences of management decisions made on the basis of uncertain evidence increases; and therefore, the interval before follow-up survey is required becomes shorter.

*Assumptions used in setting up survey scenarios for the tributaries*

Main channel length was cross-checked by tracing a continuous route between the start and end points provided by NRW based on the OS Open Rivers shapefile. For some rivers, additional digitising against an OS backdrop was necessary to extend the lower limit of the main channel from the OS Open Rivers data to the lower limit as defined by NRW coordinates. However, it proved extremely challenging to find appropriate tributary information for the rivers identified by NRW. Owing to the very short delivery timescale of the present contract, the following assumptions were made on the basis of time constraints and expected statistical requirements.

- River stretches mapped and georeferenced by NRW (see Appendix 1: App. 1 Figure 1 and App. 1 Table 1) are defined as the 'main channels' and all other watercourses including the main channel above the upper georeference are considered tributaries (see maps in Appendix 4).
- 'Major tributaries' are defined as watercourses flowing into the main channel (see above) with significant sub-catchments of their own; for example, the main river channel above the upper NRW georeference point.
- 'Tributaries' are defined as watercourses flowing into the main channel falling within the sub-catchment of the main channel (see maps in Appendix 4).
- Main channels, major tributaries and tributaries as defined above are included for each identified Important Salmonid River whether they are in England or in Wales
- All major tributaries will be surveyed only along their main channels, excluding their sub-catchment tributaries
- Tributaries selected for survey will be surveyed completely, including secondary tributaries

Table 2 presents a summary from the more complete river and tributary length data and estimates presented in Appendix 4 (see App. 4. Table 1).

**Table 2.** Length of river in km to be surveyed under different survey scenarios by catchment and main channel, major and minor tributaries as defined above. Where GIS measures of main-channel length were longer than data supplied by NRW, text is in red. For rivers marked with ** tributary and major tributary lengths are estimates (owing to insufficient time for full GIS measurement).

| River | Main channel | Tributaries and major tributaries | Main channel, +50% resurvey | Main channel with 50% resurvey, plus 25% tributaries | Main channel with 50% resurvey, plus 33% tributaries |
|---|---|---|---|---|---|
| Wye | 245 | 972 | 368 | 611 | 688 |
| ***Usk*** | 111 | 278 | 166 | 236 | 258 |
| ***Dee plus Llyn Tegid*** | 122 | 307 | 183 | 260 | 284 |
| Teifi | 117 | 376 | 176 | 270 | 300 |
| ***Tywi*** | 82 | 205 | 122 | 174 | 190 |
| Conwy | 42 | 157 | 63 | 102 | 115 |
| Dyfi | 48 | 258 | 72 | 137 | 157 |
| Clwyd | 50 | 154 | 75 | 114 | 126 |
| Mawddach | 24 | 90 | 36 | 59 | 66 |
| Cleddau (eastern) | 26 | 114 | 39 | 68 | 77 |
| Cleddau (western) | 31 | 83 | 47 | 67 | 74 |

Key findings for a **main-channel survey**, suggested:

1. Cormorant and goosander distributions are different from each other and strongly biased towards the lower reaches of the river (near the estuary).
2. A single-visit survey with no replication of the main channel only will produce population estimates with coefficients of variation (CV) of 9.5% for cormorant and 14.5% for goosander. A complete in-season repeat survey (i.e. 100% of reaches surveyed twice) delivers CV's of 6.5% for cormorant and 10% for goosander. At least 50% resurvey will significantly improve confidence in the population estimates. (see Appendix 2: App. 2 Figure 1 for cormorant, and App. 2 Figure 2 for goosander).
3. Survey performance was not affected by survey order, nor did it differ substantially between systematic and random selection of the resurveyed segments.

Key findings for a **tributary survey**, suggested:

1. In the absence of pilot data, it was assumed that birds would be similarly distributed in the tributaries to their main-channel distribution: i.e. lower in the tributary (towards the main channel) and biased towards the tributaries lower in the catchment.

2. Given the very large numbers and lengths of tributaries in Welsh catchments, it was assumed that complete coverage would be impossible.
3. Given the assumption of incomplete coverage, expected CV's were larger than those for the main channel survey. Systematic sampling throughout the catchment was less likely to produce spurious estimates than random selection.
4. Population estimate error was substantial for coverages below 20% and decreased towards similar values for the main-channel survey, as effort increased. 25-33% coverage yielded CV's of 20-25% for cormorant and 25-35% for goosander. (see Appendix 2: App. 2 Figure 3 for cormorant, and App. 2 Figure 4 for goosander).

*Uncertainty propagation into population control scenarios*

If the majority of the wintering population is distributed in the main river channel, the lower CV's of the main-channel estimates apply, which can be considered a 'best-case' scenario in the present analysis. Simulations suggest that with a survey design using 50% resampling, uncertainty around the cormorant population estimate and therefore also around the licensed control limit would be approximately +/- 10% (i.e. c. +/- 3% for a control scenario of 30% of the population). For a main-channel survey without resampling, this increases to approximately +/- 15% (i.e. c. +/- 4.5% for a control scenario of 30% of the population) (see Appendix 2: App. 2 Figure 5). For goosander, these uncertainties are larger. Simulations suggest that with a survey design using 50% resampling, uncertainty around the goosander population estimate and therefore also around the licensed control limit would be approximately +/- 15% (i.e. c. +/- 4.5% for a control scenario of 30% of the population). For main-channel survey without resampling, this increases to approximately +/- 20% (i.e. c. +/- 6% for a control scenario of 30% of the population) (see Appendix 2: App.2 Figure 6).

As the proportion of the wintering population found in tributaries rises, the uncertainty around the population estimate for the catchment will increase towards the CV's calculated for the tributary surveys. The 'true' proportion of the population removed under a licensed control limit becomes much more uncertain, in particular for survey coverage below 25%. For a modelled survey coverage of 20% of tributaries, a licensed control limit set at 30% of the population estimate might in reality represent anywhere between 15% and 75% of the true population of either cormorant or goosander (see Appendix 2: App. 2 Figure 7 for cormorant, and App. 2 Figure 8 for goosander).

The true distribution of cormorant and goosander is expected to lie somewhere between these two extremes and will also be affected to an unknown extent by stillwater availability and scaring activities.

### 3.4 Stillwaters survey method

It was suggested that stillwater surveys should be 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 determined as follows:

- Counts should be synchronised with WeBS and 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 will 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).
- Multiple waterbodies in a complex (such as separate ponds in a stillwater fishery) should be counted and recorded separately.
- Intentional disturbance activities (e.g. scaring or lethal scaring under licence) occurring on the same day or in the previous 24hrs should be recorded.

For very large stillwaters such as reservoirs and natural lakes, visual sectors can be established as for WeBS stillwaters counts. Where WeBS sectors are already set up by counters in the BTO network, it would be advantageous to use the same sectors and record birds in each sector. Sectors are set using visible landmarks and repeatable vantage points and should be recorded such that the sector boundaries can be mapped.

It is important to note that WeBS counts do not include the multiple within-day counts and will not replace the detailed stillwater counts set out in this method: comparison between the two methods at stillwaters where WeBS operates will provide an important tool in future work to scale-up from surveys to management catchments and national population estimates.

More information on the proposed stillwaters survey can be found in Appendix 5 including a proposed draft of a data recording sheet, relevant extracts from the WeBS methodology, the WeBS count dates list for winter 2020-21 and a list of active inland WeBS sites for Wales.

### 3.5 Breakdown of survey cost estimates

Full field survey and associated costs for four options were calculated and provided to NRW for consideration. Costings for each option are not presented in this report.

*Non-survey costs*

Non-survey costs that would be associated with the GIS work and setting up the 10km survey units, planning and logistics as well as data entry during the survey season (December to February inclusive) plus analytical and reporting time after the surveys were provided to NRW.

*Field survey – time and travel*

Until a more complete measurement of the lengths of major tributaries and tributaries to each river can be completed, survey cost estimates for rivers marked ** and shaded in the table are estimates based on the ratio of main-channel to tributary lengths for the rivers assessed and mapped in OS Rivers data (see Appendix 4: App. 4 Figures 4a-e).

Field survey costs were presented to NRW as increasing levels of survey effort per river, which correspond to increasing levels of statistical confidence in the derived population estimates per river channel and river catchment. Statistical modelling strongly suggests that main-channel 50% resurvey is desirable (column 2 for all rivers). Increased confidence in these population estimates would propagate into increased confidence in population estimates at management catchment and country spatial scales and would be propagated into licensed control models.

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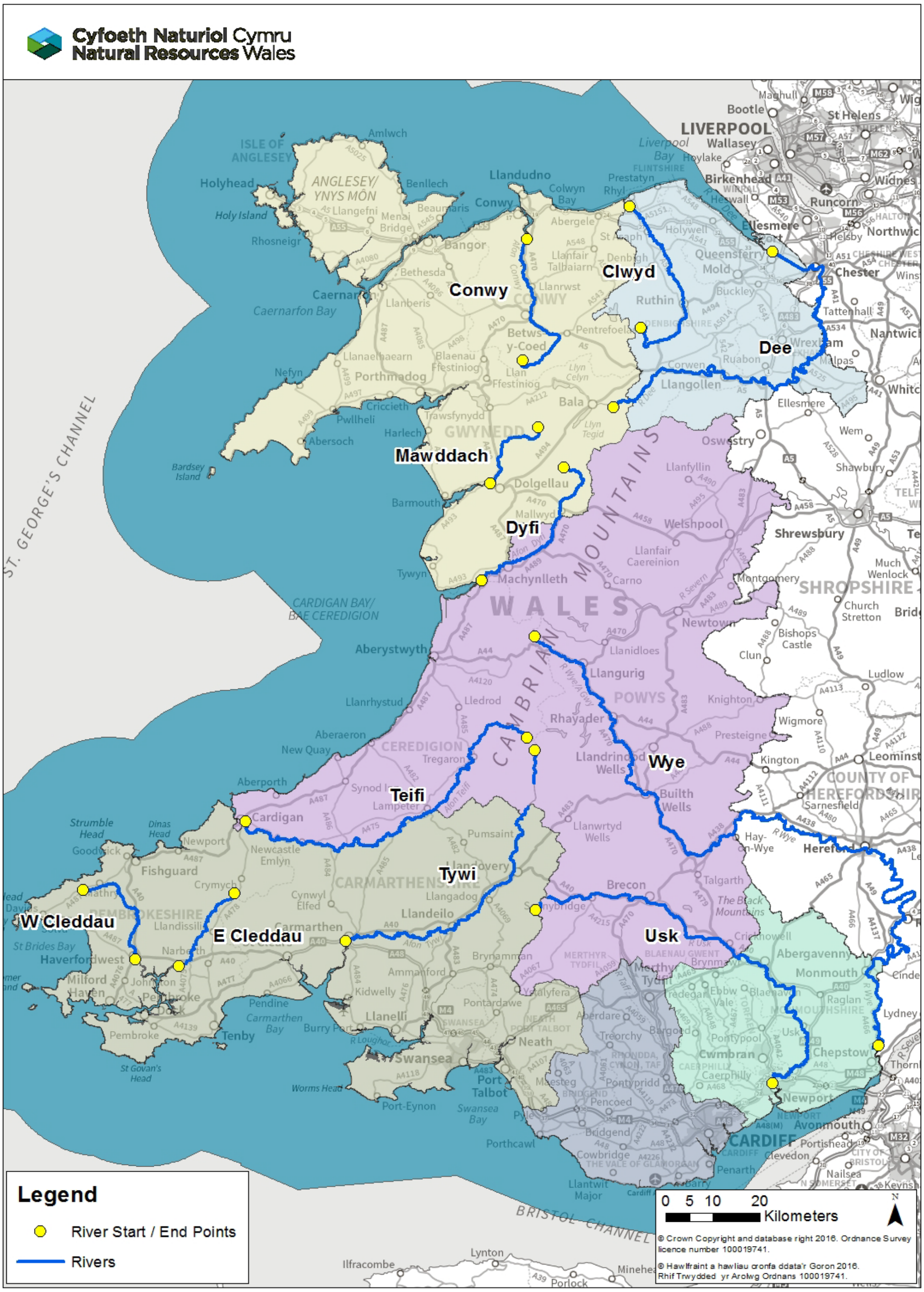
## Appendix 1. Map and GIS references provided by NRW

**App. 1. Figure 1.** Location of the ten most important salmon rivers in Wales (Cleddau – eastern and Cleddau – western are treated as one river) to be surveyed for wintering cormorant and goosander during winter 2020/21.



**App.1. Table 1.** GIS reference data for the ten most important salmon rivers in Wales (Cleddau – eastern and Cleddau – western are treated as one river) to be surveyed for wintering cormorant and goosander during winter 2020/21.

| River | Start point grid ref. | End point grid ref | Length (km) |
|---|---|---|---|
| Wye | SN8069085630 | ST5386096520 | 233.12 |
| Usk | SN8074026130 | ST3133788434 | 110.8 |
| Dee plus Llyn Tegid | SJ0314052980 | SJ3126569487 | 122.02 |
| Teifi | SN7901063610 | SN1899045430 | 103.18 |
| Tywi | SN8064060920 | SN4043019320 | 81.63 |
| Conwy | SH7815045790 | SH7893072280 | 42.13 |
| Dyfi | SH8690022450 | SN6941097890 | 44.31 |
| Clwyd | SJ0314052980 | SJ0076079340 | 50.27 |
| Mawddach | SH8137031210 | SH7108019020 | 22.51 |
| Cleddau (eastern) | SN1667029730 | SN0483013840 | 23.92 |
| Cleddau (western) | SM8433030430 | SM9548415421 | 29.75 |

# Appendix 2. Full detail of survey error estimation

## Methods

*Main channel survey*

Survey statistical error for the estimation of Cormorant and Goosander at the catchment scale was estimated based on georeferenced species records from the 2016-17 BTO survey of the lower River Dee main channel (Taylor & Noble 2017). Survey results indicated that the abundance of both species decreased with distance from the estuary. Counts for each species were aggregated to single person-day survey units (10km stretches) of the main channel and a Poisson GLM fitted to these aggregated counts to account for spatial variation in abundance.

Three survey designs for main-channel surveys were evaluated:

i) sampling each main channel segment **once**

ii) sampling each main channel segment once, and then resampling a **randomly** selected proportion of segments a second time (set proportions being 20%, 25%, 33%, 50%)

iii) sampling each main channel segment once, and then resampling a **systematically** selected set proportion of segments a second time (set proportions being 20%, 25%, 33%, 50%)

Systematic selection of segments for resurvey would be performed in practice by, for example, resurveying alternate segments (for 50% resurvey) or every third segment (for 33% resurvey).

In order to quantify the expected survey error, 100 sets of segment counts were simulated from the fitted GLMs, resampled based on the above described designs and the population total and its confidence interval back-estimated. This approach makes the assumption that the variability in species counts between revisits is comparable to the variability in species counts among neighbouring segments.

***Tributary survey***

No pilot survey data was available to inform the abundance of birds on tributaries. We therefore made the assumption that the distribution of birds within a catchment follows the same geographical pattern as the distribution of birds on the main channel (i.e. fewer birds in the upper reaches of the catchment and more birds in the lower reaches).

We resampled the simulated datasets using the following designs for tributary surveys:

i) sampling a **randomly** selected set proportion of 10km tributary segments (set proportions being 20%, 25%, 33%, 50%, 100%)

ii) sampling a **systematically** selected set proportion of 10km tributary segments (set proportions being 20%, 25%, 33%, 50%, 100%).

For both main channel and tributary surveys the sampling error was quantified as the coefficient of variation (CV) of the population estimate, which is defined as the ratio of the standard deviation of the population estimate divided by the mean population estimate.

*Uncertainty propagation into population models*

We further quantified the knock-on effect of uncertainty in catchment-level population estimates being propagated into population models intended to underpin the setting of limits for licensed lethal control as an adjunct to scaring activities (hereafter, 'licensed control').

For this we calculated a lower and upper 95% confidence interval for the true proportion of the population targeted when setting nominal licensed control limits based on an uncertain population estimate. For example, the lower confidence interval for the proportion of the population targeted was calculated as

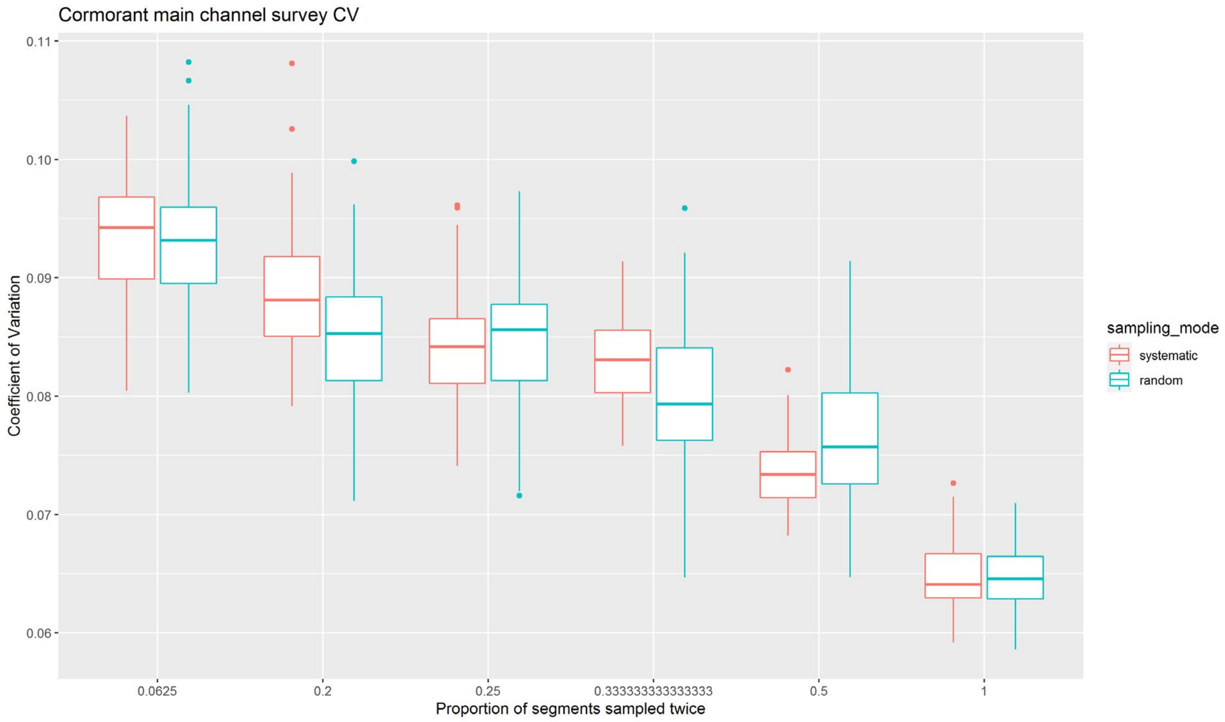
$$\frac{control\ target * mean\ population\ estimate}{upper\ confidence\ limit\ of\ population\ estimate}$$

**Results**

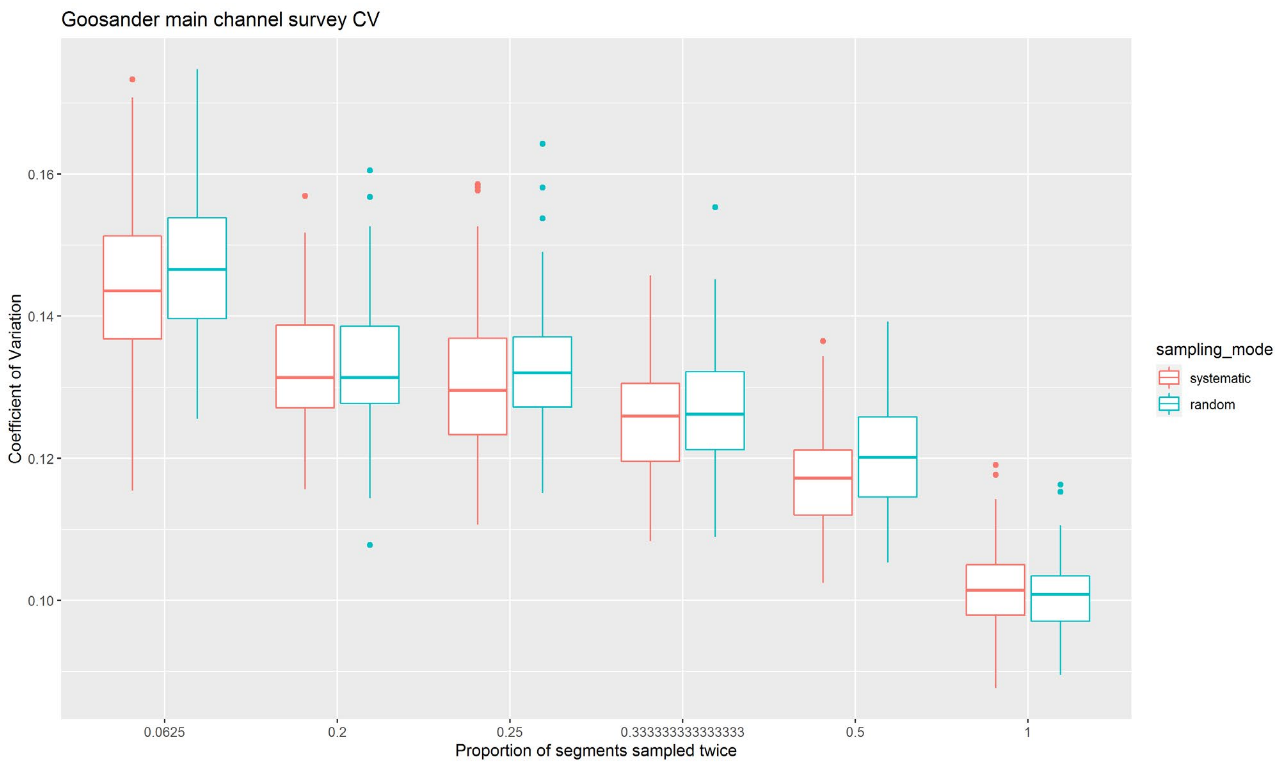
Goosander and cormorant behave differently on rivers in winter, such that their distribution and therefore the outcomes of these analyses differ between the species. Broadly, cormorant are more numerous and more likely to be recorded in larger flock sizes.

The coefficient of variation (error) around the population estimate is greater for goosander than for cormorant, because the species is less numerous and more dispersed. Error decreases as the proportion of river segments resurveyed increases, for both species (App. 2 Figures 1 and 2). Resurveying 50% of the 10km survey units (on the lower Dee) reduces error to below 7.5% for the cormorant estimate, and below 12% for goosander. Based on this dataset, a full resurvey would still produce error rates of 6.5% (cormorant) and 10% (goosander), so the statistical gains from this additional survey effort are somewhat limited.

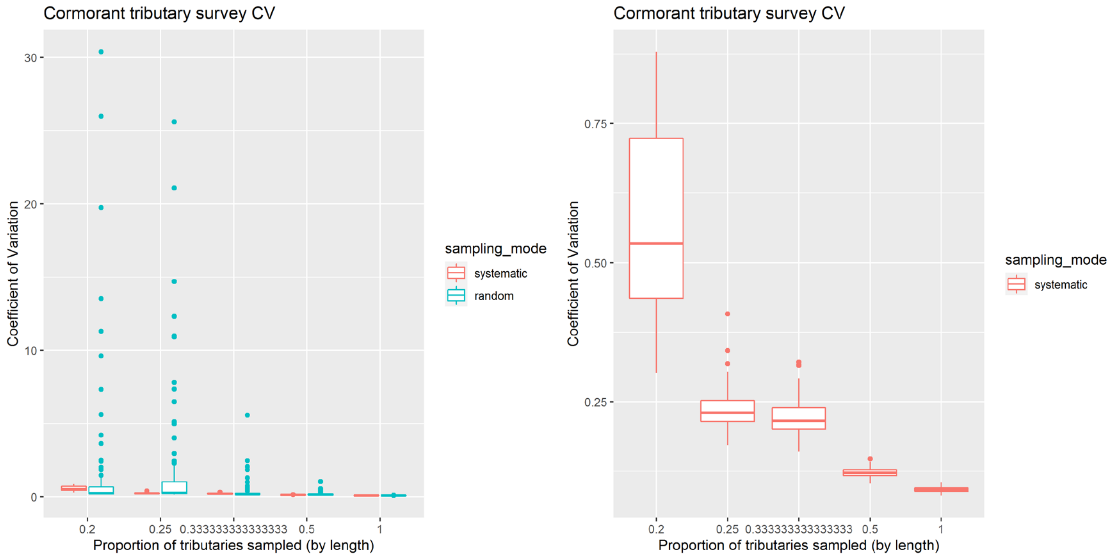
In the following figures, modeled coefficients of variation (CV's) are presented as box plots, where the line in the box represents the predicted mean value and the box the 95% confidence limits around the mean, with whiskers representing the full range of model outputs including outliers (dots).



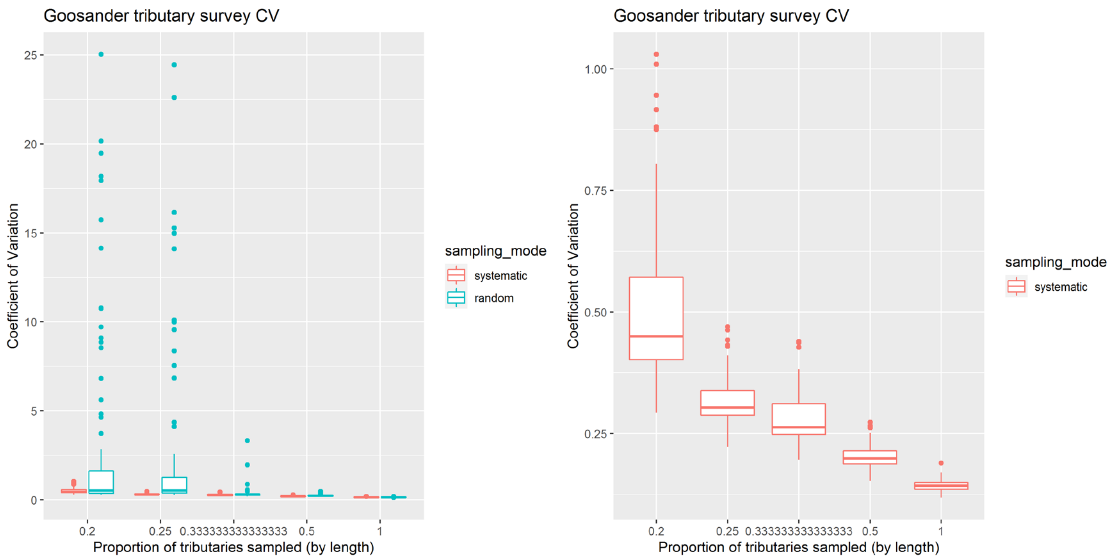

**App. 2. Figure 1.** Expected survey error in population estimates for cormorant based on main-channel surveys at different rates of resurvey.




**App. 2. Figure 2.** Expected survey error in population estimates for goosander based on main-channel surveys at different rates of resurvey.

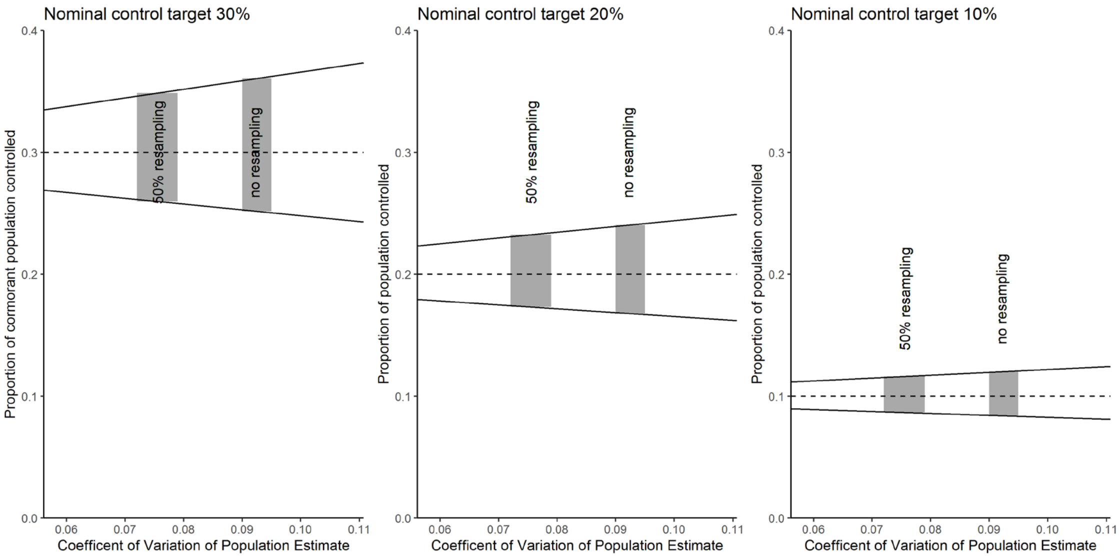



**App. 2. Figure 3.** Expected survey error in population estimates for cormorant from survey of modelled tributary data at different rates of resurvey.

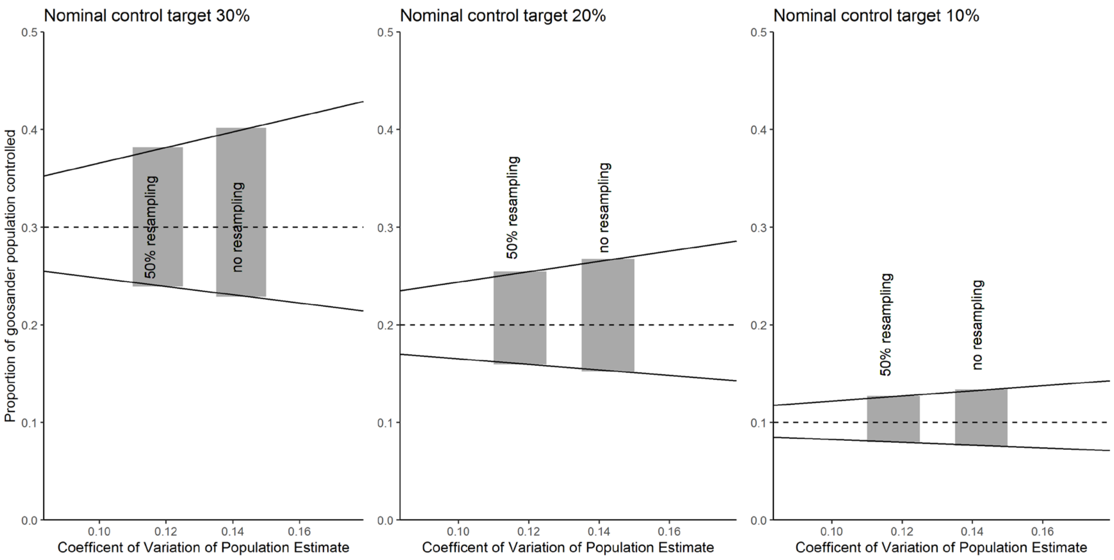



**App. 2. Figure 4.** Expected survey error in population estimates for goosander from survey of modelled tributary data at different rates of resurvey.

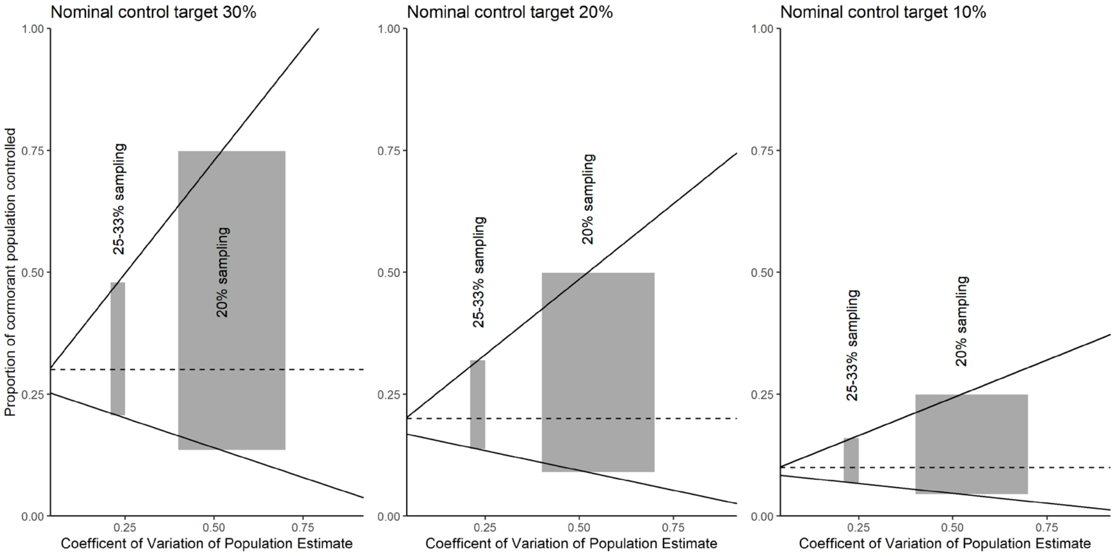
*Uncertainty propagation for population control targets*



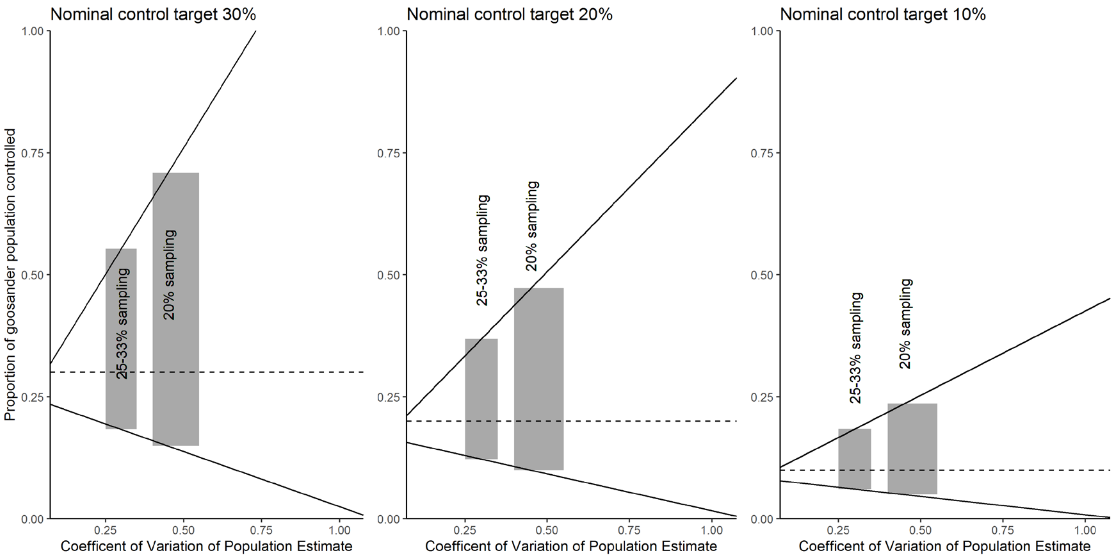

**App. 2. Figure 5.** Expected uncertainty around the true proportion of the cormorant population on main river channels affected by licensed control measures for different levels of survey error. Dashed lines show nominal control limit. Solid lines show upper and lower 95% confidence intervals for the true population proportion affected. Grey boxes highlight the expected range of survey error and thus control uncertainty for two proposed main channel survey design options.




**App. 2. Figure 6.** Expected uncertainty around the true proportion of the goosander population on main river channels affected by licensed control measures for different levels of survey error. Dashed lines show nominal control limit. Solid lines show upper and lower 95% confidence intervals for the true population proportion affected. Grey boxes highlight the expected range of survey error and thus control uncertainty for two proposed main channel survey design options.



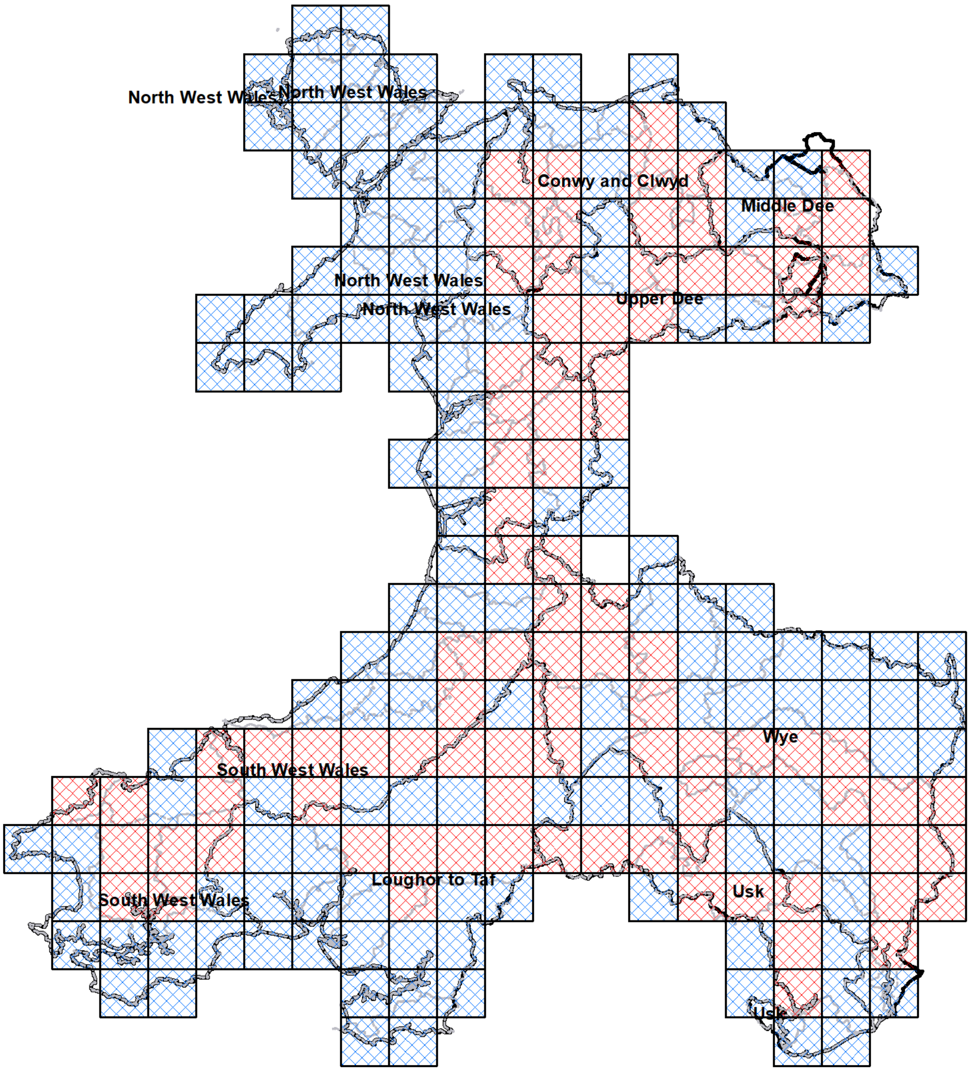

**App. 2. Figure 7.** Expected uncertainty around the true proportion of the cormorant population on tributaries affected by licensed control measures for different levels of error in population estimates. Dashed lines show nominal control limit. Solid lines show upper and lower 95% confidence intervals for the true population proportion affected. Grey boxes highlight the expected range of survey error and thus control uncertainty for two proposed main channel survey design options.



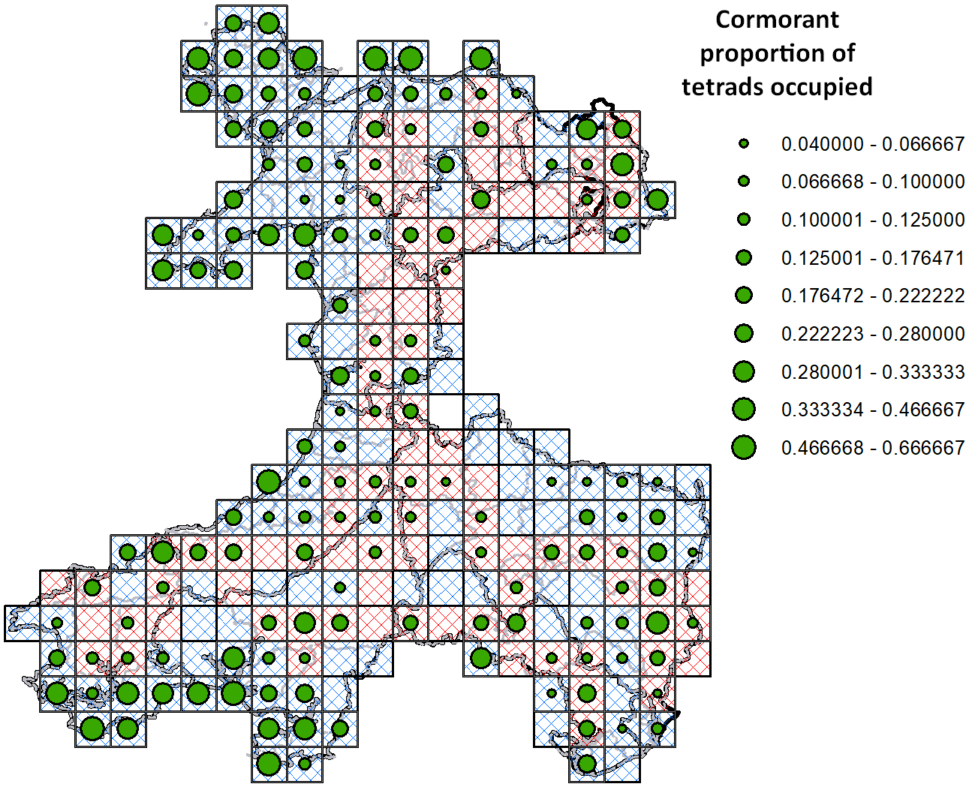

**App. 2. Figure 8.** Expected uncertainty around the true proportion of the goosander population on tributaries affected by licensed control measures for different levels of error in population estimates. Dashed lines show nominal control limit. Solid lines show upper and lower 95% confidence intervals for the true proportion of the population affected. Grey boxes highlight the expected range of survey error and thus control uncertainty for two proposed main channel survey design options.

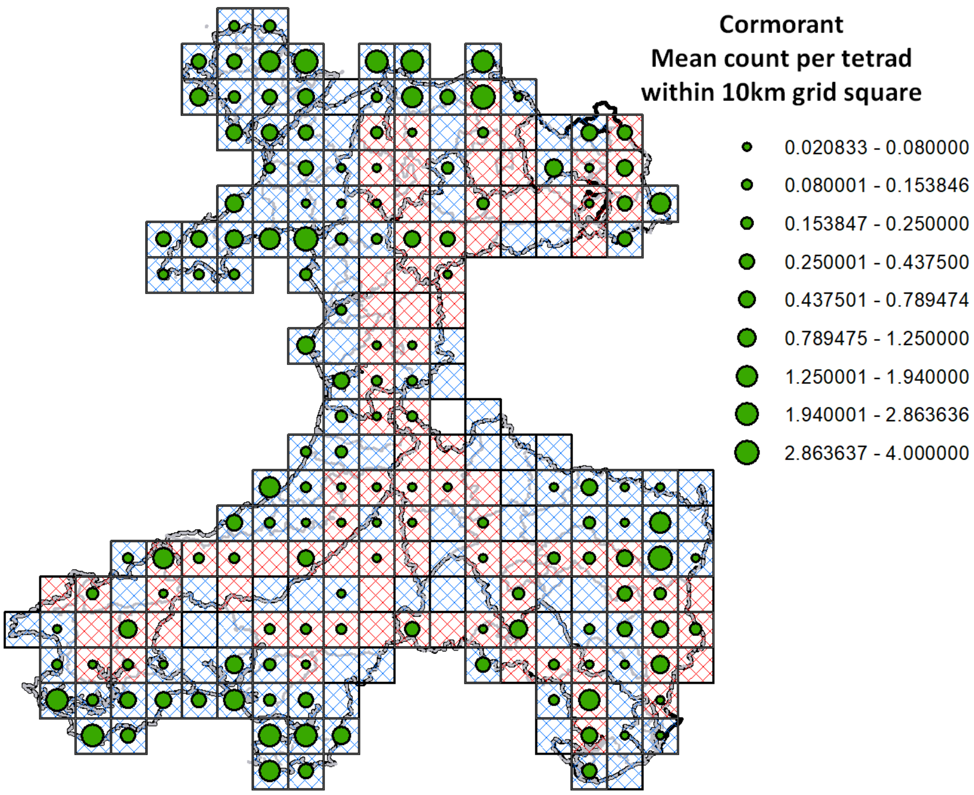
## Appendix 3. Winter Atlas data for cormorant and goosander

**App. 3. Figure 1.** 10-km grid squares with/without Main Channel. 10 Km grid squares containing Main Channels (90) are shown in red; those containing only Tributaries (138) are shown in blue. This underrepresents the importance of Tributaries because those 10-km grid squares containing main Channels may also contain substantial Tributaries. 10 km grid squares with less than 10% overlap with catchments have been excluded.

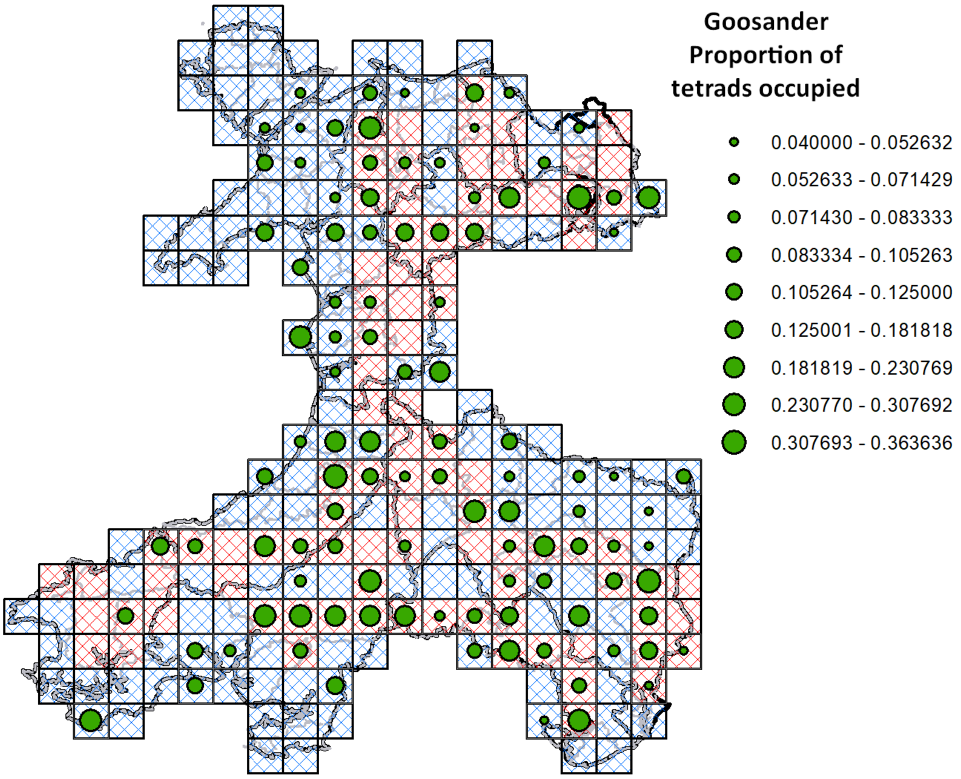


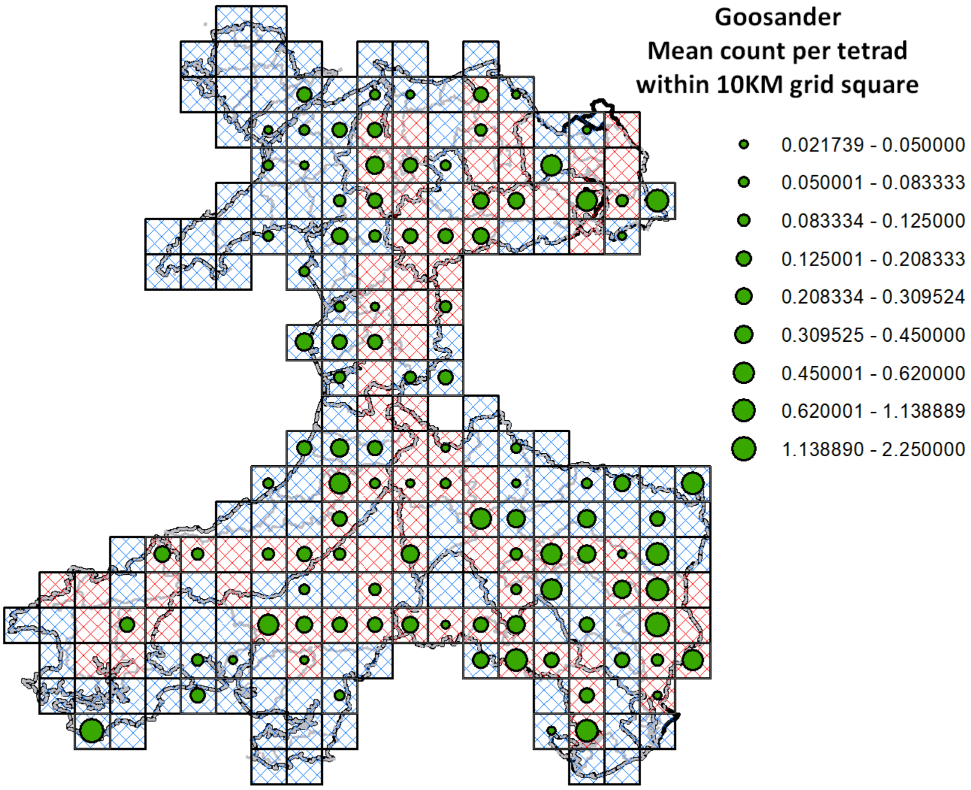
**App. 3. Figure 2.** 10-km grid squares data from BirdAtlas. Comparison of cormorant occurrence and average tetrad count for 10-km grid squares containing main channels and tributaries with those containing tributaries only with/without Main Channel.
Aside from the coastal effect, there is no stark contrast between the two types of 10-km grid squares



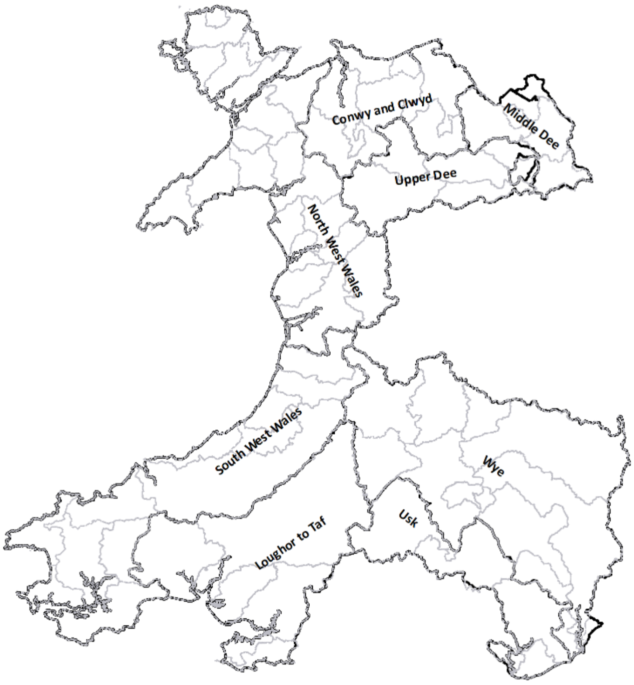
**App. 3. Figure 3.** 10-km grid squares data from BirdAtlas. Comparison of goosander occurrence and average tetrad count for 10-km grid squares containing main channels and tributaries with those containing tributaries only with/without Main Channel. Coastal bias is much less apparent for goosander than for cormorant, and there is no stark contrast between the two types of 10-km grid squares**.**



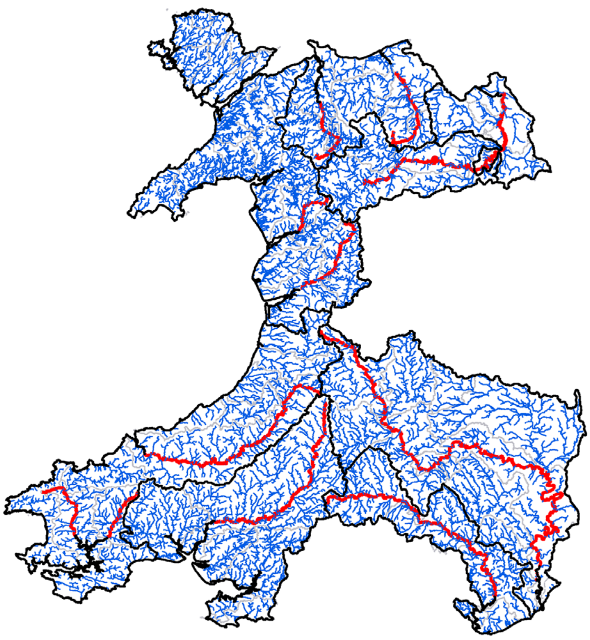



## Appendix 4. Maps and catchments to be surveyed

**App. 4. Figure 1.** Catchments to be surveyed

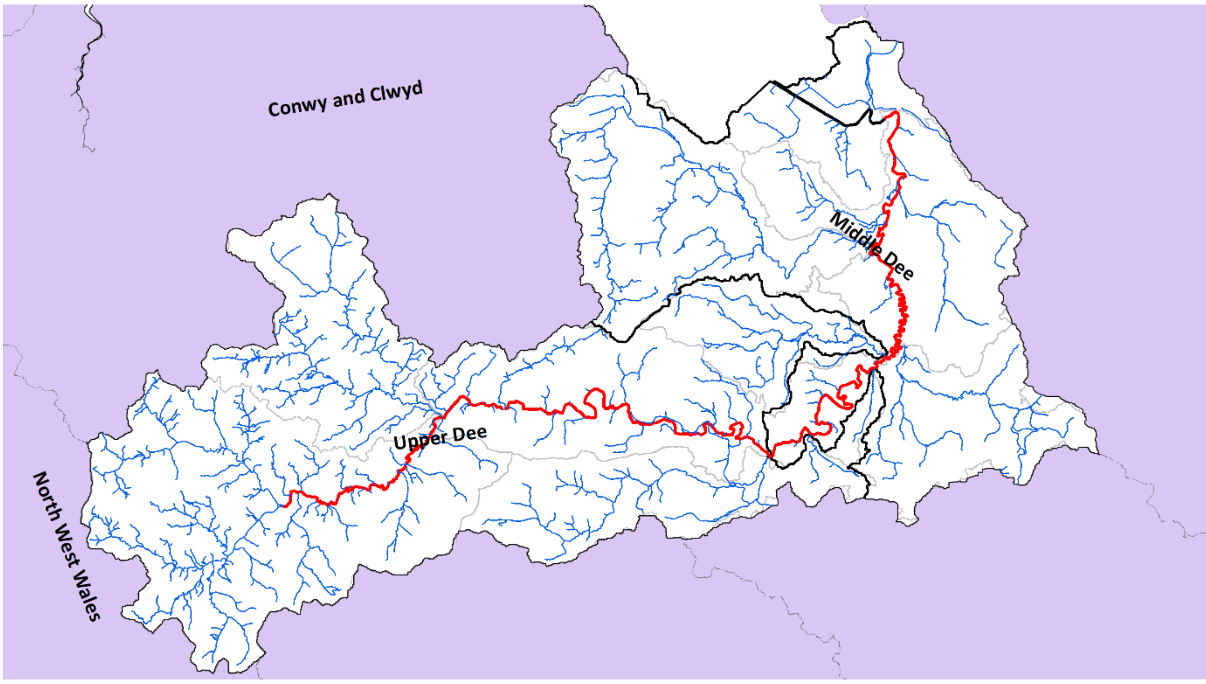



**App. 4. Figure 2.** Main Channels and Tributaries. Main Channel (shown in red) determined by tracing route between start end points provided by NRW based on the OS Open Rivers shapefile. For some rivers, additional digitising against an OS backdrop was necessary to extend lower limit of main channel from the OS Open Rivers data to the lower limit as defined by NRW coordinates.

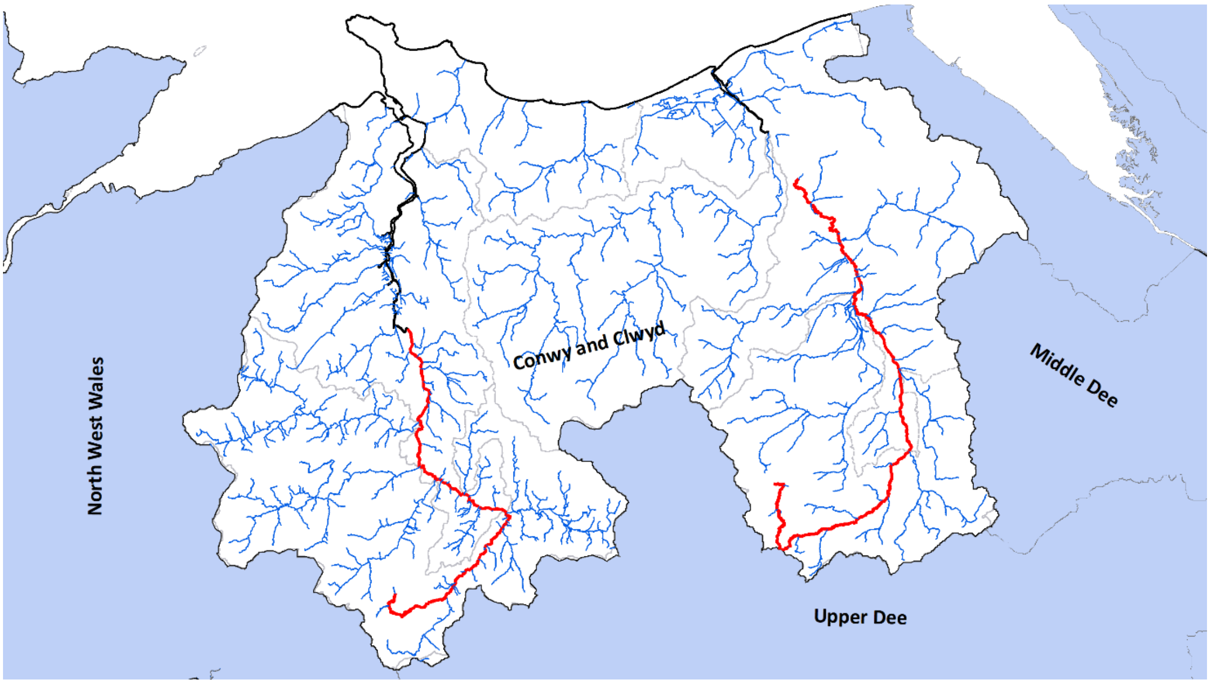


**App. 4. Figures 3a-g. Individual catchment maps**

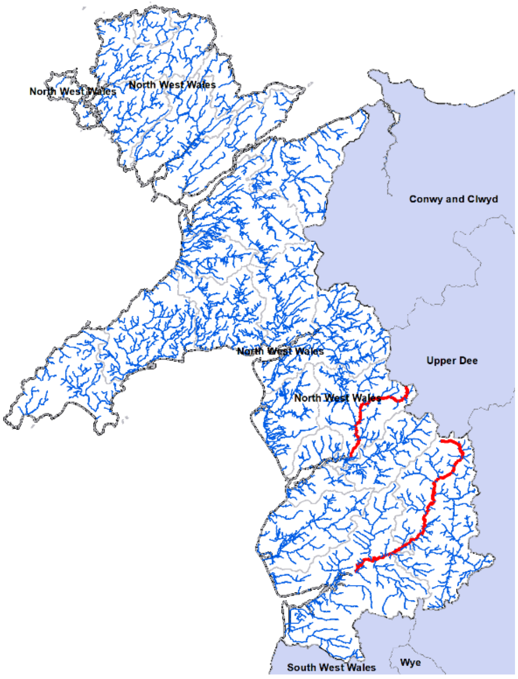
a) Dee and Tegid (Upper Dee Catchment + Middle Dee Catchment)

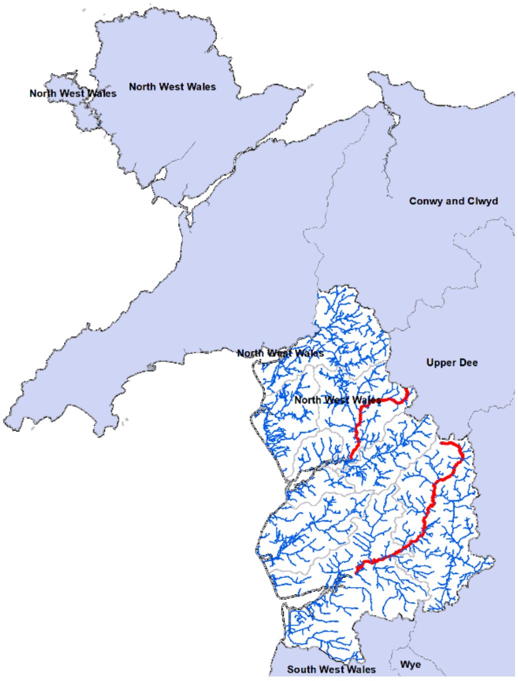



b) Conwy and Clwyd

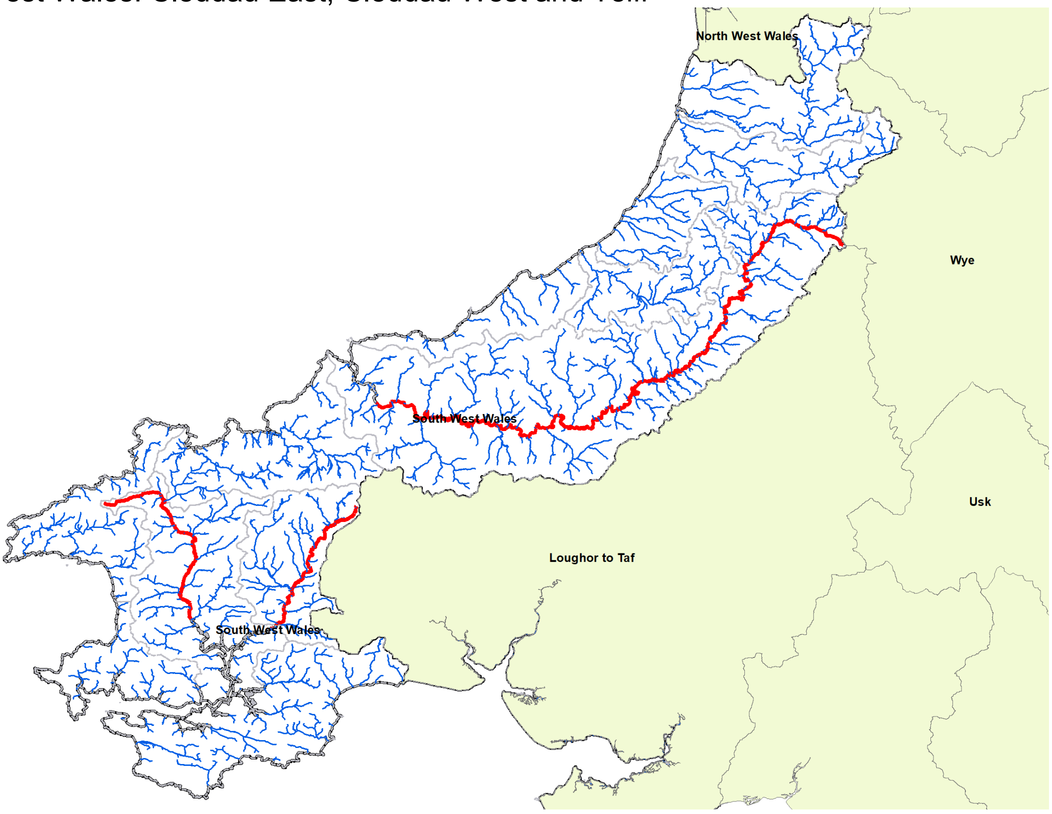


c) North West Wales: Mawddach and Dyfi only

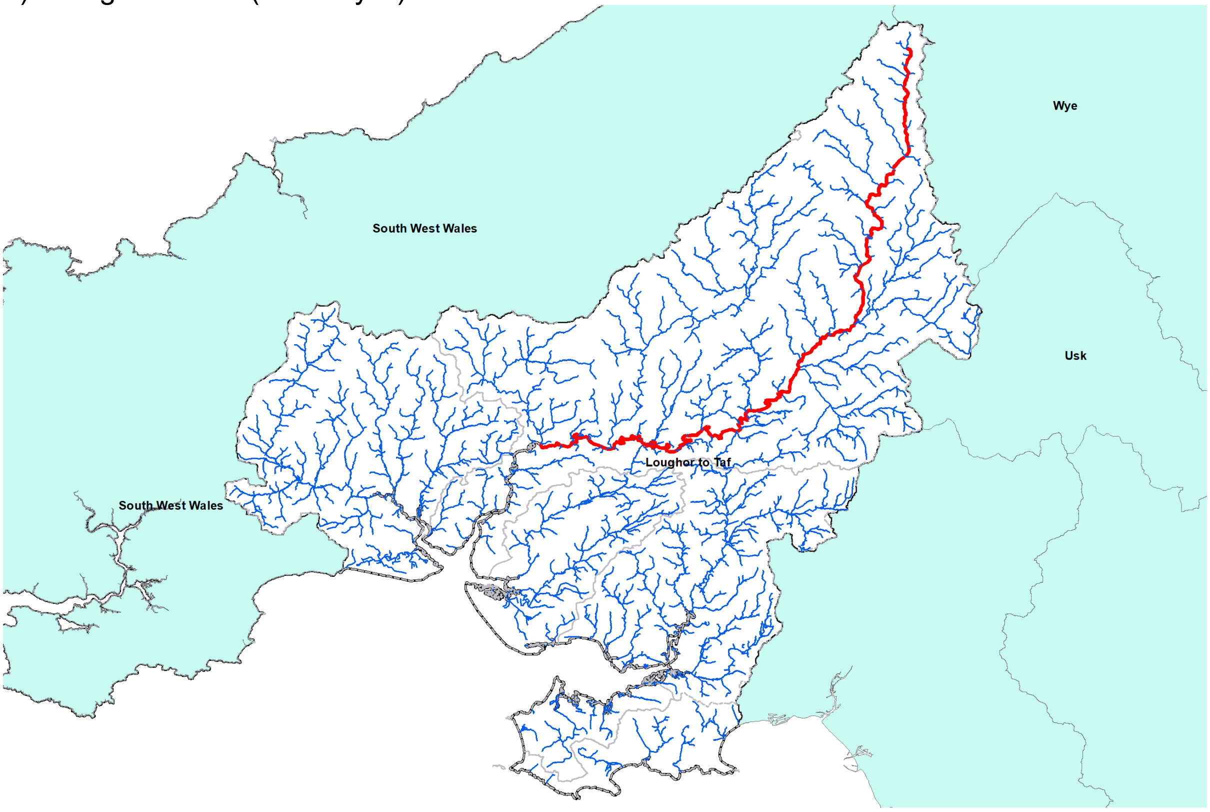


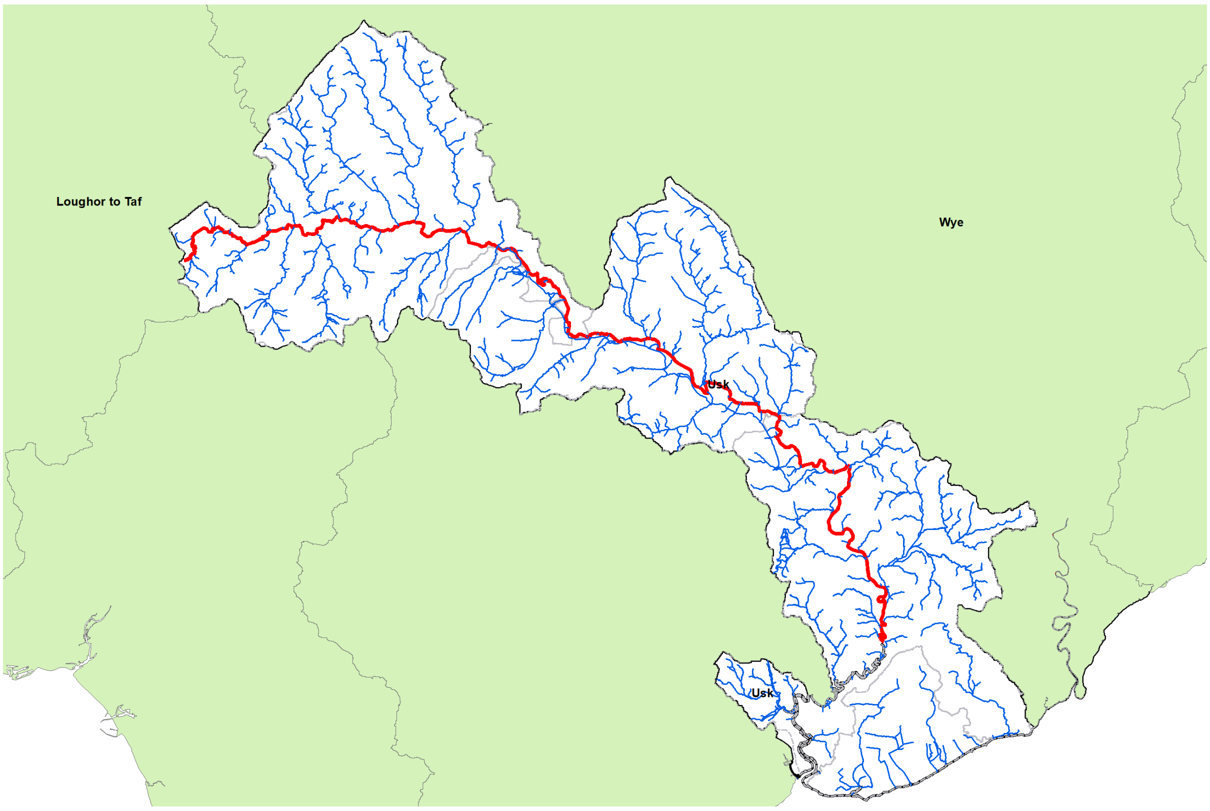

d) South West Wales: Cleddau East, Cleddau West and Teifi



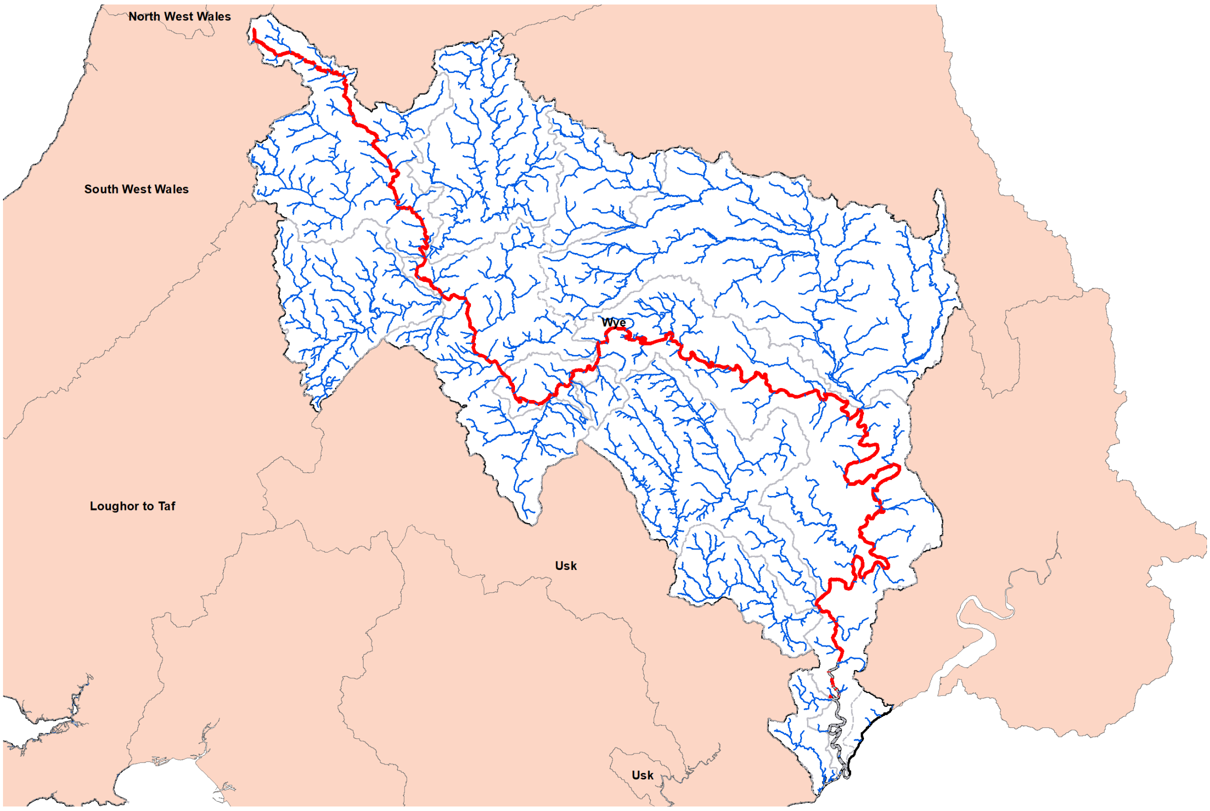
e) Loughor to Taf (River Tywi)




f) Usk



g) Wye



**Management catchment and survey structure for salmonid rivers**

**App. 4. Table 1.** Measured and estimated lengths of river and tributaries in km by catchment and main channel, major and minor tributaries as defined below. For rivers marked with ** tributary and major tributary lengths are estimates using the average ratio of main-channel to sample tributaries (2.5) calculated from GIS (owing to insufficient time for full GIS measurement). Where GIS measures of main-channel length were longer than data supplied by NRW, text is in red.

| River | Main channel | Major tributaries | Minor tributaries to main channel | Minor tributaries to major tributaries | Tributaries to be sampled |
|---|---|---|---|---|---|
| Wye | 245 | 953 | 19 | 1614 | 972 |
| ***Usk*** | 111 | n/a | n/a | n/a | ***278*** |
| ***Dee plus Tegid*** | 122 | n/a | n/a | n/a | **307** |
| Teifi | 117 | 348 | 28 | 193 | 376 |
| ***Tywi*** | 82 | n/a | n/a | n/a | **205** |
| Conwy | 42 | 143 | 14 | 198 | 157 |
| Dyfi | 44 | 231 | 27 | 174 | 258 |
| Clwyd | 50 | 134 | 20 | 120 | 154 |
| Mawddach | 23 | 80 | 10 | 69 | 90 |
| Cleddau (eastern) | 26 | 101 | 13 | 42 | 114 |
| Cleddau (western) | 31 | 82 | 1 | 50 | 83 |

**Key to catchment maps**

***Dark Green:*** "Primary River Catchments" i.e. river catchments containing the main channel of the target river as defined by NRW start-end grid references.

***Mid-green:*** "Secondary River Catchments" i.e. other river catchments containing tributaries of the target river.

**Key to river coding** (version of map without river catchment colouring below)

***Red:*** Main channel of target river. i.e. the main channel of the target river as defined by NRW start-end grid references.

***Dark Blue:*** "Primary Tributary Channel" i.e. All tributaries flowing directly into target river channel, traced (subjectively) back to source.

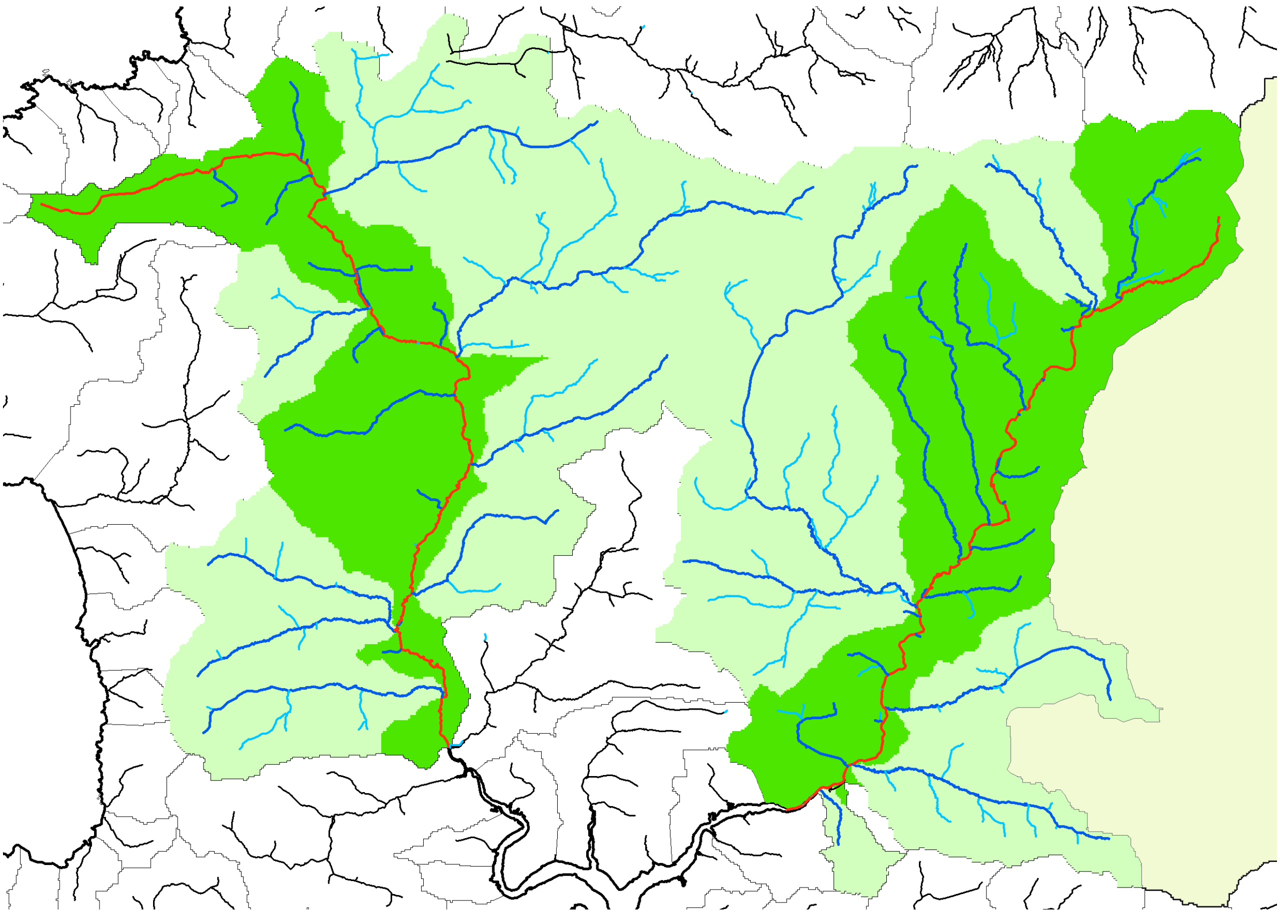
***Pale Blue:*** "Tributary spurs" i.e. all spurs off Primary tributary Channel. Note some of these may be substantial in their own right.

***Grey:*** "Not of interest" i.e. rivers and their tributaries with no direct connection to target river

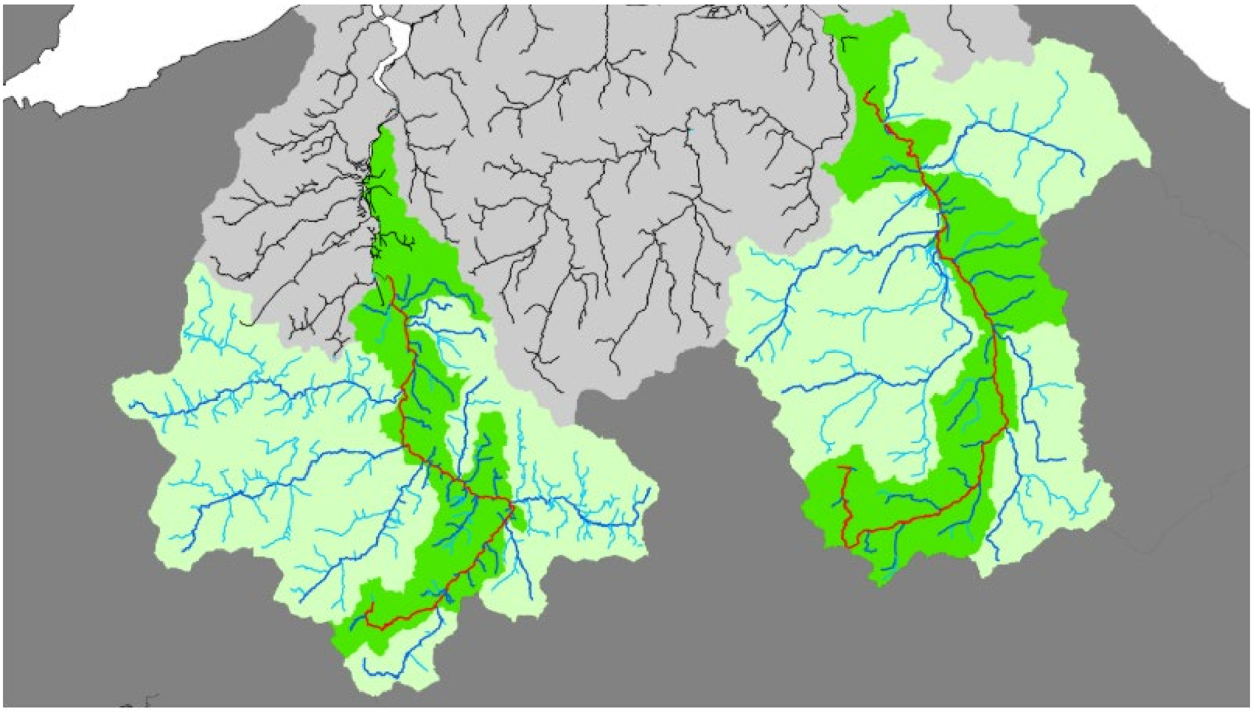
**Survey categories used in tables**

| | |
|---|---|
| Main channel | River channel coloured in red |
| Tributaries | All waterways coloured dark or pale blue within the “Primary River Catchment” area coloured dark green |
| Major tributaries | All waterways coloured dark blue in the “Secondary River Catchments” areas coloured mid-green |

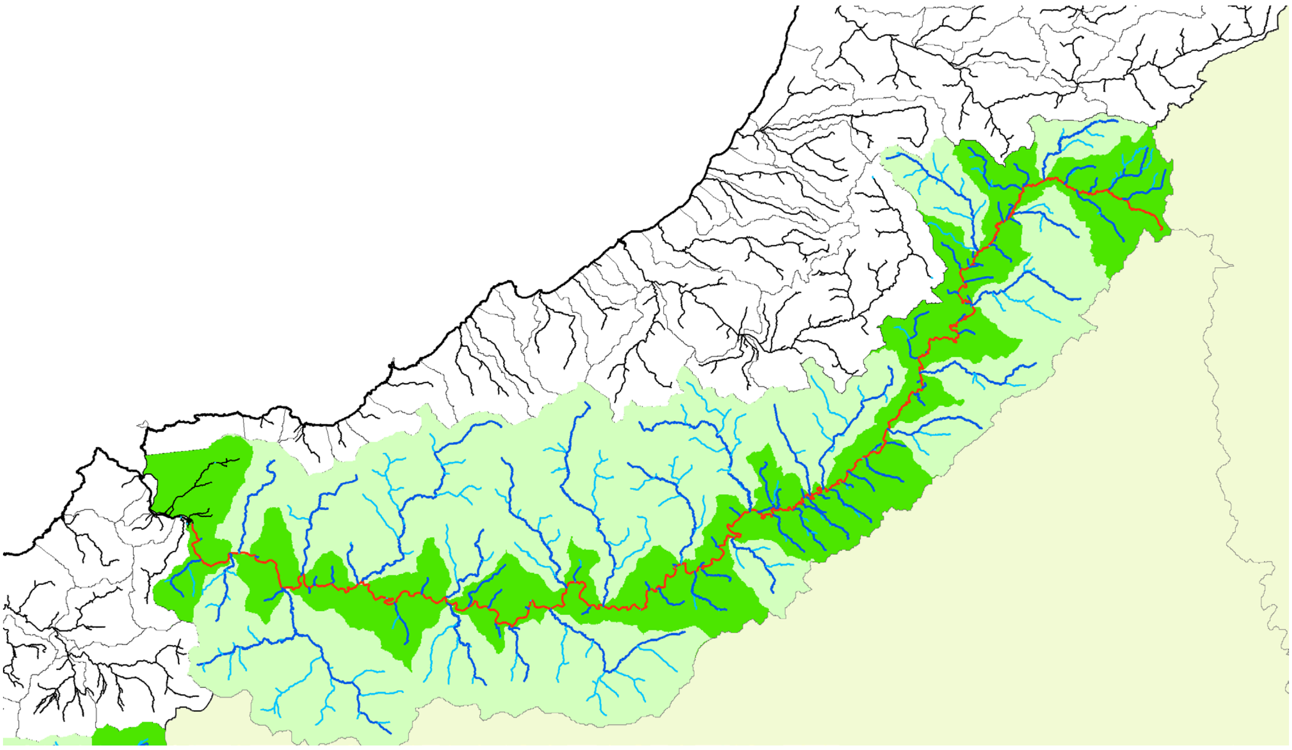
**App. 4. Figure 4a.** South West Wales (Cleddau East and West) tributary categories



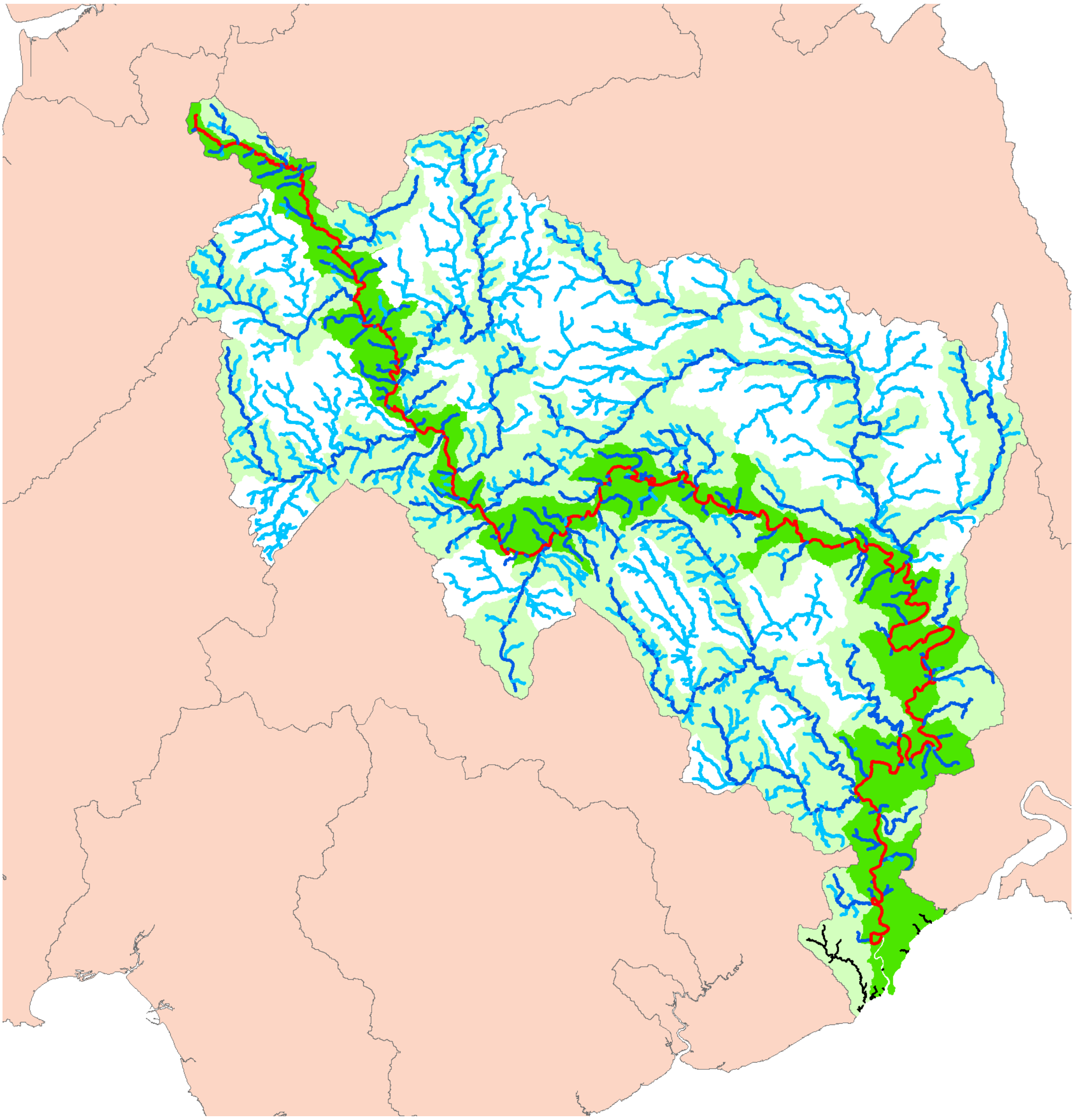
**App. 4 Figure 4b.** Conwy and Clwyd tributary categories



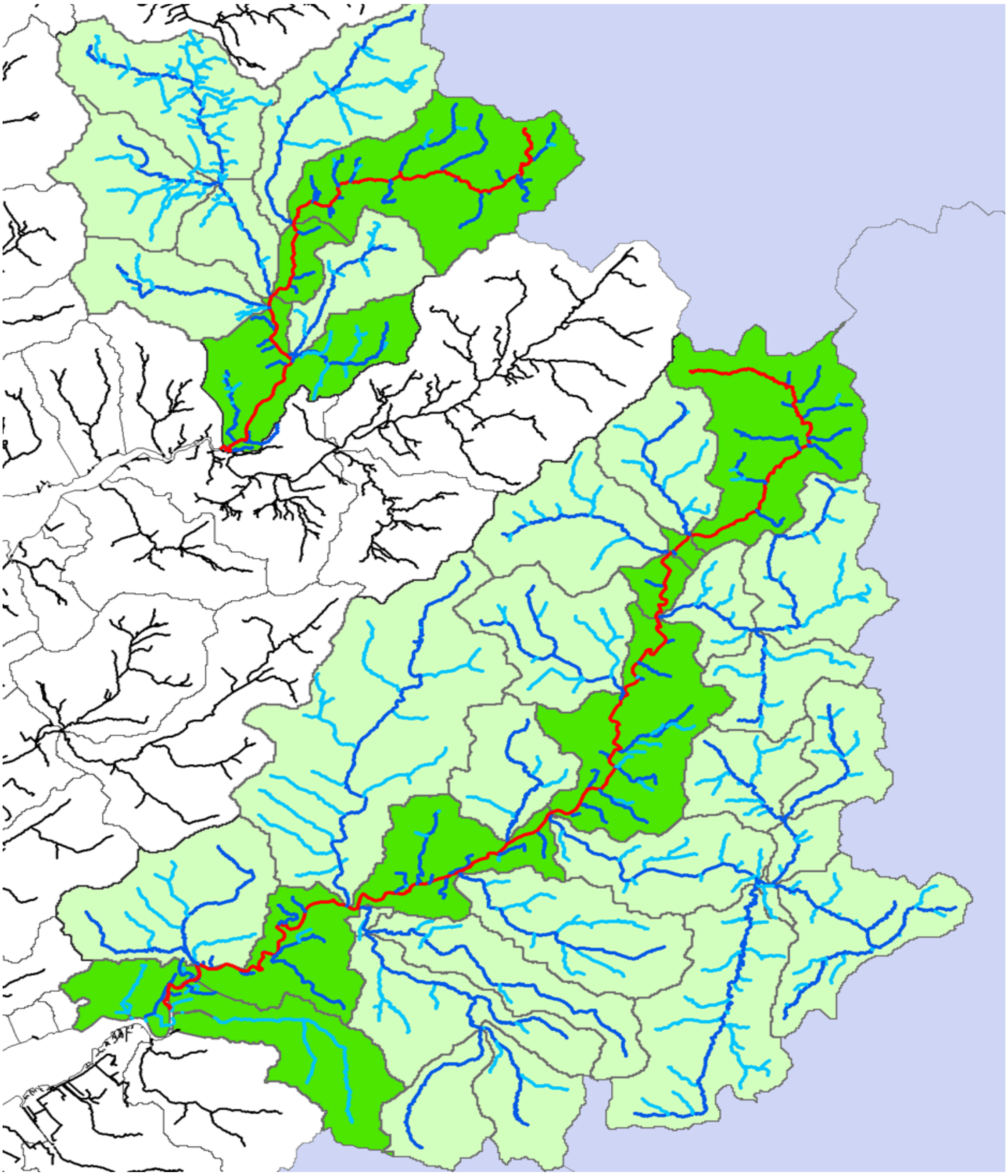
**App. 4 Figure 4c.** Teifi tributary categories



**App. 4 Figure 4d.** Wye tributary categories



**App. 4 Figure 4e.** North West Wales (Mawddach and Dyfi) tributary categories



## Appendix 5. Supporting information for the stillwaters survey method

*WeBS methodology: extracts relevant to stillwaters survey*

Counts are made using so-called ‘look-see’ methodology (Bibby *et al*., 2000), whereby the observer, familiar with the species involved, surveys the whole of a predefined area.

Cormorants and goosander are generally readily visible. Only birds seen are recorded. They are also likely to be present in relatively small numbers or dispersed widely and should be counted singly. Notebooks and tally counters may be used to aid counts.

Counts are made once per month, on predetermined ‘priority dates’. This enables counts across the whole country to be synchronised, thus reducing the likelihood of birds being double counted or missed. Such synchronisation is imperative at large sites, which are divided into sectors, each of which can be practicably counted by a single person in a reasonable amount of time.

The priority dates are pre-selected with a view to optimising tidal conditions for counters covering coastal sites at high tide on a Sunday. Coordination within a site takes priority over national synchronisation, but to aid coordination and future analysis alongside WeBS data, counts should be made on the priority dates listed below.

*WeBS count dates for October 2020 to March 2021*

| | |
|---|---|
| 2020 | 18th October |
| | 15th November |
| | 13th December |
| 2021 | 17th January |
| | 14th February |
| | 14th March |

**DRAFT Stillwaters recording sheet**

Example, allowing recording for one site (single pool or sector of a larger waterbody).

| | |
|---|---|
| SITE NAME | |
| SUB-SITE or SECTOR | |
| LOCATION inc grid ref | |
| OBSERVER | |
| DISTURBANCE (in preceding 24h) | |

| | | | | 2020 | | | | | | | | | 2021 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WeBS DATE | | 18th October | | | 15th November | | | 13th December | | | 17th January | | | 14th February | | | 14th March | | |
| | | DATE OF COUNT | | | | | | | | | | | | | | | | | | | |
| | | COUNT | | DAWN | NOON | DUSK | DAWN | NOON | DUSK | DAWN | NOON | DUSK | DAWN | NOON | DUSK | DAWN | NOON | DUSK | DAWN | NOON | DUSK |
| | | START TIME | | | | | | | | | | | | | | | | | | | |
| Cormorant | On water | Actively fishing | | | | | | | | | | | | | | | | | | | |
| | | Not fishing | | | | | | | | | | | | | | | | | | | |
| | | Other | | | | | | | | | | | | | | | | | | | |
| | Off water | Roosting | | | | | | | | | | | | | | | | | | | |
| | | Other | | | | | | | | | | | | | | | | | | | |
| | Flying | <20m high | | | | | | | | | | | | | | | | | | | |
| | | >20m high | | | | | | | | | | | | | | | | | | | |
| Goosander | On water | Actively fishing | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| | | Not fishing | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| | | Other | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| | Off water | Roosting | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| | | Other | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| | Flying | <20m high | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| | | >20m high | M | | | | | | | | | | | | | | | | | | |
| | | | F/U | | | | | | | | | | | | | | | | | | |
| CONDITIONS | | % ice cover | | | | | | | | | | | | | | | | | | | |
| | | Weather notes | | | | | | | | | | | | | | | | | | | |

**App. 5 Table 1**. Active inland WeBS count sites in Wales

| Region | Site name | GRIDREF |
|---|---|---|
| Anglesey | Cefni Reservoir | SH441775 |
| Anglesey | Holyhead Reservoir | SH222819 |
| Anglesey | Llyn Alaw | SH399864 |
| Anglesey | Llyn Bodgylched | SH585771 |
| Anglesey | Llyn Coron | SH379700 |
| Anglesey | Llyn Hafodol | SH393889 |
| Anglesey | Llyn Llygeirian | SH346898 |
| Anglesey | Llyn Llywenan | SH347815 |
| Anglesey | Llyn Maelog | SH326729 |
| Anglesey | Llyn Pen-y-parc | SH585750 |
| Anglesey | Llyn Traffwll | SH324769 |
| Anglesey | Twr Fields | SH224822 |
| Breconshire | Bailyhelig Reservoir | SO038276 |
| Breconshire | Brechfa Pool | SO118376 |
| Breconshire | Cefn Cantref Pool | SO045265 |
| Breconshire | Cray Reservoir | SN881213 |
| Breconshire | Llangorse Lake | SO131263 |
| Breconshire | Pentwyn Reservoir | SO052151 |
| Breconshire | Pontsticill Reservoir (Taf Fechan) | SO056131 |
| Breconshire | River Usk - Brecon to Fenni-fach | SO034288 |
| Breconshire | River Usk and Canal - Brynich to Brecon | SO062278 |
| Breconshire | River Usk at Crick Howell | SO223175 |
| Breconshire | River Wye - Glasbury | SO181400 |
| Breconshire | Talybont Reservoir | SO100190 |
| Breconshire | Traeth Mawr (Mynydd Illtyd) | SN965255 |
| Breconshire | Ty Mawr Pool | SO074265 |
| Breconshire | Usk Reservoir | SN819284 |
| Breconshire | Y Gors - Trecastle | SN876296 |
| Burry Inlet - North (Carmarthenshire) | Peoples Park Lake | SN500003 |
| Carmarthenshire | Llyn Brianne | SN807511 |
| Carmarthenshire | National Botanic Garden of Wales | SN521179 |
| Carmarthenshire | River Tywi - Chain Bridge, Llandovery to Railway Track, Llwynjack | SN758340 |
| Carmarthenshire | River Tywi Below Dinefwr Castle | SN609213 |
| Carmarthenshire | Tywi Floodplain | SN547201 |
| Ceredigion (incl. Dyfi Estuary) | Cors Caron (Cors Tregaron) | SN690641 |
| Ceredigion (incl. Dyfi Estuary) | Llyn Blaenmelinawr | SN715835 |
| Ceredigion (incl. Dyfi Estuary) | Llyn Pendam | SN707838 |
| Ceredigion (incl. Dyfi Estuary) | Nant-y-garreg, Saron | SN371364 |
| Ceredigion (incl. Dyfi Estuary) | Pond Llywernog | SN722814 |
| Ceredigion (incl. Dyfi Estuary) | Pond Yr Oerfa | SN728798 |
| Clwyd (coastal) | Rhuddlan Lake | SJ021778 |

| Region | Site name | GRIDREF |
|---|---|---|
| Clwyd (inland) | Acton Park Lake | SJ345520 |
| Clwyd (inland) | Brickworks Pond Rhyl | SJ013803 |
| Clwyd (inland) | Casgan Fishing Pools | SJ230523 |
| Clwyd (inland) | Cilcain Reservoirs | SJ162645 |
| Clwyd (inland) | Erddig Park Lake | SJ331485 |
| Clwyd (inland) | Hanmer Mere | SJ452391 |
| Clwyd (inland) | Heron Water Lake (Clwyd) | SH884739 |
| Clwyd (inland) | Llyn Cyfynwy | SJ217546 |
| Clwyd (inland) | Llyn Helyg | SJ112772 |
| Clwyd (inland) | Nant-y-ffrith Reservoir | SJ243530 |
| Clwyd (inland) | Pant-yr-ochain | SJ348530 |
| Clwyd (inland) | Tai Lake | SH860706 |
| Clwyd (inland) | Ysceifiog Reservoir | SJ147716 |
| East Glamorgan | Abercwmboi Lake | SO027000 |
| East Glamorgan | Afon Cynon - Tirfounder Fields | SO015018 |
| East Glamorgan | Barry Sidings Countryside Park | ST050909 |
| East Glamorgan | Bryngarw Country Park Lakes | SS905855 |
| East Glamorgan | Cadoxton Pools | ST134683 |
| East Glamorgan | Caerphilly Castle Moat | ST154870 |
| East Glamorgan | Cosmeston Lakes | ST175691 |
| East Glamorgan | Creigiau Pond | ST077812 |
| East Glamorgan | Cyfarthfa Castle Lake | SO039073 |
| East Glamorgan | Duffryn Bach Lake, Clawdd Coch | ST062784 |
| East Glamorgan | East Aberthaw Quarry Pool | ST038674 |
| East Glamorgan | East Dock Cardiff | ST193755 |
| East Glamorgan | Fairwater Park Top Pond | ST142778 |
| East Glamorgan | Flemingston and Llanbydderi Moors | ST020705 |
| East Glamorgan | Glamorgan Canal and Forest Farm | ST138808 |
| East Glamorgan | Halt Pond, Rudry | ST176878 |
| East Glamorgan | Hendre Pond (Trowbridge Lake) | ST246804 |
| East Glamorgan | Hensol Lake | ST046789 |
| East Glamorgan | Hillside Farm Pool, Llanharry | SS997797 |
| East Glamorgan | Jepson`s Pond | SO085092 |
| East Glamorgan | Kenfig Pool | SS796815 |
| East Glamorgan | Llwyn-yoy Pond (Lyn Yoy) | ST038783 |
| East Glamorgan | Llyn y Forwyn, Darren Park, Ferndale | SS996968 |
| East Glamorgan | Michaelstone-le-Pit Salmon Leaps | ST144731 |
| East Glamorgan | Mwyndy Pool | ST055817 |
| East Glamorgan | Nant Ddu Lake, Caerphilly | ST143862 |
| East Glamorgan | Parc Cwm Darran | SO117032 |
| East Glamorgan | Parc Slip NR excluding North Wetland | SS875835 |
| East Glamorgan | Parc Slip NR North Wetland | SS876842 |
| East Glamorgan | Parc Tredelerch - Cardiff | ST216783 |
| East Glamorgan | Pentwyn Pond | ST207806 |
| East Glamorgan | Penywern Middle Pond, Merthyr Tydfil | SO072083 |

| Region | Site name | GRIDREF |
| --- | --- | --- |
| East Glamorgan | Penywern Top Pond, Merthyr Tydfil | SO070086 |
| East Glamorgan | Peterston-super-Ely Moors | ST070763 |
| East Glamorgan | Pools at Oakmead Road, Llanharan | ST003839 |
| East Glamorgan | Pwll Waun Cynon | ST034997 |
| East Glamorgan | Pwll-y-Waun Pond | SS829776 |
| East Glamorgan | Pysgodlyn Mawr | ST041760 |
| East Glamorgan | Rhoose Pools | ST066656 |
| East Glamorgan | River Ely to Duffryn Bach Farm | ST066786 |
| East Glamorgan | River Ely: Leckwith to Penarth Road | ST164745 |
| East Glamorgan | River Rhondda - Ferndale to Pontygwaith | ST009960 |
| East Glamorgan | River Taff - Blackweir to Butetown | ST177763 |
| East Glamorgan | River Taff at Pontypridd | ST076898 |
| East Glamorgan | River Taff: Radyr Weir to Llandaff North | ST141800 |
| East Glamorgan | Roath Park Lake | ST185796 |
| East Glamorgan | St Brides Major Pond | SS895744 |
| East Glamorgan | St Fagans Museum Ponds | ST119771 |
| East Glamorgan | Taf Bargoed Lakes | ST103984 |
| East Glamorgan | Talygarn | ST031796 |
| East Glamorgan | The Knap Boating Lake | ST100663 |
| East Glamorgan | Wilderness Pond | SS822776 |
| Gwent (excl. Severn Estuary) | Beaufort Pond | SO174118 |
| Gwent (excl. Severn Estuary) | Bryn Bach Park | SO126100 |
| Gwent (excl. Severn Estuary) | Cwmbran Boating Lake | ST305938 |
| Gwent (excl. Severn Estuary) | Dunlop Semtex Pond | SO188111 |
| Gwent (excl. Severn Estuary) | Garn Lakes | SO233098 |
| Gwent (excl. Severn Estuary) | Garn Lydan Reservoir | SO174130 |
| Gwent (excl. Severn Estuary) | Green Moor Pool | ST386857 |
| Gwent (excl. Severn Estuary) | Liswerry Pond (Newport) | ST340876 |
| Gwent (excl. Severn Estuary) | Llandegfedd Reservoir | ST326996 |
| Gwent (excl. Severn Estuary) | LLantarnam Ponds | ST304928 |
| Gwent (excl. Severn Estuary) | Machine Pond | SO182113 |
| Gwent (excl. Severn Estuary) | Magor Reserve | ST424863 |
| Gwent (excl. Severn Estuary) | Mathern Mill Fishery | ST518913 |
| Gwent (excl. Severn Estuary) | Mon and Brecon Canal - 14 Locks Canal Centre to M4 at Barrack Hill | ST293888 |
| Gwent (excl. Severn Estuary) | Montgomery and Brecon Canal - Belle Vue Rd Old Cwmbran to Pentre Lane | ST292931 |
| Gwent (excl. Severn Estuary) | Montgomery and Brecon Canal - Bettws Lane to M4 | ST299897 |
| Gwent (excl. Severn Estuary) | Morgans and Woodstock Lakes | ST298898 |

| Region | Site name | GRIDREF |
|---|---|---|
| Gwent (excl. Severn Estuary) | Pant-yr-Eos Reservoir | ST256915 |
| Gwent (excl. Severn Estuary) | Pen-y-Fan Pond | SO196005 |
| Gwent (excl. Severn Estuary) | River Usk - Llanllowell to Newbridge | ST387976 |
| Gwent (excl. Severn Estuary) | River Usk - Newport central | ST318877 |
| Gwent (excl. Severn Estuary) | River Usk - Newport north | ST315898 |
| Gwent (excl. Severn Estuary) | Spytty Park Pond (Newport) | ST335863 |
| Gwent (excl. Severn Estuary) | St Pierre Lake | ST512905 |
| Gwent (excl. Severn Estuary) | The Hoop Lake and Ponds | SO511075 |
| Gwent (excl. Severn Estuary) | Tredegar House | ST287855 |
| Gwent (excl. Severn Estuary) | Treowen Lake and Ponds | SO464102 |
| Gwent (excl. Severn Estuary) | Wentwood Reservoir | ST429932 |
| Gwent (excl. Severn Estuary) | Ynys-y-Fro Reservoir | ST283890 |
| Merioneth (other sites) | Glaslyn Marshes | SH596404 |
| Merioneth (other sites) | Llyn Arenig Fawr | SH846380 |
| Merioneth (other sites) | Llyn Caer-Euni | SH982405 |
| Merioneth (other sites) | Llyn Celyn | SH859406 |
| Merioneth (other sites) | Llyn Pen Moelyn | SH668156 |
| Merioneth (other sites) | Llyn Trawsfynydd | SH690364 |
| Merioneth (other sites) | Llyn Wylfa | SH672163 |
| Merioneth (other sites) | Llyn Yr Oerfel | SH712389 |
| Merioneth (other sites) | Llynnau Cregennen | SH660143 |
| Merioneth (other sites) | River Dwyryd - Rhaeadr Du to Maentwrog | SH658402 |
| Merioneth (other sites) | Tal-y-llyn Lake | SH718100 |
| Merioneth (other sites) | Tan-y-Grisiau Reservoirs | SH679441 |
| Montgomeryshire | Bugeilyn | SN822922 |
| Montgomeryshire | Churchstoke Wildlife Park Pools | SO279935 |
| Montgomeryshire | Dolydd Hafren | SJ205005 |
| Montgomeryshire | Glaslyn | SN826940 |
| Montgomeryshire | Granllyn Pool, Guilsfield | SJ224117 |
| Montgomeryshire | Ladies Pool, The Stable Pool and The Lilypond | SJ212062 |
| Montgomeryshire | Llyn Clywedog | SN888893 |
| Montgomeryshire | Llyn Coed-y-Dinas | SJ222052 |
| Montgomeryshire | Llyn Du (Llanwnog) | SO006967 |
| Montgomeryshire | Llyn Ebyr | SN976881 |
| Montgomeryshire | Llyn Gwgia | SO053979 |

| Region | Site name | GRIDREF |
|---|---|---|
| Montgomeryshire | Llyn Mawr | SO008970 |
| Montgomeryshire | Llyn Y Tarw | SO020974 |
| Montgomeryshire | Montgomery Canal - The Flash to Welshpool Lock | SJ230077 |
| Montgomeryshire | Montgomery Canal - Welshpool Lock to Belan Locks | SJ223062 |
| Montgomeryshire | Powis Castle Pools - Dairy Pool | SJ218066 |
| Montgomeryshire | Powis Castle Pools - Llyn Du | SJ220071 |
| Montgomeryshire | Pwll Penarth Nature Reserve | SO138927 |
| Montgomeryshire | R.Severn - Llanllwchaiarn to Aberbechan | SO137925 |
| Montgomeryshire | River Carno, Clatter | SN996952 |
| Montgomeryshire | Severn Farm Pond Reserve | SJ228068 |
| Montgomeryshire | The Flash, Welshpool | SJ233083 |
| Pembrokeshire | Bicton Reservoirs | SM842076 |
| Pembrokeshire | Bosherston Lakes | SR976953 |
| Pembrokeshire | Broomhill Burrows Ponds | SM889004 |
| Pembrokeshire | Clarydale Water | SN043176 |
| Pembrokeshire | Crygmarren Pond | SR947989 |
| Pembrokeshire | Dwr Cleifion | SM771258 |
| Pembrokeshire | Frainslake Pool | SR899975 |
| Pembrokeshire | Llys-y-fran Reservoir | SN037254 |
| Pembrokeshire | Marloes Mere | SM774082 |
| Pembrokeshire | Newgale Marsh | SM851221 |
| Pembrokeshire | Newton Noyes Pool | SM923051 |
| Pembrokeshire | Orielton Decoy | SR950993 |
| Pembrokeshire | Orielton Pond | SR955991 |
| Pembrokeshire | Pembroke Mill Ponds | SM992016 |
| Pembrokeshire | Pembroke Power Station Ponds | SM928023 |
| Pembrokeshire | Rosebush Reservoir | SN061294 |
| Pembrokeshire | South Hook Pools | SM873061 |
| Pembrokeshire | St David's Airfield Heath SSSI | SM788264 |
| Pembrokeshire | Trefeiddan Pool | SM733251 |
| Radnorshire | Llandrindod Lake | SO063604 |
| Radnorshire | Llyn Heilyn | SO167581 |
| West Glamorgan | Baglan Pool | SS742929 |
| West Glamorgan | Broadpool | SS509910 |
| West Glamorgan | Coed Hirwaun Pond | SS820845 |
| West Glamorgan | Eglwys Nunydd Reservoir | SS794848 |
| West Glamorgan | Fendrod Pool | SS675968 |
| West Glamorgan | Gnoll Ponds | SS765974 |
| West Glamorgan | Margam Park Ponds | SS803864 |
| West Glamorgan | Oxwich NNR | SS501874 |
| West Glamorgan | Port Talbot Old Docks | SS762890 |
| West Glamorgan | River Llan - Penllergaer Woods | SS628982 |
| West Glamorgan | River Neath and Canal - Croft Road Bridge to Tonna | SS763984 |

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