

Feasibility assessment for reinforcing Curlew by a headstarting programme in Wales

Report No: 1010

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Crynodeb Gweithredol

Yn ôl asesiadau o Adar o Bryder Cadwraeth y DU a Chymru fe ei gilydd, mae'r Gylfinir (*Numenius arquata*) yn rhywogaeth Rhestr Goch, a hynny yn sgil y dirywiad sylweddol yn y boblogaeth fagu. Mae gwaith modelu demograffig a wnaed eisoes yn rhagfynegi y gallai'r Gylfinir fod ar fin diflannu'n llwyr o Gymru fel rhywogaeth fagu hyfyw o fewn y degawd nesaf. Oherwydd arwyddocâd yr argyfwng hwn, ystyrir bellach mai'r Gylfinir yw'r brif flaenoriaeth o ran cadwraeth adar yng Nghymru.

Yng Nghymru, mae dosbarthiad Gylfinirod sy'n magu yn eang a'u dwysedd yn gymharol isel. Felly, rhaid i unrhyw ymateb cadwraeth fod ar raddfa'r dirwedd a hefyd dargedu'r ardaloedd hynny lle mae poblogaethau craidd pwysig yn goroesi. Mae angen i ymyriadau o'r fath fod yn uchelgeisiol, yn hirdymor a chael eu cynnal mewn cydweithrediad â nifer o bartneriaid. Un cam hanfodol a strategol y gellid ei gymryd i osgoi diflaniad y Gylfinir fyddai techneg o'r enw 'achub y blaen' (headstarting), ble caiff wyau eu casglu o nythod gwyllt i'w deor a'u magu gan staff arbennigol, cyn eu rhyddhau yn ôl i'r ardal wreiddiol ble casglwyd yr wyau, a chan hynny osgoi llawer o'r ffactorau a all achosi marwolaeth y cywion.

Mae'r adroddiad hwn yn asesu dichonoldeb hybu lefel cynhyrchiant poblogaeth fagu'r Gylfinir yng Nghymru, a thrwy hynny atgyfnerthu'r boblogaeth, drwy gyfrwng rhaglen genedlaethol yn defnyddio techneg achub y blaen mewn detholiad o Ardaloedd Pwysig i'r Gylfinir (APG). Yn ogystal â chasglu'r wyau, eu deori, magu'r cywion a rhyddhau'r adar ifanc, byddai'r rhaglen yn cynnwys mesurau eraill ar lefel y safle i gynyddu lefelau cynhyrchiant gwyllt. Byddai'r rhain yn cael eu cynnal yn gyfochrog â'r gwaith achub y blaen, ac yn ddelfrydol am nifer o flynyddoedd wedi hynny, i gyd-fynd â Chanllawiau'r IUCN ar gyfer Ailgyflwyno Rhywogaethau a Thrawsleoliadau Eraill er Cadwraeth, sy'n cyfeirio at atgyfnerthu poblogaethau o rywogaethau targed ac sy'n gofyn am ymdrechion parhaus i fodloni anghenion ecolegol y rhywogaethau hynny. Yn achos Gylfinirod sy'n magu, mae hyn yn golygu sicrhau bod digon o gynefin addas ar gael, a rheoli'r cynefin hwn er budd yn ogystal a rheoli ysglyfaethwyr.

Mae'r adroddiad hwn yn amlinellu gwaith modelu ar y boblogaeth o Ylfinirod sy'n magu yng Nghymru i asesu canlyniadau nifer o senarios techneg achub y blaen. Trafodir hefyd y gofynion ymarferol, y cyfyngiadau a chost debygol rhaglen achub y blaen.

Ym **Mhennod** 1, datblygir model stocastig ar gyfer rhagamcanu'r boblogaeth er mwyn ymchwilio i nifer o senarios mewn perthynas â thechneg achub y blaen yn ogystal a gwelliannau ategol i lefelau cynhyrchiant gwyllt. Mae rhain wedi eu paramedru gan ddefnyddio metrigau demograffig a gwerthoedd eraill o Gymru, poblogaethau eraill o Ylfinirod gwyllt, a nifer o raglenni achub y blaen yn Lloegr. Er hwylustod, mae poblogaeth Cymru wedi'i modelu i fod yn un gaeedig (h.y. mae adar sy'n cyrraedd oedran recriwtio yn gwneud hynny yng Nghymru, heb unrhyw recriwtiaid newydd yn cyrraedd o wledydd eraill y DU), gyda rhai recriwtiaid yn gwasgaru rhwng ardaloedd sy'n llai na 30km oddi wrth ei gilydd. Mae'r rhagamcanion yn defnyddio gwerthoedd hysbys i ragamcanu o 2024 i 2026, ac yna'n

modelu poblogaeth fagu'r Gylfinir ar raddfa ofodol Cymru gyfan a graddfa'r APGau a ddewiswyd, a hynny am gyfnod o 30 mlynedd hyd at 2056, gyda'r gwaith achub y blaen yn digwydd am bum mlynedd o 2026 ymlaen a hefyd am bum mlynedd arall mewn ail bwls 15 mlynedd yn ddiweddarach mewn rhai senarios.

Mewn senarios lle gwelir 'gwelliannau yn y lefelau cynhyrchiant cenedlaethol', gwelir cynnydd yn y boblogaeth cychwynnol ar gyfer cynhyrchiant ar draws yr holl barau magu, gan gynnwys y rhai sy'n magu yn wyllt ar draws Cymru, ac ym mhob achos lle defnyddir techneg achub y blaen gwelir hefyd 'fesurau ymyrryd eraill' (sy'n cynrychioli e.e. gwelliannau i'r cynefin a/neu reoli ysglyfaethwyr) yn cynyddu lefelau cynhyrchiant yn y gwyllt yn yr APGau a ddewiswyd.

Cyn ymgorffori'r elfen stocastig ac yn absenoldeb techneg achub y blaen, mae'r metrigau demograffig fel y maent wedi'u paramedru yn cyfateb i'r gyfradd ddirywio a arsylwyd o ~6% y flwyddyn, gyda'r trothwy cynhyrchiant y mae ei angen ar gyfer sefydlogrwydd y boblogaeth yn debygol o fod yn fwy na 0.6 o adar ifanc fesul pâr gan dybio gwerth tebygolrwydd islaw hynny, h.y. nad yw pob oedolyn aeddfed (unigolion wedi recriwtio eisoes) yn ceisio magu bob blwyddyn.

Mae rhagamcanion stocastig yn awgrymu bod y boblogaeth genedlaethol, o dan senarios 'busnes fel arfer' (h.y. yn absenoldeb gwaith achub y blaen), yn debygol o ddal ati i ddirywio, hyd yn oed pe bai lefelau cynhyrchiant yn gwella. Mae hyn yn awgrymu nad yw'r trothwy o 0.6 o adar ifanc fesul pâr magu bob flwyddyn yn ddigonol i wrthdroi'r duedd bresennol yng Nghymru yn absenoldeb targedu dulliau rheoli mewn safleoedd penodol, o leiaf yng nghyd-destun y gwerthoedd demograffig eraill fel y maent wedi'u paramedru.

Er mwyn sicrhau sefydlogrwydd neu dwf ym mhoblogaeth y Gylfinir yng Nghymru erbyn y 2050au o'i gymharu â heddiw, mae angen defnyddio techneg achub y blaen hyd at y 'lefel uchaf sy'n ymarferol' (hyd at 70 nythaid y flwyddyn) neu – yn achos y lleiaf o'r ddau amcangyfrif cychwynnol o faint y boblogaeth (500 yn hytrach na 983 o barau magu) – y 'lefel isaf o fewnbwn gofynnol' i godi'r lefel cynhyrchiant o tua 0.3 i 0.6 o adar ifanc fesul pâr magu (tua 57 nythaid) – a hynny ar y cyd â chynnydd yn y cynhyrchiant cenedlaethol. Mae canlyniadau'r gwaith modelu yn cefnogi defnyddio'r nifer uchaf bosibl o'r wyau sydd ar gael drwy gasglu cyfran o ail nytheidiau (h.y. pan fo parau'n dodwy eildro ar ôl i'w nythaid gyntaf gael ei chymryd ar gyfer y gwaith achub y blaen), ac ailadrodd y pwls pum mlynedd cychwynnol ar ôl 15 mlynedd. Mae'r canlyniadau hefyd yn awgrymu nad yw achub y blaen yn debygol o achosi effeithiau negyddol i'r boblogaeth rhodd, ni waeth faint o adar a gaiff eu dychwelyd i'r APG wreiddiol, o ystyried y tybir bod lefelau isel o gynhyrchiant yn y gwyllt yn cael eu hybu gan y mesurau cysylltiedig ar lefel safle am o leiaf y pum mlynedd gyntaf (gan tua 0.4 o adar ifanc fesul pâr sy'n magu, i gyrraedd 0.6 yn absenoldeb gwelliannau cenedlaethol yn y lefel cynhyrchiant, neu 1.0 pan fo'r poblogaeth sylfaenol newydd eisoes yn 0.6).

Pan ddefnyddir techneg achub y blaen, y disgwyl yw y caiff bron i dri aderyn ifanc ei ryddhau ar gyfartaledd am bob nythaid a gaiff ei chasglu. Trafodir sawl cafeat pwysig i'r canlyniadau, yn ymwneud â chyfyngiadau o ran realaeth y gwaith modelu ac ymarferoldeb gweithredu rhaglen achub y blaen. Yn benodol, gallai gwell

dealltwriaeth o duedd magu'r Gylfinir yng Nghymru wella cywirdeb y rhagfynegiadau hyn.

Mae'r canfyddiadau hyn yn dangos bod y dirywiad ond yn debygol o sefydlogi neu o gael ei wrthdroi (yn sgil twf yn y boblogaeth yn yr APGau ble cynhelir gwaith achub y blaen) ar lefel genedlaethol erbyn y 2050au os ceir gwelliannau yn y lefel cynhyrchiant yn y gwyllt ar draws poblogaeth fagu'r Gylfinir dros Gymru gyfan; os na welir gwelliannau o'r fath yn y lefel cynhyrchiant, rhagwelir dirywiad cenedlaethol o hyd at 80%, hyd yn oed gyda rhaglen achub y blaen. Felly, prif nod rhaglen achub y blaen ar ran y Gylfinir yng Nghymru, fel cyfraniad at Gynllun Adfer y Gylfinir yng Nghymru, fyddai 'ennill amser' tra bod ymyriadau cadwraeth eraill, ar raddfa'r dirwedd, yn cael eu gweithredu neu eu hystyried.

Mae **Pennod 2** yn cyflwyno canllawiau ymarferol cynhwysfawr ar ddefnyddio techneg achub y blaen gyda'r Gylfinir, ac yn amlinellu nifer o senarios lle tybir y byddai casglu tua 50 nythaid y flwyddyn yn arwain at fagu 150 o adar ifanc i'w rhyddhau bob blwyddyn am bum mlynedd.

Mae gwahanol opsiynau o ran nifer/lleoliad y canolfannau magu a'r cam pan gaiff cywion eu trosglwyddo i'w hardaloedd rhyddhau. Mae Dull 3 (canolfan ym mhob un o dair APG/cyfuniadau o hynny) a Dull 4 (canoli'r gwaith deori mewn un ganolfan cyn trosglwyddo'r cywion i'r canolfannau eraill yng nghanol y cam magu) yn cyd-fynd â'r rhagdybiaethau a wneir ym Mhennod 1 ble mae adar ifanc yn dychwelyd i'w APG gwreiddiol.

Caiff gweithgareddau i baratoi (trwyddedu, caniatâd cynllunio, cynlluniau modrwyo a marcio), gofynion staffio, seilwaith angenrheidiol, casglu wyau, deori artiffisial, iechyd a lles adar, bioddiogelwch, gweithdrefnau rhyddhau, a monitro ar ôl rhyddhau, oll eu trafod a'u costio. Mae cyfanswm y costau am chwe blynedd (un flwyddyn baratoi ynghyd â phum mlynedd weithredol) tua £4.9 miliwn – ychydig dros £800,000 y flwyddyn neu tua £6,600 fesul aderyn a gaiff ei ryddhau. Pe bai ail bwls o waith achub y blaen yn cael ei wneud, mae'n debyg y byddai arbedion pe bai'r cyfleusterau'n cael eu cynnal yn y cyfamser. Nid yw'r costau hyn yn cynnwys ymyriadau angenrheidiol eraill, e.e. rheoli cynefinoedd ac ysglyfaethwyr.

Ystyrir bod monitro ar ôl rhyddhau yn hanfodol er mwyn pennu a yw amcanion rhaglen achub y blaen ar gyfer y Gylfinir yng Nghymru yn cael eu cyflawni, ac i sicrhau y caiff gwybodaeth/tystiolaeth ei throsglwyddo i fentrau achub y blaen eraill yn y DU ac Ewrop. Yn ogystal, o greu data hanfodol, byddai hynny'n pennu a oedd yr ymyriadau rheoli a ddefnyddiwyd yn angenrheidiol, yn ddigonol ac wedi'u hoptimeiddio. Byddai gwerthusiad o'r fath o effeithiolrwydd y rhaglen yn hwyluso gwaith rheoli addasol ac felly'n gwella canlyniadau cadwraeth yn y dyfodol.

Executive summary

The Eurasian Curlew (*Numenius arquata*, hereafter 'Curlew') is Red-listed in both the UK and Wales Birds of Conservation Concern assessments due to significant breeding population declines. Existing demographic modelling predicts that Curlew in Wales could be on the brink of extinction as a viable breeding species within the next decade. Due to the significance of this emergency, the Curlew is now considered to be the most pressing bird conservation priority in Wales.

In Wales, breeding Curlew are widely distributed at relatively low densities, and any conservation response must be both applied at a landscape scale and targeted where important core populations remain. Such interventions need to be ambitious, long-term and conducted in collaboration with multiple partners. A critical and strategic action to avoid an extinction outcome may be headstarting, whereby eggs are collected from the wild to hatch and fledge in captivity, avoiding many mortality pressures prior to release back into the area of origin.

This report assesses the feasibility of boosting productivity and hence reinforcing the Welsh Curlew breeding population through a national headstarting programme based on selected Important Curlew Areas (ICAs). In addition to egg collection, incubation, chick rearing and release of fledglings, the headstarting programme would include other site-level measures to increase wild productivity. These would occur concurrently with headstarting and ideally for a number of years afterwards, aligning with the IUCN Guidelines for Reintroductions and Other Conservation Translocations, which refer to the reinforcement of populations of target species and require continuing efforts to meet the species' ecological needs. For breeding Curlew this involves ensuring availability of sufficient suitable habitat and managing this habitat alongside predation.

This report outlines population modelling of breeding Curlew in Wales to assess the outcomes of a number of headstarting scenarios. The practical requirements, limitations and likely cost of a headstarting programme are also discussed.

In **Chapter 1**, a stochastic population projection model is developed to investigate a number of scenarios around headstarting and complementary improvements in productivity. These are parameterised using demographic metrics and other values from Wales, other wild Curlew populations, and a number of English headstarting programmes. For tractability, the Welsh population is modelled to be closed (i.e. birds reaching recruitment do so within Wales, with no new recruits arriving from other UK countries), with dispersal of some recruits occurring between areas that are less than 30 km apart. Projections use known values to project 2024 to 2026, then model the breeding population of Curlew at both all-Wales and selected ICA spatial scales for 30 years to 2056, with headstarting occurring for five years from 2026 and

additionally for a further five years in a second pulse 15 years later in some scenarios.

Scenarios with a 'national productivity improvement' have an increase in baseline productivity across all breeding pairs, including those breeding in the wild across Wales, and in all cases where headstarting occurs it is accompanied by 'other intervention measures' (representing e.g. habitat improvement and/or predation management) increasing wild productivity in the selected Important Curlew Areas.

Prior to the incorporation of stochasticity and in the absence of headstarting, demographic metrics as parameterised correspond to the observed decline rate of ~6% per year, with the productivity threshold required for population stability likely exceeding 0.6 fledglings per pair with the assumption of a propensity value below i.e. that not all mature adults (previously recruited individuals) attempt breeding every year.

Stochastic projections show that under 'business as usual' scenarios (i.e. in the absence of headstarting), the national population is predicted to continue declining, even if productivity were to improve. This suggests that the threshold of 0.6 fledglings per breeding pair per year is insufficient to reverse the current Welsh trend in the absence of targeted management at selected sites, in line with other demographic values as parameterised.

In order to achieve stability or growth for the Welsh Curlew population by the 2050s relative to today, headstarting to the 'maximum feasible' level (up to 70 clutches per year) or, for the smaller of our two estimated starting population sizes of 500 rather than 983 breeding pairs the 'minimum necessary' input to bring productivity from approximately 0.3 to 0.6 fledglings per breeding pair (approximately 57 clutches) is required alongside a national productivity improvement. The modelling results support maximising the number of eggs available by collecting a proportion of second clutches (i.e. when pairs re-lay after their first clutch is taken for headstarting), and repeating the initial five-year headstarting pulse after 15 years.

The results also reveal that headstarting is unlikely to cause negative impacts on the donor population, regardless of the number of headstarted birds returned to the source ICA, given that low wild productivity is assumed to be boosted by the accompanying site-level measures for at least the five years of headstarting (by approximately 0.4 fledglings per breeding pair, to reach 0.6 in the absence of a national productivity improvement, or 1.0 when the new baseline is already 0.6).

When headstarting is deployed, the expectation is to release almost three fledglings per collected clutch on average. A number of important caveats to the results are discussed, involving both limitations to model realism and the practicalities of

implementing a headstarting programme. Notably, a better understanding of Welsh Curlew breeding propensity could improve the accuracy of these predictions.

These findings show that national-level stabilisation or reversal of the decline (driven by population growth in the ICAs hosting headstarting) is only likely to occur by the 2050s if wild productivity improvement occurs across the entire Welsh Curlew breeding population; if such productivity improvement does not occur, national declines of up to 80% are predicted even with a headstarting programme. Hence the principal aim of Curlew headstarting in Wales, as a contribution to the Wales Curlew Recovery Plan, would be to ‘buy time’ while other conservation interventions, at the landscape scale, were implemented or under consideration.

Chapter 2 provides comprehensive guidance on Curlew headstarting, outlining a number of scenarios by which collecting approximately 50 clutches per year is assumed to result in the rearing to release of 150 fledglings each year for five years.

Options differ in the number/location of rearing hubs and the stage at which chicks are transferred to their release areas. Methods 3 (a hub in each of three ICAs/combinations thereof) and 4 (centralising incubation to a single hub before transferring chicks to the other hubs at mid-stage rearing) align with the assumptions made in Chapter 1 where fledglings return to their ICAs of origin.

Preparatory activities (licensing, planning permission, ringing and marking schemes), staffing requirements, necessary infrastructure, egg collection, artificial incubation, bird health and welfare, biosecurity, release procedures, and post-release monitoring are all discussed and costed. Total costs for six years (one preparation year plus five operational years) amount to approximately £4.9 million – just over £800,000 per year or approximately £6,600 per released bird. If a second pulse of headstarting was deployed, savings could likely be made if facilities were maintained in the interim. These costs do not include other necessary interventions e.g. habitat management and predation control.

Post-release monitoring is considered critical to determine whether the objectives of a Welsh Curlew headstarting programme are being achieved and ensuring that knowledge/evidence is transferred to other UK and European Curlew headstarting initiatives. In addition, collation of essential data would determine whether the deployed management interventions were necessary, sufficient and optimised. Such evaluation of programme effectiveness would facilitate adaptive management and hence improve future conservation outcomes.

Background

The Eurasian Curlew (*Numenius arquata*, hereafter ‘Curlew’) is Near Threatened at the global and European levels (BirdLife International, 2017, 2021), but in the UK’s Birds of Conservation Concern (BoCC) is Red-listed due to ‘severe’ breeding population decline (Stanbury *et al.*, 2021). In light of the global importance of this breeding population, the Curlew has been described as the most pressing bird conservation priority in the UK (Brown *et al.*, 2015). In Wales, it is also BoCC Red-listed since the initial assessment in 2002; in the most recent fourth iteration it qualifies due to a breeding population decline of at least 50% over 25 years, putting the population “*at real risk of being lost from Wales*” (Johnstone *et al.*, 2022). Taylor *et al.* (2020) projected extinction of the Welsh breeding population of Curlew to occur sometime between 2027 and 2160, with their ‘best estimate’ being sometime in the first half of the 22nd century, assuming no changes to the species’ demography and ecology. In their words, “*population modelling offers a further perspective on the rate of decline of breeding Curlew in Wales, and the opportunity to understand the spatial- and time-scales required for successful conservation interventions*” (Taylor *et al.*, 2020).

One such proposed conservation intervention, endorsed by Gylfinir Cymru (see [A framework for head-starting Eurasian Curlew in Wales](#) [v1]), is headstarting: the release back into the wild of individual animals that have been reared in captivity following collection at an early life stage. This technique is well-suited to waders (Donaldson *et al.*, 2025) and has been implemented for a number of Curlew populations across Europe, including England (Ewing *et al.*, 2025). The high risk of extinction facing the Welsh population under current conditions supports a clear conservation case to consider headstarting as an appropriate intervention (Lee, 2019a). Hence given the urgency to address Curlew declines together with pressures of accountability and competing resources it is right to ask whether headstarting is a beneficial intervention to aid Curlew recovery in Wales. This question was agreed in principle by Gylfinir Cymru in 2025, on the understanding that any headstarting proposal: carries high risk, requires buy-in from rural communities, requires rigorous decision-making, needs to be defensible, and requires detailed planning, expertise and importantly multi-year funding, both to deploy headstarting as a conservation intervention and to monitor its effectiveness.

The aim of this report is to aid Natural Resources Wales (hereafter ‘NRW’) in assessing the feasibility of a Welsh Curlew headstarting programme for reinforcing the national breeding population through boosted productivity. A subset of the previously identified Important Curlew Areas (hereafter ‘ICAs’) are assumed to be potential source and recipient sites. In Chapter 1, we deploy population modelling to present ICA- and population-level impacts of a range of scenarios including ‘business as usual’ (no headstarting), different headstarting intensities (numbers of

collected clutches), and failed headstarting (i.e. clutches collected but no headstarted fledglings released), from two initial estimated national population sizes. Different timing and duration of headstarting and potential complementary interventions are also considered. In Chapter 2, we detail best-practice Curlew headstarting protocols, along with the required specialist skills for the necessary avicultural/veterinary and post-release monitoring activities. Different facility configurations are presented with logistical and cost implications. Across both chapters, we identify the factors most likely to influence the success of any proposed Curlew headstarting programme in Wales.

On the understanding that any headstarting programme should comply with relevant guidance, including AEWA's Guidelines for the Translocation of Waterbirds for Conservation Purposes (Lee *et al.*, 2012) and the IUCN/SSC Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC, 2013) this report refers throughout to wader headstarting guidance developed by Rebecca Lee (Lee, 2019a, 2019b, 2019c), that explicitly draws from the AEWA guidelines as well as the Scottish Code for Conservation Translocations (National Species Reintroduction Forum, 2014). This is itself based on the IUCN guidance. Specifically, this report covers a number of the key stages involved in wader headstarting, as identified in Lee (2019b).

A collaborative appraisal has already been conducted by Gylfinir Cymru, who agreed that headstarting is a justifiable intervention to support Curlew recovery in Wales. Here Chapter 1 initiates the 'planning' stage by considering feasibility and some elements of risk (e.g. impacts on the donor site populations should captive rearing fail to produce any fledglings – an extremely unlikely occurrence). Were NRW to proceed, following completion of a comprehensive risk assessment, socio-economic and biological feasibilities, the actual steps involved in headstarting and associated post-release monitoring are described in Chapter 2.

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Chapter 1. Population modelling to explore Curlew headstarting scenarios

Introduction

Population modelling plays a crucial role in the feasibility assessment and justification of proposed headstarting programmes (Donaldson *et al.*, 2025a):

“Population modelling as part of the headstarting plan enables projects to determine the viability of this intervention for population recovery and propose or set feasible targets, with due consideration for practical constraints, such as the number of eggs that are available for headstarting or that could realistically be hatched and raised in captive-rearing facilities in any given year”.

Here we first parameterise (multiple versions of) a matrix population model, to ensure that the asymptotic dynamics predicted from the selected demographic variables align with the observed trajectory in the absence of interventions – Breeding Bird Survey data indicate that the Welsh breeding Curlew population is declining by approximately 6% per year (Gylfinir Cymru, 2021; Heywood *et al.*, 2024). We then develop a stochastic population model that incorporates natural variability in vital rates, as well as the headstarting process and expected dispersal patterns. This model is used to project 30 years from 2026, across a range of scenarios, including ‘business as usual’ and a number of headstarting options.

Methods

Core assumptions

Given the complexity involved with incorporating known minor exchange between breeding Curlew in Wales and neighbouring countries, the Welsh population is modelled to be closed i.e. birds reaching recruitment do so within Wales, with no new recruits arriving from elsewhere. See the ‘Dispersal between segments’ Methods section for modelled metapopulation structure within Wales.

Density dependence is not incorporated: Viana *et al.*’s (2023) demographic model for Curlew was density-independent, partly informed by Cook *et al.*’s (2021) conclusion that current declines are more likely to be driven by low productivity. More specifically, Cook and colleagues did not find a relationship between survival and density at the Welsh ringing site of Traeth Lavan. Furthermore, severe declines (by 78% 1995-2023; Heywood *et al.*, 2025) mean that the national population is currently

well below historic levels. The logical assumption, given the lack of ICA-specific population estimates prior to their establishment, is that trends in the areas that now form the selected ICAs have paralleled those at the wider scale, such that current populations are much smaller than in the past. However, it should be acknowledged that carrying capacities will at some point impose on population growth at smaller spatial scales such as that of individual sites and eventually whole ICAs. Additionally, while the stochastic population model facilitates inclusion of the random events that particularly imperil small populations (Lande, 2002), it does not incorporate Allee effects to account for positive density-dependence when few individuals remain (such that, for example, it becomes harder to find a mate; Gascoigne *et al.*, 2009).

Spatial scale

The population of interest is that of Welsh breeding Curlew as a whole. However, headstarting would take place at a more local scale: as active projects with data available for 2024, ICAs 2&3 (taken together), 5, 9 and 12 were considered to be the most relevant combined donor-recipients. Further information on the ICA network can be found in the Wales Action Plan for the Recovery of Curlew (hereafter 'Welsh Action Plan'; Gylfinir Cymru, 2021), but Table 1.1 summarises the selected ICAs. Figure 1.1 contextualises the selected ICAs within the ICA network, and all ICAs within the Welsh population; hereafter we refer to each of ICAs 2&3, ICA 5, ICA 9, ICA 12, the remainder of ICAs, and the rest of Wales as population 'segments'. The spatial interrelationships between the selected ICAs and other population segments is detailed below in the section on 'Dispersal between segments'.

Table 1.1. Summarised information for the selected ICAs, derived from Table 2 of the Welsh Action Plan (Gylfinir Cymru, 2021).

ICA(s)	Name	Location	Estimated population (breeding pairs) in 2020
2&3	Mynydd Hiraethog; Ysbyty Ifan	Conwy, North West Wales	30-35
5	South Clwyd Mountains	Denbighshire, North East Wales	51
9	Montgomeryshire	Powys, Mid Wales	40
12	Usk catchment and Llangorse Lake	Breconshire, Mid Wales	9

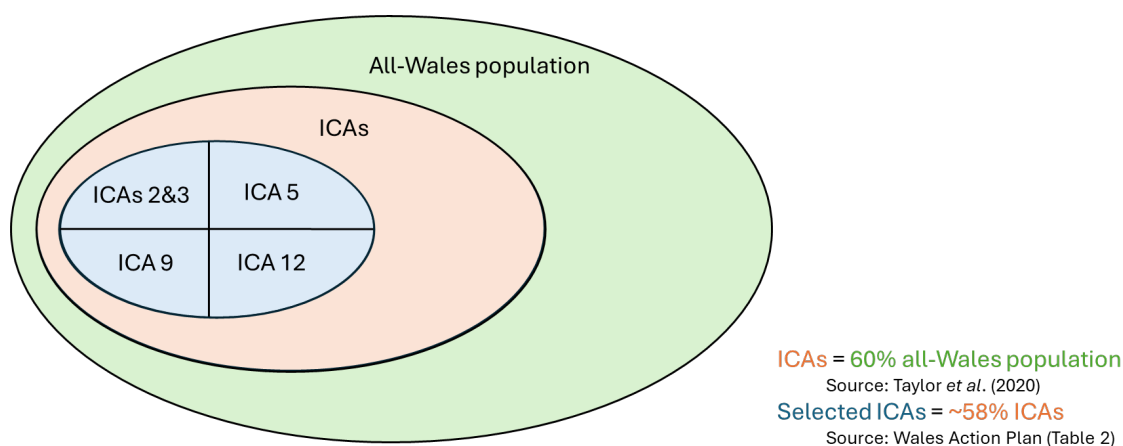


Figure 1.1. Nested relationships between the selected ICAs, all ICAs, and the Welsh population. A diagram illustrating the nested relationship between the total Welsh breeding curlew population, the proportion across all ICAs, and that in selected ICAs. The selected ICAs - ICAs 2&3, 5, 9, and 12 - are shown in an equally divided blue oval, nested within a larger peach oval for all ICAs, itself nested within a green oval for the all-Wales population. Sources are provided: ICAs = 60% all-Wales population (Taylor *et al.*, 2020); selected ICAs = ~58% of all ICAs (Wales Action Plan, Table 2).

Demographic metrics

As much as possible, demographic metrics informing population models should be accurate, contemporary and relevant to the specific focal population. The demographic metrics used to parameterise the matrix population models and stochastic projection model analysed in this chapter are summarised in Table 1.2 and contextualised below. Approximate values are presented to two decimal places unless otherwise specified.

Table 1.2. Demographic metrics used to parameterise the matrix population models and stochastic projection model analysed in this chapter, and the sources from which they were derived. SD = standard deviation. Approximate values are presented to two decimal places unless otherwise specified.

Demographic metric	Value(s)	Source(s)
2024 population size selected ICAs	181 breeding pairs	<i>Pers. comms.</i> from selected ICAs
2024 population size all ICAs	639 or 311 breeding pairs	Extrapolation based on selected ICA/all-Wales information and the Welsh Action Plan (Gylfinir Cymru, 2021)
2024 population size all Wales	983 or 500 breeding pairs	Derived from Taylor <i>et al.</i> (2020) and <i>pers. comms.</i> from NRW

Demographic metric	Value(s)	Source(s)
Survival adult (2+yo)	0.905	Taylor <i>et al.</i> (2020)
Survival immature (1-2yo)	0.905	Based on Cook <i>et al.</i> (2021)
Survival juvenile (fledging to 1yo)	0.43	Viana <i>et al.</i> (2023)
Recruitment propensities (probabilities of breeding for the first time at X years old)	~0.12 @ 2yo ~0.31 @ 3yo ~0.73 @ 4yo 1 @ 5yo	WWT unpublished data (Curlew headstarting/monitoring programme for Severn & Avon Vales)
Breeding propensity	1 or ~0.71	Latter derived from tagging data in Taylor <i>et al.</i> (2020)
Clutch size	~3.75 ± ~0.56 SD, range 1-5 ICAs 2&3,5, 9 and 12 individually parameterised	<i>Pers. comms.</i> from selected ICAs; WWT unpublished data (ICA 8)
Relaying probability	0.54	Derived from Taylor <i>et al.</i> (2020)
Wild productivity	Selected ICAs individually parameterised; indicative average: 0.20 ± 0.05SD Remainder ICAs: 0.21 ± 0.11SD Remainder Wales: 0.20 ± 0.06SD In all cases, range = 0-1.4	<i>Pers. comms.</i> from selected ICAs and NRW; Taylor <i>et al.</i> (2020); Viana <i>et al.</i> (2023)
Hatching success in captivity	Weighted mean ≈ 0.84 20% @ ~0.68, 80% @ ~0.87	WWT unpublished data (Curlew headstarting programmes for Severn & Avon Vales and Dartmoor)
Fledging success in captivity	Weighted mean ≈ 0.84 20% @ ~0.57, 80% @ ~0.90	WWT unpublished data (Curlew headstarting programmes for Severn & Avon Vales and Dartmoor)
Sex ratio to fledging	Assumed 50:50	Taylor <i>et al.</i> (2020); Viana <i>et al.</i> (2023)
Dispersal probability (proportion of surviving individuals recruiting away from their hatch site)	0.19	Gerritsen (2021)

Starting population sizes:

Starting population vectors for stochastic projection were generated from estimated numbers of breeding pairs.

- *Selected ICAs breeding population:*

The selected ICAs together held an estimated 181 breeding pairs in 2024 (*pers. comms.*, 2025).

- *ICA breeding population:*

The Welsh Action Plan suggests that the selected ICAs accounted for 56-61% of the ICA breeding population in 2020 (Table 2 in Gylfinir Cymru, 2021). If this held to 2024, we could extrapolate to an estimated 311 breeding pairs across all ICAs (130 in addition to the 181 in selected ICAs).

- *National breeding population:*

In their Welsh Curlew population projection, Taylor *et al.* (2020) estimated 1,101-1,578 breeding pairs in 2019. Here we extrapolated the midpoint of this range forward to 2024 using the Welsh Action Plan's (Gylfinir Cymru, 2021) estimated population decline rate of 6% per year: 1,340 in 2019 → 983 in 2024. However, expert opinion estimates the Welsh breeding population may have been as low as 500 breeding pairs by 2024 (NRW, *pers. comms.*), so we project from two starting points: 983 breeding pairs as the larger and 500 breeding pairs as the smaller.

- *Combined scenarios:*

It is thought that up to 65% of the Welsh Curlew breeding population are located within the ICA network (Gylfinir Cymru, 2021). We therefore present scenarios with paired national and ICA breeding population estimates, as it is presumably unlikely to have ICAs actually constituting only 32% of the national population, as would be the case for 311 ICA pairs and 983 national pair (while 65% of 500 is 325, very close to the back calculated value of 311). Hence the larger population scenario has 983 breeding pairs in Wales of which 639 are found in ICAs (based on ICAs as a proportion of the total Welsh population), while the smaller population has 311 ICA pairs within a total of 500 (based on selected ICAs as a proportion of the total ICA population). In either case, the 181 breeding pairs believed to represent the selected ICAs, are removed from the total ICA population to estimate the breeding pairs present in the rest of the ICA network. This means that the

larger population scenario assumes that the selected ICAs represent a smaller part of the ICA network as a whole.

Survival:

- *Adult survival:*

Adult survival was taken to be 0.905, as in Taylor *et al.* (2020). This value is specific to Wales, derived from Taylor & Dodd (2013). It also represents the approximate midpoint of a number of other estimates: 0.81 (Viana *et al.*, 2023; Europe-wide literature review), 0.90 (Viana *et al.*, 2023; from the ‘most probable parameter combination’ using newly-derived Europe-wide survival estimates), and 0.922 (Cook *et al.*, 2021; based on the UK breeding population since 1996).

- *Immature survival:*

Survival of immatures (aged 1 to 2 years old) was also taken to be 0.905, as Cook *et al.* (2021) support not splitting this rate from that of adults. Our value is therefore higher than Taylor *et al.* (2020)’s estimate of 0.656, that they derived by applying a post-hunting ban increment to a value that had been previously estimated for UK and Ireland (Bainbridge and Minton, 1978).

- *Juvenile survival:*

Survival of juveniles (from fledging to 1 year old) was taken to be 0.43. This is the midpoint of the two UK-relevant estimates from Viana *et al.*’s (2023) synthesis, including Cook *et al.* (2021). Our value is therefore slightly lower than Taylor *et al.* (2020)’s estimate of 0.489, derived as for their immature survival rate. However, our estimate (as well as the existence of two survival age-classes, grouping immatures with adults) is supported by unpublished capture-mark-recapture analyses on the headstarted Curlew released at WWT Slimbridge in 2019 (for further information see the ‘Monitoring released birds’ section in Chapter 2).

Age-specific recruitment propensities:

Rather than assuming, for example, that all birds recruit at 2 years old (as in e.g. Taylor *et al.*, 2020), age-specific recruitment propensities were derived from the observed distribution across known-age birds in the Severn & Avon Vales (mostly headstarted individuals, with mean/median/mode age at first breeding = 4 years old; unpublished data). We estimate recruitment propensity at age X (for X = 2-5 years

old) as follows: 0.12 for 2yo, 0.31 for 3yo, 0.73 for 4yo, 1 for 5yo. This means that individuals reaching 2 years old have a 12% probability of recruiting that year, while those that don't recruit and survive another year then have an almost one-third probability of breeding for the first time at age three. Recruitment probability at age 5 is set to 1 in order to solve for the other values, as this is the oldest observed age of recruitment. For details of a similar methodology see Appendix C in Nicol-Harper *et al.* (2023).

Breeding propensity:

Once individuals have recruited into a breeding population, it is often assumed that they subsequently attempt breeding at every opportunity (e.g. each year for annually-breeding species). We therefore include model parameterisations with full breeding propensity (i.e. breeding propensity = 1). However, there is evidence of intermittent breeding (i.e. breeding propensity <1) in many species; see Nicol-Harper *et al.* (2025).

Hence, we also derived a lower breeding propensity estimate from the tagging data presented in Taylor *et al.* (2020). Of 18 birds tagged prior to initiation of incubation (pooling sexes to increase sample size but avoiding double-counting of what appear to be a breeding pair), 12 birds went on to breed: this would give a breeding propensity of ~0.67. We adjust this to ~0.71 (12/17) based on our calculated stable stage distribution, which suggests that one of the 18 apparently adult birds would actually be a pre-breeder (i.e. not yet recruited, and hence subject to recruitment rather than true breeding propensity). While this value may seem low, it is supported by observations from the selected ICAs: in one case, an estimated 5-8% of total pairs were thought to be holding territory but were not considered to be breeding, with a further 16-32% having initially held territory but moving off due to poor conditions or anthropogenic disturbance. See 'Wild productivity' further down in this section for an explanation of the treatment of breeding propensity at selected ICAs.

Clutch size:

Clutch size was parameterised based on data from the selected ICAs plus ICA 8 ('Curlew Country' in Shropshire, where WWT has assisted with an existing headstarting programme). The overall mean was 3.75 ± 0.56 (standard deviation), ranging from 1 to 5 eggs. ICAs 2&3, 9 and 12 had individually parameterised clutch size distributions, while ICA 5 (for which we were provided with minimum and maximum values only), the rest of the ICAs, and the remainder of Wales took the overall parameters as above (see Figure 1.2).

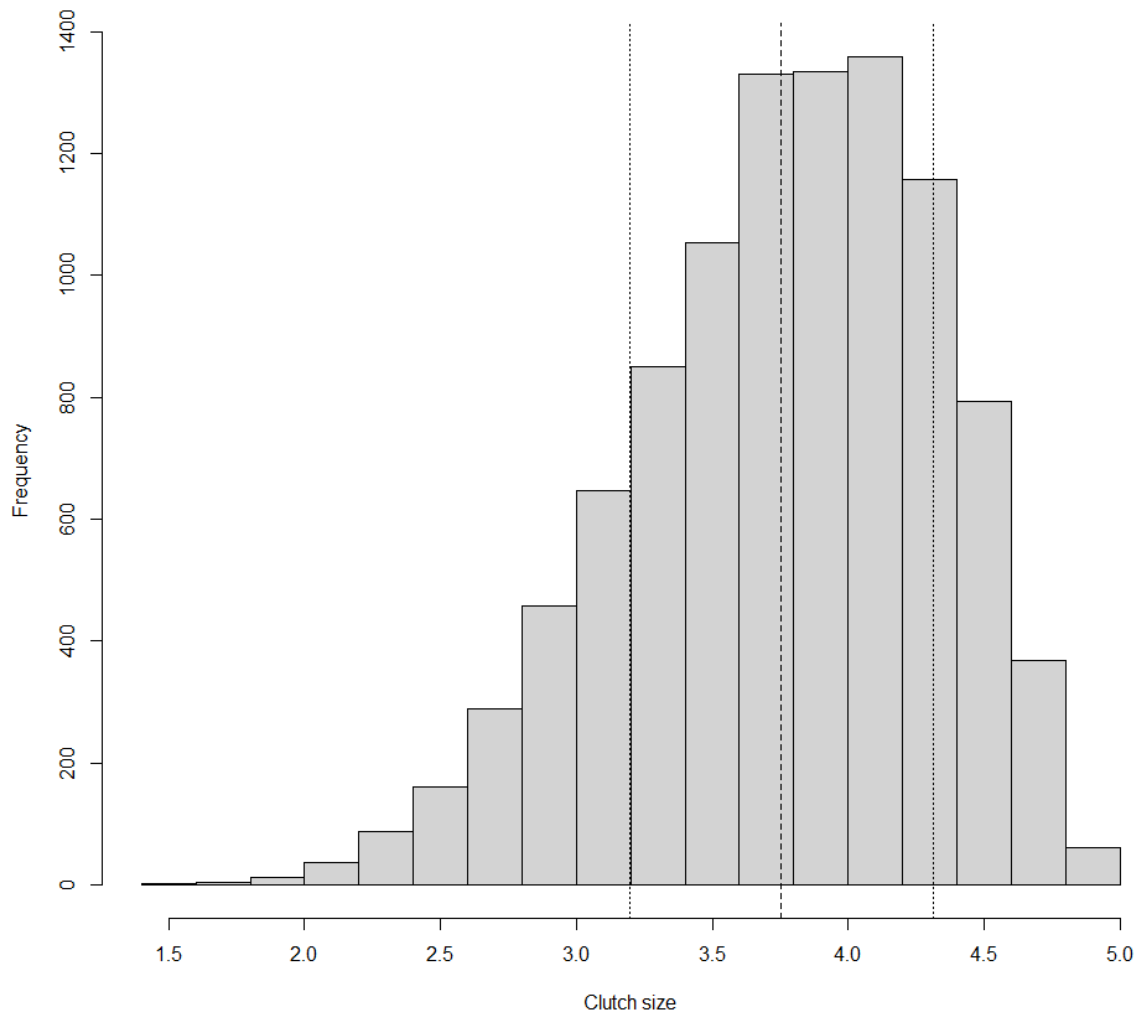


Figure 1.2. Visualisation of the stretched beta distribution for clutch size as parameterised outside of the selected ICAs (i.e. for the remaining ICAs and the rest of Wales, and ICA 5 which wasn't parameterised separately). Frequency refers to 10,000 draws from the distribution. The dashed line denotes the mean and dotted lines ± 1 standard deviation.

Histogram showing the stretched beta distribution of clutch size, with frequency on the y-axis (ranging 0-1400) and clutch size on the x-axis (ranging 1.5-5.0). The distribution peaks around a clutch size of 4, with a vertical dashed line marking the mean at ~ 3.75 , and vertical dotted lines for ± 1 standard deviation at ~ 3.2 and ~ 4.3 .

Relaying probability:

The probability that a pair relay after their clutch is collected for headstarting was taken to be ~ 0.54 , based on tagging data from Taylor *et al.* (2020): of 13 failed first nesters, seven went on to lay a second clutch.

Wild productivity:

The Welsh Action Plan (Gylfinir Cymru, 2021) emphasises a productivity target of at least 0.6 chicks per pair per year, derived from Taylor *et al.*'s (2020) value of 0.63. This is compared to an estimated realised productivity of 0.31 (from Taylor and colleagues' trend-matching exercise), suggesting a shortfall of approximately 0.3 fledglings per breeding pair per year. However, provided data from the selected ICAs, covering one to four years of observations between 2022-2025, suggest that even in these areas, average productivity is currently $\sim 0.20 \pm 0.05$ (standard deviation, with area-specific mean productivities ranging from ~ 0.15 to ~ 0.26 ; selected ICAs, *pers. comms.*). This is confirmed when considering productivity across the ICA network as a whole based on 2024 (53 confirmed fledglings and 81 probable, from 256 breeding pairs, with the former taken as the mean and the latter to represent one standard deviation above the mean; NRW, *pers. comms.*): 0.21 ± 0.11 (see Figure 1.3). Similarly, contemporary estimates placed Welsh Curlew productivity close to 0.2 (NRW, *pers. comms.*), with Taylor *et al.*'s (2020) estimate of 0.31 assumed to represent an upper boundary, or more specifically one standard deviation above the mean (i.e. standard deviation = 0.11). In all cases minima were set to 0 and maxima to 1.4 (the latter drawn from Table 1 in Viana *et al.*, 2023).

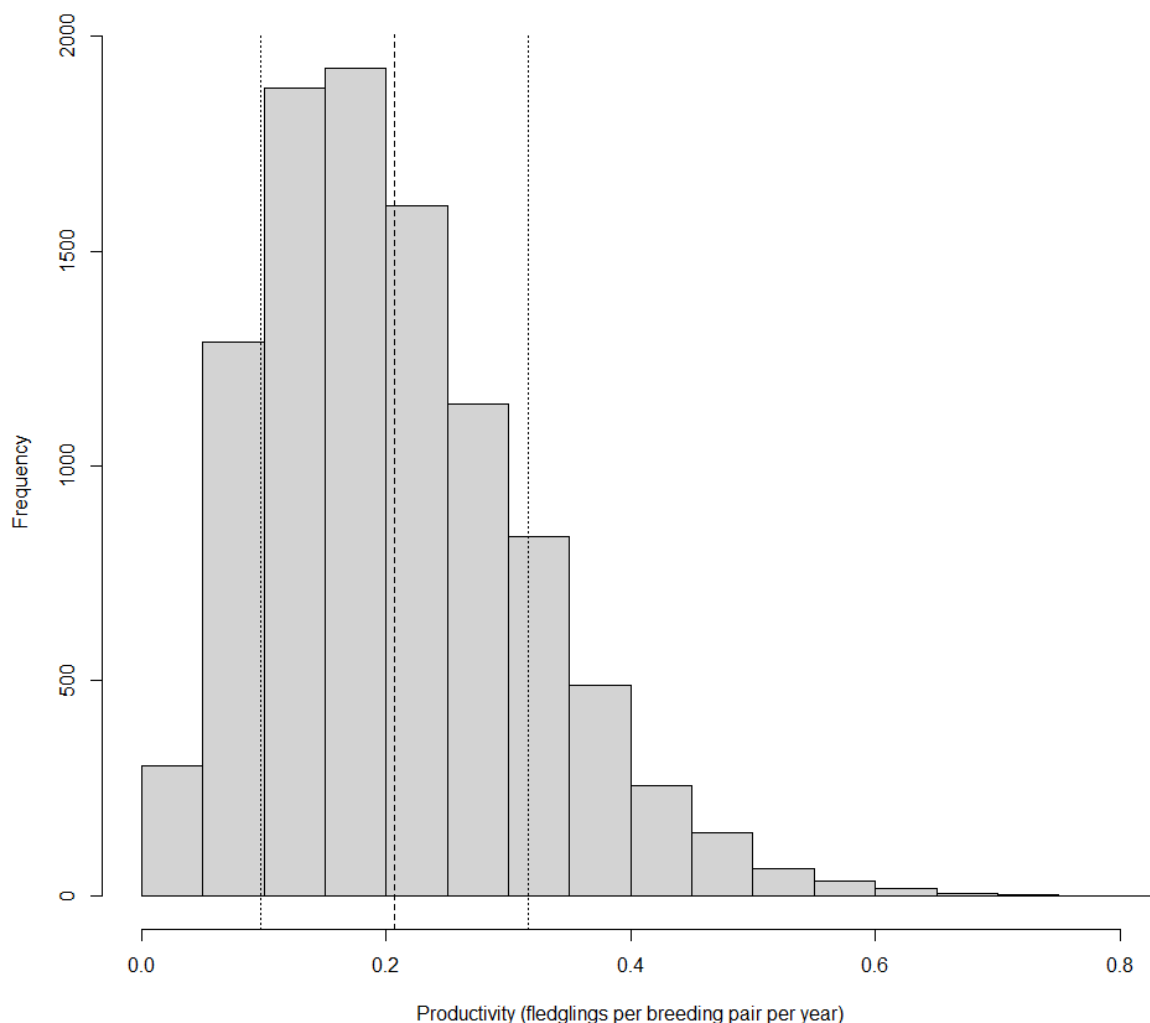


Figure 1.3. Visualisation of the stretched beta distribution for wild productivity as parameterised from information across the ICAs in 2024. Frequency refers to 10,000 draws from the distribution. The dashed line denotes the mean and dotted lines ± 1 standard deviation.

Histogram showing the stretched beta distribution of productivity (fledglings per breeding pair per year), with frequency on the y-axis (ranging 0-2000) and productivity on the x-axis (ranging 0-0.8). The distribution peaks around a productivity of 0.15, with a vertical dashed line marking the mean at just over 0.2, and vertical dotted lines for ± 1 standard deviation at ~ 0.1 and 0.3 .

For the selected ICAs, reported observed fledglings were taken to be spread across all reported breeding pairs (as opposed to the closely monitored attempts only), with all pairs breeding – i.e. breeding propensity is essentially wrapped into productivity for the selected ICAs (so, the aforementioned breeding propensity rate is applied only to non-selected ICAs and rest of Wales).

Headstarting hatch and fledge success rates:

For both hatching success and fledging success, available data from WWT Curlew headstarting (for the Severn & Avon Vales in 2019, and Dartmoor 2021-2024) show one notably bad year compared to four much better years (the bad site-years being Dartmoor 2022 for hatching and Dartmoor 2023 for fledging). Hence, in the model there is a random draw with 20% chance of a bad year (observed values: ~0.68 hatch; ~0.57 fledge) and 80% good (means across the four values: ~0.87 hatch; ~0.90 fledge). Where an average value is needed (e.g. for calculations of number of clutches required under different headstarting scenarios), a weighted mean is taken (~0.84 for both hatch and fledge).

Sex ratio:

Sex ratio to fledging was assumed equal (as in Taylor *et al.*, 2020 & Viana *et al.*, 2023).

Dispersal probability:

Dispersal probability, or the proportion of surviving individuals moving away from their hatch site for recruitment, was taken to be 0.19, based on a Dutch study of wild Curlew ringed as chicks: Gerritsen (2021) found that 81% of resights returned to their area of origin to breed (with a mean dispersal distance of 3.8 km, up to a maximum 12 km).

Population modelling

Population viability analyses were conducted through population projection modelling. Models project a single limiting sex (it is generally assumed that this represents females, but it could equally represent males as none of the included demographic metrics are disaggregated by sex) and were formulated based on annual pre-breeding censusing of a five-stage life cycle. The stage classes modelled were: 1-year-olds, 2-year-old pre-breeders, 3-year-old pre-breeders, 4-year-old pre-breeders, and recruited adults (i.e. birds that have bred previously, not necessarily then breeding every subsequent year – see ‘Breeding propensity’ in the ‘Demographic metrics’ section). Population vectors to initiate projection were generated by using the relevant asymptotic model’s stable stage distribution to convert estimates of breeding pairs into individuals of the limiting sex in each stage class. For simplicity, and due to a lack of parameterising data, all recruited adults are treated the same – for example, there is no difference in survival or reproduction rates with increasing age or experience.

A simplified life cycle – that is converted into a matrix population model to assess asymptotic predictions and to calculate stable stage distributions (Caswell, 2001) – is illustrated in Figure 1.4. This represents a pre-breeding census, such that an individual born last breeding season is (almost) a year old at the start of the focal year (noting that juvenile survival is built into the fertility rate, with individuals first censused at one year old). Division by two in the fertility rate represents half of offspring being of the limiting sex under an assumed equal sex ratio.

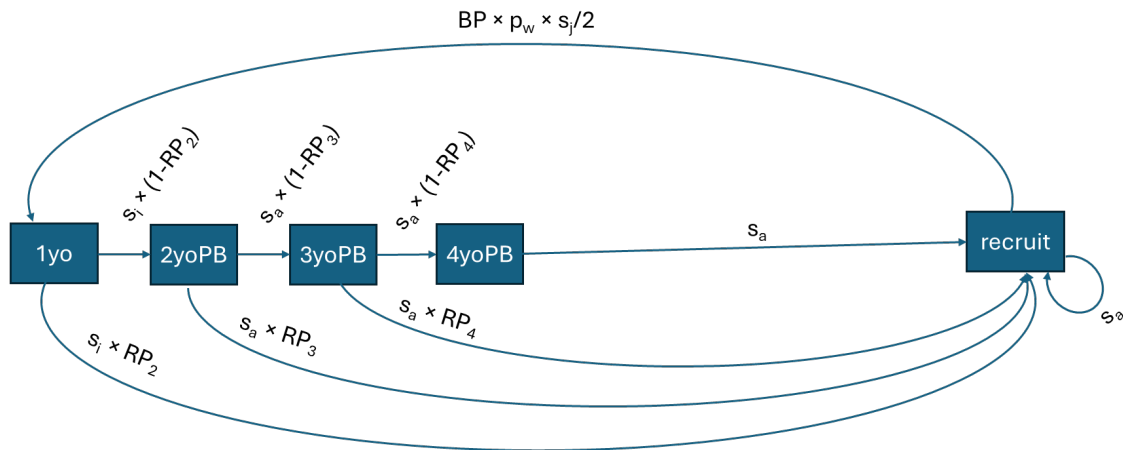


Figure 1.4. Simplified life cycle underlying the matrix population model used to assess asymptotic predictions and calculate stable stage distributions. Boxes represent stage classes and arrows represent possible transitions between states (noting that the top arrow represents fertility rate i.e. production of new 1yo individuals by breeders). $s_{j/i/a}$ = juvenile/immature/adult survival; BP = breeding propensity; p_w = wild productivity; RP_X = recruitment probability at age X (taken to be 1 at age 5).

Life-cycle diagram with stages labelled "1yo", "2yoPB", "3yoPB", "4yoPB" and "recruit". 1yo goes to 2yoPB [$s_i \times (1 - RP_2)$] and recruit [$s_i \times RP_2$]. 2yoPB goes to 3yoPB [$s_a \times (1 - RP_3)$] and recruit [$s_a \times RP_3$]. 3yoPB goes to 4yoPB [$s_a \times (1 - RP_4)$] and recruit [$s_a \times RP_4$]. 4yoPB goes to recruit only [s_a]. Recruit has a self-returning loop [s_a]

Figure 1.5 illustrates how intermediate stages (shown in orange) are split out to facilitate segment-specific parameterisation and incorporation of stochasticity where appropriate: breeding adults (paired), eggs (separated for headstarting only), hatchlings (separated for headstarting only), fledglings (headstarted and wild-reared, subsequently combined), new recruits (produced in focal segment, staying in focal segment, dispersing from focal segment, coming from another segment). Stochasticity is parameterised through:

- binomial distributions for probabilities (i.e. bounded 0-1): survival rates, recruitment propensities, breeding propensity, hatching and fledging rates (in captivity), sex ratio, and all elements of inter-segment dispersal (described below). Note that relaying probability is incorporated only as a mean expectation due to the complexity of the equations in which it

features (with 'Relaying Probability' and its complement '1-RIP' being calculated across multiple lines of code).

- stretched beta distributions for rates (i.e. bounded with minimum 0 but no specified maximum): clutch sizes and productivities.

Note that headstarted individuals are modelled to be indistinguishable from wild-reared individuals, i.e. there is no fitness 'penalty' to being captive-reared. This has been evidenced in Black-tailed Godwit (*Limosa limosa*) where "*apparent survival and breeding success of headstarted individuals is comparable to wild-reared conspecifics*" (Donaldson *et al.*, 2005b). Note that it is possible, as theorised in the [framework for head-starting Eurasian Curlew in Wales](#) [v1], for headstarted birds to enjoy a fitness 'bonus', as they will tend to only be released in good condition and hence presumably more resistant to threats. Donaldson and colleagues provide examples of this in Common Crane (*Grus grus*) - "*Survival of all age-classes [of released birds] was apparently higher than survival of healthy wild individuals, particularly in juvenile age-classes*" (Donaldson *et al.*, 2023) - and Black-tailed Godwit - "*Our estimate of 1-year-old survival (0.50) is slightly higher than for other populations [...], potentially because headstarted godwits are released in good condition having had access to sufficient food and protection during rearing*" (Donaldson *et al.*, 2025b).

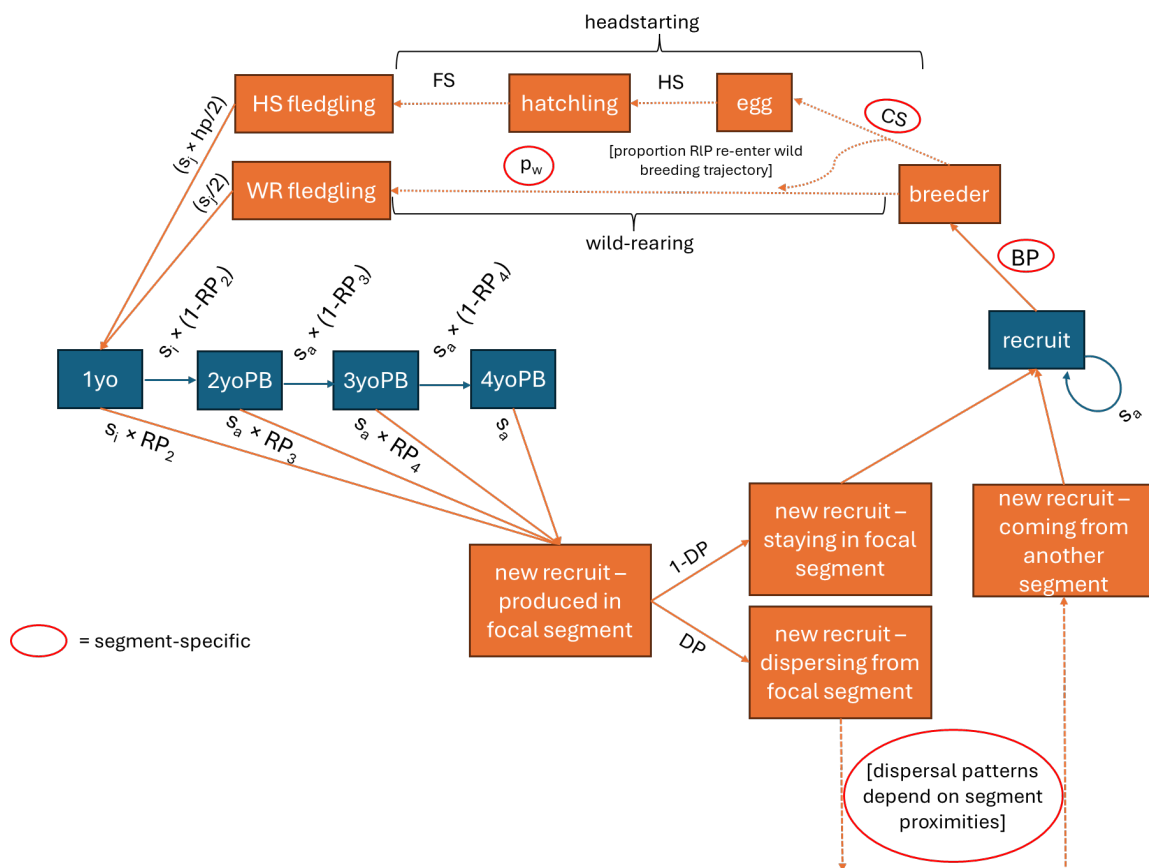


Figure 1.5. Life-cycle model as projected for all main scenarios (ignoring the 'headstarting' loop for 'business as usual' scenarios and for segments not headstarting under the other scenarios).

Red circles highlight values which differ between some segments. $S_{j/i/a}$ = juvenile/immature/adult survival; BP = breeding propensity; p_w = wild productivity; RP_X = recruitment probability at age X (taken to be 1 at age 5); CS = clutch size; RIP = relaying probability; HS = hatching success; FS = fledging success; RP_X = recruitment propensity at age X; DP = dispersal probability; hp = headstart penalty (set to 1 due to insufficient evidence – see ‘Welsh context’ section in Chapter 2).

An expanded version of the life-cycle diagram from Fig. 1.4. The transitions from 1yo & 2-4yoPB that went to recruit now go to "new recruit - produced in focal segment", which splits across new recruits either "staying in focal segment" [1-DP] or "dispersing from focal segment" [DP]. Dashed lines from the dispersers and from outside

Dispersal between segments

Having survived to the age at which they will breed for the first time, newly-produced recruits were subjected to dispersal probability. Birds are subsequently assumed to be site-faithful (at the level of population segments) post-recruitment. Non-dispersers remain in their segment of origin; dispersers are assigned to the rest of the ICA network (65%) versus the rest of Wales (35%) based on proportional population sizes. ICA-directed dispersers are then assigned to other selected ICAs versus the rest of the ICA network (Table 1.3), based on proportional coverage of the area surrounding the focal ICA (using 30 km buffers around the selected ICAs, as shown in paler colours in Figure 1.6). The applied 30 km threshold is essentially arbitrary and reflects the British Trust for Ornithology’s Curlew headstarting recruitment survey method design (*pers. comms.*, BTO); it is likely conservative, in the sense of overestimating ordinary dispersal distances, as resighting data for wild Curlew chicks in the Netherlands suggest that the vast majority recruit less than 12 km from their site of origin (Gerritsen, 2021).

Table 1.3. Proportions of individuals dispersing from their segment of origin (column 1), into one of the selected ICAs or the rest of the ICA network (remaining columns). Non-applicable movements (exceeding 30 km between ICAs excluding buffers) are marked with ‘N/A’.

	ICAs 2&3	ICA 5	ICA 9	ICA 12	Other ICAs combined
ICAs 2&3	N/A	0.41	N/A	N/A	0.59
ICA 5	0.26	N/A	0.21	N/A	0.53
ICA 9	N/A	0.07	N/A	N/A	0.93
ICA 12	N/A	N/A	N/A	N/A	1.00

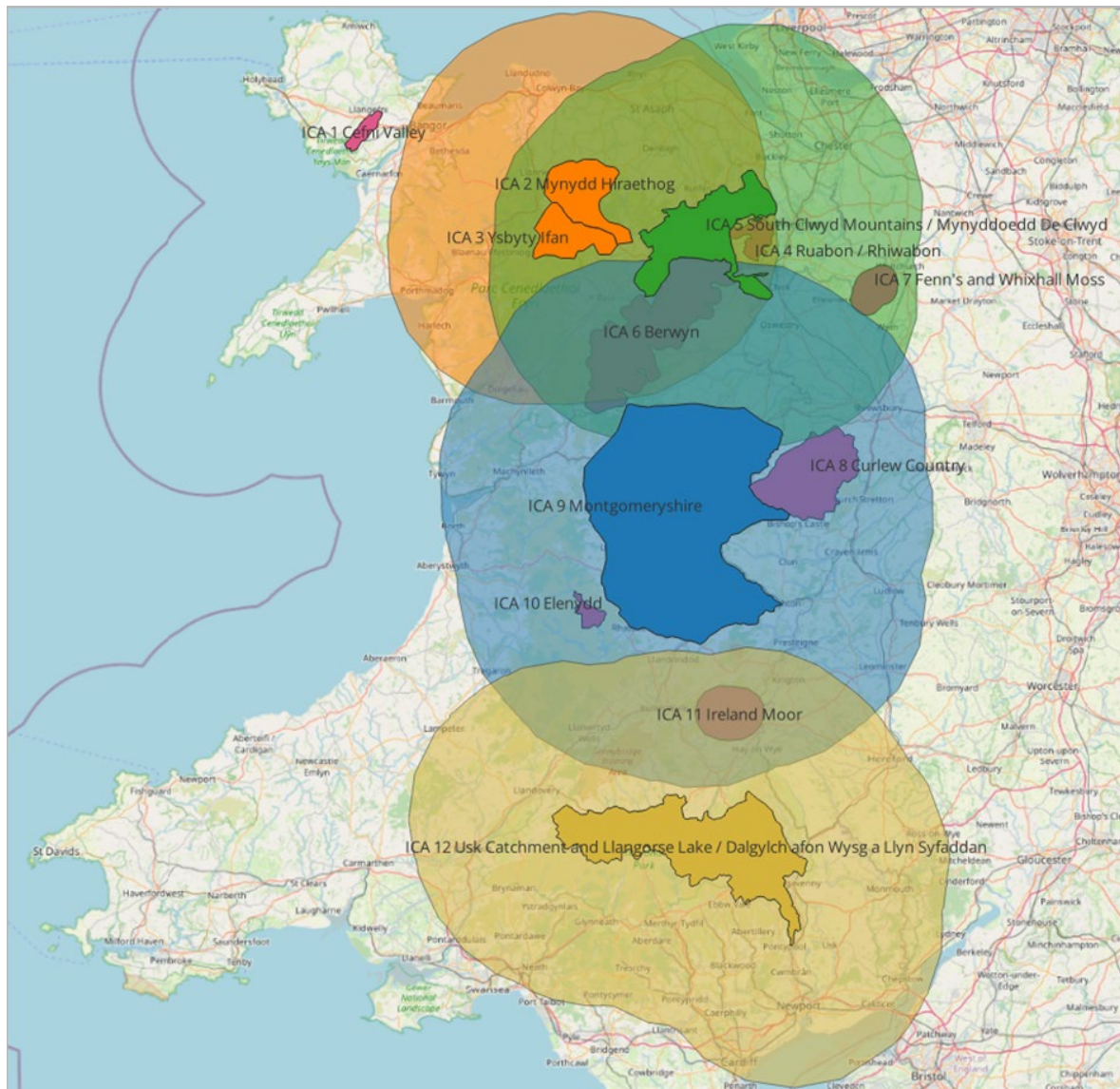


Figure 1.6. A map of Wales showing all ICAs (darker colours), with 30 km buffers around the selected ICAs (paler colours). ICAs 2 and 3 are merged here, with a joint buffer. Created in QGIS using the ICA layer available at https://datamap.gov.wales/layers/geonode:nrw_ica_wales.

Map of Wales showing labelled ICAs 1 through 12 (moving southwards from 1 on Anglesey to 12 in southeast Wales), each polygon filled with a distinct colour. The selected ICAs (2&3, 5, 9, 12) are shown in stronger contrast, each with a paler buffer around the shape. All of the buffers overlap, but the outline of ICA12 is not reached by the buffer of ICA 9 to the north (or those of ICAs 2&3 and ICA 5, further north again).

Recruits originating from non-selected ICAs and the rest of Wales can also disperse into the selected ICAs of 2&3, 5, 9 and 12; these probabilities were determined via the proportion of the whole ICA network covered by each of the selected ICAs (Table 1.4).

Table 1.4. Proportional cover of the whole ICA network area by each of the ICA segments.

ICA(s)	Proportion of total ICA area
ICAs 2&3	0.07
ICA 5	0.09
ICA 9	0.40
ICA 12	0.18
Remainder ICAs	0.26

Projection scenarios

Numbers of clutches to be collected under headstarting (Table 1.5) were calculated by dividing the relevant number of fledglings by the product of clutch size (overall mean), captive hatch success (weighted mean) and captive fledge success (weighted mean). For 'minimum necessary clutches' (to hit the stability threshold at the national level), it was assumed that the breeding population is falling short by the difference between current Welsh productivity (0.3) and the number of fledglings per pair necessary for a stable population (0.6). For 'maximum feasible clutches', the numerator is determined based on a reported maximum feasible cohort size of approximately 40 fledglings, potentially increased by a factor equal to relaying propensity when modelling a second round of collection and hence a second (smaller) cohort moving through the rearing process.

Under both clutch collection scenarios, it is assumed that all first clutches are potentially available for collection, re-lays (second clutches) are left for wild-rearing under the one-bout collection scenario but collected in the second bout when there are two. Therefore, the 'minimum necessary clutches' scenario is only relevant for the smaller national population, as for the larger population it is not feasible to achieve the minimum necessary clutches via headstarting (at least given assumptions defining the maximum feasible scenario used here). 'Middle-ground' headstarting scenarios use the 'minimum feasible' clutches estimate (=57), which exceeds the amount that can be collected with a single bout of collection (=45), hence these scenarios require two collection bouts (up to 70 clutches).

Table 1.5. Numbers of clutches to be collected under headstarting, across different headstarting and population size scenarios. bp = breeding pairs.

Scenarios	Clutches
Min. necessary – larger Welsh population estimate (983 bp)	112
Min. necessary – smaller Welsh population estimate (500 bp)	57
Max. feasible – 1 bout // 2 bouts	45 // 70

When clutches are collected for headstarting, the overall number of clutches to be collected (from the totals calculated above) is distributed across the selected ICAs proportionally to their previous maximum number of nests found in a year: 35% from ICAs 2&3, 17% from ICA 5, 36% from ICA 9, and 12% from ICA 12. For the highest modelled scenario of 70 clutches, these values align with the maximum nest numbers for each ICA, i.e. ICAs are modelled to provide up to the total number of nests previously found in a year (note: this is expected to be lower than the total number of nests present, i.e. not all nests are found, with nest-finding probability incorporated implicitly). The model accounts for the fact that breeding populations may fall: the upper limit for the number of nests to be collected from any ICA, is the total number of breeding pairs (accounting for relaying probability where clutches are modelled to be collected in two bouts). Given known population sizes and productivities for some selected ICAs for 2024 and 2025, the modelled period starts in 2024, with available values incorporated into the annual projections for 2024-2025 and 2025-2026. Models then project over the following 30 years, as this is equivalent to the IUCN Red List's three-generation threat assessment period, taking Curlew generation length to be approximately 10 years per the new database (BirdLife International, 2025). These values are also supported by the variables presented in Taylor *et al.* (2020): 10 years is the average age of wintering Curlew in Wales, and 30 years approaches maximum lifespan (and is hence imposed as maximum age in their modelling – note that here we do not explicitly model a maximum age or senescence). Where relevant, projections have headstarting initiating in 2026 for ease of modelling.

All scenarios involving headstarting have it occurring for the first five years of projection; 'two-pulse' scenarios have additional headstarting during projection years 16-20. **Whenever headstarting occurs, it is assumed to be accompanied by other conservation measures occurring at the selected ICAs** (e.g. habitat improvement to benefit chicks during rearing, predation management to reduce predation risk either directly via control or indirectly e.g. diversionary feeding) This productivity improvement is either solely during the headstarting period(s) or

continuing for another five years. The result of such interventions is modelled as wild productivity reaching the stability threshold (modelled as either 0.6 or 1.0, see below) for the first 5-10 years of projection, and also for 5-10 years from year 16 where there is a second headstarting pulse, afterwards immediately returning to the previous value.

On a broader spatial scale, some scenarios include a potential national-level productivity increase, to represent broader action such as agri-environment schemes or widespread reductions in mesopredator densities. This is modelled through the attainment of the accepted broad-scale threshold i.e. mean productivity increases to 0.6 fledglings per pair (ramping up over the first 10 projection years) in which case mean productivity in selected ICAs under 'other conservation measures' increases to 1.0 fledged chicks per pair (close to the estimated productivity of 1.05 fledged chicks per Curlew pair nesting on UK grouse moors i.e. effectively under intense management due to associated predator control; Baines *et al.*, 2023). Productivity of 0.6 is accompanied by the same variability as for the mean values ~ 0.2 , whereas for the 1.0 level standard deviation is boosted by the proportional mean increase, scaled over the ramping-up period.

Modelled headstarting programmes included the 'minimum necessary' and 'maximum feasible' clutch-collection options as presented above, in addition to a 'maximum failure' outcome in which sufficient clutches for the 'maximum feasible' number of fledglings are collected, but fledge and/or hatch rates are zero such that no birds are released (noting that even 'bad' headstarting years for WWT's programmes thus far have in fact had minimum success rates exceeding 50%; unpublished data). In the latter case it is assumed that such a failure in initial headstarting would preclude a second pulse. Scenario combinations considered in this report are displayed in Table 1.6.

Projection results represent means (and in some cases minimum and maximum values) across 1,000 iterations. These iterations differ based on incorporated stochasticity: for each draw (year within iteration within scenario), demographic parameters were sampled from a distribution around the mean where sufficient data were available. However, in order to move dispersing individuals between sites, projection occurs year-on-year with the mean number of individuals of each stage-class being carried forward to the following year. This may mean that trajectories are constrained relative to a simpler model where each iteration projects the population from start to finish.

All code was run in the software R v4.4.1 (R Core Team, 2024), with packages *popbio* (Stubben and Milligan, 2007) and *popdemo* (v1.3-0; Stott *et al.*, 2021).

Table 1.6. Modelled scenarios across estimated starting population sizes, breeding propensity levels, and theorised outcomes of actions implemented at selected ICAs (headstarting and other conservation measures) and more broadly (national productivity improvement). h/s = headstarting, BAU = ‘business as usual’, NPI = national productivity improvement. Cell colours are indicative, differentiating values within each column.

Scenario	Breeding pairs in 2024	Breeding propensity	H/s programme	# h/s pulses	# collection bouts	# years ‘other measures’	NPI
BAU, larger pop. (w/out NPI)	983, 65% ICA	Lower	None	N/A	N/A	None	No
BAU, larger pop. (w/ NPI)	983, 65% ICA	Lower	None	N/A	N/A	None	Yes
BAU, smaller pop. (w/out NPI)	500, 311 ICA	Lower	None	N/A	N/A	None	No
BAU, smaller pop. (w/ NPI)	500, 311 ICA	Lower	None	N/A	N/A	None	Yes
Comparator for tests: best-case, larger pop. (but w/out NPI)	983, 65% ICA	Lower	‘Max. feasible’ clutches	2	2	10	No
Comparator for tests: best-case, larger pop. (w/ NPI)	983, 65% ICA	Lower	‘Max. feasible’ clutches	2	2	10	Yes
Test: full BP (w/out NPI)	983, 65% ICA	Full	‘Max. feasible’ clutches	2	2	10	No
Test: full BP (w/ NPI)	983, 65% ICA	Full	‘Max. feasible’ clutches	2	2	10	Yes
Test: 1 collection bout (w/out NPI)	983, 65% ICA	Lower	‘Max. feasible’ clutches	2	1	10	No
Test: 1 collection bout (w/ NPI)	983, 65% ICA	Lower	‘Max. feasible’ clutches	2	1	10	Yes
Test: 1 h/s pulse (non-failure; w/out NPI)	983, 65% ICA	Lower	‘Max. feasible’ clutches	1	2	10	No

Scenario	Breeding pairs in 2024	Breeding propensity	H/s programme	# h/s pulses	# collection bouts	# years 'other measures'	NPI
Test: 1 h/s pulse (non-failure; w/ NPI)	983, 65% ICA	Lower	'Max. feasible' clutches	1	2	10	Yes
Worst case, larger pop. (w/out NPI)	983, 65% ICA	Lower	Max. failure	1	2	5	No
Best-case, smaller pop. (w/ NPI)	500, 311 ICA	Lower	'Max. feasible' clutches	2	2	10	Yes
Middle-ground, smaller pop. (w/out NPI)	500, 311 ICA	Lower	'Min. feasible' clutches	2	2	5	No
Middle-ground, smaller pop. (w/ NPI)	500, 311 ICA	Lower	'Min. feasible' clutches	2	2	5	Yes
Worst-case, smaller pop. (w/out NPI)	500, 311 ICA	Lower	'Max. failure'	1	2	5	No

Results

Table 1.7 summarises deterministic expectations for population growth rates across approximated 'business as usual' (mean productivity of approximately 0.2 fledglings per year for all Welsh breeding Curlew pairs), lower stability threshold (productivity $\approx$ 0.6) and higher stability threshold (productivity $\approx$ 1.0) scenarios, with either full breeding propensity ($=1$) or the value estimated from Taylor *et al.* (2020) as adjusted to account for recruitment later than two years old. The values in the first column confirm that the combination of vital rates used parameterises a life cycle corresponding to the observed decline rate of $\sim 6\%$. The values in the latter columns highlight that 0.6 fledglings per breeding pair achieves stability only when all individuals breed every year; for lower breeding propensity, a higher value such as the suggested 1.0 threshold may be necessary.

Table 1.7. Population growth rates from matrix population models parameterised as in Table 1.2, with specified breeding propensity (BP) and productivity (p) values.

BP \ p	0.2	0.6	1.0
1	0.944	1.004	1.051
~ 0.71	0.933	0.979	1.017

Projections present population size as the number of recruited adult individuals of the limiting sex, which can be interpreted as the number of breeding pairs. Population projection plots for all segments (and Wales as a whole) across the 17 presented scenarios (Table 1.6) can be found in Appendix 1, summarised in Table 1.8, with selected outcomes and comparisons highlighted in Figures 1.7-1.16. Mean values are most instructive, while minima and maxima represent extremes; all can slightly vary between iterations due to the nature of stochasticity. Note that the 'middle ground' scenario is only shown for the smaller starting population, as this is the situation in which it is potentially feasible to produce the minimum necessary number of fledglings to hit the stability threshold productivity (as estimated at 0.6 fledglings per breeding pair per year).

Table 1.8. Summarised outcomes (population change by the end of the projection period of 30 years relative to the start, with approximate proportional increases or decreases presented at the national level) for the all-Wales population and selected ICAs. Detailed plots for each scenario can be found in Appendix 1 (Figures S1-S17, see final column). See Table 1.6 for further detail on the scenarios. BAU = ‘business as usual’ (no headstarting nor associated ‘other conservation measures’ at ICA level), pop. = population, NPI = national productivity improvement, h/s = headstarting.

Scenario	National	ICAs 2&3	ICA 5	ICA 9	ICA 12	Appendix
BAU, larger pop. (w/out NPI)	Decrease of ~80%	Decrease	Decrease	Decrease	Decrease	Fig. S1
BAU, larger pop. (w/ NPI)	Decrease of ~50%	Decrease	No Change	Increase	No Change	Fig. S2
BAU, smaller pop. (w/out NPI)	Decrease of ~80%	Decrease	Decrease	Decrease	Decrease	Fig. S3
BAU, smaller pop. (w/ NPI)	Decrease of ~50%	Decrease	Decrease	No Change	No Change	Fig. S4
Comparator for tests: best-case h/s, larger pop. (w/out NPI)	Decrease of ~70%	No Change	No Change	Increase	No Change	Fig. S5
Comparator for tests: best-case h/s, larger pop. (w/ NPI)	No Change	Decrease	Decrease	Increase	Decrease	Fig. S6
Test: full breeding propensity (w/out NPI)	Decrease of ~60%	No Change	No Change	Increase	No Change	Fig. S7
Test: full breeding propensity (w/ NPI)	Increase of ~20%	Increase	Increase	Increase	Increase	Fig. S8
Test: 1 collection bout (w/out NPI)	Decrease of ~70%	Decrease	No Change	No Change	No Change	Fig. S9
Test: 1 collection bout (w/ NPI)	Decrease of ~20%	Increase	Increase	Increase	Increase	Fig. S10
Test: 1 h/s pulse (non-failure; w/out NPI)	Decrease of ~80%	Decrease	Decrease	Decrease	No Change	Fig. S11

Scenario	National	ICAs 2&3	ICA 5	ICA 9	ICA 12	Appendix
Test: 1 h/s pulse (non-failure; w/ NPI)	Decrease of ~40%	Increase	Increase	Increase	Increase	Fig. S12
Worst-case h/s, larger pop. (w/out NPI)	Decrease of ~80%	Decrease	Decrease	Decrease	Decrease	Fig. S13
Best-case h/s, smaller pop. (w/ NPI)	↑ ~50%	Increase	Increase	Increase	Increase	Fig. S14
Middle-ground h/s, smaller pop. (w/out NPI)	Decrease of ~60%	Decrease	Decrease	Decrease	No Change	Fig. S15
Middle-ground h/s, smaller pop. (w/ NPI)	No Change	Increase	Increase	Increase	Increase	Fig. S16
Worst-case h/s, smaller pop. (w/out NPI)	Decrease of ~80%	Decrease	Decrease	Decrease	Decrease	Fig. S17

Figure 1.7 shows 'business as usual' i.e. no headstarting, compared to a range of intervention scenarios: 'best-case' headstarting (explored in further detail below), 'maximum [headstarting] failure' as a 'worst case', and (for the smaller estimated starting population size only) 'minimum necessary' headstarting with five years of other conservation measures as a 'middle-ground'. 'Business as usual' without a national productivity improvement is projected to lead to a decline of ~80% over the 30-year projection period, while the inclusion of a national productivity improvement reduces the decrease by about one-half. In the absence of a national productivity improvement, 'maximum failure' of headstarting results in projections that closely parallel 'business as usual', with slight improvements due to a net positive effect of the wild productivity improvement during five years of interventions counterbalancing removal of clutches for headstarting.

For the smaller estimated starting population size, headstarting with the 'minimum necessary' number of clutches to achieve stability based on the estimated 0.6 threshold results in a population decrease of approximately 70% in the absence of a national productivity improvement, or else declines but then increases to reach the initial level after the second pulse of headstarting when national productivity improves.

Figure 1.8 shows the 'business as usual' scenario for the smaller starting population, without a national productivity improvement, in more detail including at the level of the selected ICAs.

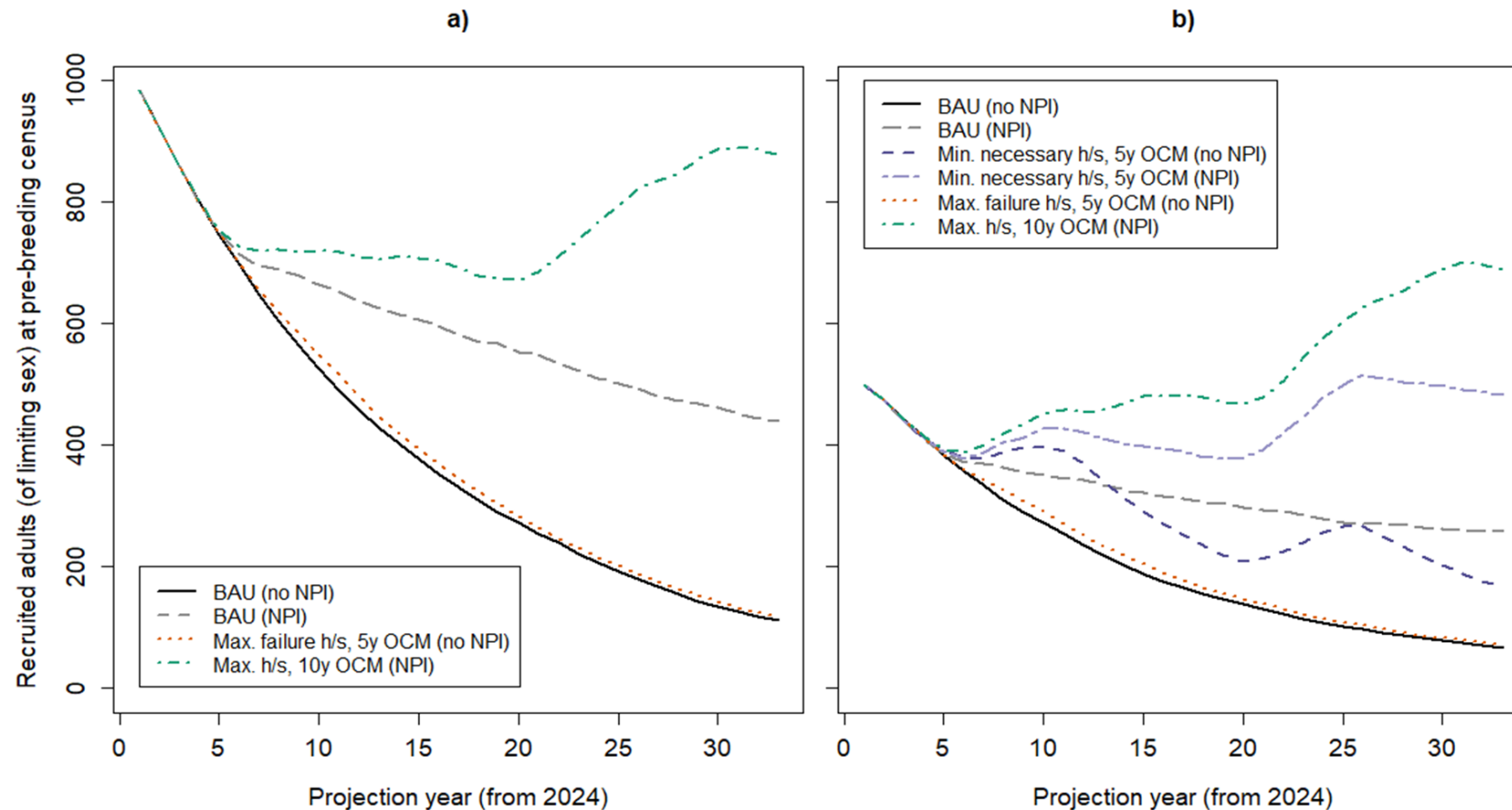


Figure 1.7. All-Wales comparative plots showing mean projected population sizes for '**business as usual**' and **selected headstarting scenarios**, for a) the larger population estimate (983 breeding pairs), and b) smaller population estimate (500 breeding pairs). BAU = 'business as usual'; NPI = national productivity improvement; h/s = headstarting; OCM = other conservation measures. Line charts comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years under different scenarios; those in the left panel (labelled 'a') start from the larger population estimate (~1000) while those in the right panel ('b') start from the smaller population estimate (500).

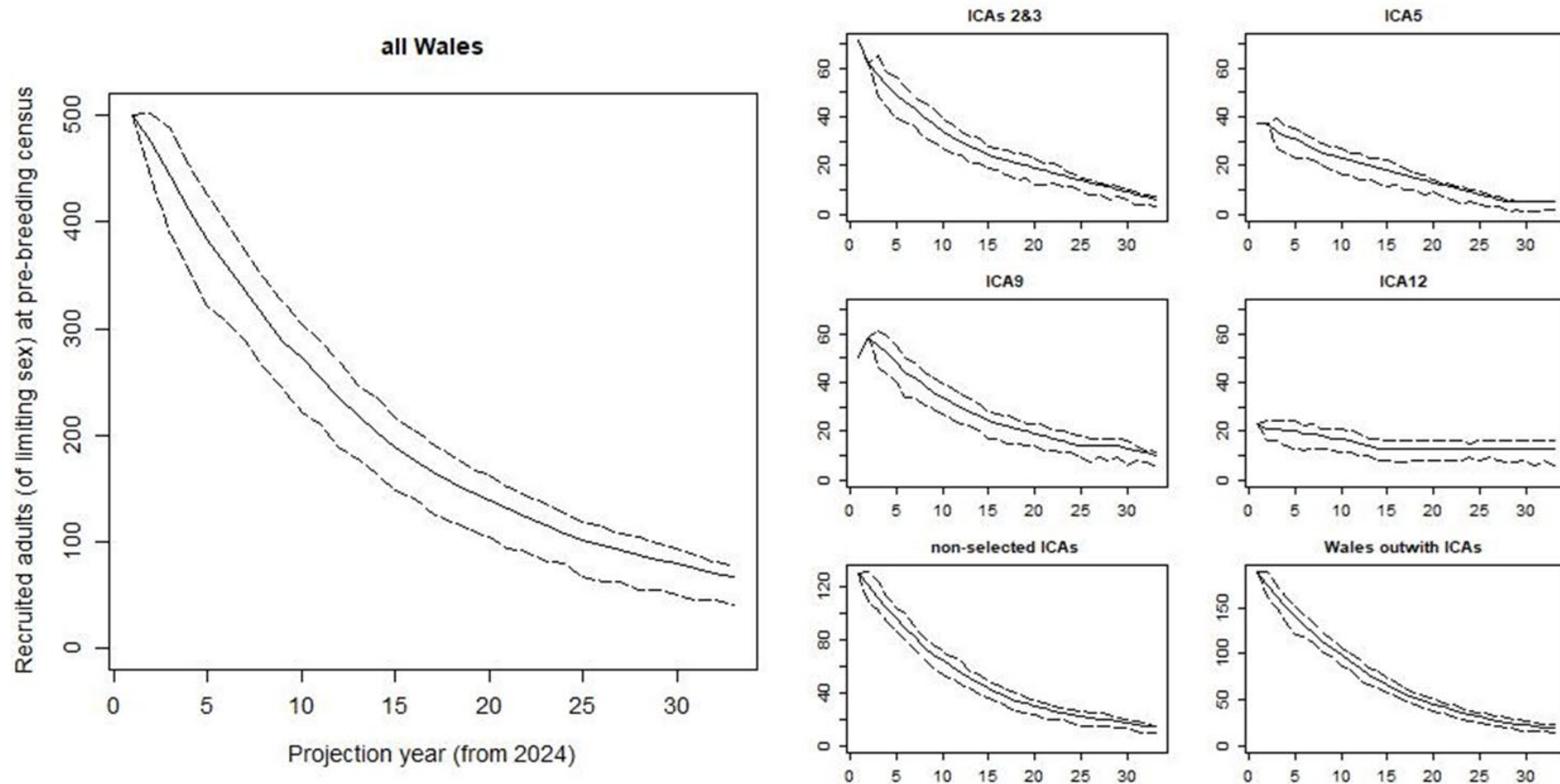


Figure 1.8 [also Figure S3]. **All-Wales and disaggregated** mean projected population sizes for the ‘business as usual’ scenario, for the **smaller estimated starting population size** (500 breeding pairs), **without national productivity improvement**. Axis labels for the segment-specific plots on the right are the same as for the all-Wales plot on the left. The y-axis scale is held constant across selected ICAs to facilitate comparison. Solid black lines = means; dashed black lines = maxima and minima.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

In all cases the populations decline (e.g. from 500 to <100 for all-Wales), although the slope is much less steep for ICA 12. The other selected ICAs start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period.

Figure 1.9 reinforces that even 'best-case' headstarting ('maximum feasible' clutches and 10 years of other conservation measures) can only stabilise/reverse current national population declines (in this case projecting from the larger estimated starting population size) in combination with a national productivity improvement. In the absence of such a broad-scale change, the Welsh Curlew breeding population is projected to decline by 60-80% by the 2050s, depending on breeding propensity and headstarting intensity and frequency.

Additionally, the baseline 'comparator' projections from Figure 1.9 (representing 'best-case' headstarting, with two collection bouts and two headstarting pulses but the lower value of breeding propensity) are shown in more detail in Figures 1.10 (without a national productivity improvement) and Figure 1.11 (with a national productivity improvement), including disaggregation across the population segments. These highlight more positive projections for the selected ICAs (where headstarting and other targeted interventions occur) compared to the rest of the ICA network and the rest of Wales, which show only very minor improvements as a result of headstarting due to small numbers of individuals immigrating having dispersed from the selected ICAs.

Figures 1.12-1.14 then disaggregate the 'middle-ground' and 'worst-case' scenarios, both with and without a national productivity improvement for the former and in the absence of a national productivity improvement for the latter, while Figure 1.15 shows more detail on the one-pulse headstarting comparison.

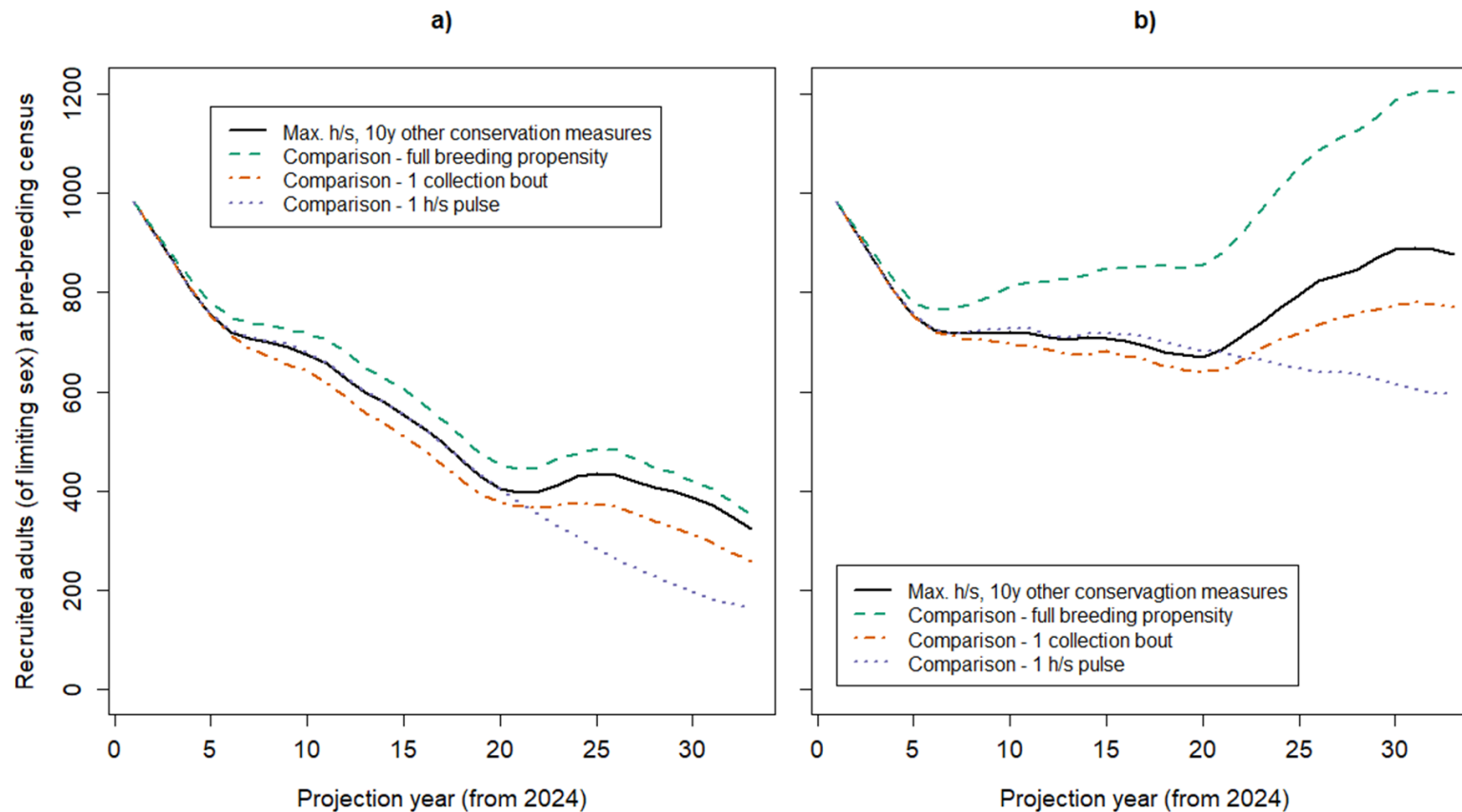


Figure 1.9. All-Wales comparative plots showing mean projected population sizes for the ‘best-case’ headstarting scenario, and **deviations when varying breeding propensity, collection effort and headstarting frequency** from the values considered elsewhere, for the **larger estimated starting population size** (983 breeding pairs), without national productivity improvement (a) and with national productivity improvement (b). h/s = headstarting. See Figures 1.10 and 1.11 for further detail on the baseline projections.

Side-by-side line charts similar to Figure 1.7, comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years under different scenarios; here both start from the larger population estimate (~1000) but the left panel (labelled 'a') shows general decline while the right panel ('b') has a wider mix of trajectories. In both panels, three lines follow a similar trajectory: the upper line is green dashed [“Comparison - full breeding

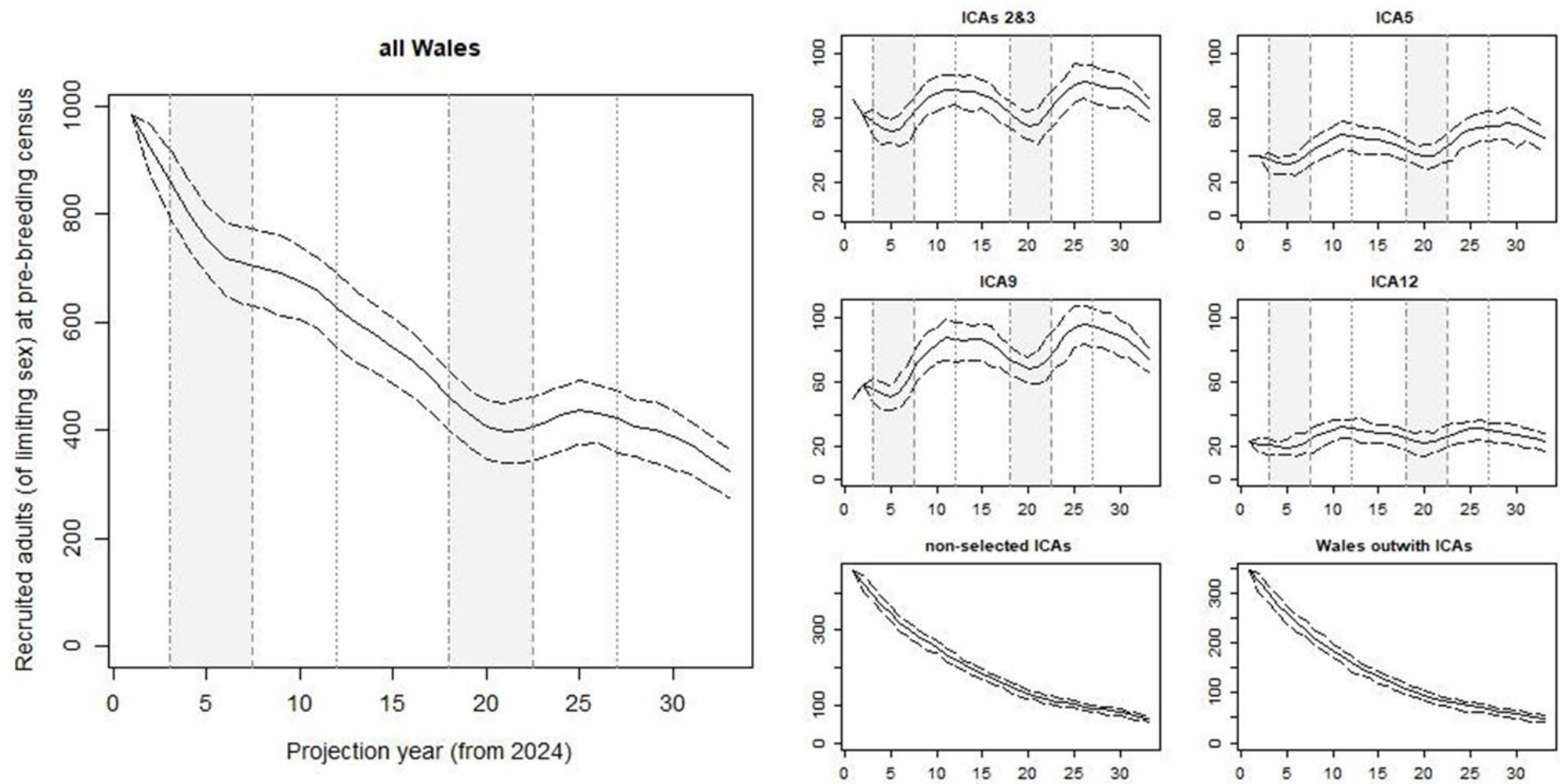


Figure 1.10 [also Figure S5]. **All-Wales and disaggregated** mean projected population sizes for the **'best-case'** headstarting scenario, for the **larger estimated starting population size** (983 breeding pairs), **without national productivity improvement**.

Axis labels for the segment-specific plots on the right are the same as for the all-Wales plot on the left. The y-axis scale is held constant across selected ICAs to facilitate comparison. Solid black lines = means; dashed black lines = maxima and minima. Vertical grey lines indicate intervention periods (for selected ICAs and hence all Wales also), from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below. Here the all-Wales population shows overall decline, the selected ICAs show approximate stability (2&3, 12) or slight increases (5, 9) with peaks at ~12 years and ~27 years, and the non-selected ICAs and rest of Wales show steep declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

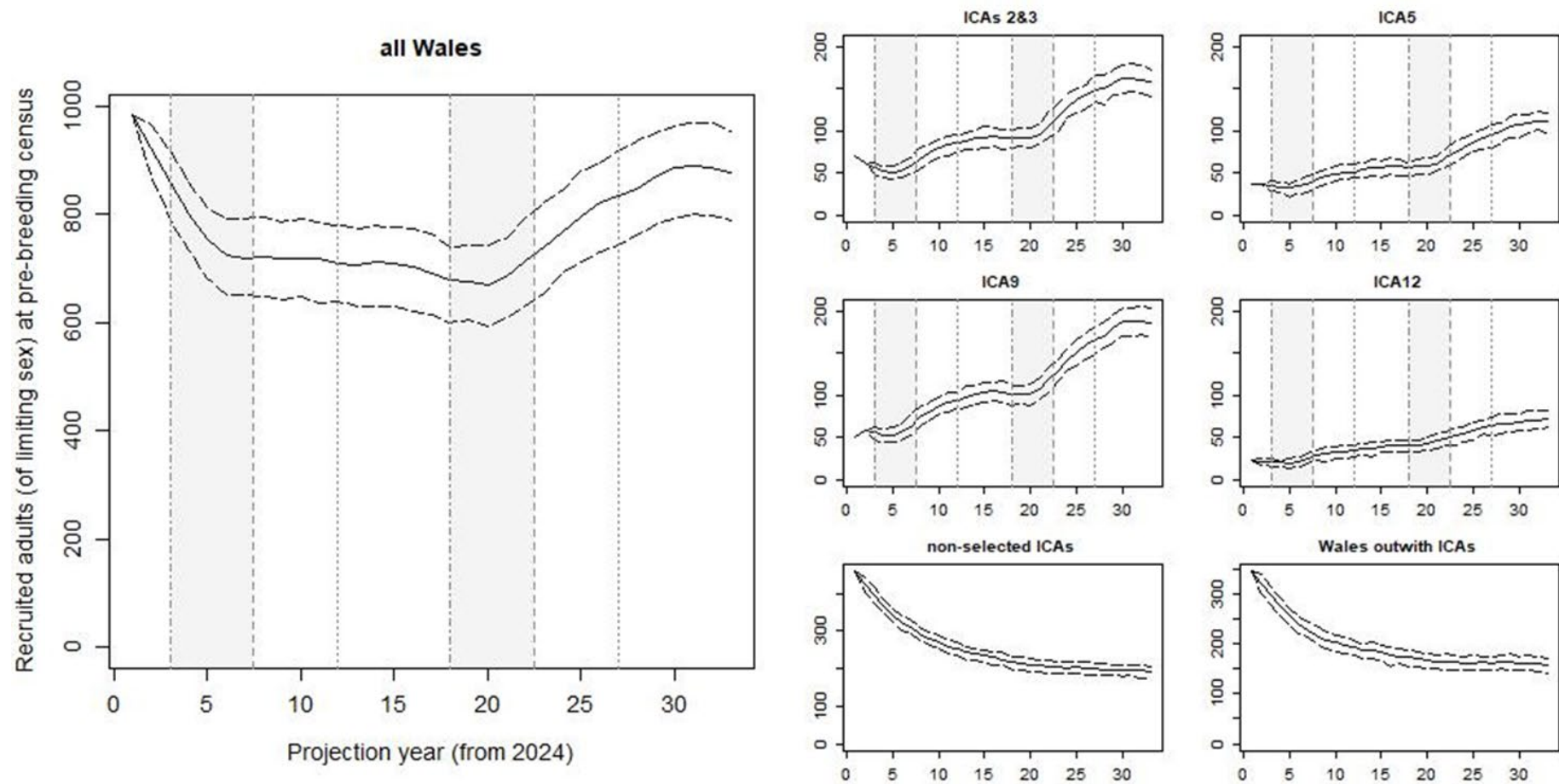


Figure 1.11 [also Figure S6]. **All-Wales and disaggregated** mean projected population sizes for the 'best-case' headstarting scenario, for the larger estimated starting population size (983 breeding pairs), with national productivity improvement.

Axis labels for the segment-specific plots on the right are the same as for the all-Wales plot on the left. The y-axis scale is held constant across selected ICAs to facilitate comparison. Solid black lines = means; dashed black lines = maxima and minima. Vertical grey lines indicate intervention periods (for selected ICAs and hence all Wales also), from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population shows a steep decline, which largely levels out ~5-20 years, followed by an increase back up to around the starting population size. The selected ICAs all show increases, to a lesser extent for ICA 5 and ICA12, and the non-selected ICAs and rest of Wales show shallow declines levelling out to about half the starting population. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

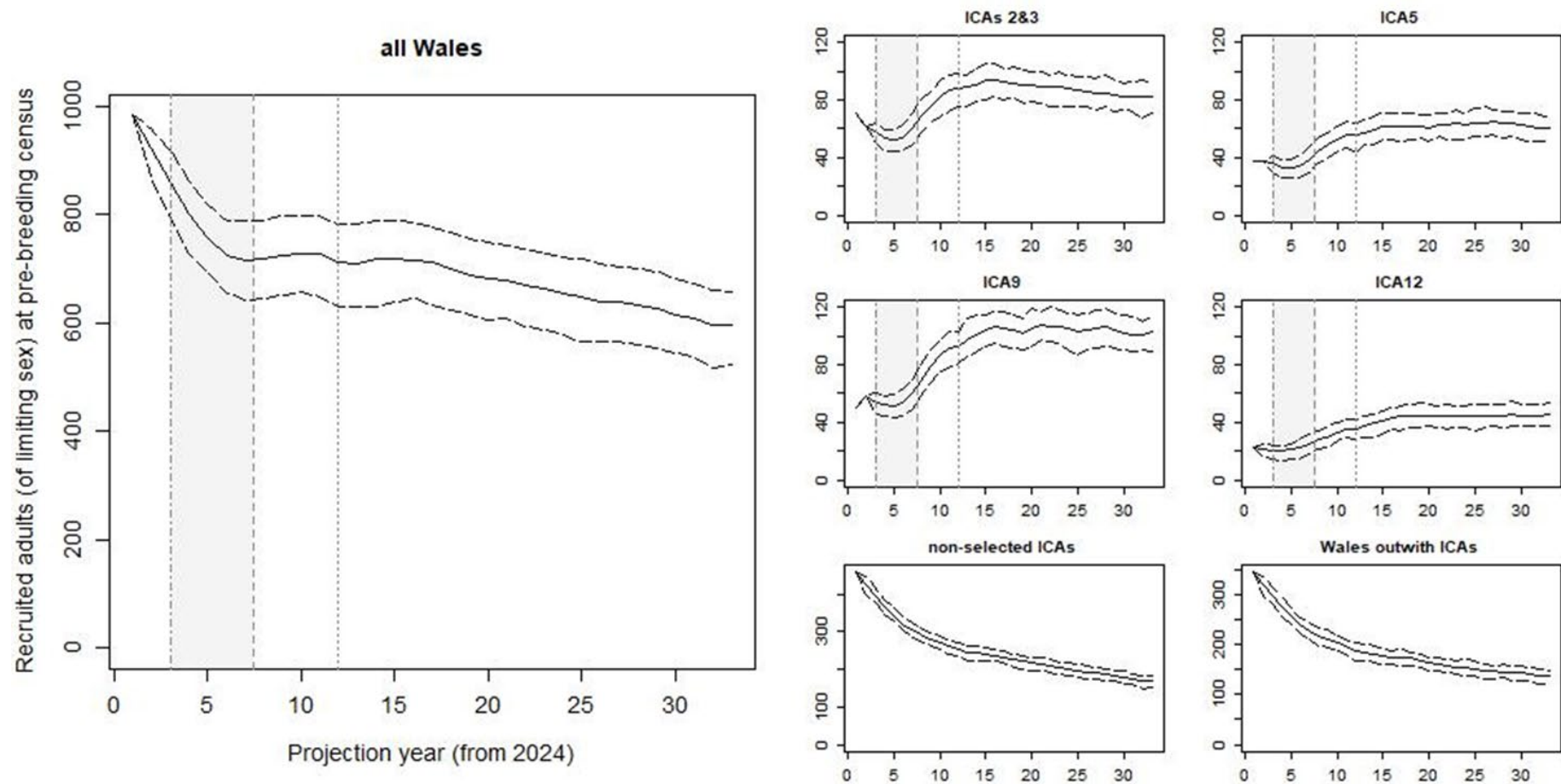


Figure 1.12 [also Figure S12]. **All-Wales and disaggregated** mean projected population sizes for the **'best-case'** headstarting scenario, for the **larger estimated starting population size** (983 breeding pairs), **with national productivity improvement**.

Axis labels for the segment-specific plots on the right are the same as for the all-Wales plot on the left. The y-axis scale is held constant across selected ICAs to facilitate comparison. Solid black lines = means; dashed black lines = maxima and minima. Vertical grey lines indicate intervention periods (for selected ICAs and hence all Wales also), from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting period is also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below. Here the all-Wales population shows an overall decline, steeper for the first ~5 years, with an overall decline from ~1000 to ~600. The selected ICAs all show increases, to a lesser extent for ICA 5 and ICA12, and the non-selected ICAs and rest of Wales show shallow declines to a little below half the starting population. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

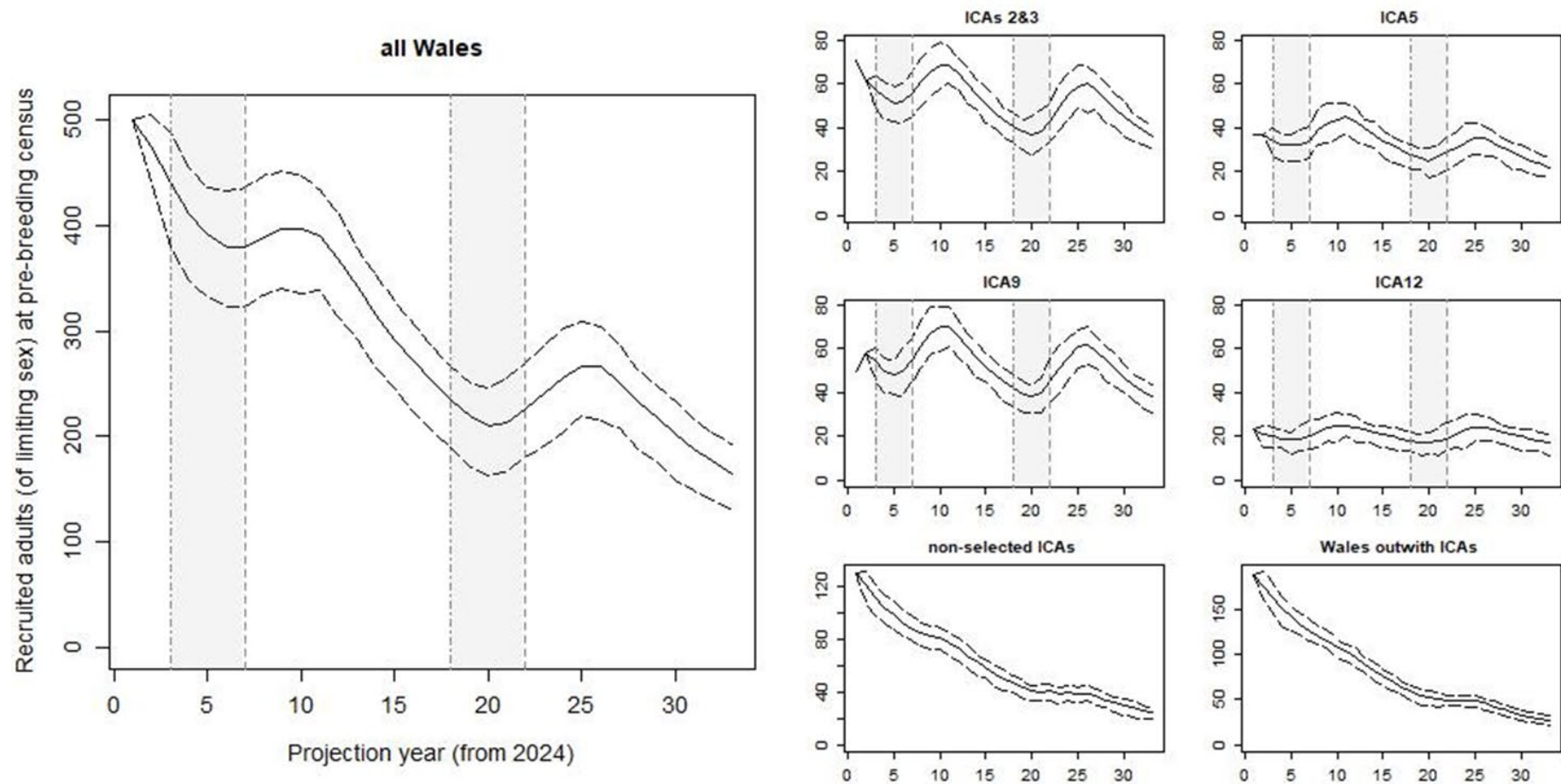


Figure 1.13 [also Figure S15]. **All-Wales and disaggregated** mean projected population sizes for the ‘middle-ground’ headstarting scenario (‘minimum necessary’ clutches collected in each of the five-year headstarting pulses, with five years of other conservation measures), for the **smaller estimated starting population size** (500 breeding pairs), **without national productivity improvement**. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below. Here the all-Wales population and ICAs 2&3, ICA 5 and ICA 9 all show a two-peaked overall decline, while ICA12 remains overall stable with minor peaks at ~10 years and ~25 years, and the non-selected ICAs and rest of Wales show steep declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years and 18-22 for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

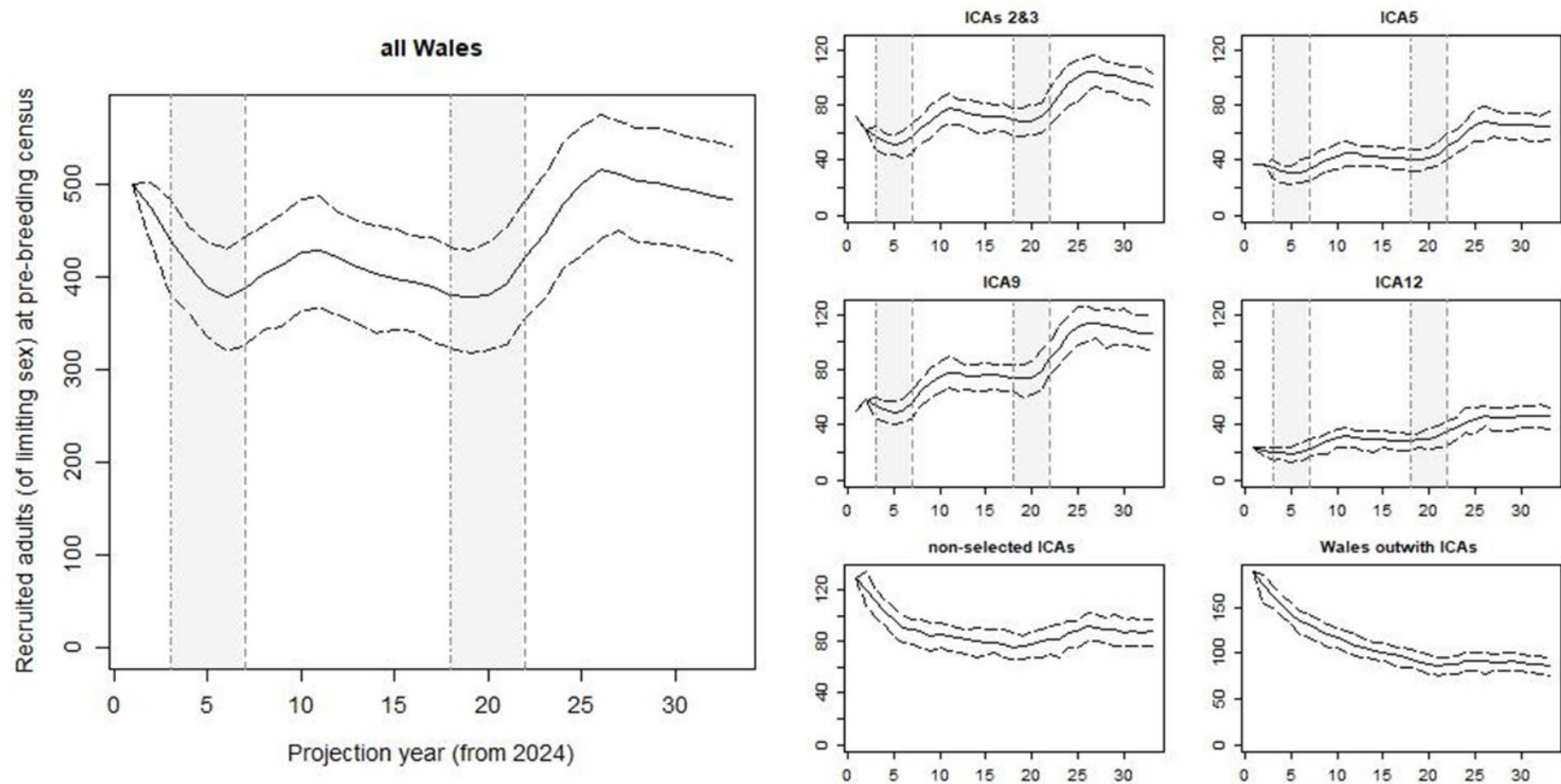


Figure 1.14 [also Figure S16]. **All-Wales and disaggregated** mean projected population sizes for the ‘middle-ground’ headstarting scenario (‘min. necessary’ clutches collected in each of the five-year headstarting pulses, with five years of other conservation measures), for the **smaller estimated starting population size** (500 breeding pairs), **with national productivity improvement**. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below. Here the all-Wales population shows two sets of troughs and peaks, with an eventual slight decline bringing the trajectory back to around the starting population. The selected ICAs all show moderate to strong increases, and the non-selected ICAs and rest of Wales show moderate declines (steeper in the latter). The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years and 18-22 for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

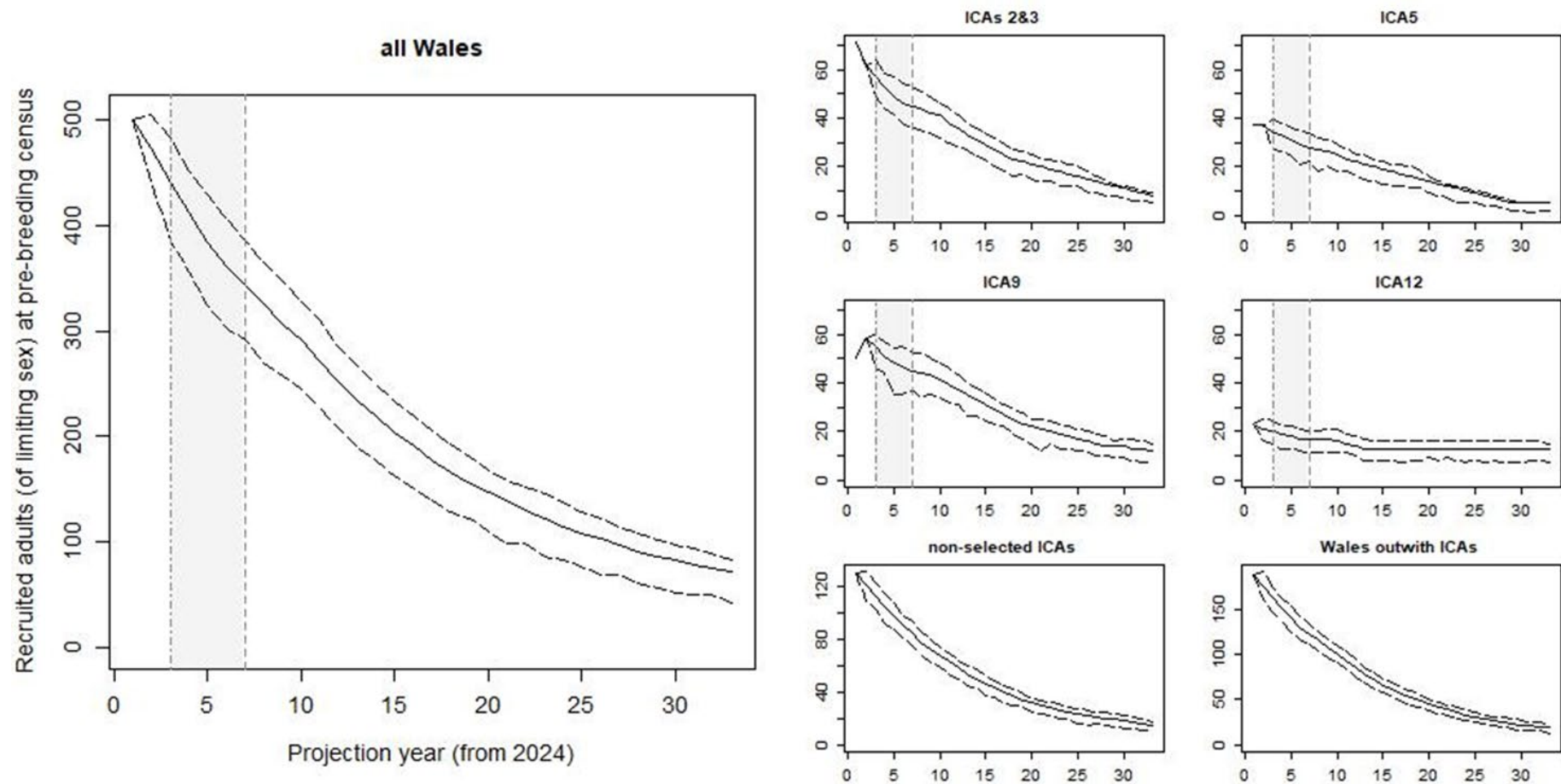


Figure 1.15 [also Figure S17]. **All-Wales and disaggregated** mean projected population sizes for the ‘**worst-case**’ headstarting scenario, for the **smaller estimated starting population size** (500 breeding pairs), **without national productivity improvement**.

Axis labels for the segment-specific plots on the right are the same as for the all-Wales plot on the left. The y-axis scale is held constant across selected ICAs to facilitate comparison. Solid black lines = means; dashed black lines = maxima and minima. Vertical grey lines indicate intervention periods (for selected ICAs and hence all Wales also), from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting period is also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here all plots show overall declines, less steeply for ICA 12. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years for the first 5 plots.

Finally, Figure 1.16 presents a selection of scenarios disaggregated by ICA. Patterns are generally shared across the selected ICAs, scaled up or down based on relative starting population sizes.

Under 'business as usual' scenarios, all selected ICAs approach extinction unless there is a national productivity improvement, in which case their populations tend to hold broadly stable. Responses to headstarting scenarios are paralleled across the selected ICAs, scaled up or down relative to their starting population sizes, segment-specific wild productivity and clutch size estimates, and differential interchange proportions (e.g. ICA 12 does not receive headstarted birds from any of the other selected ICAs due to its geographical separation).

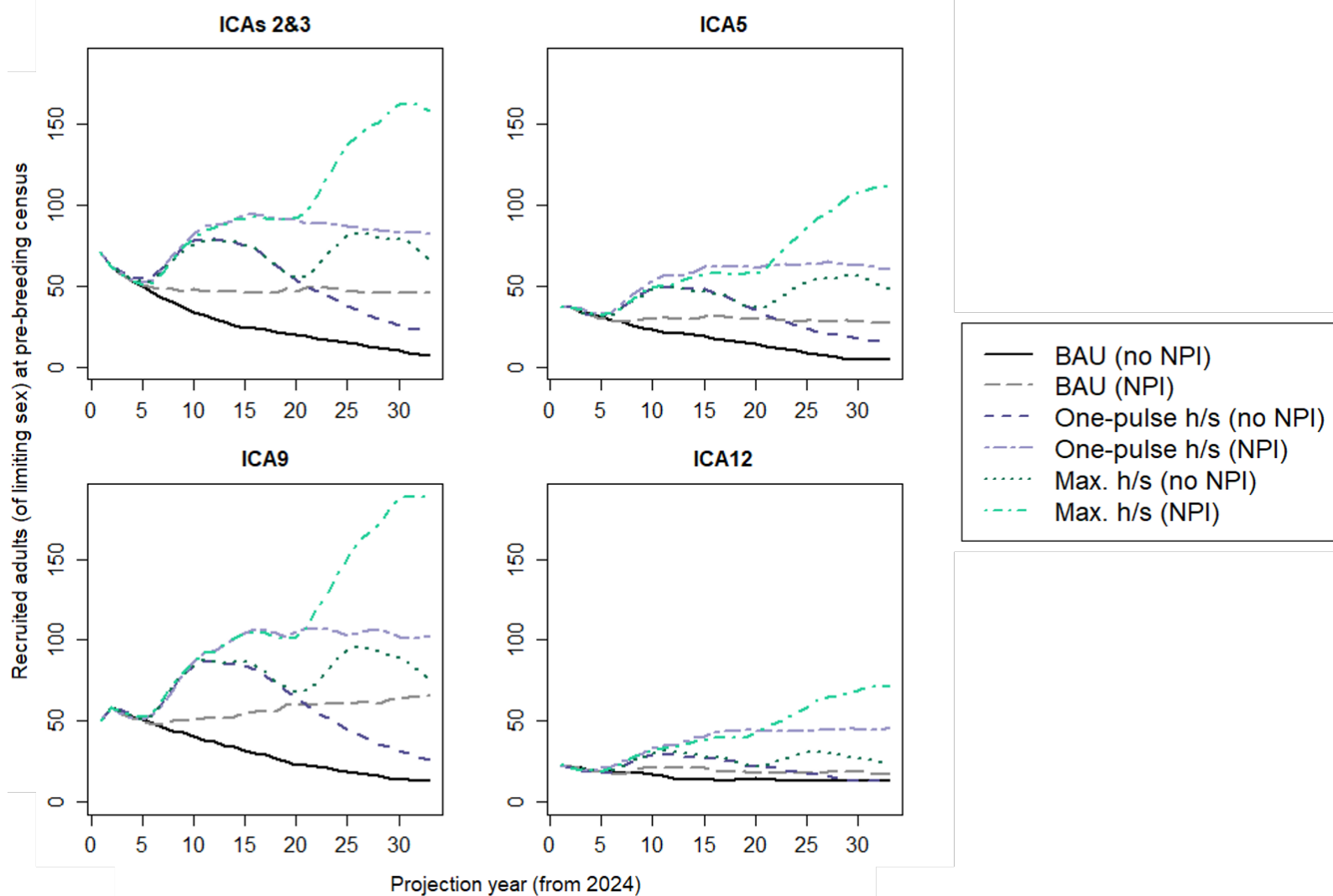


Figure 1.167. Mean projected population sizes for comparative scenarios across the **selected ICAs**. All of the headstarting scenarios shown are **accompanied by 10 years of other conservation measures**, for the **larger estimated starting population size (983 breeding pairs)**. The y-axis scale is held constant to facilitate comparison.

Four line charts comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years under different scenarios across the selected ICAs (ICAs 2&3, ICA 5, ICA 9, ICA 12).

In all panels a black line (labelled "BAU (no NPI)") drops smoothly to approx. one-quarter of the starting population, except for ICA 12 where the decline is more shallow. A dashed grey line ["BAU (NPI)"] declines slightly then levels out for ICAs 2&3 and ICA 5, whereas it increases slightly for ICA 9 and stays approximately level for ICA 12. The four plots then share four lines that follow the same relative trajectories, scaled across a wider area for ICAs 2&3 and ICA 9 (top line exceeding 150), intermediate for ICA 5 (top line exceeding 100 but not 150), and most narrow for ICA 12 (top line exceeding 50 but not 100). The top line is light green dot-dashed ["Max. h/s (NPI)"] and increases initially from ~5 years and then again from ~20 years, peaking just before the end of the projection period. This is paralleled at approximately half the amplitude by a dark green dotted line ["Max. h/s (no NPI)"], while a light purple dot-dashed line ["One-pulse h/s (NPI)"] stays level following the first peak. Finally, a dark purple dashed line ["One-pulse h/s (no NPI)"] declines after the first peak, ending up only slightly above or meeting the black line.

On average, the expected number of headstarted fledglings that could be produced from a given site in a given year will be the number of recruited adults of the limiting sex, multiplied by mean values of breeding propensity (estimating breeding pairs), clutch size (estimating eggs collected for headstarting), hatch success (estimating captive hatchlings) and fledge success (estimating released headstarts).

Figure 1.17 shows that the mean expectation is just under three fledglings per headstarted clutch, although the distribution is bimodal with a smaller peak at less than two fledglings, presumably reflecting the scenarios with poor hatching and/or fledging success. Nevertheless, even a productivity of 1.5 fledglings per breeding pair per year greatly exceeds that required for stability, and more than compensates for the 'lost' wild productivity of collected clutches not replaced by relaying. The latter can be approximated as:

$$(1 - \text{relaying probability}) \times \text{wild productivity}$$

which with the estimates used here (relaying probability of 0.54 and wild productivity of approximately 0.2) is less than 0.1.

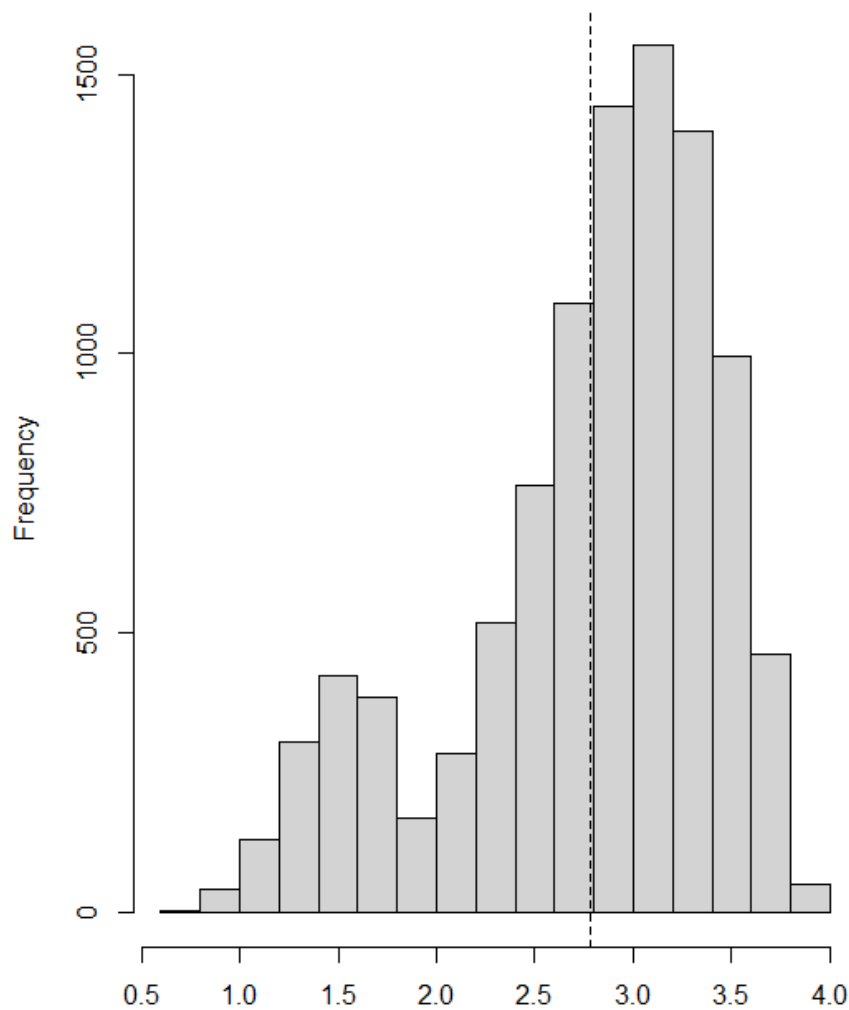


Figure 1.178. Frequency distribution of expected fledglings per headstarted clutch, based on 10,000 iterations of clutch size $\times$ hatch success $\times$ fledge success, where clutch size is drawn from a stretched beta distribution (mean $\approx 3.75 \pm 0.56$, range 1-5) and hatch and fledge success are weighted means (hatch success: ~ 0.84 , based on an 80% probability of ~ 0.87 and a 20% probability of ~ 0.68 ; fledge success: ~ 0.84 , based on an 80% probability of ~ 0.90 and a 20% probability of ~ 0.57). The dashed line denotes the overall mean value.

Histogram showing the frequency distribution (y-axis ranging 0-1500) of expected fledglings per headstarted clutch (x-axis ranging 0.5-4.0). The distribution is bimodal, with a smaller peak (up to ~ 500) around 1.5 and the larger around 3 expected fledglings per headstarted clutch, with a vertical dashed line marking the mean value at ~ 2.75

Discussion

The modelled scenarios presented above suggest that even with headstarting, in the absence of a national productivity improvement (bringing fledglings per breeding pair per year up to an average value of 0.6) declines of at least 60% can be expected over the 30-year projection period.

Such a productivity improvement, combined with headstarting, which is expected to generate an average of three fledglings per collected clutch, can support stability or growth of the Welsh breeding Curlew population. This is to a greater extent for the smaller estimated starting population size of 500 breeding pairs. The benefits of national productivity improvement are shared across all population segments, while improvements to the national trajectory from headstarting efforts are driven by population growth at the selected ICAs. There will be minimal carryover to the rest of the ICA network and the remainder of the Welsh population due to the assumed relatively low dispersal rates across the wider landscape.

The innovative approach of planning a second headstarting pulse at the point that the effects of the first are dwindling, assists in 'buying time' for wider-scale and/or longer-term interventions to take effect (see 'Interpreting these results' further down in this section).

Demographic metrics

It is likely most estimated demographic thresholds (such as the level of productivity required for population stability) are based on the assumption of all recruited pairs breeding each year. While we believe that a breeding propensity of 1 is unlikely to represent reality (Nicol-Harper *et al.*, 2025), our non-full breeding propensity estimate is relatively uncertain, as it was extrapolated from a pooled-sex sample derived from one tagging study (albeit a study that was Wales-specific; Taylor *et al.*, 2020). Models also showed reasonable sensitivity to this parameter: asymptotic population growth rates as estimated from matrix population models were up to approximately 2% lower for breeding propensity ~0.71 versus full breeding, with this making the difference between population decline versus growth when productivity = 0.6 fledglings per breeding pair per year (~0.98 versus ~1.00).

What is unclear is whether Curlew breeding propensity varies this highly between landscapes of the UK; for example, in the Severn & Avon Vales Curlew project area the best guess based on extensive monitoring is that almost all recruited females attempt breeding each year (with spare males being the only adults that 'skip'; WWT, unpublished data). This links to the question of whether Curlew are capital or income breeders i.e. arriving on the breeding grounds having already stored the necessary resources, or needing to do this on-site, respectively. If the former, with females bringing their resources from the coast, then there shouldn't really be much

difference between upland Wales and lowland England. Perhaps future work could look for a marine signal in eggs via stable isotope analysis to investigate this.

Similar uncertainty may underlie other estimates. For adult survival we used Taylor *et al.*'s (2020) value of 0.905, which is specific to Wales, but there could be arguments to favour, for example Cook *et al.*'s (2021) higher estimate of 0.922, based on the UK breeding population. For a long-lived species such as Curlew, population dynamics are likely to be quite sensitive to adult survival (e.g. Gallardo *et al.*, 2019), such that projections using a higher value will tend to be more positive – requiring a lower productivity threshold for stability. Our use of only two different survival classes (with immature survival matching that of adults, and juveniles experiencing much higher mortality) can be considered well-justified (based on Cook *et al.*, 2021, and supported by unpublished WWT data), and the expectation would be for lower sensitivity of population dynamics to these demographic metrics. With very little data available on age of recruitment, we parameterised this variable based on a small sample of headstarted birds from one location in England; while more information on this vital rate would be welcomed, it is unlikely to be highly influential on population dynamics (see e.g. Nicol-Harper *et al.*, 2025).

A key limitation of the approach used here is that most demographic parameters were not assumed to change systematically over time (the exception being productivity under national improvement scenarios or during other conservation measures accompanying headstarting). This is unlikely to remain the case over the 30-year projection period, but future changes are difficult to predict for a number of reasons, including climate change, a shifting policy landscape, etc. Furthermore, while the projection results generally emphasise the need for conservation measures to be applied at both smaller and larger scales, we do not necessarily know what these interventions will be and to what extent they would be successful.

There is also considerable uncertainty around the current population size, which was handled here by using two starting estimates for 2024: 500 breeding pairs (based on expert judgement; NRW, *pers. comms.*) and 983 breeding pairs (extrapolated from Taylor *et al.*, 2020, using the Welsh Action Plan's estimated 6% decline rate; Gylfinir Cymru, 2021). These different starting population sizes also had varying associated proportions/absolute values of breeding pairs within the full ICA network, affecting the relative contribution of the selected ICAs. Current population size represents a crucial information gap for ongoing conservation decision-making; for the scenarios modelled here, although 'business as usual' (and the parallel 'worst-case' headstarting) trajectories are broadly similar across the two different start points, 'best-case' headstarting results in stability for the larger population versus growth for the smaller. This speaks to the fact that a set level of headstarting input will tend to have a larger impact the smaller the population, particularly if eggs are brought in

from a donor site and hence not limited by the number of breeding pairs at the focal site (Donaldson *et al.* 2025a).

Limitations of predictive modelling

We note that the envelopes around our projected trajectories (i.e. the extent to which maxima and minima deviate from mean estimates) are quite tight, which is likely partially a reflection of the model set-up (projection occurring year-on-year carrying forward mean values). Hence trajectories are somewhat constrained relative to a simpler model where each iteration projects the population from start to finish, such that ‘business as usual’ (no headstarting) scenarios as modelled are perhaps not the best prediction of what can actually be expected at these sites in the absence of any interventions. While the method chosen allows for fair comparison to the headstarting scenarios as a representation of any expected benefits, for detailed examination of baselines a different method of projection could presumably work better.

While the model incorporated as much stochasticity as practicable, limited evidence base for some parameters (particularly for variance around the mean) leaves room for future improvements in terms of better representing reality. For example, it may be that variable annual climatic conditions create ‘good’ and ‘bad’ years for a range of vital rates, that be modelled using a covariance structure – tending towards wider population fluctuations and likely a decreased overall growth rate (Fay *et al.*, 2022). Here such autocorrelation was only incorporated for captive hatch and fledge rates across ‘good’ and ‘bad’ years. As noted in the Methods, we also did not incorporate density dependence.

Comparison with reality

It is important to consider how closely the ‘business as usual’ scenario(s) actually represent what we expect to happen in the absence of any headstarting and associated interventions. For example, the best available current estimates put ICA productivity overall essentially indistinguishable (very slightly higher but also more variable) from that of the rest of Wales (~0.2), when we hope and expect that interventions for breeding pairs within ICAs should yield higher productivity levels. Additionally, we might expect these values to change going forward even in the absence of targeted recovery programmes. The recently launched UK-wide Curlew Action Plan (Thompson *et al.*, 2026) calls for actions including wader-friendly habitat interventions such as rewetting and active management of egg and chick predators, which could affect multiple demographic metrics (e.g. breeding propensity, productivity). Additionally, any loss or degradation of the habitat quality of Curlew wintering grounds could negatively affect adult survival, which, as mentioned above, we expect to be the most influential demographic metric in a slow life-history species such as Curlew.

Where we are modelling interventions, it is important to consider the role of time lags. ‘National productivity improvement’ scenarios assume a rather arbitrary 10-year ‘ramping up’ period over which productivity increases to the national stability threshold (with that of selected ICAs rising incrementally above this under headstarting scenarios), partly based on the UK Action Plan identifying a number of actions related to increased productivity as needing to occur ‘ASAP’ towards 0.6 fledglings per pair per year by 2030 (Thompson *et al.*, 2026). However, where other conservation measures are occurring alongside headstarting in the absence of a national productivity improvement, these are assumed to push productivity in selected ICAs up to the threshold value immediately. Even if practitioners knew exactly what to do to achieve this, we would expect a time lag in this filtering through to adult population counts (as seen in the relevant projections, which display the number of recruited adults and hence notable uplifts due to headstarting from about three years after initiation). This is especially true for slow life-history species: Donaldson *et al.* (2025a) state that “*time lags tend to be longer where interventions cover geographically large areas, as is typical of shorebird nonbreeding ranges; require changes among human communities, which tend to require the building of trust over many years; require multiagency legal or regulatory change; and are untested and thus require a period of adaptive learning before they become effective*”.

There are inevitably a number of ways in which our model cannot sufficiently represent reality, in many cases relating to necessary simplifications of the headstarting process. For example, we did not disaggregate captive hatch and fledge rates based on clutch origin, such that we haven’t accounted for potential differences between first and second clutches (i.e. second clutches may be smaller or of lower quality due to the effort of relaying, and/or subject to a different level of predation pressure in the wild based on breeding season progression). Additionally, results for Black-tailed Godwits headstarted under ‘Project Godwit’ suggest that post-release survival increases with the number of birds in a release cohort (WWT, unpublished data), whereas here all fledglings experience the same juvenile survival rate. Furthermore, return and recruitment probabilities may be affected by the surroundings in which headstarts are raised – particularly immediately prior to and post-release. It may be that sites with more breeding pairs and/or a higher breeding density are perceived as ‘better’ and are hence more likely to result in headstarts returning to set up territory. This raises questions of where rearing of headstarted birds would occur and, if remote from the release site/s, how and at what age young birds would be transported. Finally, exact release numbers and locations for headstarting to be implemented in due course would obviously need to be discussed with the relevant authorities to ensure compliance with licensing requirements.

Interpreting these results

Overall, our parameterisation of the Welsh Curlew life cycle is supported by the fact that the matrix population model-associated asymptotic population growth rate of ~ 0.94 corresponds to the decline of $\sim 6\%$ per year as estimated in the Welsh Action Plan (Gylfinir Cymru, 2021). It is worth noting that this expectation corresponds to a halving of the population in approximately 10 years or by the mid-2030's, a point by which some of Taylor *et al.*'s (2020) projections predict extinction to have already occurred or be imminently occurring – although their loglinear projection retains an estimated 1,500 individuals in 2036 and has the population persisting at low levels into the latter half of the 21st century (derived from their Figure 1.6). It is interesting to note that the value we chose to represent a more stringent productivity threshold at site level (i.e. 1.0 fledglings per breeding pair per year, rather than the broader-scale estimate of 0.6) corresponds to the midpoint of the range of values presented by Taylor *et al.* (2020) as necessary to reverse declines and restore the population to 2009 levels in 10 years from 2019: 0.87-1.14.

It is perhaps surprising that the highly unlikely outcome of 'maximum failure' of headstarting (i.e. clutches being collected to meet 'maximum feasible' effort but no birds making it to release) results in projections that closely parallel 'business as usual', given that under this scenario a large proportion of wild productivity has been diverted with no payoff.

This is partially explained by the fact that headstarting is always assumed to be accompanied by at least five years of other conservation measures increasing wild productivity, such that remaining wild clutches have an increased chance of producing fledglings (or, more specifically, one-year-olds entering the population prior to the following breeding season). Additionally, over half of donor pairs are expected to re-lay, although some of these are also subject to collection under the two-bout collection scenario (noting that expected 'lost' wild productivity when birds do not relay is < 0.1 fledglings per breeding pair per year). This finding presents the intensity of headstarting as modelled to be a sort of 'no regrets' option (in terms of net population effects but of course not in terms of resources invested), when wild productivity is insufficient to support population stability. This is especially true at the national level, as even if pairs donating clutches were driven to abandon the area due to a perceived high failure rate (for which we know of no evidence, and note many nests fail naturally anyway; see Donaldson *et al.*, 2025a, pp. 4-5), they would still be within the wider population of interest after relocation (albeit perhaps not e.g. in an ICA where they may have benefitted from other conservation measures being put in place, although anecdotally we expect most such relocations to occur very locally).

Given the identified key role of a national productivity improvement in a Welsh Curlew population recovery, a headstarting programme would primarily meet the second of the two potential aims identified by Lee (2019): to maintain a population while problems in the environment are being addressed – perhaps transitioning to: accelerating recovery once environmental conditions became favourable. These are referred to, respectively, as ‘buying time’ and ‘accelerating recovery’ by Donaldson *et al.* (2025a), who note that the former endorses headstarting as an option that “*can produce rapid and major increases in productivity with reasonably high confidence in situations where few other interventions can*”. The population modelling presented here determines the potential impact headstarting could have on the Welsh breeding Curlew population and hence required release targets (expressed here as clutch collection targets), completing Lee (2019)’s pre-project checklist section on ‘aims and objectives’.

The projections presented here also inform some of Lee (2019)’s ‘justification’ questions; specifically ‘*Would the project’s benefits outweigh potential negative impacts?*’ (in terms of the focal population rather than any wider implications) and ‘*Are existing conservation measures insufficient for recovery within a reasonable timescale?*’ (considering the ‘business as usual’ scenarios). Additional actions were assumed to be a necessary part of any headstarting activities (all headstarting pulses being accompanied by 5-10 years of other conservation measures supporting wild productivity), and results demonstrated the necessity of improving wild productivity across Wales in order for headstarting at selected ICAs to support national-scale growth. It is worth emphasising here that headstarting does represent one of very few currently established methods by which wild Curlew recovery can be achieved.

While highly intensive predator control can be effective over both extensive (e.g. grouse moors) or more localised areas (e.g. [Glenwherry, Northern Ireland](#)), this may be controversial with the general public and hence politically unpalatable. Predator-exclusion fencing for individual nests can boost nesting success, but this is highly time-intensive, and the protective effect does not carry over onto chicks, such that fledging success is still limiting (Ewing *et al.*, in prep.).

In the scenarios modelled here, we assumed headstarted chicks were returned to their source; however, this would not necessarily need to be the case (if, for example, one selected ICA was able to produce a surplus of chicks relative to the others). The Wales Action Plan for the Recovery of Curlew defines headstarting as returning captive-reared birds to their population of origin (Gylfinir Cymru, 2021) – but Donaldson *et al.* (2025a) define headstarting *sensu lato* to include operations in which animals are released at sites other than that from which they were collected. Taking 30 km as a dispersal distance threshold defines an ICA ‘metapopulation’ whereby almost all Welsh ICAs are connected by these buffers and hence open to

some level of interchange – particularly when considering the known ‘long tail’ on dispersal, with at least one headstarted Curlew released in England’s Severn & Avon Vales recruiting over 100 km to the county of Rutland, for instance (WWT, unpublished data).

Most of the headstarting scenarios modelled here assumed some level of take from second clutches laid following an initial round of collection for headstarting – with this additional input facilitating more positive population trajectories at the selected ICAs, converting the overall trend from decline to stability under a national productivity improvement (as compared for the larger estimated starting population size). There is limited evidence of impacts on Curlew of specifically taking two clutches for headstarting, given that much of the English curlew headstarting effort uses eggs from airfields where all nests are destined to be collected (or legally destroyed) for aviation safety purposes. Looking to other wader headstarting efforts: for Black-tailed Godwit in the English Fens, a number of collected clutches represented re-lays following predation of first nests (WWT, unpublished data) – with disappearance of the eggs following human approach likely indistinguishable from ‘normal’ predation to the incubating parents. Additionally, a small proportion of eggs collected for Spoon-billed Sandpiper (*Calidris pygmaea*) headstarting in Russia 2012-2021 were from replacement clutches, and over 100 eggs were laid in replacement clutches following collection for headstarting, the majority of which survived to hatch (see Figures 2 & 3 of Loktionov *et al.*, 2023).

If it were deemed preferable to avoid collection of second clutches in the context of Welsh ICAs, while aiming to achieve the outcomes predicted using more clutches than could be provided with a single bout of collection, other sources of eggs could potentially be used, for example ‘no regrets’ rescues of clutches doomed to fail (e.g. due to flooding; see Lee *et al.*, 2024, p. 20) where this could be identified outside of ICAs, or import of available nests from outside of Wales. It is worth noting here that the [framework for head-starting Eurasian Curlew in Wales](#) [v1] specifies restricting collection for headstarting to such doomed clutches; the assumption of more expansive collection had to be made here in order to source sufficient eggs to make any headstarting effort worthwhile. However, collection effort could potentially favour those patches expected to produce few, if any, wild fledglings (for example, due to known high predator pressure) over those where the outlook appears brighter.

Looking more closely at outcomes in the selected ICAs, the ‘business as usual’ decline in the absence of a national productivity improvement is most gradual for ICA 12, presumably reflecting the fact that this ICA has the highest wild productivity rate of the four. This does not translate into the strongest benefit from headstarting, presumably due to a combination of ICA 12 starting from the smallest population size and not receiving dispersing headstarts from other selected ICA due to a larger separating distance – ICA 9 has slightly lower mean wild productivity and clutch size estimates, but starts from an intermediate population size and receives from one other selected ICA, while ICA 5 again has slightly lower vital rate estimates but receives from both ICAs 2&3 and ICA 9.

Qualitative differences under the ‘business as usual’ scenario with a national productivity improvement between selected ICA trajectories for the two starting estimated population sizes must represent differential inputs to the selected ICAs from a larger or smaller national population; ICA 9 benefits from the larger surrounding population (showing growth as opposed to stability with the smaller starting point) presumably due to the fact that it represents the highest proportion of total ICA area and hence receives more dispersing birds from the wider landscape.

In conclusion, the results presented in this chapter suggest that reinforcing the Welsh breeding Curlew population through headstarting at selected ICAs could form one part of a recovery plan, but would require improvements to wild productivity at the national level in order for the ‘bought time’ to contribute to a sustainable solution.

While Principle 5 of the [framework for head-starting Eurasian Curlew in Wales](#) [v1] states that headstarting should be considered only if (among other things) “*Other methods of resolving insufficient productivity, as practically possible, within an area are in place and have not increased productivity to at least 0.6 fledged young per pair per annum*”, we believe that both types of interventions need to be considered holistically in order to maximise the likelihood of reversing the current decline.

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Chapter 2. A guide for headstarting curlew, from nest-finding to post-release monitoring

Introduction

In this chapter we aim to meet a number of considerations from the ‘wader headstarting feasibility checklist’ (Lee, 2019a). Specifically, we provide detailed information regarding:

- Curlew life history
- egg collection
- incubation and rearing
- transport and release techniques
- post release monitoring

In all cases we assume that birds are being released back into habitat already hosting breeding Curlew. The required number of eggs to be collected is discussed in Chapter 1 in terms of available numbers and potential impacts at the donor site. Chapter 2 outlines nest-finding/egg-collection activities, egg transport, and biosecurity.

Indicative budgets are provided to illustrate the scale of necessary financial resources and hence to inform considerations of cost-effectiveness (per Lee, 2019b). Stakeholder engagement, relevant laws and regulations, and required technical resources where appropriate are outlined throughout this chapter.

General underlying factors vital to the success of a proposed Curlew headstarting programme include:

- Experienced staff across all stages from nest-finding and egg transport, through incubation and rearing, to post-release monitoring. Aviculturists and avian veterinarians with strong ‘bird sense’ allow potential problems to be spotted and hence rectified as quickly as possible (a good example being protein content of diets in relation to birds’ activity levels)
- Biosecurity. Even something as simple as changing food bowls regularly and cleaning spilled food to prevent decomposition, which risks aspergillosis
- Reliable equipment (incubators etc.) with experienced operators
- Tending towards moving birds through the rearing stages (e.g. from indoors to outdoors) quickly rather than slowly, avoiding mixed-age cohorts where possible; it

is always preferable to look at a new set-up and think “*don’t they look small in their new space*” rather than suspecting overcrowding , which is thought to stress the birds and hence increase susceptibility to certain health conditions

- Creating outdoor spaces that are predator-secure with protection from the elements (cover from rain; plentiful shade and multiple water options available during hot weather; etc.)
- Ensuring that the release site has other waders present at the time of release (these would preferably but not necessarily need to be Curlew) ideally likely to be moving in the desired direction e.g. towards the coast, with adequate predator protection in place e.g. by deploying fencing and/or predator control measures
- A willingness to be flexible: any protocol is only the basis from which you build, adapting to specific project conditions and over time – with the awareness that changes often have knock-on effects requiring further adjustment (as emphasised by Clements *et al.*, 2025, when reflecting on captive breeding of Spoon-billed Sandpipers, *Calidris pygmaea*).

More specifically, here we consider the aim of a Welsh Curlew headstarting plan to be to raise annual productivity of an estimated 500 breeding pairs by 0.3 fledglings per breeding pair (per the Welsh Action Plan; Gylfinir Cymru, 2021), through the headstarting of 150 fledglings per year over five years. With reference to Chapter 1, this represents the ‘minimum necessary headstarting’ scenario with the lower population estimate. We therefore present a method to raise and release a target of 150 fledglings each year. Fifty clutches yields an estimated 188 eggs and hence 150 fledglings when assuming an average clutch size of 3.75 eggs and an 80% egg-to-fledgling success rate. This is WWT’s benchmark across wader headstarting programmes, and is also approximately equal to the product of the ‘usual’ Curlew hatching and fledging rates(excluding occasional ‘bad years’ discussed in Chapter 1). Fifty clutches also represents a sensible target as it is approximately the maximum amount that could be collected in only one bout across the selected ICAs, without returning for second clutches to create a second cohort of birds to move through the rearing process.

We envisaged four possible methods to headstart a total of 150 Curlews at one, two or three headstarting hubs:

- Method 1: Incubate eggs and hatch, raise and release 150 Curlew at one hub (Hub #1)
- Method 2: Incubate eggs and hatch, raise and release 75 Curlew at each of two hubs (Hubs #1 & #2)

- Method 3: Incubate eggs and hatch, raise and release 50 Curlew at each of three hubs (Hubs #1, #2 & #3)
- Method 4: Incubate eggs and early-stage raise 150 Curlew at one hub (Hub #1), then mid- and late-stage rear and release 50 Curlew at three hubs (Hubs #1, #2 & #3). This method requires 50 chicks to be transferred to each of Hubs #2 & #3 from Hub #1 for mid-stage and late-stage rearing prior to release.

The four methods require three hubs to cater for different numbers of eggs and chicks (Table 2.1).

Table 2.1. Numbers of clutches, eggs and chicks at one to three hubs when considering four methods to raise 150 chicks for release

Method #	1	2	3	4*	4*	4*
Hub	1	1 & 2	1, 2 & 3	1	2	3
clutches per hub (rounded to nearest integer)	50	25	17	50	0	0
eggs per hub (rounded to nearest integer)	188	94	63	188	0	0
Target chicks per hub	150	75	50	50	50	50
Max chicks per hub	188	94	63	63	63	63

NB: 'Max. chicks per hub' refers to the highly unlikely but theoretically possible scenario in which all collected eggs produce fledglings (i.e. hatch and fledge success both 100%).

*For Method 4. 3 hubs but with zero egg incubation or early-stage chick rearing facilities at Hubs #2 & #3 as all incubation and early-stage rearing undertaken at Hub #1

The four methods will require hubs to have different facilities, equipment, materials and numbers of staff due to the different numbers of eggs to be incubated and chicks to be raised for release. For the purposes of costing, we restrict consideration to Methods 3 and 4 i.e. those where individuals are released at their origin ICA (or combination thereof), as modelled in Chapter 1.

Planning

Licensing requirements

The Project Manager (PM) should ascertain from NRW the licensing requirements for Curlew egg collection and subsequent releases of raised birds. The PM should apply for and obtain appropriate licences ideally in the year before the project commences. The terms and conditions of licences must be adhered to at all times.

The PM should ascertain planning permission requirements for the infrastructure required to hatch and raise Curlew from local government planning authorities. The PM should obtain planning permission before acquiring/constructing infrastructure.

Prior to attaching 'special marks' (e.g. GPS tags) to released birds, endorsements for the bird ringers should be obtained from the British Trust for Ornithology (BTO). The BTO should also be consulted and asked to devise a leg banding/flagging scheme unique to the project (see also the 'Monitoring released birds' section below).

Important notes on staffing

- A Project Manager (PM) should be appointed in the year before the headstarting project commences, ideally in the January of the year before commencement – i.e. 12 month's employment. Thereafter, the PM should be employed for each year of the project.
- A Veterinarian Officer (VO) should complete a Disease Risk Analysis (DRA) to support licence application to collect eggs and release fledglings in the year before the headstarting project commences. The DRA should be completed by the end of June in the year before commencement. The VO should have 10 months' employment in the year before commencement (e.g. January to October to compile the DRA for submission to NRW with the translocation licence application, and to ensure availability to produce further drafts should NRW require these). Thereafter, the VO should be employed annually for 10 months in each year of the project.
- A Lead Aviculturist and Deputy Lead Aviculturists should be appointed in the year before commencement beginning March before year of commencement – i.e. 10 months employment. Thereafter, employed annually for 10 months in each year of the project.
- Aviculturists should be appointed at the beginning of the year that the headstarting project commences, beginning January in the year of commencement. Thereafter, employed annually for 8 months in each year of the project.
- All government agency licences/permissions for headstarting should be obtained in the year before the headstarting project commences (applied for by the PM and VO by the end of June and secured by the end of October in the year before commencement – note that there may be delays due to e.g. Avian Influenza outbreaks).
- Facilities should be established in the year before the headstarting project commences (completed by the end of December in the year before commencement).
- Equipment and materials should be procured at the beginning of the year that the headstarting project commences (completed by the end of March in the year of commencement).

Nest-finding

Nest-finding techniques should be those recommended by experienced local fieldworkers. As Curlews show year-on-year breeding territory fidelity, visits to traditional breeding territories should be made from early spring (early March) in each year of headstarting to locate pairs.

Searches for nests should only be made when breeding territory establishment has commenced, and thereafter during known egg-laying periods (mid-April to late-June).

Nest-searches should be made by fieldworkers driving/walking through suitable habitat. When a pair of Curlew is found to be defending a territory, more intensive searches should be made to find a nest. Initial nest searches should be made by conducting visual observations of the birds i.e. birds should be watched with a telescope or binoculars to observe a laying or incubating pair-member returning to a nest. When a nest is found, date, time, finder and relevant nest and egg details should be recorded to a standardised format (i.e. on a form). Geographical co-ordinates (lat-long, What3Words, etc.) should be obtained for all nest sites. All nests should be assigned a unique code. This code should be marked on the eggshells with indelible ink upon arrival to the Egg Incubation/Early-stage Rearing Facility.

Relevant fieldworker guidance for surveying and monitoring breeding Curlew can be accessed through the [Curlew Recovery Partnership](#). The use of GPS tags is discussed in a subsequent section on 'Monitoring released birds'; having some wild birds tagged prior to headstarting would likely be very helpful for nest-finding, particularly for subsequent clutches initiated following failure or collection for headstarting. It is also worth noting that [drones have already been trialled in at least one ICA](#) as part of nest-finding efforts.

Facilities and infrastructure

The four methods require different facilities at one, two or three hubs (Table 2.2) to cater for different numbers of eggs and chicks at different stages of the rearing process (as summarised in Table 2.1).

Facilities should include:

- Egg Incubation and Early-stage Rearing Facilities (for Method 4, NOT required at Hubs #2 & #3)
- Food Storage and Preparation Facilities (for Method 4, at Hubs #2 & #3 only)
- Rearing Aviaries with external predator-proof perimeter fences (for all methods, at all hubs)
- Release Enclosures with external predator-proof perimeter fences (for all methods, at all hubs)
- Storage Facilities (for all methods, at all hubs)
- Power-washing Facilities (for all methods, at all hubs)

Table 2.2. Facilities required at each hub for the 4 different methods

Method	1	2	3	4	4	4
Hub	1	1 & 2	1, 2 & 3	1	2	3
EIESRF LARGE also functioning as a Food Store/Prep Facility for Method 1 (at Hub #1), 2 (at Hubs #1 & #2) & 4 (at Hub #1)	2	2 (1 at each)	0	2	0	0
EIESRF MEDIUM also functioning as a Food Store/Prep Facility for Method 3 (Hubs #1, #2 & #3) and Method 4 (at Hub #1)	0	0	3 (1 at each)	0	0	0
FSPF	6	0	0	0	1	1
RA	6	6 (3 at each)	6 (2 at each)	2	2	2
RE	2	6 (3 at each)	6 (2 at each)	2	2	2
SF	1	2 (1 at each)	3 (1 at each)	1	1	1
PWF	1	2 (1 at each)	3 (1 at each)	1	1	1

NB: EIESRF = Egg Incubation and Early-stage Rearing Facility (e.g. Portakabin);

FSPF = Food Storage and Preparation Facility (e.g. Portakabin, like a medium-sized EIESRF); RA = Rearing Aviary; RE = Release Enclosure; SF = Storage Facility (e.g. shipping container/s); PWF = Power-washing Facility

Function of Facilities

Egg Incubation/Early-stage Rearing Facilities (EIESRF)

Needed for:

- Method 1 & 4 @Hub #1 where 2 are large-sized and function as an egg incubation and early-stage chick rearing facility as well as a food storage and preparation facility for birds at all stages i.e. including those in Rearing Aviaries (RAs) (with their Mid-stage/ Late-stage Rearing Units (MSRUs/LSRUs)) and Release Enclosure Facilities (REFs).
- Method 2 @Hubs #1 & #2 where 1 at each is large-sized and functions as an egg incubation and early-stage chick rearing facility as well as a food storage and preparation facility for birds at all stages i.e. including RAs (with their MSRUs/LSRUs) and REFs.
- Method 3 @Hubs #1, #2, & #3 where one at each is medium-sized and functions as an egg incubation and early-stage chick rearing facility as well as a food storage and preparation facility for birds in outside facilities i.e. RAs (with their MSRUs/LSRUs) and REFs.

The EIESRF should be a building e.g. a Portakabin to function as the egg incubation, early-stage chick rearing, food storage and food preparation area. The EIESRF will also function as a storage space for perishable goods such as bird food during the headstarting period. Outside of the headstarting season, the EIESRF should be used as a storage space for electrical items, e.g. incubators, heat and UV lamp sets, car batteries, electric fence energisers, generators and miscellaneous avicultural equipment e.g. food bowls, water bowls, mat substrates etc.

The EIESRF should have easy to clean and disinfect smooth surfaces separated into two rooms by a solid wall and door. The larger room is the Early-Stage Rearing Room (ESRR), and the smaller room is the Egg Incubation Room (EIR). Separation allows biosecurity to be maintained inside the EIR and limits disturbance to chicks in the ESSR during the period when incubation, hatching and early-stage rearing are concurrent.

The EIESRF should have an external door through which the building is accessed. Access should be restricted to aviculturists, or personnel authorised by aviculturists. A simple step-over barrier should be installed at the entrance to the EIESRF and used as a shoe-changing space to maintain biosecurity within. Note: all personnel should change into bespoke shoes upon entry.

The EIESRF should have an electricity supply for overhead lighting and an array of double sockets both in the EIR and ESRR to operate incubators and heat bulb/UV light bulbs in Early-stage Chick Rearing Units (ESRUs), respectively. The ESRR should have a mains water supply for sinks with appropriate mains drainage.

Both parts of the EIESRF should be supplied with electricity to operate overhead lighting (e.g. Full Spectrum Flicker-Free T8 LED Tube Lights fitted to appropriate ballasts), the stationary incubators, an egg candler, weighing scales, air conditioner/s (AC) and heater. Electrical outlets should be placed 1.4-1.6m high on the EIR walls to reduce ingress of water through floor mopping which is possible if positioned at 'skirting board' level. The AC and heater should maintain the incubation room at ambient temperatures ranging 15-20°C.

Specifically for the EIR, the room should be large enough to accommodate tables on which incubators can operate. All surfaces should be easy to clean and disinfect. The room should have windows that can be opened, and which can be covered (e.g. with cardboard or black bin bags) to prevent sunlight heating the room leading to incubator malfunction or lighting up the room preventing optimal egg candling. The EIR should **not** have a water supply i.e. taps and a sink, to reduce microbial hazards emanating from wastewater pipes.

Specifically, the ESRR should also have windows that can be opened, and which can be covered to prevent sunlight overheating the room. The ESRR should have a deep double sink with hot and cold mains water supply and mains drainage for hand washing and cleaning/disinfection of food and water dishes and other rearing equipment. The sink should have drainage boards and worktop. The sinks should have sealed splash zones on walls to prevent water damage and to avoid septic conditions.

Food Storage and Preparation Facilities (FSPF)

Needed for:

- Method 4 @Hubs #2 & #3.

The FSPF should be a building e.g. a Portakabin (identical to a medium-sized EIESRF but without the internal partitioning wall to separate an ESRR from an EIR as these are not needed). The FSPF should be supplied with electricity for appropriate overhead lighting, an air conditioner (AC) and heater etc. Electrical outlet placement, ambient temperature target range, the sink and drainage set-up and restricted access/biosecurity protocols are the same as for the EIESRF (see above). Similarly, all surfaces should be easy to clean and disinfect and the room should have windows that can be opened. The FSPF should have an external door through which the building is accessed.

Equipment Storage Facilities (SF)

Needed for:

- Method 1, 2, 3 & 4 @Hubs #1, #2 & #3

The SF could be one or more shipping containers where mid-stage and late-stage rearing equipment (e.g. Animal Houses, stokbord panels, road pins) are stored when not in use.

The ESF should have an electricity supply for appropriate overhead lighting within and electric socket outlets, and a mains water supply to an outside standpipe. Electrical outlets should be placed 1.4-1.6m high on the walls to reduce ingress of water through floor mopping which is possible if positioned at 'skirting board' level.

Power-washing Facility (PWF)

Needed for:

- Method 1, 2, 3 & 4 @Hubs #1, #2, & #3.

The PWF is where dirty floor mats are cleaned with a pressure washer, before being soaked in disinfectant solution and air-dried. The PWF should comprise a concrete pad e.g. 3m x 2m, ideally with 1m high walls on two sides to reduce aerosol dispersal, with mains floor drainage for wastewater.

The PWF should be close to a mains water supply and electricity so that the power washer can be operated. The PWF could be located near the SF (e.g. shipping container/s) against which a lean-to shelter can be positioned with 'washing lines' on which to air-dry mats.

Rearing Aviaries (RAs) (for mid- and late-stage rearing)

Needed for:

- Methods 1, 2, 3 & 4 @Hubs #1, #2, & #3.

The RAs are outdoors. An RA should measure 9m (wide) x 30m (long) providing an area of 270m² overall. The RA should be 2m high. The RAs are where Curlew broods are mid-stage and late-stage raised in Mid-stage Rearing Units (MSRUs) and Late-stage Rearing Units (LSRUs). Each RA should be large enough to accommodate 24-28 Curlew chicks e.g. 8 or 9 broods of 3 chicks or 6 or 7 broods of 4 chicks. WWT recommends that each chick has an area of 9-11m² from when aged approximately 21 days. Thus, an RA with an area of 270m² should provide 24 chicks with 11.25m² each, or 28 chicks with 9.6m² each.

WWT recommends that RAs are constructed from bespoke-made pheasant panels each measuring 3m (wide) x 2m (high) attached to round posts e.g. with cable ties. These bespoke-made pheasant panels should be constructed from treated timber including an approx. 0.3m-high kickboard at their base and nylon net on their sides. The RAs should have a nylon top-net as a 'ceiling' secured to the upper edge of the pheasant panels with cable ties. At least one pheasant panel should have a door for entry and exit of personnel.

RAs should be predator-proof. Wire mesh should be fixed to the external kickboard with staples from a staple gun and folded out onto the ground to a width of 0.3m where it is

pinned to the ground e.g. with tent pegs. This is to prevent ingress by digging predatory mammals e.g. Brown Rat (*Rattus norvegicus*), Weasel (*Mustela nivalis*) and Stoat (*M. erminea*). At least 2 electric hot wires powered by a 12v car battery should be fixed to the kick board using electric fence bobbins to exclude climbing predatory mammals.

The RAs should be arranged in arrays e.g. for

- Method #1: 1x array of 6 RAs at Hub #1;
- Method #2: 2x arrays of 3 RAs at Hubs #1 & #2;
- Method #3: 2x arrays of 2 RAs at Hubs #1, #2 & #3;
- Method #4: 2x arrays of 2 RAs at Hubs #1, #2 & #3 (i.e. same as Method 3).

Each array should be surrounded by a 1.8-2m high perimeter fence constructed from wooden posts and heavy gauge wire mesh. The perimeter fence should have an external ground apron of wire mesh, e.g. 'Otter Stop' mesh. This perimeter fence is to exclude large digging mammalian predators e.g. Red Fox (*Vulpes vulpes*) and Eurasian Badger (*Meles meles*). At least 3 electric hot wires, powered by a 12v car battery, should be fixed around the base of the perimeter fence using electric fence bobbins.

Release Enclosures (REs)

Needed for:

- Methods 1, 2, 3 & 4 @Hubs #1, #2, & #3.

The REs should be located at the Release Site/s. The Release Site/s should ideally be placed close to a natural wetland where wild post-breeding Curlews are known to congregate. REs are identical in their array arrangement and construction to RAs except:

One end of the predator exclusion perimeter fence should be easily removable to facilitate releases, i.e. by opening one end of each RE aviary and its perimeter.

A second top net should extend over the RAs. This second top net is to prevent birds of prey – Goshawks (*Accipiter gentilis*) and Sparrowhawks (*Accipiter nisus*), in particular – from injuring flying birds through the single top-net ceiling of RAs. This second top net should be fixed to sides of the perimeter fence using e.g. cable ties and propped up with clothes-line props within the perimeter fence.

Lethal management of Red Fox should be considered at the Release Sites, at least two months running up to releases.

Maintenance of facilities

Maintenance checks should be conducted daily and weekly by bird caretakers.

Daily maintenance checks should include ensuring (i.e. repairing when necessary) the integrity and functionality of the supporting infrastructure, in particular:

- The perimeter fences
- The net cover/ceiling of RAs and REs
- The dividing barriers to e.g. each MSRU and LSRU
- The entry/exit doors
- The water supply
- The wastewater drainage system
- Heat lamps
- Replacement of disinfectant solution in foot baths and wheel washes

Weekly maintenance checks should include:

- Stock-checking bird food, disinfectant and washing supplies and ordering replacements when necessary
- Guttering systems to buildings
- Assessing condition of changing and cleaning areas
- Assessing condition of food storage and preparation areas
- Assessing all tools and machinery functionality

Vegetation Management of RAs and REs: The RAs and REs should contain grass swards or natural plant communities in which birds can forage. The vegetation type should be like that growing in the ICA of the release area of the hub, e.g. MG4 grassland. Vegetation should not include prickly plants e.g. thistles (*Cirsium*, *Carduus*, or *Onopordum* spp.), or bushes or trees. Vegetation should be managed using different cutting regimes in autumn-spring (when unoccupied by birds) and summer (when occupied by birds) using bird- and human-safe cutting equipment and following H&S procedures for safe operation. To reduce pathogens, biolime should be applied to substrates in the rearing areas occupied by birds during the winter i.e. when there are no birds present.

The autumn-spring regime: Vegetation should be cut to a low height using fuel or electric powered cutting implements e.g.. lawn mowers and brush-cutters. All cut vegetation should be removed. Vegetation growing against the edges of perimeter fences and outer sides of RAs should be managed to a low height through the springtime application of an appropriate herbicide to prevent re-growth during the summer.

The summer regime: Vegetation should be cut to a low height before being occupied by birds. Once occupied, vegetation in RAs and REs should be left to grow with only 'light gardening', if and when required. This light touch gardening should be done with hand tools e.g. shears. Thistles should be removed 'from the root', as they appear, by digging.

Egg collection and transportation

Eggs should be collected as soon as a clutch is completed, i.e. when incubation is believed to be underway and when there are 3-5 eggs in the nest (note: 5 egg clutches are extremely rare). This is to reduce the risk of clutch 'loss' to predation, and, to increase the likelihood of a second clutch being laid (note: second clutches are most likely to be laid when first clutches are "lost" within 1-10 days' of incubation – see also p. 4 of Donaldson *et al.*, 2025).

Eggs should be collected by trained personnel, ideally an aviculturist. Personnel should wear clean nitrile gloves when handling eggs to prevent microbial contamination of eggshells. Eggs should be inspected for damage before translocation. Damaged eggs should be carried separately from intact (i.e. undamaged) eggs. Eggs should be transported in pre-heated 12v battery operated portable incubators. Eggs should be carefully placed, air-cell ('fat' end) uppermost, in the trays of the portable incubator. The incubator should be carefully carried by hand to the transport vehicle for transfer to the EIESRF.

On arrival to the transport vehicle, portable incubators should be connected to a power supply so that they are heated to 36.0 °C and an ambient RH (~50-60% RH). During vehicular transport, the portable incubator should be held on the lap of an aviculturist sitting in the rear seat of the vehicle and driven to the EIESRF destination at a speed appropriate to the road conditions to protect the eggs from jolts. Alternatively, incubators should be strapped on to the rear seat with appropriate padding below and behind to maintain the incubator at a 'square' angle, i.e. 180° at base and 90° at sides.

Nest and egg collection details should be recorded at the point of collection.

See the 'Monitoring released birds' section for thoughts on potential collection impacts on donor pairs.

Portable incubators

Curlew eggs should be translocated in pre-tested (i.e. dependable) portable incubators e.g. 12v AB 12-volt DC portable incubators. These portable incubators measure approximately 0.35m x 0.35m x 0.32m and hold up to 18 Curlew eggs. These portable incubators have the following design features:

- Powered by 12v DC from a car battery, by using:
- crocodile clips connected directly to terminals, or
- a plug to fit into the cigarette lighter socket on a car's dashboard
- 12v DC thermostat for close temperature control (set at 36.0°C)
- Overheating thermostat and alarm buzzer (set at 37.0°C)
- Digital temperature display unit (32-42°C accurate to $\pm 0.1^\circ\text{C}$).

Before use, all portable incubators should be cleaned according to the manufacturer's recommendations. During transport the portable incubator lid should be lifted every 30 minutes for 10 seconds to allow an air exchange. The lid should also be lifted for the same length of time should the incubator overheat.

Receiving and processing eggs

At the EIESRF, the EIR should be entered via the ESRR. Prior to entry to the EIR, aviculturists should wash their hands in the ESRR and change into bespoke shoes and coveralls at the threshold of the EIR to maintain biosecurity for incubation.

In the EIR, an aviculturist should process the eggs prior to transfer to stationary incubators therein. The aviculturist should wear nitrile gloves when handling eggs, changing gloves between clutches. Eggs should be extracted from the portable incubator one at a time and each marked with a unique egg-code. The mark should be made with indelible ink below the equator (i.e. towards the 'pointy' end) of the egg. The mass of each egg should be recorded to the nearest 0.1g using calibrated electronic scales and its linear measurements (length and breadth) should be recorded with Vernier or dial callipers to the nearest 0.1mm. These measurements will enable incubation stage to be ascertained for each egg/clutch (i.e. fresh, early-stage incubated, mid-stage incubated or late-stage incubated). Incubation stage assessment will indicate the appropriate artificial egg incubation conditions to be provided to each egg. Each egg should be 'candled' with an egg candler to assess its embryonic development and shell integrity. Eggs found to be damaged (e.g. cracked) should be repaired e.g. with nail varnish and incubated separately from others. Eggs with dead embryos should not be incubated further; these should be stored appropriately (e.g. in a fridge away from the incubation facility) until a veterinarian

(i.e. the VO) can perform a postmortem examination and/or collect samples to ascertain cause of death. The scales, callipers and egg candler should be wiped with a disinfectant solution before and after use.

Artificial incubation

Artificial incubation should be divided into four stages according to the incubation requirements of the developing Curlew embryo (Table 2.3). Each Curlew egg should be provided with optimum artificial incubation conditions (temperature, turning frequency and humidity) based on its incubation stage. Incubation stage might be known e.g. through field observation of incubation onset (indicated by parental behaviour cues) or 'estimated' using egg incubation stage assessment techniques (i.e. density/mass loss techniques) and/or by egg-candling.

Table 2.3. Temperature, egg-turning and relative humidity (RH) settings of incubators for each of four stages of artificial incubation of Curlew eggs

Incubation stage	Temperature	Turning rate	Relative humidity (RH)	Substrate
STAGE 1 (0-26 days)	37.5°C	180° 40 mins ⁻¹	Approximately 55-60% RH (but depends on mass loss through incubation)	Incubator floor in egg spacer tray
STAGE 2 (26-28 days or internal pip)	37.2°C	Nil	Approximately 80% RH (but depends on mass loss through incubation)	Rubber mat (egg spacer tray removed)
STAGE 3 (28-30 days or external pip/hatching)	37.2°C	Nil	≥80% RH	Rubber mat (egg spacer tray removed); eggs placed 'pip' up and touching at pointed end
STAGE 4 (post-hatch)	36°C	Nil	Ambient (approximately 50-60% RH)	Rubber mat

Assessment of egg incubation stage

For each egg, incubation stage should be estimated using egg density/mass loss techniques. The estimated stage of incubation at collection should be recorded and the predicted hatch-date specified on the nest/egg form and mass loss spreadsheet. The latter should generate a graphic display of optimal and actual egg mass loss over time. Optimal mass loss is 15% from the estimated fresh mass (i.e. at day 0 of incubation) to 'internal pip' mass (day 26 of incubation).

Curlew eggs should be artificially incubated in mains-powered electric incubators, e.g. Rcom 50 DO12 - PRO Digital Incubator (Automatic). Incubators operating at 6 different settings should be available to provide optimum conditions for embryonic development (Table 2.4). Incubators should be positioned on levelled tables so that temperature gradients within are not distorted. Table levels should be checked daily using a spirit level.

Table 2.4. Incubation settings in each of six incubators. See Table 2.3 for each stage's temperatures and turning frequencies (which do not differ across normal/wet/dry incubators). Note: relative humidity (RH) is controlled using distilled water in an incubator's humidifier.

Incubator #	1	2	3	4	5	6
Designation/ name (see Table 2.3 for definitions of incubation stage)	Normal incubator (Stage 1)	Wet incubator (Stage 1)	Dry incubator (Stage 1)	Pre- hatch incubator (Stage 2)	Hatcher incubator (Stage 3)	Dryer incubator (Stage 4)
Egg/incubator interface	Incubator floor in egg spacer tray	Incubator floor in egg spacer tray	Incubator floor in egg spacer tray	Rubber mat (egg spacer tray removed)	Rubber mat (egg spacer tray removed)	Rubber mat
Relative humidity (RH)	<i>circa</i> 55- 60% RH	<i>circa</i> 80% RH	<i>circa</i> 30- 40% RH	<i>circa</i> 80% RH	80% + RH	<i>circa</i> 55- 60% RH

Each incubator's temperature and RH should be checked and recorded on standard incubator forms at regular intervals between 0600-2400 hrs each day. Adjustments should be made to settings to maintain optimum conditions. Incubators should be fitted with alarms to notify personnel of temperature extremes and power outages. RH in each incubator should be controlled using distilled water.

Cleaning eggshell surfaces (disinfection)

Eggshell surfaces should not be disinfected routinely as this may destroy advantageous micro-organisms on the eggshell surface. Only if eggs are excessively soiled should they be cleaned by dipping in an egg disinfectant solution (following manufacturer's instructions).

Monitoring embryonic development

Egg incubation stage should be estimated at the time of collection using density/mass loss techniques. At the EIR, embryonic development should be monitored further by:

- Weighing eggs to assess the rate of water loss through the eggshell. Egg incubation stage assessment, at the point of clutch collection, using the egg density/mass loss techniques, will indicate the expected daily mass for eggs across a range of known or estimated fresh masses, enabling aviculturists to monitor water loss from each egg. Eggs should be managed to achieve a mass loss of 15% of their estimated fresh mass over the incubation period (to 'internal pip') achieved by moving the eggs to incubators of high or low humidity to slow or increase evaporative water loss rates through eggshell pores, respectively.
- Candling eggs to ascertain the status of the embryo.

Egg movements

Egg Movement Between the 'Normal Incubator' (#1), 'Wet Incubator' (#2) or 'Dry Incubator' (#3) During Stage 1 of Incubation (see Table 2.4 for incubator settings)

Most eggs should be placed in an incubator with 'Normal RH Incubator' RH setting (i.e. incubator #1). Curlew eggs should be weighed every two days to establish the rate of water loss through the eggshell. Birds' eggs lose, on average, 15% (range: 13-17%) of their fresh mass over the incubation period because of evaporative water loss through the eggshell pores. Thus, those Curlew eggs that are losing mass at a high rate (i.e. equivalent to a loss of >17% of their estimated fresh mass by the point of 'internal pipping') should be moved to the 'Wet Incubator' (i.e. incubator #2) operating at higher RH. If eggs are thought to be losing too little mass, they should be moved to the 'Dry Incubator' (i.e. incubator #3). This dry incubator may operate with a tray of silica gel to increase evaporative water loss from eggs. Eggs that begin to attain a mass within the 13-17% range of their estimated fresh mass by the 'pre-hatch' stage, should be returned to the 'Normal RH Incubator' (i.e. incubator #1).

Egg Movement from the ‘Normal’ (#1), ‘Wet Incubator’ (#2) or ‘Dry Incubator’ (#3) to the ‘Pre-hatch Incubator’ (#4) (see Table 2.4 for incubator settings)

When an egg is at stage 2 (see Table 2.3) and 2-3 days from its expected hatch date and when ‘internally pipped’ (i.e. when the chick has broken through the inner membranes into the air cell and is starting to breathe air), it should be transferred to the ‘Pre-hatch Incubator’ (#4). Here, egg-turning should cease, and incubation temperature should be 37.2°C. The floor of this incubator should be lined with a removable piece of indoor/outdoor carpeting or rubber mat to prevent egg rolling. This transfer is a precaution against ‘unexpected hatch-offs’ of eggs in Stage 1 incubators (i.e. incubators #1, #2 or #3) at a time when they are approaching their predicted hatch dates, preventing contamination of Stage 1 eggs with debris from hatched chicks. At this stage, the chick may be seen moving within the air space when the egg is candled or might be audible, i.e. heard to be tapping, scratching, or cheeping inside the egg.

Hatching

Pre-hatching stimuli

Parent Curlews are known to ‘brood-call’ to their eggs during the latter stages of incubation (to encourage the chick through the hatching process). Recorded vocalisations of Curlew should be played, e.g. from a phone, to each egg for 5-15 minute periods, approximately four times per day beginning at around day 26 of incubation to facilitate the hatching process.

Egg movement from the ‘Pre-hatch Incubator’ (#4) to the ‘Hatcher Incubator’ (#5)

When it is ‘externally pipped’ (i.e. the chick has started to break the eggshell), the egg should be transferred to the ‘Hatcher Incubator’ (i.e. incubator #5). During hatching, eggshell membranes may become dry and adhere to the chick. Therefore, the RH in the ‘Hatcher Incubator’ should be maintained at as high a level as possible. This should be achieved by spraying the egg and the inner walls of the incubator with distilled water. ‘Internally pipped’ eggs should be moved to the ‘Hatcher Incubator’ if they are not being checked again for several hours (e.g. overnight) to reduce the risk of ‘dehydration’. The ‘pipped’ egg should be placed in the ‘Hatcher Incubator’ with the ‘pip’ uppermost. This position is believed to facilitate hatching by the chick. Additionally, this position allows observation of hatching progress through the transparent lid of the ‘Hatcher Incubator’. If two or more clutches are hatching at the same time, they may occupy the same ‘Hatcher Incubator’ but only if the clutches can be separated inside the machine by dividing it using vinyl-coated dividers. This is to prevent brood identities becoming mixed. The dividers should allow air to circulate, and be non-abrasive to chicks and tall enough to prevent the chicks escaping and mixing. The floor of the ‘Hatcher Incubator’ should be lined with a removable piece of indoor/outdoor carpeting or rubber mat to prevent the chick from catching its toes in the floor of the incubator and/or slipping. After a ‘hatch-off’, no other

'externally pipped' eggs should be placed in the 'Hatcher Incubator' until it has been cleaned and disinfected.

It is normal for Curlew chicks to hatch 36-96 hours after they begin to 'internally pip' and for cheeping to be heard throughout this period. If a chick's cheeping becomes less audible or its movements (as seen during candling) less vigorous, the chick may be weakening. These eggs should be checked four times daily and the chick's progress and condition recorded. The chick should be stimulated by constant playing of a tape-recorded Curlew brood-call. The chick should be helped from the egg if it fails to hatch within 72-96 hours (3-4 days) of 'external piping' or if it becomes noticeably weak.

Chick movement from the 'Hatcher Incubator' (#5) to the 'Dryer Incubator' (#6)

Hatched chicks should be transferred to the 'Dryer Incubator' (i.e. incubator #6) immediately post-hatch. The chick should be examined and weighed. To weigh the chick, it should be placed in a clean disinfected plastic tub lined with a clean rubber mat and placed on electronic scales accurate to 0.1g. The chick's umbilicus should be checked and swabbed with an iodine antiseptic solution e.g. Tamodine solution. Upon hatching, all data including an allocated 'identity' reflecting the chick's clutch and egg number (as marked on the eggshell) and chick identification marks (e.g. wing down clips, coloured leg bands or coloured cable ties), hatching history, and medical information, should be recorded on the chick's individual record. When the chick has 'fluffed up' (approximately 4-12 hours post-hatch), the chick should be transferred to an Early-stage Rearing Unit (ESRU) within the ESRR of the EIERF.

Incubator hygiene

Incubators should be cleaned according to the manufacturer's recommendation, before use, and after any 'hatch-off' event.

Hand-rearing

Curlew chicks should be provided with different, age-related regimes of care. These regimes should be designed to ensure that birds are reared to behave as 'wild birds' as opposed to 'tame birds'. Thus age-specific management protocols should be prepared, for chicks aged 0-56 days.

Chick accommodation: Overview

Chicks should be accommodated in broods of 3-4 in Early-stage Rearing Units (ESRUs) for 4-6 days post-hatching. These ESRUs should be in the ESRF of the EIERF. After 4-6 days chicks should be transferred in their broods of 3-4, to outside Mid-stage Rearing Units (MSRUs) within the predator-proof Rearing Aviary (RA). Each RA will hold 6-7 broods of 3-4 chicks (i.e. 18-28 chicks). When chicks are aged 14-21 days, MSRUs should

be opened to become Late-stage Rearing Units (LSRUs), which are simply larger MSRUs where broods become mixed. Chicks remain in LSRUs until almost fledged (i.e. at 35-42 days/ 5-6 weeks) of age) when they are transferred to Release Enclosures (REs) at the Release Site. From here chicks are released at 56-63 days (8-9 weeks) of age and when fully fledged i.e. flying (see Table 2.5).

Table 2.5. Accommodation for Curlew chicks of different ages and optimal group size.

Age of chick (days)	Accommodation	Optimal group size (number birds)
0-4/5/6	ESRU (in ESRR of EIESRF)	3-4 (sometimes 5)
4/5/6-21	MSRU (in RA)	3-4 (sometimes 5)
21-35/ 42	LSRU (in RA)	24-28
35/42-56/63	RE	24-28

Chick accommodation: Early-stage Rearing Unit (ESRU) in the Early-stage Rearing Room (ESRR)

When chicks have dried and are ‘fluffed’ up (4-12 hours post-hatch) they should be transferred from the ‘Dryer Incubator’ in the EIR to an ESRU in the ESRR. Note that the ESRR should be large enough to accommodate the number of ESRUs required at the hub.

WWT uses ESRUs measuring 1.15m (L) x 0.67m (W) x 0.55m (H). ESRUs should be constructed from materials with easy to clean surfaces – WWT uses fibreglass with smooth non-abrasive surfaces to minimise injury to chicks. The ESRU should not have a slippery floor surface which may lead to chicks developing splayed legs, hock rotations, joint damage, or slipped tendons. Therefore, the ESRU should have a non-toxic, non-slip floor covering that dries quickly e.g. a carpet which has short fibres, does not unravel or fray and does not have loops to catch toenails, such as Flotex mat. The carpet should be cut to the size of the ESRU so that it does not slide on the floor. Each ESRU should be allocated two carpets to allow for replacement during daily cleaning. The top of the ESRU should be open to promote air circulation, and to hasten the drying of wet surfaces.

ESRUs should accommodate broods of 2-5 chicks (ideally 3-4 brood-mates) before these are transferred to outdoor accommodation at age 4-6 days, (ideally 4-5 days) and when each weighing $\geq 90\text{g}$. Chicks in ESRUs should be brooded from a 150W heat lamp suspended by an adjustable chain from the ceiling of the ESRR so that the ESRU floor temperature, directly beneath the lamp, is approximately 33°C initially. Brooding temperatures should be monitored using thermometers. Brooding temperatures should be reduced gradually to 28°C by the time chicks are to be transferred to rearing units outside (i.e. at age 4-6 days). Temperatures should be controlled by raising or lowering heat lamps, to maintain a suitable temperature. Heat lamps should not be so low as chicks might touch their heads on the extremely hot surface of the bulbs and/or shades as they grow. Heat lamps emitting 150W are preferred to those emitting 250W as the former

provide the ESRU with wide-ranging temperature gradients i.e. warm and cold areas encouraging chicks to actively forage, eat and move round the ESRU. 250W lamps do not provide these temperature gradients, instead, they provide the chicks with a uniform temperature across the ESRU often leading to the chicks eating less. A feather duster might be suspended above the ESRU or rolled fleece towels positioned on the floor approximately 30cm from the heat lamp so chicks 'feel' naturally brooded.

As the chicks in ESRUs are not exposed to natural sunlight indoors, ultraviolet (UV) light for vitamin D₃ synthesis and normal vision should be provided using e.g. 20W Arcadia Bird bulbs emitting 2.4% UVb suspended above food bowls. These bulbs should be emitting between 08:00-21:00 hrs daily.

Water should be placed in a non-spillable bowl deep enough to enable a chick to drink but shallow enough to allow it to escape should it stumble in. Water should also be presented in a 'chick drinker' when chicks are aged 3 days. Food should be available from a non-spillable bowl.

The brood groups do not need to be siblings, rather chicks of a comparable size (mass) or age. The brood groups should be changed according to the development of individuals.

Chicks should be transferred to clean ESRUs daily, ideally corresponding to two ESRUs per brood group. Alternatively, and as a cost saving, at least one spare ESRU should be ready to receive a brood each day, so that the previous day's ESRU can be cleaned, disinfected and dried before receiving a new brood – i.e. 'a transfer-out/clean-disinfect-dry/transfer-in' approach. The latter approach is not ideal when rearing >5 broods.

The substrate of the ESRU should be a combination of Flotex carpet, quick-drying towel, fleece blanket and non-slip mat. If chicks show aggressive behaviours towards one another, broods may be provided with pieces of artificial Christmas tree in which to 'hide' and forage for live and dry food items, thus providing greater enrichment and reducing intraspecific aggression. However, this may bring the risk of gizzard impaction due to ingestion of shed 'needles' from artificial Christmas trees.

Each ESRU should be positioned next to two water resistant electrical sockets on the ESRR wall. These sockets will operate heat and UV lamps.

Chick accommodation: Mid-stage Rearing Units (MSRUs) and Late-state Rearing Units (MSRUs) in Rearing Aviaries (RAs)

RAs are outdoors. The RAs contain MSRUs which are converted to LSRUs as the chicks grow.

Chicks should be transferred to MSRUs when aged 4-6 days old, ideally when they have a body mass ≥ 90 g, and preferably as brood groups of 3-4 birds. In MSRUs, chicks should be provided with an enclosure e.g. a Solway Recycling Animal House (AH) with an infrared

150W heat lamp suspended from the ceiling for 'brooding' purposes and an adjoining 'grassy front garden'. The floor of the AH should be a firm surface covered with Flotex mat. The mats should be replaced daily. A small food dish and 'chick drinker' should be provided in the AH. Food and water should be refreshed at least twice daily. The 'front garden' perimeter should be constructed from rigid smooth-surfaced plastic (e.g. Stokboard sheets from Solway Recycling), approximately 0.4m high and held in place with 'road pins'. As stokboard is pliable the front garden perimeter should be 'rounded' i.e. with no corners. When broods are first transferred from an ESRU to a MSRU, they should be 'shut in' the AH for approximately 30 mins. This provides chicks with 'a critical learning': by being confined to the AH initially, they learn "where home is" with respect to shelter and warmth provision when exposed to inclement weather conditions once outdoors i.e. once they have access to their 'front gardens'.

The 'front garden' should be increased in size from ~2m² on the first day chicks have access to 'the outdoors' to 27m² when chicks are aged 14-21 days, thus providing each bird in a brood of 4 with an area of 6.75m². The 'front garden' chicks should be provided with water bowls, trays and drinkers and small and large round plastic dishes for food and flint grit provision. Food and water should be refreshed twice daily. Drinkers and food dishes should be replaced with cleaned and disinfected equivalents every morning.

When chicks are 21 days old, they should enter the late-stage rearing phase and be given access to LSRUs in the RAs. A LSRU is simply an ever-increasing area of the MSRU set-up in which chicks can forage with other broods, i.e. broods are mixed. Eventually all broods held in MSRUs are mixed and given access to the entire 270m² area of the 9m x 30m RA providing birds with 9.6-11.25m² each (for groups of 28 or 24 chicks, respectively).

Chick accommodation: Release Enclosures (REs)

REs are identical to RAs and located at the Release Site – see under 'Facilities and infrastructure' above.

Ringling and tagging

Curlew chicks should be uniquely marked to enable individual identification throughout their life. Marks should include:

Down clipping: Initially, broods of 4 chicks aged 0-6 days will be separable by clipping down on the tips of wings e.g., on the right wing, on the left wing, on both wings and on no wings. Down clipping will be performed using sharp scissors immediately post-hatch so chicks can be linked to their egg identification codes.

Coloured cable ties: Upon transfer to MSRUs in RAs chicks should be marked with coloured cable ties to enable 'remote' individual identification – these will enable individuals to be monitored, from a distance, when in MSRUs. Cable tie marks should be

recorded against egg identification codes marks. Cable ties are available in 12 colours and should be fitted individually to right or left legs. When broods are mixed upon graduating to LSRUs, 1 or 2 extra cable ties should be fitted to 1 or both legs to ensure chicks are separable.

Permanent marks i.e. split metal BTO rings, colour rings and leg flags: At approximately 28 days old when chicks are approximately 14-21 days from transfer to the RE, cable ties should be replaced by metal BTO rings, colour rings and/or leg flags in accordance with the permanent marking scheme devised by the BTO for the project. All permanent marks should be attached by a licensed BTO ringer.

Special marks, e.g. GPS tags or radio tags: If these are to be deployed, these should be attached when Curlews are aged 49-56 days i.e. 7-14 days pre-release and when chicks are in the REs. GPS tags should only be attached to birds that have a body mass >650g. Tags should be fitted by a licensed BTO ringer in possession of appropriate endorsements.

Post-attachment of leg marks and GPS or radio tags, all birds should be monitored closely by aviculturists. If any mark distresses a bird, it should be removed immediately by a BTO licensed/endorsed ringer.

While birds should be handled for ringing/marking as efficiently and safely as possible, it is equally important that the handler is not placed under undue time pressure, as this can increase the risk of errors or incidents; it is recommended that the ringer in charge and the attending vet (the VO) agree an appropriate handling timeframe in advance of any operation, tailored to the conditions and experience of the team. Marking should commence early morning (e.g. 07:00 hrs), avoiding hot days to reduce the likelihood of myopathy.

Chick handling and containment for transfer between rearing units and health check events

Curlew chicks are susceptible to injury during handling and should only be handled when necessary. Hence, handling should be limited to the occasions when birds are transferred between rearing accommodation units and for leg band attachment, health screening, veterinary treatments, or GPS/radio tag attachment (see Table 2.6).

Only experienced caretakers should handle birds. Handling should be conducted with extreme care and in well-illuminated areas following appropriate protocols for birds of different ages (see Table 2.6, plus Hiscock & Costa, 2023, for further detail in relation to Black-tailed Godwit (*Limosa limosa*) chicks).

Important note: Birds should not be handled for routine health checks (e.g. daily general physical examinations of eyes, nares, vent). These checks should be done visually from a distance.

Table 2.6. Ages at which Curlew chicks are routinely handled with a description of their age-specific containment requirements

Age of chick (days)	Purpose	Frequency	Containment	Notes
0-5	Transfer between ESRUs	Daily	By gloved hands and/or by small plastic box with paper towel base (i.e. when being weighed)	Same time each day when body mass is recorded and cable tie ID marks fitted (at 3-6 days)
6	Transfer to MSRUs	Once	By ungloved hands and in plastic box with a microfibre towel base	Only birds that have a body mass of $\geq 90\text{g}$ should be transferred to MSRUs. Transfer, in boxes, should be by vehicle (if $>500\text{m}$ and/or ≥ 10 minutes) and/or by foot
21-22	Health check and 'feather sexing'	Once	By gloved hands and in plastic box with a microfibre towel base (i.e. when being weighed)	The veterinarian (VO) collecting swabs and feathers should wear nitrile gloves, replaced between birds
Approx. 28	Leg-banding	Once	By ungloved hands and for weighing – a cardboard box e.g. paper recycling box with perforated plastic cover over letter-box lid, with Flotex carpet base	
35-42	Transfer to RE	Once	As for leg-banding	Transfer is by vehicle (if $>500\text{m}$ and/or ≥ 10 minutes) and/or by foot
49-56 (approx. 1 week pre-release)	GPS or radio tag attachment	Once	As for leg-banding	Only chicks $>650\text{g}$ will be fitted with GPS tags

Diet: Food

Curlew chicks should be provided with a nutritionally balanced diet. The chicks should be offered a variety of food items, the amounts of which should vary according to their age and development (see Table 2.7). The primary food should be an artificial extruded pellet e.g. Lundi Micro 35 (35% protein), and Lundi Micro 20 (20% protein) and small live artificially propagated '1st' and '2nd' stage Brown Crickets (*Acheta domesticus*). Lundi diet should be offered wet and dry. Pellet should be offered in small or large dishes (e.g. plant pot saucers) depending on chick age. Live crickets may be offered to chicks aged 1-3 days. The crickets should be used only to encourage young chicks to eat and should be quickly 'phased out' once chicks are eating Lundi Micro pellet. Crickets should also be offered to chicks which are not feeding well or not gaining weight.

Between days 1-5, wet Lundi Micro 35 should be offered. From day 3, dry Lundi Micro 35 should be offered in increasing proportions. When chicks are outside (e.g. from age 5 or 6 days), Lundi Micro 20 should be offered with Lundi Micro 35, both wet and dry, reaching a ratio of 50:50 by 8-10 day of age, i.e. when primary feathers begin to emerge. Proportions should change according to chicks' growth rates, e.g. the proportion of Lundi Micro 35 should be reduced if 'slipped wings' are observed, or increased if birds are growing slowly. At approximately 35 days, when birds are close to fledging, they should be **offered only wet and dry Lundi Micro 35** to boost their body mass, pre-release.

Diet: Supplements

A probiotic supported by a prebiotic (e.g. Vetark Avipro Avian) should be offered from 1 day of age. The probiotic/prebiotic supplement should be made into a solution with water in accord with manufacturer's instructions and Lundi Micro pellet pre-soaked in the solution before being offered in wet food dishes. Avipro Avian is a soluble probiotic, with soluble fibre prebiotics enhanced with vitamins A, C and E. Avipro Avian helps to maintain digestive health and is recommended for birds undergoing the physiological stress of body and feather development and/or veterinary treatments for long- or short-term ailments. The probiotic is supported by the prebiotic to promote establishment of 'friendly' natural bacteria in a bird's gut. Vitamins A, C and E are the known to be lost during periods of stress and so are enhanced in Avipro Avian to support birds' immune system.

To relieve heat stress, e.g. in the run-up to and during weather forecasts of temperatures exceeding 24°C, chicks should be offered AviVit Electro-Plus as a solution made with water in accordance with manufacturer's instructions and offered in shallow water dishes only (i.e. not shallow trays or drinkers). AviVit Electro-Plus is a nutritional aid for captive birds and is specially formulated for the relief of heat stress and metabolic disorders associated with dehydration. AviVit Electro-Plus should also be offered when chicks show any show signs of heat stress (i.e. not only that caused by high ambient temperatures, such as heat stress induced by handling events).

To facilitate gizzard function and digestion chicks should have ad lib access to non-soluble flint bird grit from 2 days of age. Grit should be scattered on the Flotex mats and in water dishes of ESRUs and on the natural (grassy) substrates and in water dishes/trays of MSRUs, LSRUs and in the RE. Flint grit should be offered in diameter sizes of approximately 1-2mm for chicks aged 2-7 days, increasing to 2-5mm for chicks >7 days.

Diet: Drinking water

Fresh water presented in a variety of non-spillable dishes should be constantly available to chicks and replaced whenever contaminated (Table 2.7). Drinking should be encouraged in ESRUs by scattering Lundi pellet on water dishes (e.g. plant pot saucers or microwavable trays) and/or by placing marbles or other shiny objects such as small stones in the water and/or dripping water from a height above the water dishes/trays so it splashes into the water receptacle at regular intervals. Water should also be presented in 'chick drinkers'. In MSRUs, LSRUs and REs, chicks should be provided with water in dishes (e.g. plant pot saucers), water trays (shallow initially, and then for older chicks, deeper tomato grow-bag trays in which they are able to wade and bathe). As some birds may be slow to drink, dehydration is a significant health concern when raising Curlew chicks. A failure to drink from an early age sometimes reduces a Curlew chick's desire to eat, leading to lethargy and death. Chicks that have started to eat well may stop entirely if they become dehydrated. Thus, aviculturists should carefully monitor chick drinking behaviour, especially in the first week post-hatch. If significant dehydration is evident, the veterinarian overseeing avian health care (the VO) should consider giving fluids subcutaneously. This is known to prompt a dehydrated chick to drink on its own.

Table 2.7. Food and water provision for Curlew chicks of different ages.

Age (days)	1	2	3	4-5*	6-35*	35-63*
Food type	L35 wet (pre-soaked in Avipro) Crickets Water	L35 wet (pre-soaked in Avipro) Crickets Flint Grit (1-2mm) Water	L35 wet (pre-soaked in Avi-pro) & dry Crickets (but phased out if birds are eating Lundi) Flint grit (1-2mm) Water	L35 wet (pre-soaked in Avipro) & dry Fint Grit (1-2mm) Water	L35 wet (pre-soaked in Avipro) & dry L20 wet (pre-soaked in Avipro & dry mixed in a 50:50 ratio with L35 by day 8-10 days old Flint Grit (1-2mm increasing to 2-5mm at 7 days old) Water	L35 wet (pre-soaked in Avipro) & dry Flint grit (2-5mm) Water
Presentation	Petri dishes with non-slip mat (2x food and water together and 1x with water only)	Small diameter dishes with non-slip mat (2x food and water together and 1x water only) 1x shallow microwave tray with non-slip mat (food and water together)	As for day 2 with additional saucer of dry food	As for day 3 Chick drinker (water only)	Initially small dishes (food and water together) increasing to large dishes from approx. age 14 days Shallow tomato grow-bag tray (water only) from age approx. age 14 days Deep water tray (water only) when aged 28 days Chick drinker (water only)	Large dishes (food and water together) Large water trays e.g. tomato grow-bag trays (water only) Deep water trays (water only) Chick drinker (water only)

*: Some broods will be outside by this age, so diet is likely to include naturally available 'live' food.

Diet: Hygiene control

Food and water dishes should be checked 2-5x daily. Soiled water or food should be replaced as should faeces and pellets spilled on the surrounding substrate. Daily cleaning and feeding chores should be undertaken in silence unless chicks are not present nearby.

Health management

Disease Risk Analysis

A Disease Risk Analysis (DRA) should be completed by the veterinarian (VO) or veterinary team in the year before the project begins. The DRA should be reviewed annually and updated after and during (as required) each year of the project. Infectious and non-infectious threats should be identified in the DRA with mitigations presented to control these through e.g. a disease prevention and surveillance plan which informs operational protocols. Protocols should be produced for:

- Biosecurity measures to mitigate risks of disease incursion
- Husbandry actions to ensure good avian health
- Disease surveillance to ascertain and react to bacterial, fungal and viral detection during rearing stages.

Veterinary care to ensure that health checks are conducted to a uniform standard, and that handling and transport events are safe and that prophylactic treatments and other treatments for sick or injured birds are appropriate.

It is likely that natural (commensal) parasitic and bacterial presence will be low in outdoor rearing areas in the early years of the project, especially if the hubs are at sites not previously occupied by domestic birds. It is also likely that predation risks will be low with impenetrable predator exclusion barriers and appropriate legal lethal control measures operational (e.g. snap traps set 24/7 for Brown Rats, Weasels, and Stoats).

Over recent years, Curlew headstarting projects in England have encountered high-risk health hazards including: extreme weather events e.g. heatwaves, rain-wind storms; trauma through e.g. inappropriate handling, flying collisions with infrastructure; myopathy through prolonged containment and handling; and, especially during mid-stage rearing stages, gut impactions through ingestion of plant debris (e.g. grass roots) in RAs. The DRA should identify hazards encountered by other headstarting projects and provide instruction on mitigation measures.

Routine monitoring by caretakers

Each day, caretakers should visually check all birds to ensure that their behaviour and general health and condition are satisfactory. With respect to bird behaviour, caretakers should check that each bird is:

- Bright-eyed, alert, and reactive
- Feeding normally
- Drinking normally
- Acting appropriately in its environment
- Expressing other normal behaviours
- Not showing any signs of fear and distress (e.g. caused by other chicks or inclement weather, etc.)
- Not showing signs of illness including unusual/abnormal faeces, plumage, deportment, locomotion, breathing, disposition, or signs which suggest the bird is 'not quite right'.

When a bird is suspected to be unwell, the veterinarian (VO) should be notified. If treatment requiring handling over multiple days is required, then:

- If the bird is in an ESRU, it should remain there and be held back until it is clinically fit to progress to the next rearing stage.
- If the bird is in a MSRU/LSRU in an RA, a small area of ground should be 'partitioned-off' with stockboard panels to isolate the bird for a period of treatment. This isolation should reduce the risk of cross-contamination to other birds if e.g. the condition is thought to be caused by an infectious agent. Note that keeping the unwell bird within the same rearing setup maintains familiarity with its surroundings, while the reduced space lowers stress from social interactions e.g. competition for food with brood-mates, and enables caretakers to monitor for clinical improvement or deterioration.

Once treatment has been completed, and both the veterinarian (the VO) and caretakers are satisfied with the bird's recovery, the partitioning boards should be removed and the bird given access to its former living space.

Depending on the nature of the ailment, clinical signs may indicate that aspects of the rearing regime require alteration. For example:

- Gut impactions may require increased surveillance for, and removal of, debris, including dead grass (thatch).

- Bumblefoot may require increasing or varying the substrate (e.g. adding sand) or changing the configuration of e.g. MSRUs/LSRUs to reduce pressure on birds' feet.
- Trauma may require reconfiguration of e.g. MSRUs/LSRUs' infrastructure and removal of potential hazards.
- Unusual faeces in multiple birds simultaneously may require assessment of food and water quality, including checking for ingress of contaminated water from outside the rearing area (e.g. rain run-off) and a review of biosecurity measures.

Treatments should be discussed with the veterinarian (VO) on a case-by-case basis, considering available resources and staffing. If an individual bird requires prolonged or intensive treatment, euthanasia may need to be considered, as intensive care might compromise the daily management of healthy chicks and lead to preventable issues being missed.

If a notifiable disease (e.g. Avian Influenza or Newcastle Disease) is suspected, the veterinarian must inform DEFRA. No birds should be released following an actual or suspected notifiable disease incident until APHA investigations have been completed.

Routine monitoring by the veterinarian (VO) – scheduled 'in-the-hand' health checks

The veterinarian (VO) should be notified whenever transfers between rearing stages or hubs are planned so that a pre-travel health check can be completed. They should accompany birds that are being transferred between hubs and from LSRUs to REs. Where distances are significant, they should also attend transfers between ESRUs and MSRUs, or be present on arrival, in case veterinary intervention is required.

Disease screening of clinically healthy chicks

Whether or not it is a mandatory requirement of the NRW-issued licence to headstart Curlew in Wales, disease screening of healthy chicks should be considered. Attention should be given to parasitic and bacterial presence at each stage of the rearing process, as well as to notifiable disease presence.

Screening for parasitic and bacterial presence at each stage of the rearing process should be made of pooled faecal samples collected from separable cohorts of chicks, at each stage of the rearing process prior to a transfer (i.e. transfer from ESRUs in the EIESRF to the MSRUs in the RA and transfer from LSRUs in the RA to the RE). 'Flock' treatment may be needed if ova, cysts or parasites are detected. Faecal testing should be for zoonotic pathogens such as *Campylobacter* spp., *Pseudomonas* spp., and *Salmonella* spp.

Screening is likely to reveal the presence of *Campylobacter* spp., These bacteria are common in waterbird gut flora and may be carried by Curlew chicks without causing

disease and so presence is likely of little clinical significance to the birds. However *Campylobacter* can cause illness in humans. The detection of *Pseudomonas* spp. and/or *Salmonella* spp. may require antibiotic treatment of the chicks prescribed by a veterinarian (the VO), typically administered via drinking water. The presence of these bacteria may necessitate enhanced hygiene measures due to these organisms' zoonotic potential.

It is likely that year-on-year use of hubs, albeit for a brief period, will result in parasite and bacterial build-up in outdoor rearing areas. This build-up may be reduced through environmental management and husbandry practices, e.g. aviaries should be re-turfed between years and/or biolime applied to substrates at the end of each summer, and cohorts (broods) should be maintained to a small a size as possible, never exceeding 24-28 birds per RA or RE. Small cohort size will naturally reduce pathogen loading in the RAs and REs and also reduce stress levels in birds thus reducing the likelihood of clinical disease from naturally occurring commensal organisms. If in any particular year, faecal parasites are detected in abundance, consideration should be given to providing preventative (prophylactic) anti-parasitic treatments to birds in subsequent years.

Screening for notifiable diseases, specifically Avian Influenza (AI) and Newcastle Disease Virus (NDV), should be undertaken by the veterinarian approximately 14 days before their transfer from the RAs to the REs, i.e. when all chicks are handled for their final routine in-the-hand health check.

Samples for AI and NDV screening should be collected using two separate swabs per bird: one to sample the oropharyngeal cavity (mouth) and another to sample the cloaca. The veterinarian should advise on the necessary equipment for sampling and their despatch to APHA laboratories.

Common ailments of Curlew chicks

Curlew chicks are prone to several common ailments which, in most cases, can be corrected through veterinary or avicultural intervention including e.g. alteration to the diet and/or by prescribing medication. Common ailments include:

Slipped Wing

Slipped wing, sometimes referred to as droopy or dropped wing, is a reversible condition in which the wings appear lowered due to rapid growth of developing primary feathers placing excessive force on the muscles and ligaments of the wing carpal area while these are still 'soft'. It typically affects chicks between 10 and 20 days of age and is more commonly observed in broods hatched later in the season. Correction can often be achieved by reducing dietary protein levels - for example, by replacing the Lundi 35 Micro pellet ration with the Lundi 20 Micro pellet ration and/or by temporarily restricting food access for part of the day, and/or by providing additional exercise space. Supporting the

wings over the shoulders (e.g. with tape or bandage) for 24–48 hours may also help the chick to recover its normal wing positioning.

If slipped wing is not addressed during rapid growth, there is a risk that it will lead to the development of a more severe wing deformity, sometimes resembling angel wing (outward rotation of the wings).

Upon detection of either condition, the affected chick/s should be monitored closely by the caretakers, with dietary adjustments and wing support applied, as necessary.

Post-hatch Deformity

Exceptionally, chicks may hatch with hip deformities presenting as splayed legs. Attempts may be made to correct this by taping leg joints to straighten legs. However, this intervention is not usually successful, resulting in euthanasia by the veterinarian (VO).

Curled/Bent Toes

Chicks often hatch with curled toes, due to the restricted space they occupy within the egg prior to hatching. In most cases, the toes straighten naturally within about 24 hours once the chick begins walking around the ESRU. If the toes do not correct within 24-48 hours, or if the chick has difficulty walking, intervention may be required. This involves individually splinting the affected toes using cut-down (approx. 10mm) lengths of Q-Tip shafts and securing them with micropore tape. The splints should usually remain in place for up to 72 hours but be replaced after 24 hours to assess progress, after which treatment can be continued or discontinued as appropriate. Once corrected, the condition rarely reoccurs.

Gut Impaction through Foreign Body Ingestion

When Curlew chicks are moved outside from approximately 4-6 days of age, they are prone to eat non-food items i.e. 'foreign bodies' including grass roots, stalks and seed heads, grassy pellets that are coughed-up by other chicks and/or regurgitated/semi-digested grassy stems, dried faeces, glass shards, bark, twigs, plastic and large pebbles or stones. These may cause gut impaction and lead to chick death. Gut impactions are usually untreatable meaning prevention is the most effective intervention. Therefore, the avicultural team should remove all foreign bodies from the substrate of outdoor rearing areas (i.e. in the RAs) both prior to chick introduction and throughout the rearing period, as sub-surface objects are likely to migrate to the surface over time. Dried faeces should be removed each time food and water dishes are refreshed, usually 5 times per day. Areas of exposed thatch (dead grass) should be covered with silica sand, rubbed into the ground to bury the thatch. Burying is favoured to raking-up thatch as raking usually exposes more sub-surface thatch and/or plant roots, which chicks may ingest. Chicks do not appear to outgrow the risk of foreign body ingestion. However, by approximately 21 days of age, they can ingest organic objects, such as grass roots and stems, without gut impaction ensuing.

Some birds may develop a tendency to dismantle grass turves placed at the threshold of AH shelters in the MSRUs. These turves are usually positioned to ease chicks' entry to and exit from the AH. If chicks begin dismantling them, the turves should be removed and replaced with silica sand to enable AH access. The sand should be regularly 'ramped up' to maintain easy ingress and egress. Aviculturists should observe chicks closely throughout the day and remove any foreign material, such as grass stems protruding from their beaks to prevent ingestion and gut impaction.

Heat Stress

Exposure to strong sunlight and high ambient temperatures should be managed by providing additional shade (e.g. shade-net attached to aviary walls and/or ceilings), refreshing water bowls and dishes frequently, and offering vitamin supplement such as AviVit Electro-Plus in water according to the manufacturer's instructions. Supplements should be provided in dishes and trays in the run-up to, and during, forecasted periods of temperatures exceeding 24°C. If left unaddressed, prolonged heat exposure can result in secondary health complications, including myopathy, feather damage, gut disorders, and, in severe cases, death.

Foot Lesions and Bumblefoot

Signs of healing foot lesions and/or bumblefoot are often detected during routine physical examination at health screening and/or leg-banding events. These presentations are most frequently observed in chicks that have spent extended periods (e.g. >5 days) in ESRUs, and are thought to result from prolonged walking on the 'hard' artificial surfaces (i.e. Flotex matting) at a stage in their life when their feet are at their 'softest'.

As most lesions appear healed or healing upon their detection, treatment is not usually required. However, as a precaution against infection, an antiseptic ointment effective against bacteria, fungi, and viruses (e.g. F10 ®) should be applied. F10® ointment contains lanoline and glycerine emollients, which help to maintain and restore skin integrity, and, by adhering to the skin surface, forms an effective antimicrobial barrier.

Biosecurity

All rearing facilities including the RE at the release site must be managed to protect the Curlews from disease-causing organisms, toxins, and predators. A series of rigorous biosecurity guidelines should be followed to prevent introduction of these agents to hubs. These guidelines should seek to limit the risks from:

- Direct contact with wild or other captive birds
- Indirect contact with wild or captive birds e.g. through faeces carried on footwear or clothing of people

- Direct or indirect contact with predatory species
- Direct contact with infective or dangerous (e.g. toxic) material on equipment or in food or water

Site security

Access should be limited to named caretakers who are authorised and trained in the implementation of all operational procedures. These caretakers should not have physical contact with wild or captive birds outside the facilities. In addition, no non-project birds or other animals should be brought to the hubs under any circumstances.

The entry and exit doorways to the facilities should always remain locked. Only visitors authorised by caretakers should be permitted access. Authorised visitors must be informed of all operational procedures before entry, always be accompanied by a caretaker, complete relevant paperwork before and after entry, and wear appropriately disinfected protective clothing e.g. footwear.

Only vehicles authorised by caretakers should be permitted to the facilities and these must be cleaned according to standard disinfection procedures. Tools and machines, e.g. grass cutting shears and lawn mowers, should be cleaned and disinfected between use in different outdoor rearing areas i.e. RAs and REs.

In addition, appropriate measures and guidance should be developed for individuals who keep captive birds at home, to minimise any risk of disease introduction or transmission. This should be addressed by the PM or the veterinary team (the VO) responsible for implementing the DRA.

Personal hygiene of caretakers

Caretakers must maintain high standards of personal hygiene. They should wear clean outer clothing and disinfected footwear when entering facilities accommodating eggs or chicks.

Disinfection procedures

Disinfection procedures should be in place at entry and exit points of the facilities (for personnel and vehicles). For personnel, alcohol free, virus-effective hand sanitiser dispensers, disinfectant foot dips with shoe changing facilities and mains water hot and cold taps and sinks with biocidal hand soaps for handwashing should be positioned at key entry and exit points. For vehicles, wheel disinfection mats should be in place at the entrance to the EIESRF.

Bird food and its storage

All bird food should be fresh or recently milled. Bird food should be stored in a cool, dry, dark, and disinfected room of a building designated for food storage (see 'Function of Facilities' above for information on where food is stored at each hub for each method #1-4). Opened bags of bird food should be stored in sealed plastic bins that are cleaned, disinfected, and dried between batches.

Bird feeding equipment

Each hub should have dedicated dishes, drinkers, barrows, buckets, scoops, and cleaning brushes, which should not be interchanged or used anywhere outside the hub. Each morning uneaten food should be replaced with fresh food irrespective of whether it is soiled. Feeding utensils, including 'waste' and 'fresh' food buckets, should be cleaned, disinfected, and air-dried before reuse. Dirty dishes should be collected in 'waste food buckets' and clean dishes should be delivered in 'fresh food buckets'.

Waste disposal

Waste food and paper towels etc. generated at each hub should be disposed of in bags, in ≤15kg batches and collected by a local registered waste disposal company. Carcasses of 'controlled' predators should be disposed of appropriately e.g. by a registered animal waste disposal company.

Pest/predator control

Integrated Pest Management (IPM) control methods should be deployed around the facilities to safeguard the welfare of birds, and to ensure that pest/predatory animals have zero impact. Pests/predators to control may include birds and mammals which may:

- Cause physical damage to the Curlew or facilities' structures
- Cause distress to the Curlew
- Spread disease to the Curlew.

IPM methods should be legal, humane, safe and effective techniques to manage pest or predatory species to acceptable levels with the least disruption to the epidemiology of the site. IPM will require deployment of a range of methods to manage an undesirable species so that reliance on one technique, and its potential shortcomings, is avoided.

Release

When the Curlews are aged 56-63 days (8-9 weeks) they should be released. Releases should occur in the morning and ahead of a week with a weather forecast of no heavy rain or strong wind.

Releases should be achieved by firstly removing a section of perimeter fence surrounding the REs, then secondly by removing three pheasant panels at the ends of the REs closest to the removed perimeter fence. Thus, birds should be able to leave REs through this opening of their own accord. The opened perimeter fence and opened REs' 'ends' should face onto an open landscape, ideally a wetland. When all birds have left the RE the removed ends should be re-erected as should the perimeter fence in readiness to receive more birds for release. Alternatively, and if positioned in a wetland landscape that is predator safe e.g. because the Release Site comprises a 2ha wetland surrounded by a predator-proof perimeter, the REs did not require their own predator-proof perimeter and if no other birds are to be released, the RE panels should not be re-erected immediately. They should be re-erected when all Curlews have departed the site.

Procedures for 'soft' release as described above, as well as a 'direct' alternative, are described in detail for black-tailed godwits in the [Project Godwit Headstarting Manual](#) (Hiscock & Costa, 2023). Preliminary analysis of return rate across headstarted Black-tailed Godwit fledglings released in the Fens of eastern England as part of Project Godwit suggest a beneficial effect of releasing birds in larger cohorts (WWT, unpublished data) – noting that this effect may be conflated with release type, as 'soft' releases involved larger cohorts than 'direct' releases. With no significant age-at-release effect identified in the Black-tailed Godwits (in contrast to, for example, the ecologically more disparate Spoon-billed Sandpiper; Clements *et al.*, 2022), grouping across different hatch dates to create larger release cohorts could optimise project success by maximising the proportion of birds returning to the release site and hence being present for potential recruitment.

Staffing

Skilled and experienced staff should be employed for the project. Numbers of staff vary according to the Method adopted (Table 2.8).

Staff should include:

Project Manager (PM)

The PM should be employed to line-manage the Assistant PM, Lead Aviculturists and the Veterinary Officer and oversee all aspects of the project from liaison with stakeholders, establishment of infrastructure and procurement of equipment and materials for each hub, all licence/permission application and procurement, implementation of post-release monitoring strategies and budget management.

The PM should be employed at least 12 months in the pre-year/s of the headstarting project and then for 12 months in each year that the project is operational.

Assistant PM (APM)

The APM(s) should be employed to assist, and deputise for, the PM. The APM(s) should be employed at least 12 months in the pre-year/s of the headstarting project and then for 12 months in each year that the project is operational.

Veterinary Officer (VO)

The VO should be employed to compile a Disease Risk Analysis (DRA) to support the licence application to NRW to collect Curlew eggs and release chicks, devise and oversee implementation of biosecurity protocols, oversee and deliver bird health care and ensure disease screening is compliant with NRW licences. The VO should be employed 10 months in the pre-year of the headstarting project (for DRA preparation, protocol writing) and then 10 months (January to October) in each year that the project is operational.

Lead Aviculturists (LAs)

The LAs (numbering 1-3 depending on method) should be employed to oversee all aspects of facilities' set-up, egg collection, egg incubation, chick rearing and release. LAs should line-manage Deputy Lead Aviculturists and Aviculturists. LAs should lead, i.e. be 'hands-on', for all egg collection, egg incubation and early-stage chick rearing activities.

LAs should be employed for 6 months in the pre-year of the headstarting project, then for 10 months (January to October) in each year that the project is operational.

Deputy Lead Aviculturists (DLAs)

The DLAs (numbering 1-3 depending on the method) should be employed to deputise for LAs on non-working days and to supervise activities of Aviculturists caring for birds.

DLAs should be employed for 2 months in the pre-year of the headstarting project, then for 10 months (January to October) in each year that the project is operational.

Aviculturists ('avics')

The avics (numbering 3-8 depending on method) should be employed to help set-up and deliver egg and bird care. Avics should be employed for 0 months in the pre-year of the headstarting project, then 8 months (March to October) in each year that the project is operational.

It should be noted that the aviculturist roles are very specialised, and there is no guarantee that there would be sufficient qualified staff available and willing to be based out of the relevant hub(s) for 8-10 months in each of the five years of the project. This is something that would need to be investigated further, particularly in the light of wader headstarting

programmes elsewhere in the UK (with some known to be concluding in 2025, others ongoing and perhaps more being planned).

Table 2.8. Staff needed for the different methods

Method	Hub #	Target #s birds reared for release	Poss. #s eggs	Max poss. #s chicks at early-stage rearing stage	PM	APM	VO	LA	DLA	Avics	Total
1	#1	150	188	188	1	1	1	2	2	8	15
2	#1	75	94	94	1	1	1	1	1	4	9
	#2	75	94	94	0	0	0	1	1	4	15
3	#1	50	63	63	1	1	1	1	1	3	8
	#2	50	63	63	0	0	0	1	1	3	5
	#3	50	63	63	0	0	0	1	1	3	18
4	#1	50	188	188	1	1	1	1	1	3	
	#2	50	0	0	0	0	0	1	1	3	
	#3	50	0	0	0	0	0	1	1	3	18

NB: For Method 4, for incubation/early-stage chick rearing at Hub #1, the LAs and avics from Hubs #2 & #3 will be based at Hub #1.

Costs

Detailed annual budgets, with almost 300 expenditure lines, have been calculated to indicate costs for Methods 3 and 4 in each of 6 years, i.e. the pre-project preparation year (year 0 [FY 2025-'26] – necessary for set-up ahead of egg collection from April of year 1) and five operational years (year 1-5 [starting FY 2026-'27]). Staff cost estimates represent salaries, National Insurance and 3% pension. The annual budgets do not include insurance, or accommodation expenses for those staff not employed year-round (the LAs, DLAs, avics and VO).

It should be noted that the costs associated with the nest-finding effort necessary to supply eggs for collection, and with post-release monitoring, could vary substantially depending on a number of factors associated with the relevant ICA(s): habitat, land access, prior knowledge and availability of fieldworkers, etc. As an indicative guide, one of the selected ICAs reported finding the relevant number of nests with about twice the effort (people-days per week) of that deployed in England's Severn & Avon Vales as part of WWT's solutions-testing project. In the below we assume that nest-finding and post-release monitoring could be achieved with two 0.5 full-time equivalent Monitoring Officers (employed for half of the year) at each of the selected ICAs in each year of headstarting. Note that post-release monitoring should also occur for five years after the final release (see 'Monitoring released birds' section below), and that cost-savings could potentially be achieved by using volunteers for some of this effort. We also include 0.1 FTE of a senior-level scientist (post-doctoral researcher or equivalent) to oversee a ringing scheme for all released birds

and GPS-tagging for one-third of the released birds. Vehicle, fuel and subsistence costs have not been factored in. The above also assumes knowledge around the most likely nesting areas to be selected by Curlew and hence searched; additional effort and hence funding would be required if starting from scratch in an area that hadn't been recently monitored, in order to conduct early season surveys for territory mapping.

Reminder of methods

Method 3 requires three hubs (Hubs #1, #2 & #3) to be set up to incubate and hatch Curlew eggs so that 50 chicks can be raised for release at each hub.

Method 4 requires. One hub (Hub #1) is set up to incubate and hatch all eggs and to raise approximately 150 chicks to the point that two-thirds (i.e. 100 birds) can be transferred to mid-stage rearing facilities at Hubs #2 & #3 for raising to point of release. Fifty chicks would remain at Hub #1 for raising to release.

Three hubs (Hubs #1, #2 & #3) to be set up to raise 50 Curlew chicks for release at each

Budget estimates

Table 2.9. Costs by expenditure per operational area for METHOD 3 (4.5% inflation for non-staff nominals and 3.5% for staff nominal annually from year 0).

OPERATIONAL AREA	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	OVERALL TOTAL
Incubation/Early-stage Rearing (combined utility)	£192,742	£134	£140	£146	£153	£160	£193,475
Food Storage/Prep	£129,663	£691	£722	£755	£789	£824	£133,444
Power-washing	£16,472	£1,117	£1,168	£1,220	£1,275	£1,332	£22,585
Storage	£11,475	£0	£0	£0	£0	£0	£11,475
General Hub Operations	£21,759	£13,582	£14,194	£14,832	£15,500	£16,197	£96,065
Egg Collection	£6,780	£164	£172	£179	£187	£196	£7,678
Incubation	£22,058	£1,550	£1,620	£1,693	£1,769	£1,848	£30,537
Early-stage Rearing	£42,102	£8,184	£8,552	£8,937	£9,339	£9,760	£86,875
Mid-/Late-stage Rearing	£108,788	£11,927	£12,464	£13,025	£13,611	£14,223	£174,038
Release	£62,443	£21,759	£22,738	£23,761	£24,830	£25,948	£181,479
Ringling/Tagging	£0	£55,000	£56,925	£58,917	£60,979	£63,114	£294,936
ANNUAL TOTAL FOR OPERATIONS	£614,282	£114,109	£118,694	£123,466	£128,443	£133,612	£1,232,587
Staff - Rearing and release	£204,101	£533,207	£551,869	£571,184	£591,176	£611,867	£3,063,403
Staff - Ringling and tagging	£0	£4,107	£4,250	£4,399	£4,553	£4,712	£22,022
Staff - Monitoring at selected ICAs	£0	£118,064	£122,196	£126,473	£130,900	£135,481	£633,114
ANNUAL TOTAL FOR STAFF	£204,101	£655,377	£678,315	£702,056	£726,628	£752,060	£3,718,539
OVERALL TOTAL	£818,383	£768,795	£796,287	£824,768	£854,273	£884,839	£4,951,216

For METHOD 3, Table 2.9 summarises costs by WWT's category/area of expenditure, for the process of raising 150 birds per annum. Appendix 2 (Table S1) includes the same

budget grouped across WWT nominal expenditure codes for reference. The **overall budget** for this method is **£4,951,216 over 6 years**, working out at approximately £803k per year and **£6,601 per bird** (assuming 750 birds would be released across years 1-5).

Table 2.10. Costs by expenditure per operational area for METHOD 4 (4.5% inflation for non-staff nominals and 3.5% for staff nominal annually from year 0).

OPERATIONAL AREA	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	OVERALL TOTAL
Incubation/Early-stage Rearing (combined utility)	£140,179	£89	£93	£98	£102	£107	£140,667
Food Storage/ Prep	£129,663	£691	£722	£755	£789	£824	£133,444
Power-washing	£16,472	£1,117	£1,168	£1,220	£1,275	£1,332	£22,585
Storage	£11,475	£0	£0	£0	£0	£0	£11,475
General Hub Operations	£21,759	£13,582	£14,194	£14,832	£15,500	£16,197	£96,065
Egg Collection	£3,544	£65	£68	£71	£75	£78	£3,901
Incubation	£16,563	£1,146	£1,198	£1,252	£1,308	£1,367	£22,833
Early-stage Rearing	£41,048	£7,315	£7,644	£7,988	£8,347	£8,723	£81,065
Mid-/Late-stage Rearing	£108,788	£11,927	£12,464	£13,025	£13,611	£14,223	£174,038
Release	£62,443	£21,759	£22,738	£23,761	£24,830	£25,948	£181,479
Ringling/Tagging	£0	£55,000	£56,925	£58,917	£60,979	£63,114	£294,936
ANNUAL TOTAL FOR OPERATIONS	£551,934	£112,692	£117,213	£121,919	£126,816	£131,913	£1,162,487
Staff - Rearing and release	£204,101	£533,207	£551,869	£571,184	£591,176	£611,867	£3,063,403
Staff - Ringling and tagging	£0	£4,107	£4,250	£4,399	£4,553	£4,712	£22,022
Staff - Monitoring at selected ICAs	£0	£118,064	£122,196	£126,473	£130,900	£135,481	£633,114
ANNUAL TOTAL FOR STAFF	£204,101	£655,377	£678,315	£702,056	£726,628	£752,060	£3,718,539
OVERALL TOTAL	£756,034	£768,069	£795,529	£823,975	£853,444	£883,973	£4,881,026

For METHOD 4, Table 2.10 summarises costs by WWT's category/area of expenditure for the process of raising 150 birds per annum. Appendix 2 (Table S2) includes the same budget grouped across WWT nominal expenditure codes for reference. The **overall budget** for this method is **£4,881,026 over 6 years**, working out at approximately £814k per year and **£6,508 per bird** (assuming 750 birds would be released across years 1-5).

Method 3 is estimated to be slightly more expensive, largely due to a higher cost of building works not being completely offset by smaller savings in other areas such as equipment (compare Tables S1 and S2 in Appendix 2). However there would likely be further savings for Method 4 in areas such as waste disposal and other service costs, with two hubs being staffed for shorter periods – those have not been adjusted here.

A note on two-pulse headstarting scenarios

The above estimates apply to an initial pulse of headstarting, assuming that preparations began in Financial Year 2025-2026 (the current period at the time of writing), with headstarting being undertaken in the breeding seasons 2026-2030. Inflation could be applied at the above suggested rates, or other rates as advised by relevant parties, to shift the six-year plan later in time. However, it is worth noting that a second pulse of headstarting, as modelled under relevant scenarios, would not incur some of the budgeted set-up costs, such as building works (assuming the original facilities were still in place and workable). Hence the second pulse would be cheaper than the first (both overall and on a cost-per-bird basis), notwithstanding inflation over the intervening period.

Monitoring released birds

Post-release monitoring (PrM) is essential for ensuring that conservation breeding projects achieve meaningful, long-term outcomes. By following released individuals, practitioners can assess survival, reproduction, and adaptation to the wild, while also identifying challenges such as predation, disease, or unsuitable habitat conditions. Crucially, PrM provides the evidence needed to determine whether a headstarting programme is achieving its objectives and whether management interventions are appropriate, insufficient, unnecessary, or require modification. Monitoring serves as an early warning system, allowing conservationists to detect and respond to emerging threats before they compromise the success of the project. Evaluating the effectiveness of management actions enables projects to adapt their approaches and improve future conservation interventions. It also generates valuable data that strengthens the evidence base for Curlew conservation, helping to refine management practices, guide future headstarting programmes, and ensure that conservation resources are directed towards interventions that deliver the greatest benefit for population recovery, rather than simply improving our understanding of species' behaviour and ecology.

Post-release monitoring also provides accountability and transparency, demonstrating to funders, governments, land managers and local communities that conservation programmes are being evaluated rigorously and that management decisions are guided by evidence. Sharing monitoring results promotes openness, facilitates learning between projects, and enables successful approaches, as well as lessons from less successful interventions, to be applied elsewhere. It can also strengthen collaboration with local stakeholders by demonstrating progress and maintaining long-term support for conservation initiatives. For these reasons, PrM is not simply a follow-up activity, but an essential and integral component of project design (IUCN/SSC, 2013).

When planning post-release monitoring for Curlews, the first steps should focus on setting clear objectives, selecting suitable methods, and ensuring the right resources and partnerships are in place. Key starting points include:

1. **Define monitoring goals:** Decide what you need to learn – e.g., survival rates, dispersal patterns, habitat use, recruitment, breeding success, or causes of mortality. A common mistake is to decide how monitoring will be undertaken before deciding what information is actually needed. Instead, monitoring should be question-driven: define the questions first, then select the methods that are most appropriate for answering them. Having clear objectives will guide the choice of methods and level of effort, and the data required to evaluate whether the project is achieving its aims.
2. **Choose appropriate monitoring techniques:** For Curlews, this often includes a mix of colour-marking and tagging (see 'Techniques to aid Post-release Monitoring')

section below) and systematic field surveys to track individual movements, survival, and site fidelity.

3. **Establish baseline data:** Before birds are released, gather information on the release sites and surrounding habitats, including predator presence, predator control or interventions (e.g. the use of electric fences around release sites), food availability, and disturbance pressures. This provides context for interpreting outcomes: "*Pre-release baseline ecological data add great value to subsequent monitoring information*" (IUCN/SSC, 2013).
4. **Plan monitoring effort and timeline:** Determine how frequently birds will be tracked, for how long, and during which key periods (e.g., post-release dispersal, first winter, or subsequent breeding seasons).
5. **Build capacity and partnerships:** Ensure trained personnel, local volunteers, and relevant stakeholders (landowners, NGOs, statutory agencies) are engaged and understand their roles in the monitoring programme.
6. **Address welfare and ethical considerations:** Select tracking devices and methods that minimise stress and avoid impairing flight or foraging. Secure appropriate licenses and ethical approvals in advance (see 'Tools to aid Post-release Monitoring' section below).
7. **Plan data management and reporting:** Develop a clear system for storing, analysing, and sharing data so results can inform adaptive management and be communicated to funders and stakeholders.

Ideal post-release monitoring programme

An effective PrM programme for headstarted Curlew should be explicitly question-driven, designed to evaluate the performance of headstarts relative to wild-reared counterparts and to determine their contribution to population recovery. Four core questions provide the foundation for structuring monitoring activities, each linked to clear metrics, methods, and timelines; a summary is provided in Table 2.11.

First, PrM should assess how headstarts' rates of survival, seasonal return, and eventual recruitment compare with those of wild birds or other appropriate reference populations. Where wild counterparts are present, this requires marking both groups, ideally using a combination of colour rings for widespread resightings and GPS tags for detailed tracking. Where direct comparisons with sympatric birds are not possible, comparisons should instead be made with suitable control or reference data, such as nearby wild populations, published demographic estimates, or data from comparable headstarting projects. In situations where no wild birds are available for comparison – such as when headstarts are released into largely empty landscapes – monitoring should instead focus on absolute

measures of headstart performance, alongside broader population surveys to detect evidence of colonisation. In all cases, monitoring effort should be most intensive in the immediate post-release period, when survival bottlenecks are most likely, and then continue seasonally and annually to capture longer-term recruitment.

Second, understanding where headstarts return or recruit relative to their release sites is vital in evaluating the effectiveness of chosen release locations. GPS tracking, supported by colour-ringing and coordinated resighting effort, can reveal dispersal distances, recruitment to release versus non-release sites, and interactions with existing breeding populations. This work should be ongoing, with continuous GPS data collection supplemented by seasonal resighting during migration and breeding periods.

Third, PrM must evaluate whether headstarts breed as successfully as wild Curlew. Monitoring should therefore focus on nesting attempts, clutch sizes, hatching success, and chick survival, with checks timed carefully to the breeding cycle. Where feasible, productivity of offspring should also be considered, though this will often be constrained by small sample sizes and generally low breeding success across Curlew populations. Current evidence from Curlew headstarting programmes suggests that, once recruited into the breeding population, headstarted individuals breed as successfully as their wild-reared counterparts. Continued post-release monitoring is nevertheless essential to confirm that this remains true across different release sites, management approaches and environmental conditions, and to identify any factors that may influence breeding performance. Better understanding the distribution of age at first breeding would improve the underlying modelling (see 'Demographic metrics' in Chapter 1) and contribute to a relatively sparse body of knowledge for this vital rate in Curlews.

Finally, the integration of survival, dispersal, and breeding data allows projects to assess the population-level impact of headstarting relative to programme goals. This involves quantifying the proportion of breeders that are headstarts, their net recruitment into the population, and their influence on overall population trajectory. These analyses should be conducted on an annual to multi-year basis, feeding into periodic reviews of project effectiveness and guiding adaptive management. Lee *et al.* (2012) state that PrM strategy "*should be treated as a working document that is updated and adjusted as necessary depending on the behaviour and dispersal of the released birds*", allowing for continually iterated analyses and hence evidence-based changes to the headstarting programme. In this way, PrM becomes a strategic tool focused on answering the key questions that determine whether headstarting is delivering meaningful conservation gains for Curlew populations.

Table 2.11. Question-driven framework for post-release monitoring of headstarted Curlew.

Key Question	Monitoring Approach	Metrics	Tools & Methods	Frequency / Timeline
How do headstarts' rates of survival, return, and recruitment compare to wild-reared Curlew?	Where possible mark and track both headstarted and wild cohorts across multiple years.	Annual survival rate, proportion returning, recruitment into breeding population.	Colour rings, GPS tags, resighting networks, systematic field surveys.	Frequent checks immediately post-release (daily-weekly), then seasonal and annual resightings.
To where do headstarts return/recruit, relative to release sites and other breeding Curlew?	Track dispersal and settlement patterns; compare site fidelity and range overlap.	Distance and direction of dispersal, recruitment to release vs. non-release sites, overlap with wild breeders.	Colour rings, GPS tags, resighting networks, mapping/GIS analysis.	Continuous data collection from GPS tags; seasonal resightings (migration, return, breeding).
Do headstarts breed as successfully as their wild counterparts?	Monitor breeding attempts, clutch size, hatching/fledging success of both groups.	Pairing rates, nest initiation, clutch size, hatching success, fledging rates, offspring survival.	Nest monitoring, behavioural observation, colour rings, nest cameras.	Breeding season (annually), with checks timed to nesting cycle (laying → fledging).
What impact do headstarted birds make on the target population relative to programme goals?	Integrate demographic data with population models.	Proportion of breeders that are headstarts, net recruitment, contribution to population trajectory.	Capture–mark–recapture analysis, population modelling, integration with other survey data.	Annual/long-term assessment (multi-year), with periodic review against project targets.

Techniques to aid post-release monitoring

Colour-marking is a valuable and cost-effective method for PrM of headstarted Curlew, providing a reliable way to identify individuals in the field without the need for recapture. By fitting birds with unique combinations of colour rings and/or leg flags, practitioners can gather information on survival, dispersal, habitat use, and site fidelity through visual resightings by both project staff and the wider birdwatching community. This broadens monitoring capacity, as data can be collected across large areas and over long timeframes with minimal disturbance to the birds. Importantly, colour-marking can help to establish whether released Curlew return to breeding areas and contribute to population recovery, while also generating opportunities for community engagement by involving volunteers and citizen scientists in conservation monitoring.

Colour-marking of headstarted birds needs to be carried out by BTO bird ringers who hold the appropriate licence and endorsements to ring Curlew pulli (chicks) and a special methods endorsement (if using leg flags) (Table 2.12). Further, a colour-marking scheme should be registered with the International Wader Study Group (IWSG). In the UK there is already a registered leg-flag colour-marking scheme for use by headstarted projects; this is administered by WWT's Kane Brides. If leg flags are used as a marking method, Curlew chicks must be at least 25 days old before fitting as applying them earlier can place undue strain on the legs, increasing the risk of injury.

Flexibility is required when marking headstarts, as not all individuals will be at the same stage of development, and some may benefit from having rings or tags fitted later – either due to growth issues or on veterinary advice. However, wherever possible, marking should be carried out in a timely manner to maximise opportunities for subsequent monitoring and to minimise repeated handling of the birds.

GPS tracking in post-release monitoring of headstarted Curlew provides an invaluable tool for understanding how individuals adapt to life in the wild and whether conservation goals are being met. Unlike visual observations alone, GPS devices generate high-resolution data on movement, dispersal, habitat use, and survival, even when birds travel to remote or inaccessible areas. This level of detail allows practitioners to identify critical feeding and roosting sites, assess risks such as predation or disturbance, and evaluate whether released birds are establishing territories and returning to breed. Importantly, the insights gained help refine release strategies, guide habitat management, and provide robust evidence to funders and stakeholders of the effectiveness of headstarting programmes. By linking individual outcomes to population-level recovery, GPS tracking strengthens the adaptive management process and increases the likelihood of long-term success for Curlew conservation.

Several Curlew headstarting projects are successfully using GPS tags fitted with leg-loop harnesses to track post-release movements, and to undertake this work licensed BTO bird ringers must hold the appropriate training and special method endorsements specific to

this tagging technique (Table 2.12). Existing English Curlew headstarting projects have proven that GPS tags can be safely deployed on juveniles, providing several years' worth of movement data (which can be critical in identifying issues with bird survival in the post-release period). While capacity has increased in recent years, fitting harness tags to juvenile or headstarted Curlew remains a relatively new practice, and only a very small number of licensed bird ringers currently hold the necessary endorsement. It is therefore essential to identify and secure the involvement of suitably endorsed personnel well in advance of planned tagging activities. Flexibility is required in determining the timing of tagging, as not all individuals will be at the same stage of development. It may also be advantageous to GPS-tag birds across different release cohorts, which can influence when tags are deployed.

Looking ahead, increasing capacity in this area by upskilling local bird ringers through targeted training would be highly advantageous, ensuring greater resilience and continuity in delivering this specialised work. Whilst there are no set targets for the number of Curlew a ringer must tag before gaining a licence; the decision to issue one is based on the professional judgement of those providing the training, in conjunction with the BTO's licensing team, alongside the ringer's own confidence in applying sound judgement on harness selection and ensuring an appropriate fit. In addition, for a ringer to be considered trained in harness fitting, they must also hold the relevant endorsement to ring Curlew pulli (chicks).

Radio tracking, using temporary glue-on radio transmitters for headstarted Curlew at the point of release, offers clear advantages but also some limitations. These tags provide a practical way to monitor short-term survival, dispersal, and behaviour during the critical immediate post-release period, when mortality risks are highest. They are less costly than GPS tags, though it is important to note that the associated receiving equipment (handheld antenna and VHF receiver) can be relatively expensive. As for GPS tags, this technique requires licensed BTO bird ringers to hold the appropriate training and specific special method endorsements (Table 2.12). A key drawback is that glue-on transmitters usually detach within a few weeks, restricting their value for investigating longer-term questions such as seasonal survival, migration, or recruitment into the breeding population. Further, if radio-tagged birds leave the area of detection (i.e. go out of range of the person operating the receiving equipment) then connection with the bird and its transmitter will be lost. Retention times can also be variable, leading to inconsistent tracking durations between individuals. For these reasons, glue-on transmitters are best viewed as a cost-effective tool for assessing short-term outcomes, but they should ideally be used in combination with longer-term marking methods such as colour rings to provide a more complete picture of the contribution headstarted birds make to population recovery.

The cost-effectiveness of using GPS tags alongside standard colour-ringing: The use of GPS tags alongside standard colour-ringing in Curlew headstarting projects

represents a balance between cost and the depth of data obtained. Colour-ringing remains inexpensive, costing only a few pounds per bird, and enables individual identification through resightings. This makes it possible to monitor a large number of released Curlew over long periods, particularly with the help of volunteers and the wider birdwatching community. However, colour-marking relies on visual detection, which can be inconsistent and limited to areas where observer coverage is strong.

GPS tags are considerably more expensive than colour rings, typically costing several hundred to over a thousand pounds per unit depending on the technology. Their use also requires skilled, licensed personnel to fit leg-loop harnesses, adding to staff time and project costs. As a result, only a small proportion of released birds can usually be tagged. However, the quality of information gained makes GPS tracking a highly valuable addition to monitoring programmes. Recent trials using new harness materials by the Max Planck Institute have achieved tag retention of up to five years, allowing long-term data collection that extends into the critical recruitment-to-breeding phase, provided the tags remain functional.

Unlike colour rings, GPS devices provide continuous, fine-scale data on individual movements, survival, and habitat use, even when birds disperse into remote or poorly surveyed areas. They can identify mortality hotspots, stopover sites, and patterns of site fidelity, offering insights that would otherwise be missed. This detail is particularly important in the early stages of a project, when understanding post-release dispersal, settlement, and risks such as predation or disturbance can directly inform management actions.

The most cost-effective approach is to use GPS tags strategically, deploying them on a carefully chosen subset of birds to answer key questions, while continuing to colour-ring the majority of individuals. GPS tagged birds should also be colour-marked. This combination offers both breadth and depth: colour-ringing provides population-level monitoring at scale, while GPS delivers the detailed behavioural and ecological data needed to refine release methods and habitat management. In this way, the higher upfront investment in GPS technology can be justified by the long-term gains it delivers in improving conservation outcomes and ensuring that the overall investment in headstarting is more likely to succeed.

Table 2.12. Summary of the requirements for implementing colour-marking and tagging as part of post-release monitoring.

Method	Undertaken by	Licencing / authorisation	Estimated days	Notes
Colour-marking	BTO bird ringer with Curlew (pullus) endorsement	Project must be registered with and authorised by the International Wader Study Group (IWSG). Use of leg flag requires additional endorsement obtained through SMTP approval. Applications submitted via licensed ringer.	1–2 days per cohort (dependent on cohort size). Flexibility required.	Option to join the national Curlew headstart colour-marking scheme
GPS & radio tagging	A BTO bird ringer with the relevant Curlew (pullus) endorsement	Deployment requires BTO Special Methods Technical Panel (SMTP) endorsement. Application submitted via licenced ringer	1–2 days, depending on numbers; can often be combined with ringing. Flexibility required.	If not working under an existing permit holder, additional 1–2 days needed to apply for BTO SMTP endorsement.

Impact on donor pairs and how to monitor this

When harvesting eggs from Curlew nests for headstarting operations, it is advantageous to monitor donor pairs to quantify the effects of egg removal on breeding performance and longer-term fitness, and to determine whether these impacts remain acceptable given the overall conservation benefits of the programme. Monitoring donor pairs provides essential evidence for assessing the demographic consequences of egg harvesting and informing population modelling of the intervention. Donor adults should, wherever possible, be marked with colour rings or GPS tags, enabling reliable identification and continued tracking after egg collection. Breeding/donor adults are best colour-marked and GPS-tagged during the early stage of the breeding season, when they are defending territories and before egg laying commences. This allows practitioners to determine whether pairs remain on territory, attempt to re-lay, and successfully rear chicks within the same season, while also providing insights into longer-term site fidelity and survival.

Monitoring should also quantify key demographic responses following egg harvest, including the probability of donor pairs re-laying, the timing and success of replacement clutches, and patterns of return and breeding-site fidelity in subsequent years, including whether donor pairs relocate to different territories or breeding areas following egg collection. Comparing these outcomes between donor and non-donor pairs allows practitioners to determine whether egg harvesting has measurable effects on breeding performance, annual productivity, or longer-term site fidelity. Individually marking donor adults ensures that individual breeding histories can be linked directly to donor status, enabling robust assessment of any effects. In this way, monitoring provides the evidence needed to determine whether egg harvesting has any unintended consequences for the donor population and whether the intervention remains a sustainable conservation tool.

There are limited data regarding impacts on donor pairs. In England's Severn & Avon Vales, currently intensively monitored without any ongoing headstarting collections, the mean estimated number of days from nest failure to initiation of a replacement clutch is 10 days, with a slightly smaller replacement clutch size (mean 3.6 versus >4; WWT, unpublished data). In the Russian Spoon-billed Sandpiper population from which clutches were collected for headstarting 2012-2021, across 75 known-outcome collected clutches (parent-incubated for a mean of 3 days, range = 0-13 days):

- 49 (65%) re-laid
- of which 27 (55%) hatched
- of which 26 (100%) with known fledge status succeeded (mean 3 fledglings, range 1-4).

Additionally, of 13 identified pairs from which clutches were collected more than once, eight always re-laid (and the other five re-laid on at least one occasion; unpublished WWT/Birds Russia analyses).

Further guidance and reading

Projects should draw on already published best practice guidance to shape and inform their PrM programmes, ensuring that methods are consistent, ethical, and scientifically robust. Consulting existing literature and case studies – both from Curlew work and from wider species recovery projects – provides valuable information on effective marking techniques, appropriate tracking technologies, welfare considerations, and data management standards. By aligning with established protocols, projects not only avoid repeating past mistakes but also generate data that are more readily comparable across sites and initiatives, strengthening the evidence base at national and international levels. This approach helps ensure that PrM is targeted, efficient and contributes to meaningfully to broader conservation goals.

Welsh context

[A framework for head-starting Eurasian Curlew in Wales](#) [v1] specifies that proposals should include five-year post-release monitoring plans (interpreted to mean that PrM should occur during each year of release, and for a minimum of five years following the final release). It would likely be prudent to consider a longer PrM period for Curlew; results from the reintroduction of Common Crane to southwest England emphasise "*the need for long-term monitoring to establish reintroduction success in animals that have slow life histories: 9 years after initial releases, the Common Crane population remains dominated by first-generation birds and productivity is skewed by transient age-structure and the late onset of reproductive success*" (Donaldson *et al.*, 2023). The framework expresses specific interest in using PrM to investigate survival of headstarts across the first and second years of life, to facilitate comparison with wild-reared conspecifics (see further detail in Chapter 1).

Unpublished capture-mark-recapture analyses on the headstarted Curlew released at WWT Slimbridge in 2019 indicate that apparent first-year survival rate (43%) was broadly comparable to that of wild-reared birds. A high proportion of the 50 released birds disappeared fairly shortly after release: 22 (44%) were detected after August 2019 (i.e. 8+ weeks post-release), of which 19 were confirmed alive at age 1+ (on or after September 2020), with all but one confirmed alive at age 2+ yrs. These figures indicate that the (expected) high mortality during the first year was very heavily concentrated in the post-fledging period, and there was very high survival from early autumn of the first year onwards. It is impossible to make strong inferences about the fate of the 56% of birds that disappeared shortly after release, because we cannot separate permanent emigration from the main resighting area in the Severn Estuary from mortality.

For reference, Guiding Principle 8 of [the framework for head-starting Eurasian Curlew in Wales](#) [v1], 'Ensure a dedicated monitoring programme is built into any proposal', is reproduced below:

This will include marking/tagging to ensure the movements of released birds can be determined. [...] It is critical that outcomes are monitored so that lessons can be learned, shared and adaptations made. As a minimum: i) the size and productivity of the recipient population (and the donor population where translocation between sites is involved) should be monitored in order to understand the impact that headstarting is having; ii) released birds should be metal and colour-ringed, field readable colour marks (colour rings, leg flags that are standardised in locals or a national marking scheme) and where possible GPS tagged; iii) the recipient population should be closely monitored in subsequent breeding seasons to determine survival and recruitment rates of head-started birds and their subsequent breeding success compared to wild bred birds and consequently changes in population size; iv) detailed records should be kept of the birds during the rearing process,

including hatch date, sex, condition and health, so that the links between rearing and subsequent fitness can be learned. Additionally it will be critical to:

- closely follow birds in the immediate post-release period in order to assess whether they are behaving appropriately and detect any early mortality;*
- GPS track a proportion of birds so that their survival and movements can be directly monitored, and lessons learned about the behaviour of that population, and;*
- monitor the breeding success of head-started birds relative to that of wild birds, in order to understand their relative fitness for life in the wild.*

Additionally, Annex 1 of the Wales Action Plan for the Recovery of Curlew (Gylfinir Cymru, 2021) states that any headstarting proposals would be assessed against best practices for translocation as set out by existing guidelines including AEWA's Guidelines for the Translocation of Waterbirds for Conservation Purposes (Lee *et al.*, 2012), the IUCN/SSC Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC, 2013), and the Scottish Code for Conservation Translocations (National Species Reintroduction Forum, 2014). Some advice from these documents relating to PrM has already been referenced above; further pertinent guidance is summarised in below:

AEWA Guidelines:

- PrM strategy must be pre-planned and ready to implement immediately after release, and will ideally facilitate incorporation of pre-release information (e.g. egg source, collection information, chick health) to investigate 'early-life effects'. Although the term is not specified in the AEWA Guidelines, WWT have been developing 'early-life effects' analyses for a number of headstarting projects, whereby correlates of headstarting success indices (hatch, release, return, recruitment) are identified across the rearing and release process. For example, hatch rate might be higher for eggs collected earlier in incubation or return rate higher for individuals released in larger cohorts.
- While volunteer-collected data can be extremely valuable, its quality should be assessed.
- If possible, it may be useful to support special effort in to capture and marking of offspring of headstarts.

IUCN/SSC Guidelines:

- Identify what data will evidence progress towards the programme's objectives; ensure good data management; plan dissemination to stakeholders.

For the proposed headstarting programme modelled here, there would be two relevant spatial scales of PrM: most effort would be dedicated to the source/recipient ICAs and their surrounding areas, but as the ultimate target is a national-level recovery, the wider Welsh landscape would also be of interest. As described above, less intensive/more extensive methods such as colour-ring resighting would help with the latter, while responsibility for monitoring the all-Wales breeding population would likely fall beyond any headstarting programme.

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We are grateful for advice on Chapter 1 from Sam Franks, Rachel Taylor and Katharine Bowgen at the British Trust for Ornithology. For Chapter 2, our Curlew headstarting protocol has benefitted from input by WWT's Mark Roberts, Chrissie Kelley of Pensthorpe Conservation Trust/Deepdale Conservation Trust, and Paul Zwetsloot (private breeder). Finally, project set-up and administration assistance was provided by Eric Heath, Pam Ingram and Julie Gasston at WWT.

Appendix 1: All-Wales and disaggregated population projections for all scenarios shown in Table 1.6.

Unless otherwise specified, breeding propensity takes the derived value (<1), and headstarting scenarios include two pulses (i.e. headstarting occurring for five years, twice) and two collection bouts per pulse (i.e. some second clutches are collected with a return egg-collection visit for each year of headstarting).

In all cases: axis labels for the segment-specific plots on the right are the same as for the all-Wales plot on the left; the y-axis scale is held constant across selected ICAs to facilitate comparison; solid black lines = means; dashed black lines = maxima and minima; where relevant, vertical grey lines indicate intervention periods, with headstarting periods also shaded (for selected ICAs and hence all Wales also).

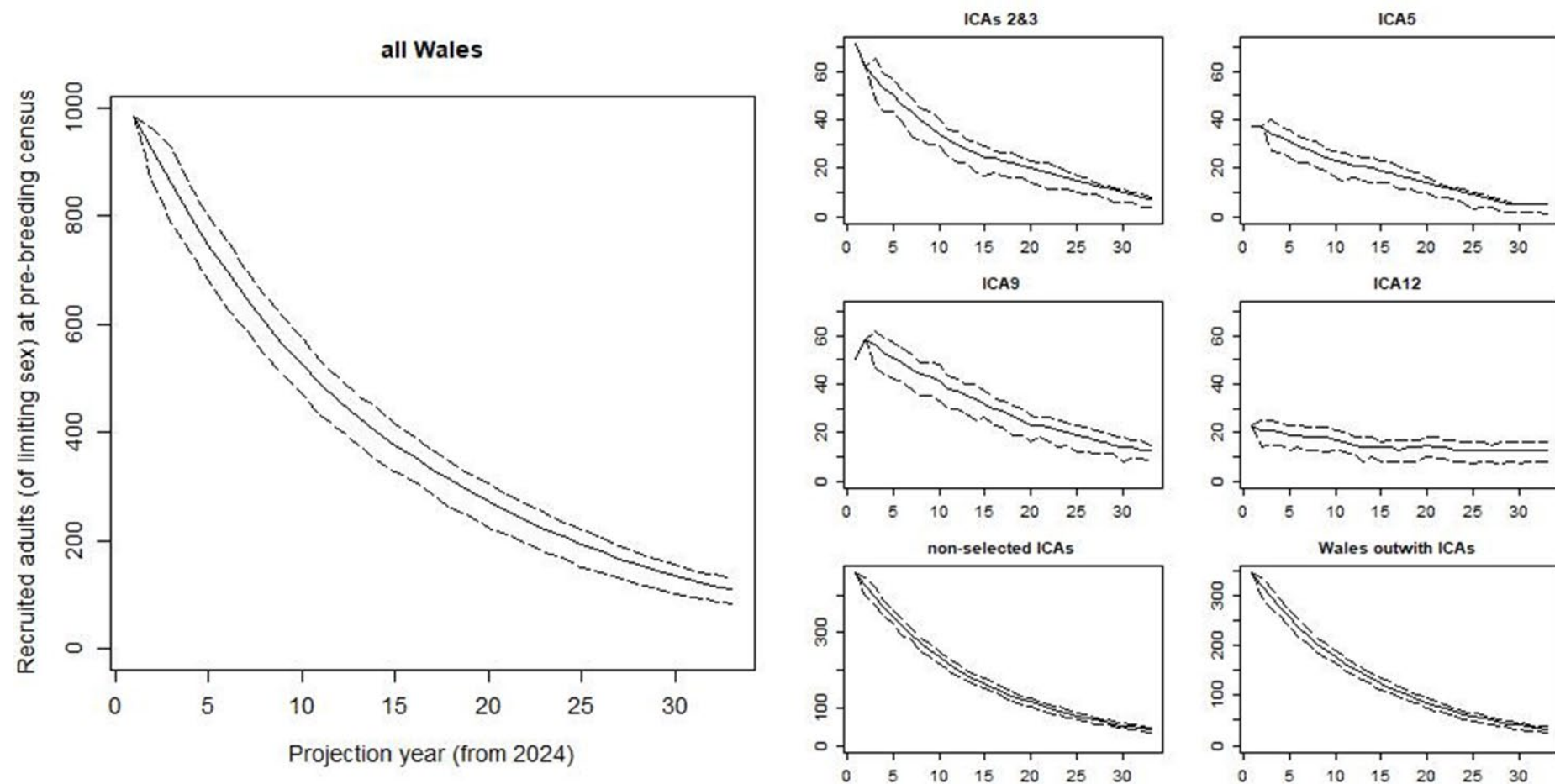


Figure S1. 'Business as usual' scenario (no headstarting and no other conservation measures) for the larger estimated starting population size (983 breeding pairs), without national productivity improvement.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

In all cases the populations decline (e.g. from 1000 to <200 for all-Wales), although the slope is much less steep for ICA 12. The other selected ICAs start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period.

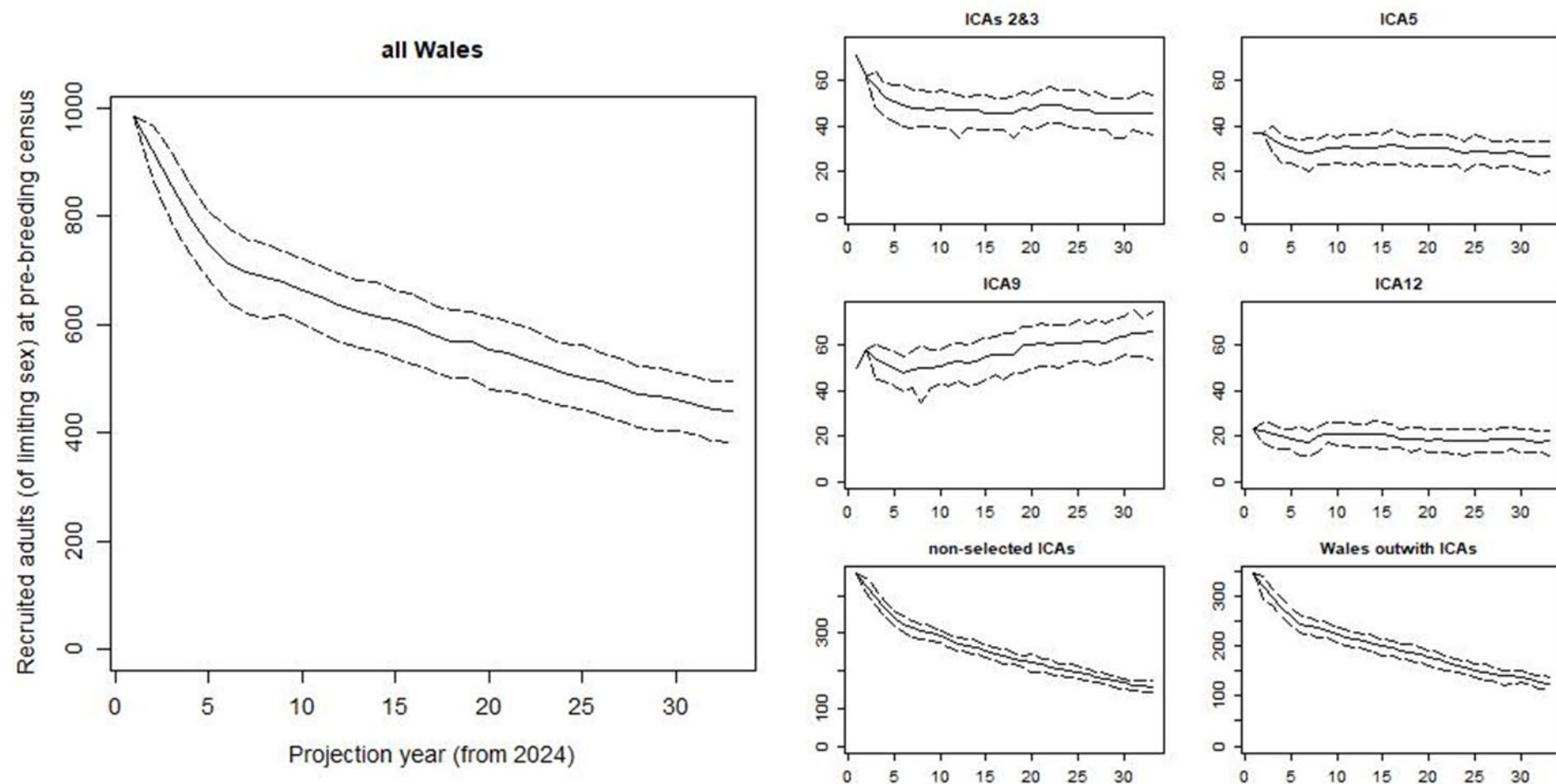


Figure S2. 'Business as usual' scenario (no headstarting and no other conservation measures) for the larger estimated starting population size (983 breeding pairs), with national productivity improvement.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Outside of the selected ICAs, the populations decline (e.g. from 1000 to <500 for all-Wales). The selected ICAs generally show stability after a short initial decline, except for ICA 9 which shows a slight overall increase. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period.

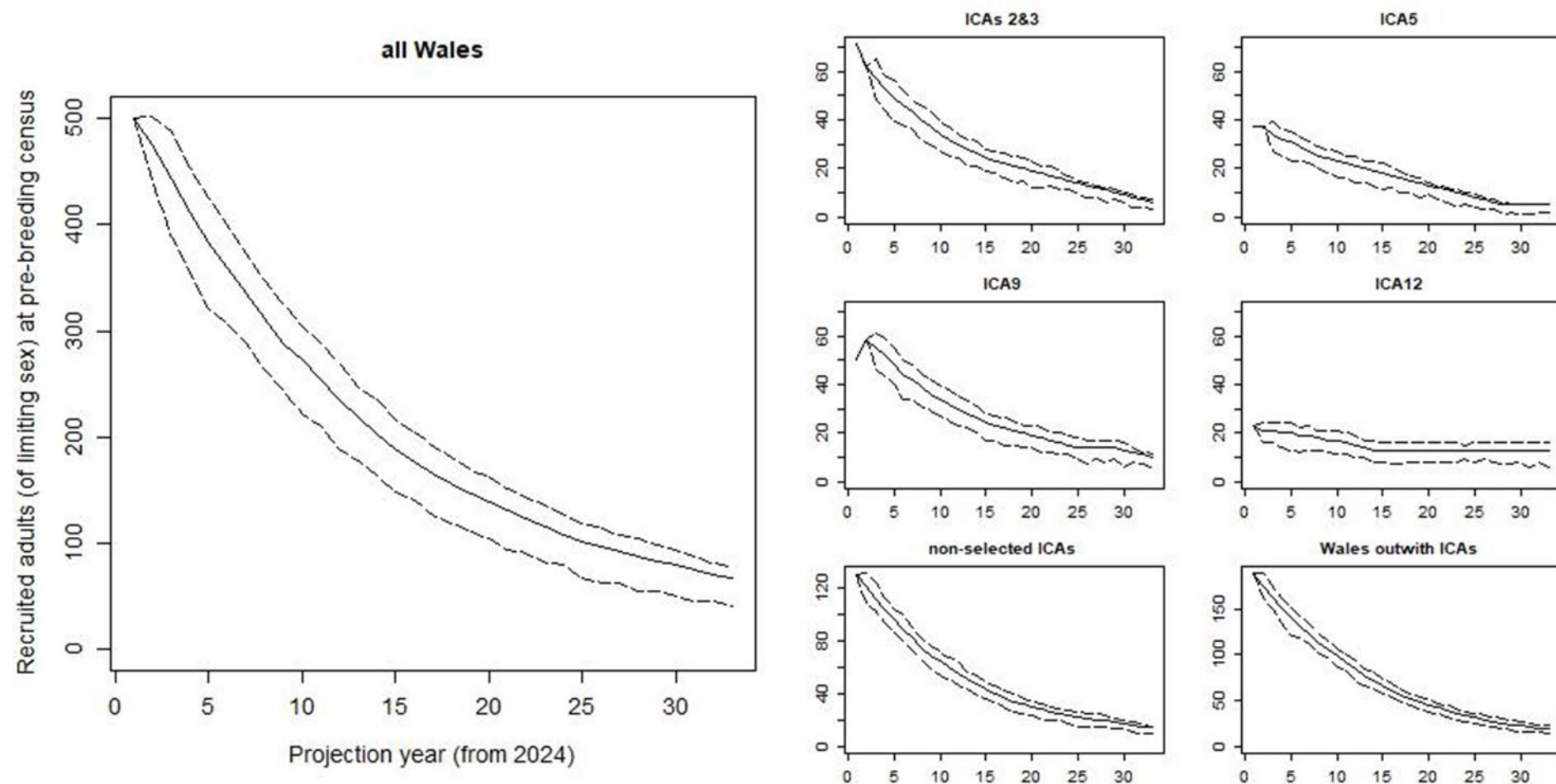


Figure S3. 'Business as usual' scenario (no headstarting and no other conservation measures) for the smaller estimated starting population size (500 breeding pairs), without national productivity improvement.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

In all cases the populations decline (e.g. from 500 to <100 for all-Wales), although the slope is much less steep for ICA 12. The other selected ICAs start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period.

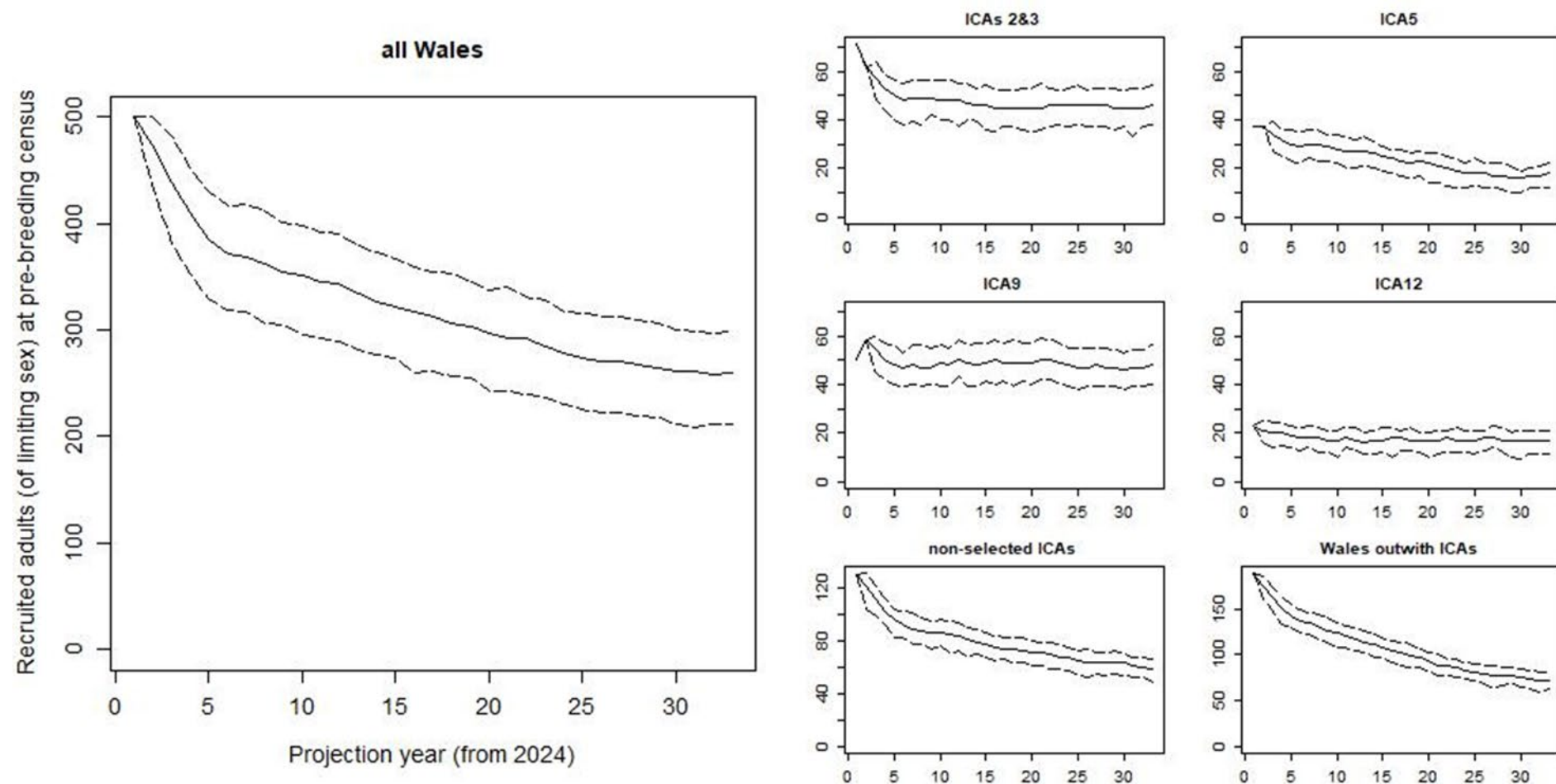


Figure S4. 'Business as usual' scenario (no headstarting and no other conservation measures) for the smaller estimated starting population size (500 breeding pairs), with national productivity improvement.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Outside of the selected ICAs, the populations decline (e.g. from 500 to <300 for all-Wales). The selected ICAs generally show stability after a short initial decline, except for ICA 5 which shows a slight overall decrease. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period.

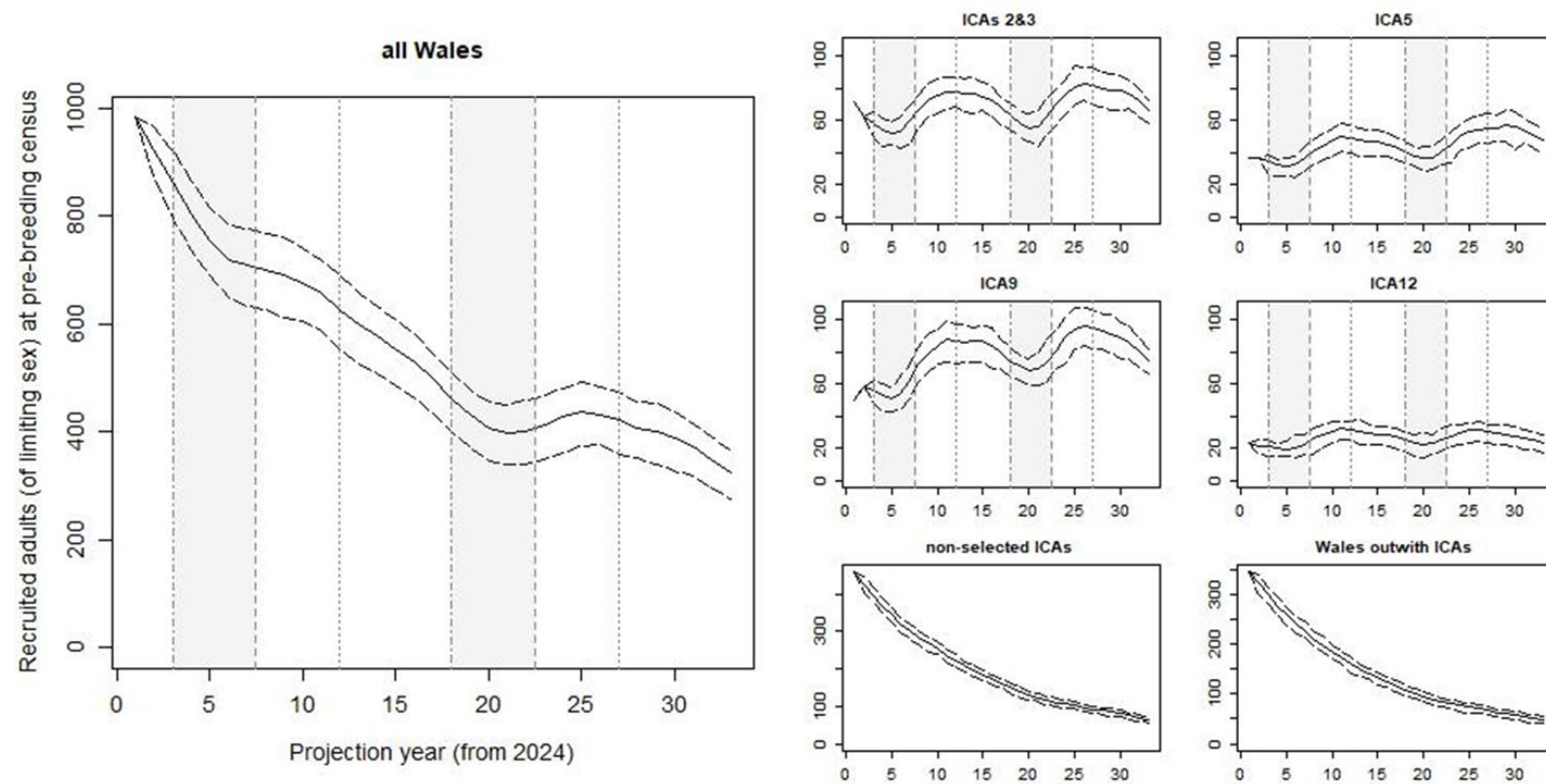


Figure S5. 'Best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below. Here the all-Wales population shows overall decline, the selected ICAs show approximate stability (2&3, 12) or slight increases (5, 9) with peaks at ~12 years and ~27 years, and the non-selected ICAs and rest of Wales show steep declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

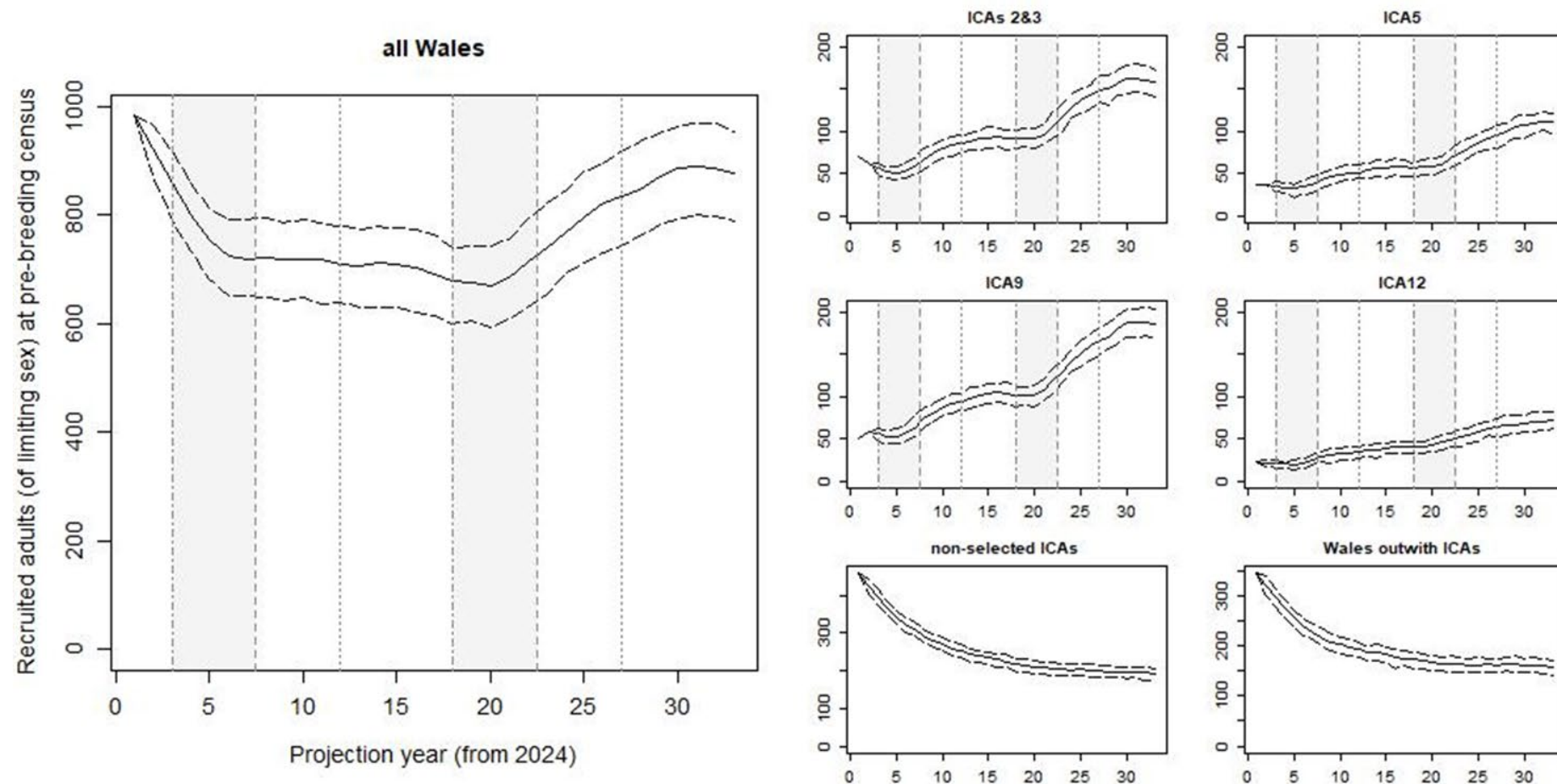


Figure S6. 'Best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), with national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

Figure S6 A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population shows a steep decline, which largely levels out ~5-20 years, followed by an increase back up to around the starting population size. The selected ICAs all show increases, to a lesser extent for ICA 5 and ICA12, and the non-selected ICAs and rest of Wales show shallow declines levelling out to about half the starting population. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

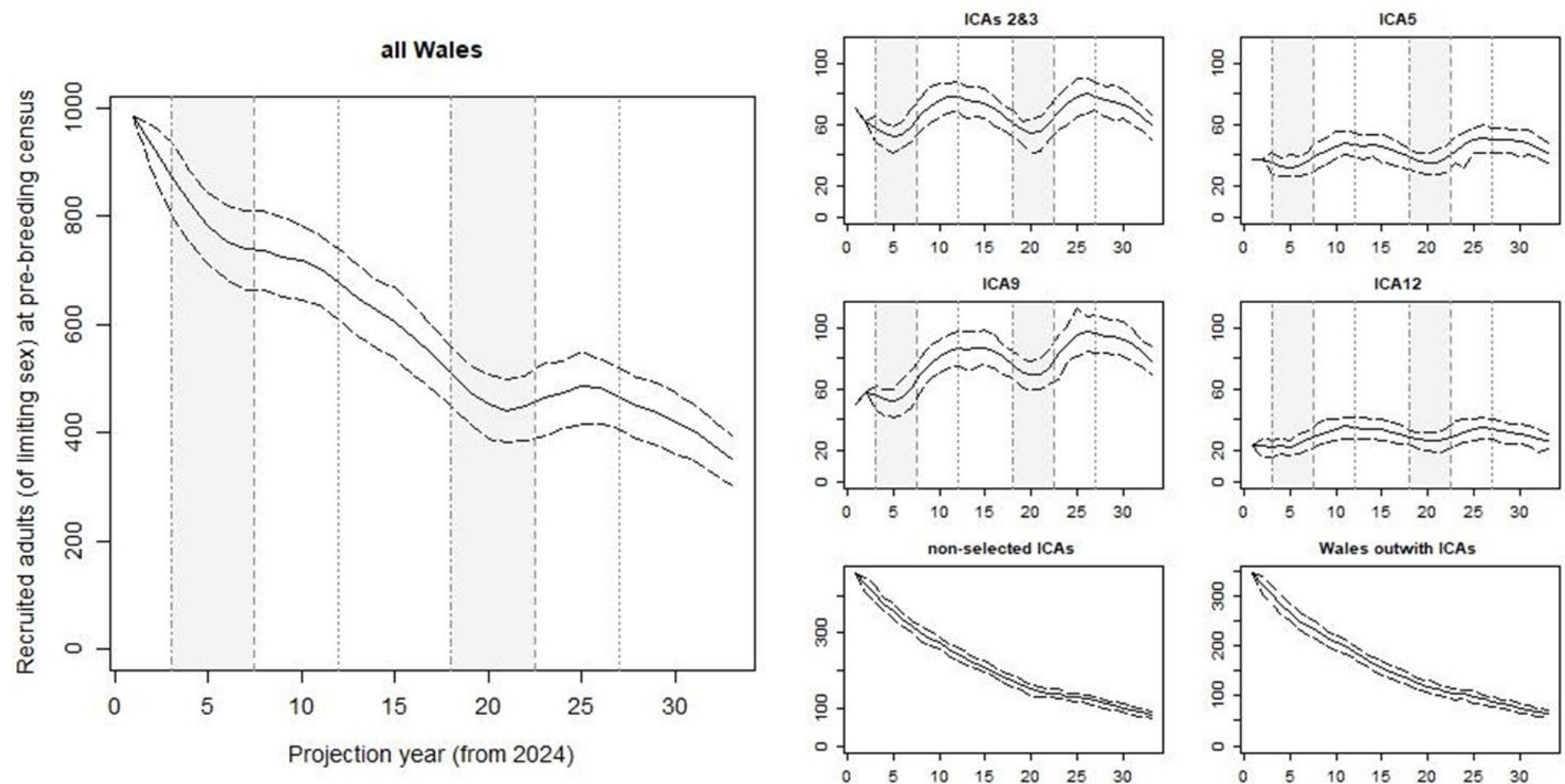


Figure S7. Full breeding propensity comparison to the 'best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population shows overall decline, the selected ICAs show approximate stability (2&3, 12) or slight increases (5, 9) with peaks at ~12 years and ~27 years, and the non-selected ICAs and rest of Wales show steep declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

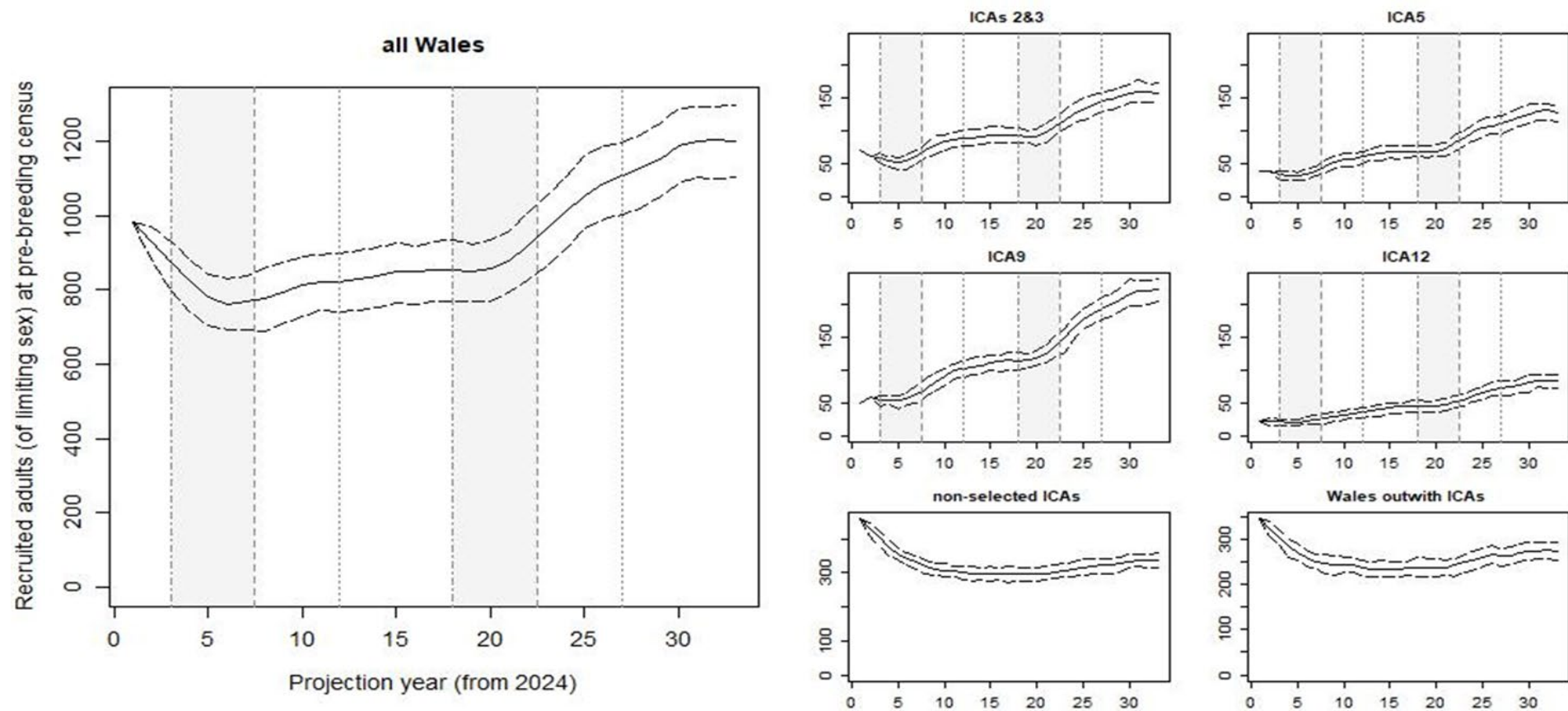


Figure S8. Full breeding propensity comparison to the 'best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), with national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales and selected ICA populations show increases (e.g. from ~1000 to ~1200 for all Wales), while the non-selected ICAs and the rest of Wales undergo shallow declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

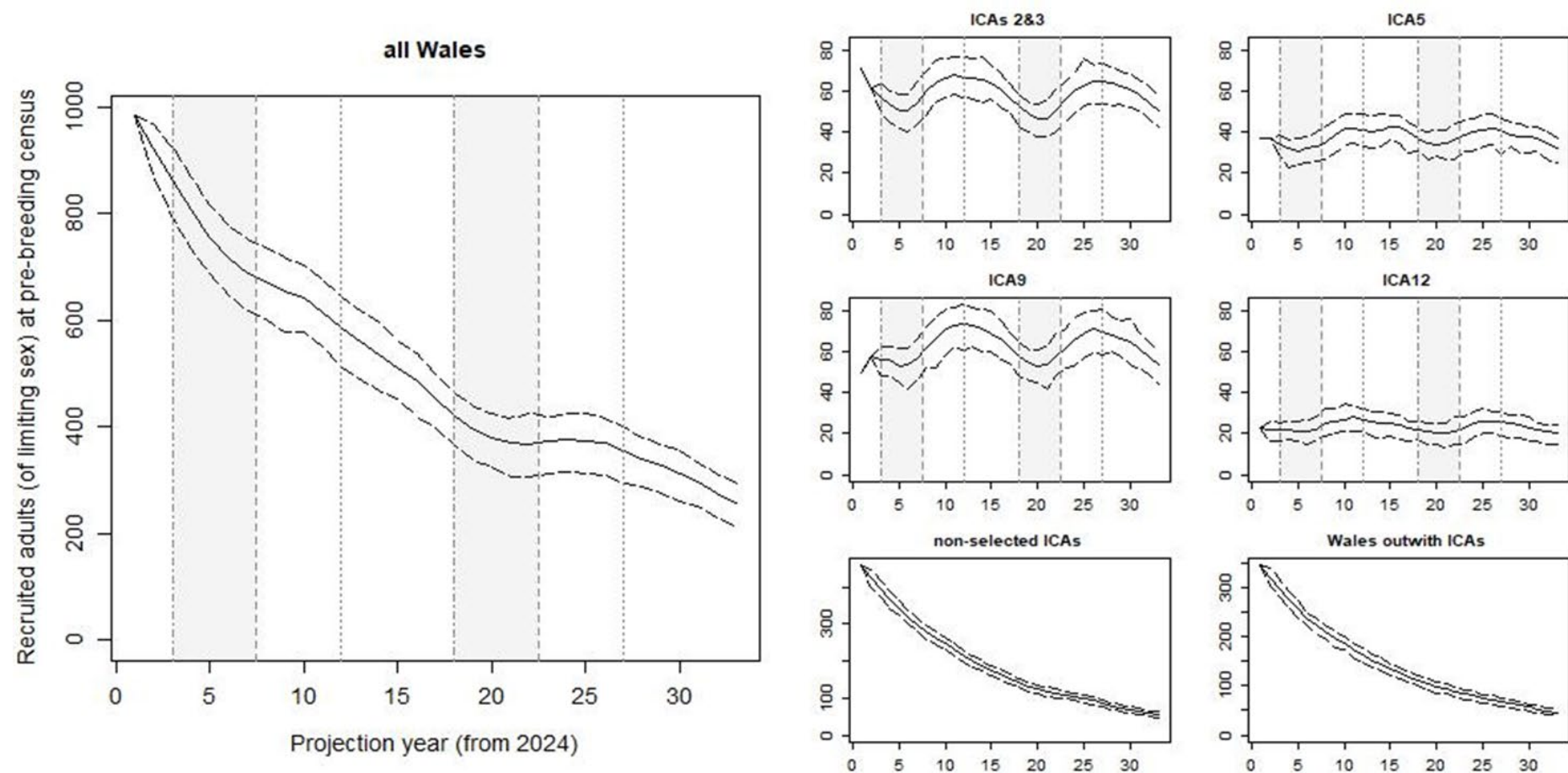
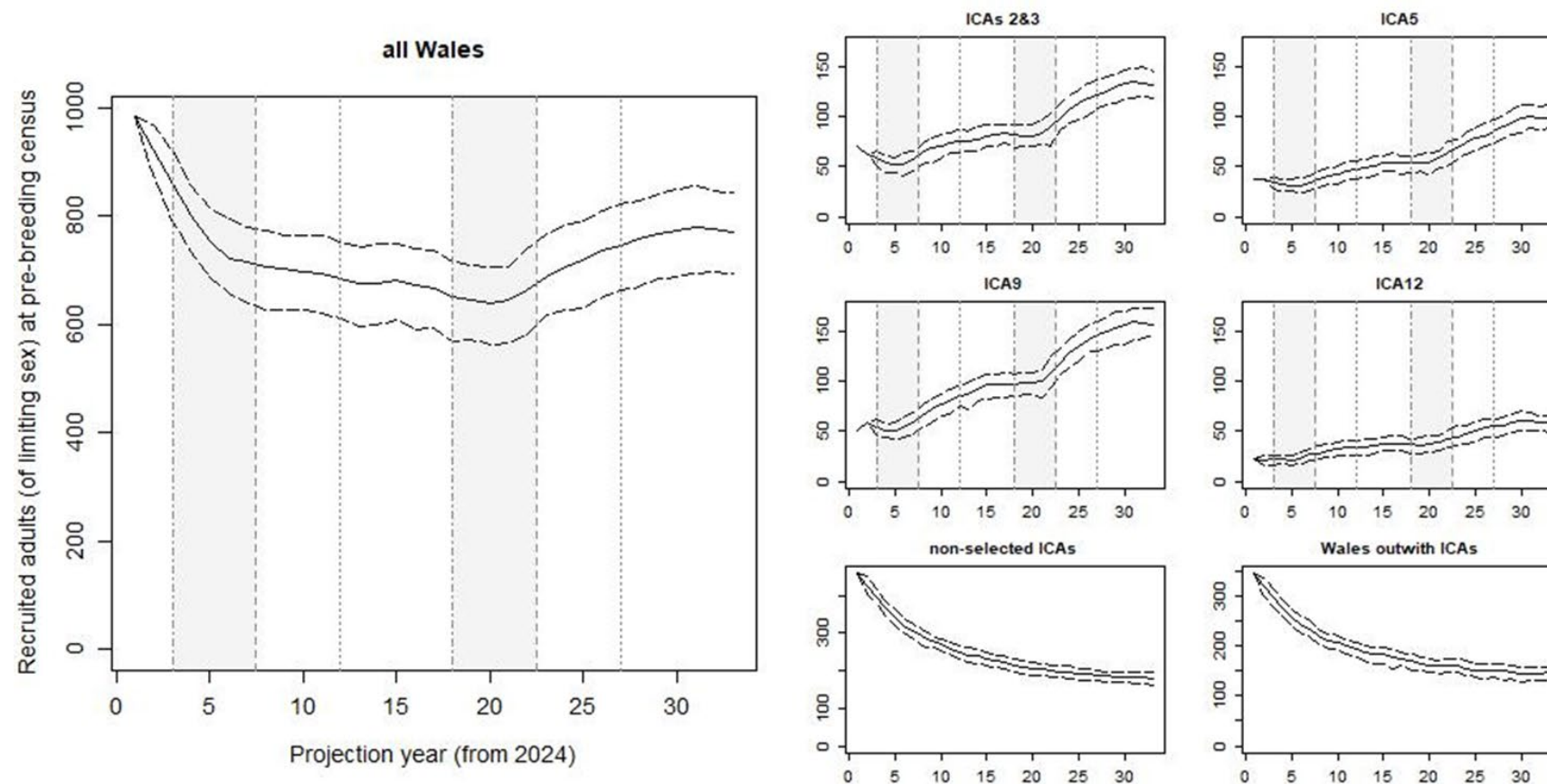


Figure S9. One collection bout comparison to the 'best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population shows overall decline, the selected ICAs show approximate stability (5, 9, 12) or a slight decrease (2&3) with peaks at ~12 years and ~27 years, and the non-selected ICAS and rest of Wales show steep declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.



Figure

S10. One collection bout comparison to the 'best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), with national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting period is also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population, the non-selected ICAs and the rest of Wales undergo shallow declines, while the selected ICA populations show increases (mostly approximately doubling). The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

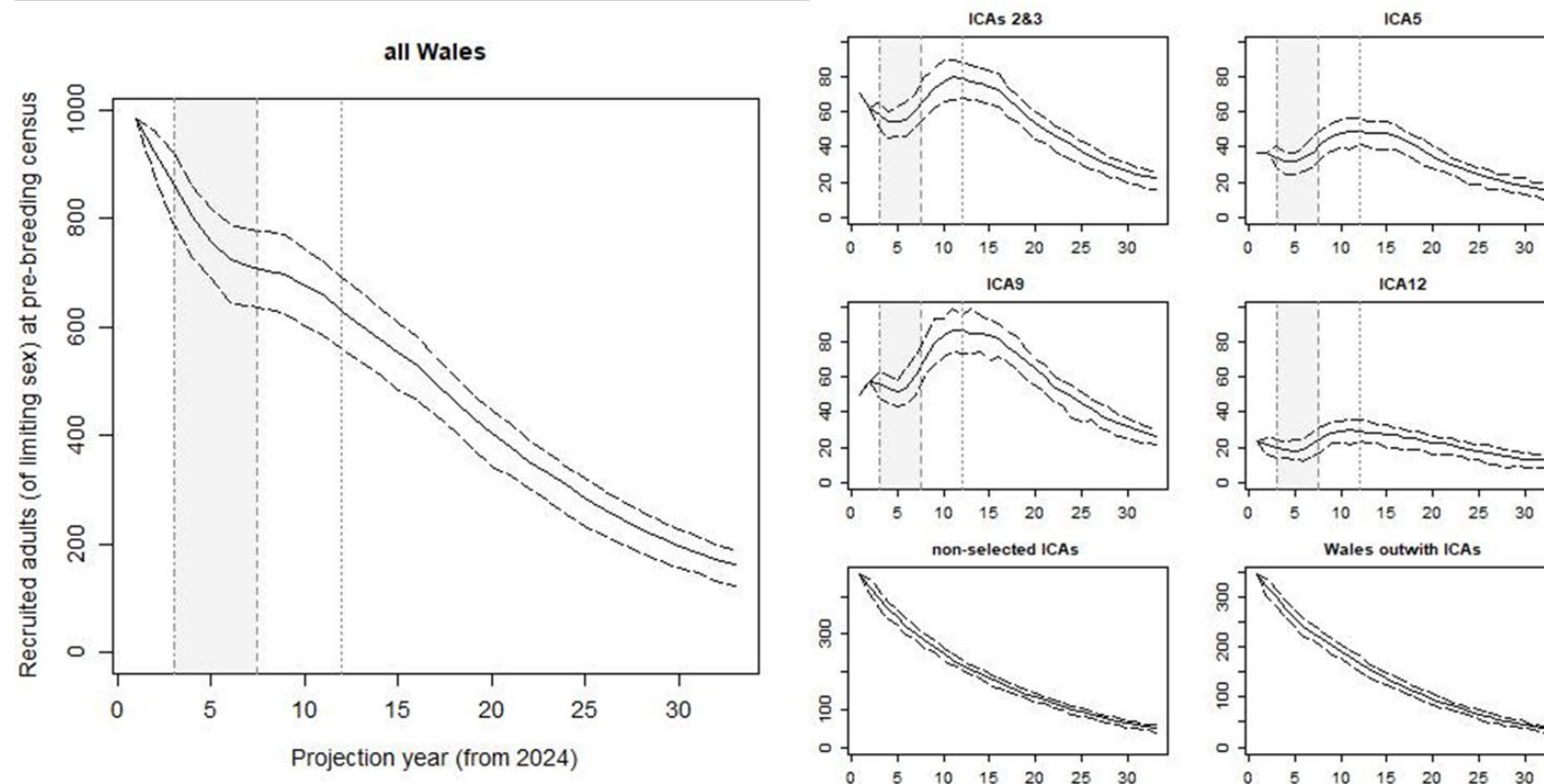


Figure S11. One pulse comparison to the 'best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting period is also shaded. A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below. All plots except ICA 12 (approximate stability) show overall decline, most steeply in non-selected ICAs and the rest of Wales, and with a peak ~12 years for the selected ICAs. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

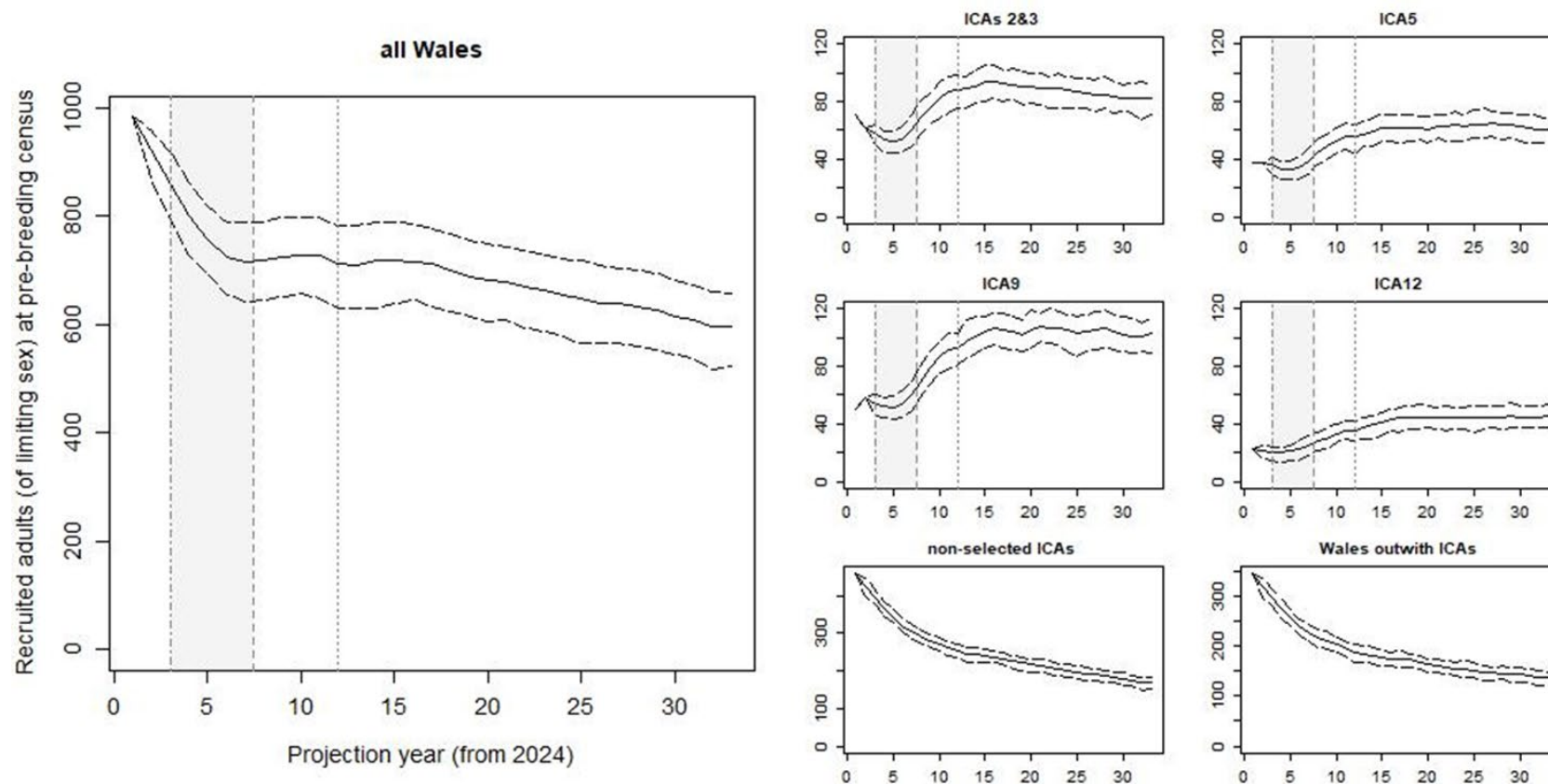


Figure S12. One-pulse comparison to the 'best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), with national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting period is also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population shows an overall decline, steeper for the first ~5 years, with an overall decline from ~1000 to ~600. The selected ICAs all show increases, to a lesser extent for ICA 5 and ICA12, and the non-selected ICAs and rest of Wales show shallow declines to a little below half the starting population. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

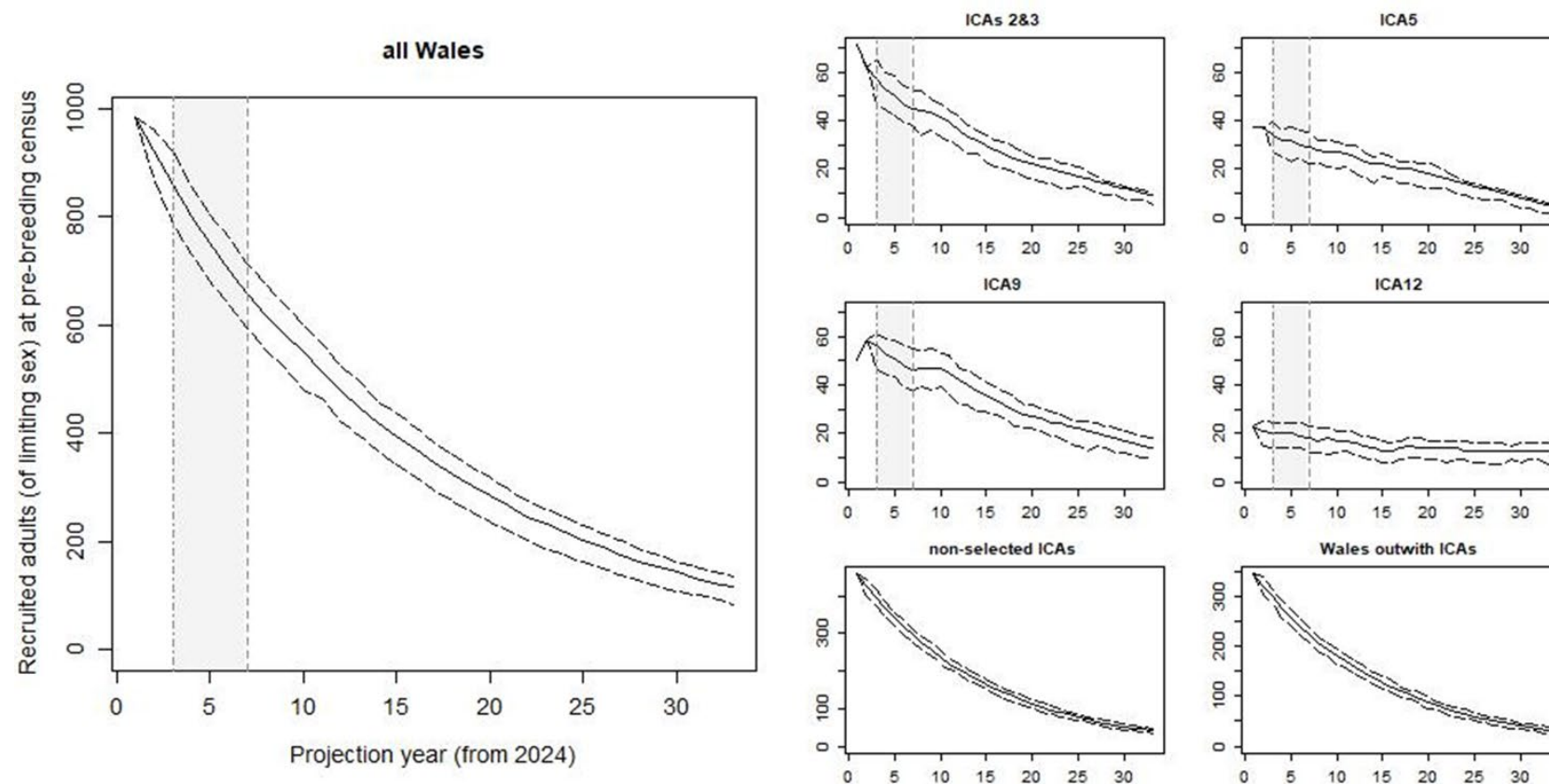


Figure S13. 'Worst-case' headstarting scenario (one pulse of 'max. failure' headstarting, with 5 years of other conservation measures), for the larger estimated starting population size (983 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting period is also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

In all cases the populations decline (e.g. from ~1000 to <200 for all-Wales), although the slope is much less steep for ICA 12. The other selected ICAs start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

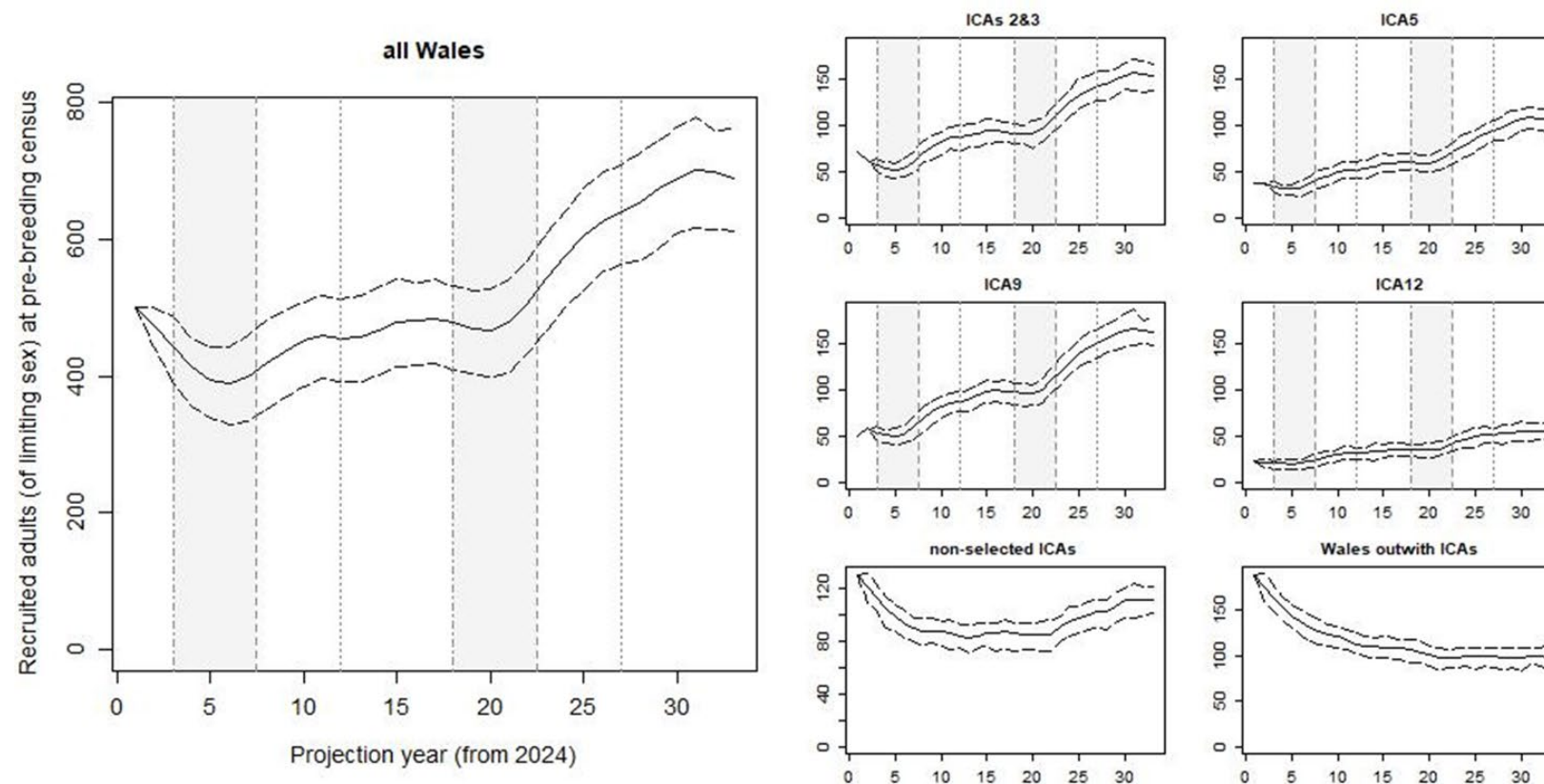


Figure S14. 'Best-case' headstarting scenario ('max. feasible' clutches collected, with 10 years of other conservation measures), for the smaller estimated starting population size (500 breeding pairs), with national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting; dotted = end of other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales and selected ICA populations show increases (e.g. from ~500 to ~700 for all Wales), while the non-selected ICAs and the rest of Wales undergo shallow declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 and 18-22 years for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

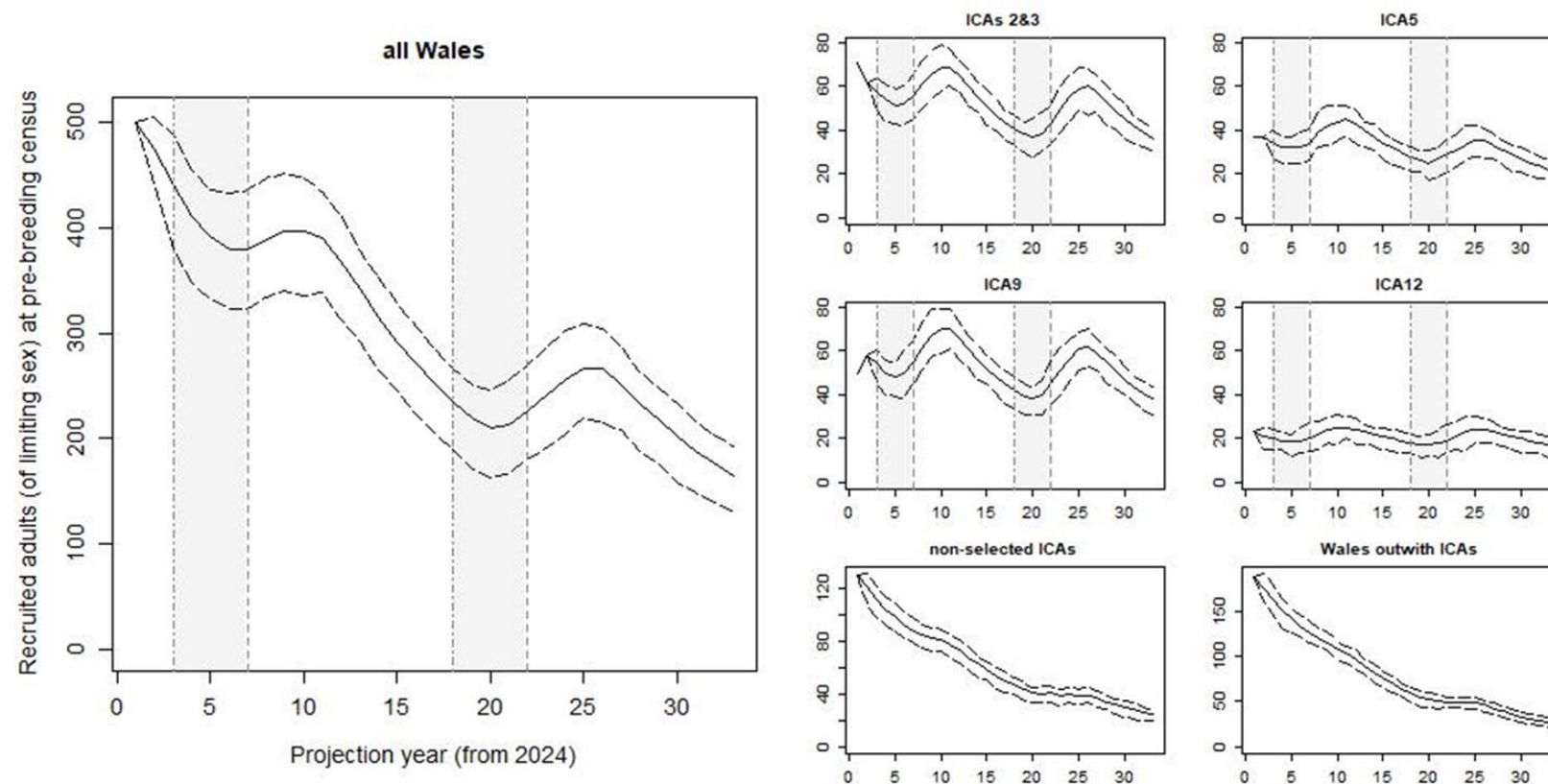


Figure S15. 'Middle-ground' headstarting scenario ('min. necessary' clutches collected in one bout per pulse, with 5 years of other conservation measures), for the smaller estimated starting population size (500 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population and ICAs 2&3, ICA 5 and ICA 9 all show a two-peaked overall decline, while ICA12 remains overall stable with minor peaks at ~10 years and ~25 years, and the non-selected ICAs and rest of Wales show steep declines. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years and 18-22 for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

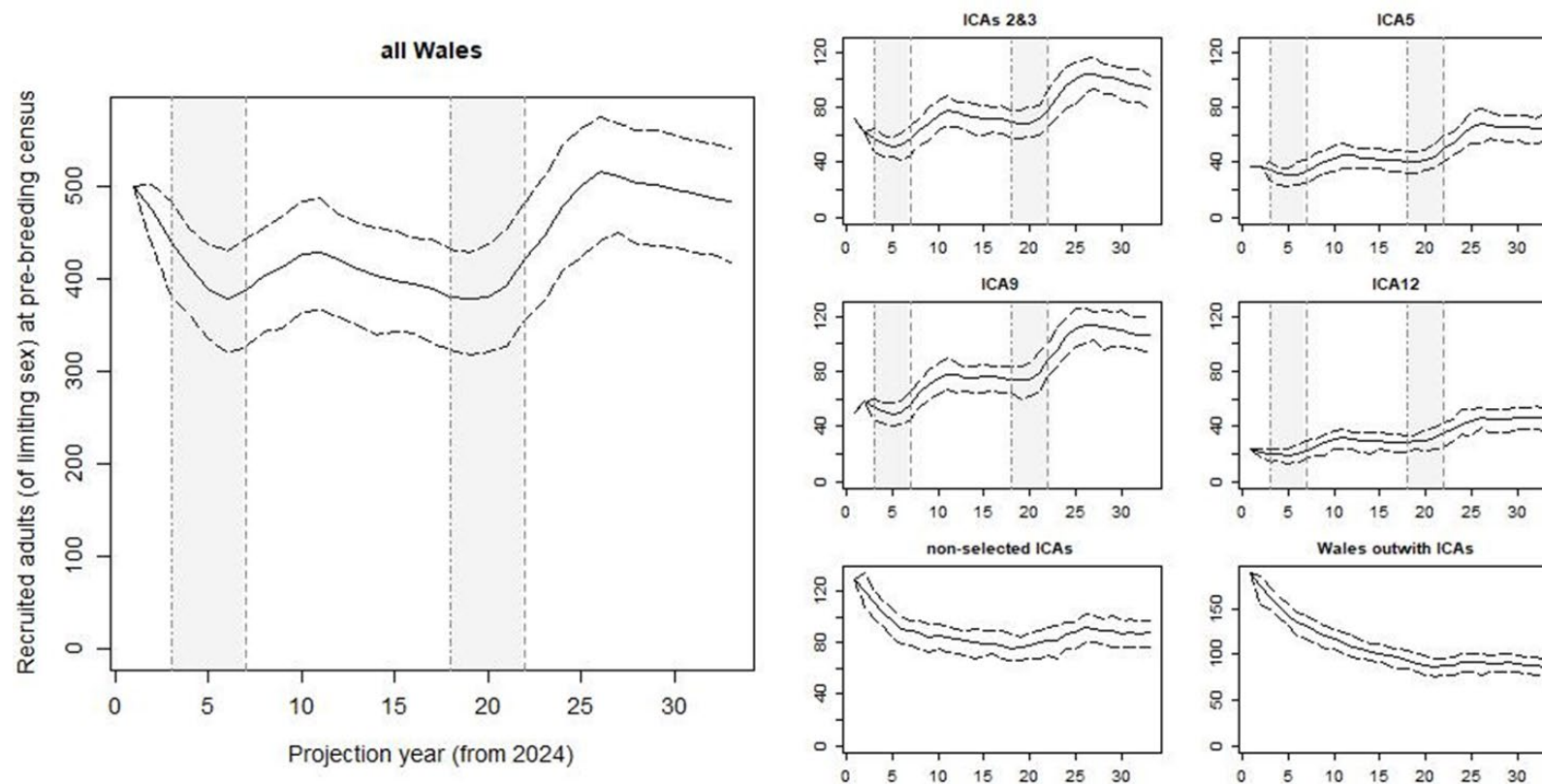


Figure S16. 'Middle-ground' headstarting scenario ('min. necessary' clutches collected in one bout per pulse, with 5 years of other conservation measures), for the smaller estimated starting population size (500 breeding pairs), with national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting periods are also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here the all-Wales population shows two sets of troughs and peaks, with an eventual slight decline bringing the trajectory back to around the starting population. The selected ICAs all show moderate to strong increases, and the non-selected ICAs and rest of Wales show moderate declines (steeper in the latter). The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years and 18-22 for the first 5 plots, with a vertical dotted line at the same interval to the right of each shaded block.

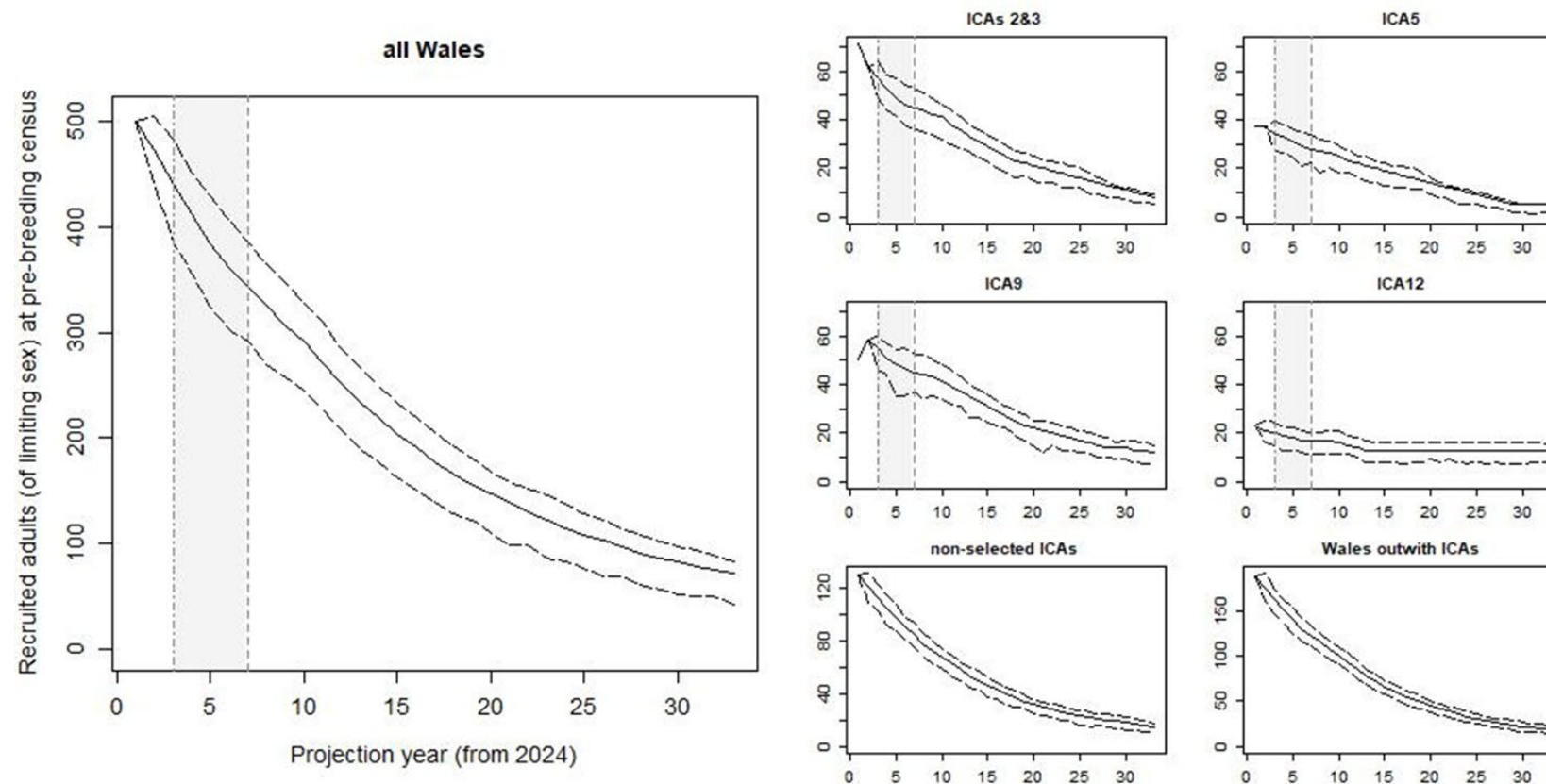


Figure S17. 'Worst-case' headstarting scenario (one pulse of 'max. failure' headstarting, with 5 years of other conservation measures), for the smaller estimated starting population size (500 breeding pairs), without national productivity improvement. Vertical grey lines, from left to right: dot-dash = start of headstarting and other conservation measures; dashed = end of headstarting and other conservation measures; the headstarting period is also shaded.

A composite set of line graphs shows 7 population projections, for "all Wales" in large on the left, and "ICAs 2&3"/"ICA5"/"ICA9"/"ICA12"/"non-selected ICAs"/"Wales outwith ICAs" stacked smaller on the right. Each plot shows lines comparing projected numbers of recruited adults (of limiting sex) at pre-breeding census over 30+ years, with a solid black line flanked by dashed lines above and below.

Here all plots show overall declines, less steeply for ICA 12. The selected ICAs except for ICA 12 start as solid lines with no max./min envelope, with ICAs 2 & 3 decreasing, ICA 5 remaining stable and ICA 9 increasing for this initial observed period. Vertical blocks are shaded from 3-7 years for the first 5 plots.

Appendix 2: Budgets presented across WWT nominal expenditure codes.

Where nominal expenditure codes represent costs for:

- **Animal Food:** artificial extruded pellet, live food, flint grit, multivitamins, probiotic and heats stress alleviator supplements.
- **Animal Health Products:** veterinary treatments.
- **Animals/Other Costs:** bird identification marks (cable ties, metal and plastic leg bands, leg flags, GPS tags, banding gear).
- **Building Works:** Portakabins, storage facilities (shipping containers), rearing aviaries, perimeter fences and predator exclusion hot-wires, power-washing facilities.
- **Consumables:** disinfectants, egg repair materials, cardboard boxes to translocate chicks, black bags, disposable washing and drying materials, nitrile gloves, herbicides, silica sand, stationary.
- **Electricity:** mains electric to power rearing areas, power-washing and storage facilities.
- **Fuel Costs:** for cutting machinery (lawn mowers, brush cutters etc., includes oil).
- **Hired and Contracted Services (Other):** installation of services e.g. water, electricity, drainage.
- **Professional Waste Disposal:** Disposal of animal waste (for 5 months per year) and portaloo for staff (for 8 months per year – assumes out-of-season work takes place in a central office).
- **Small Equipment < £1,000:** egg collection, egg incubation, chick rearing (i.e. bird life-support), and biosecurity equipment
- **Water Rates/Charges:** mains water for drinking and cleaning.
- **Staff Costs:** project management, veterinary and aviculturist staff. These are the costs most subject to change depending on NRW pay scales and periods of staff employment.

Table S1. Costs by WWT nominal expenditure codes for METHOD 3 (4.5% inflation for non-staff nominals and 3.5% for staff nominals applied annually from year 0).

NOMINAL	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	OVERALL TOTAL
Animal Food	£0	£3,858	£4302	£4214	£4403	£4601	£21,372
Animal Health Products	£0	£825	£862	£901	£941	£984	£4,513
Animals/Other Costs	£0	£19,811	£20,702	£21,634	£22,608	£23,625	£108,380
Building Works	£417,461	£0	£0	£0	£0	£0	£287,828
Consumables	£0	£9,286	£9,704	£10,141	£10,597	£11,074	£50,801
Electricity	£0	£3,135	£3,276	£3,423	£3,578	£3,739	£17,151
Fuel Costs	£0	£470	£491	£514	£537	£561	£2,573
Hired and Contracted Services (Other)	£43,500	£0	£0	£0	£0	£0	£43,500
Professional Vet Services	£0	£12,005	£12,545	£13,110	£13,700	£14,316	£65,676
Professional Waste Disposal	£6,300	£6,584	£6,880	£7,189	£7,513	£7,851	£42,316
Small Equipment < £1,000	£146,991	£0	£0	£0	£0	£0	£146,992
Water Rates/Charges	£0	£3,135	£3,276	£3,423	£3,578	£3,739	£17,151
Ringling/Tagging	£0	£55,000	£56,925	£58,917	£60,979	£63,114	£294,936
ANNUAL TOTAL FOR NOMINAL	£484,619	£113,418	£117,972	£122,711	£127,644	£132,778	£1,232,820
Staff - Rearing and release	£204,101	£533,207	£551,869	£571,184	£591,176	£611,867	£3,063,403
Staff - Ringing and tagging	£0	£4,107	£4,250	£4,399	£4,553	£4,712	£22,022
Staff - Monitoring at selected ICAs	£0	£118,064	£122,196	£126,473	£130,900	£135,481	£633,114
ANNUAL TOTAL FOR STAFF	£204,101	£655,377	£678,315	£702,056	£726,628	£752,060	£3,718,539
OVERALL TOTAL	£688,719	£768,795	£796,287	£824,768	£854,273	£884,839	£4,951,216

Table S2. Costs by WWT nominal expenditure codes for METHOD 4 (4.5% inflation for non-staff nominals and 3.5% for staff nominal annually from year 0).

NOMINAL	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	OVERALL TOTAL
Animal Food	£0	£3,095	£3,234	£3,380	£3,532	£3,691	£16,932
Animal Health Products	£0	£737	£770	£805	£841	£879	£4,033
Animals/Other Costs	£0	£19,802	£20,693	£21,624	£22,597	£23,614	£108,330
Building Works	£360,659	£0	£0	£0	£0	£0	£360,659
Consumables	£0	£8,730	£9,122	£9,533	£9,962	£10,410	£47,757
Electricity	£0	£3,135	£3,276	£3,423	£3,578	£3,739	£17,151
Fuel Costs	£0	£470	£491	£514	£537	£561	£2,573
Hired and Contracted Services (Other)	£46,500	£0	£0	£0	£0	£0	£46,500
Professional Vet Services	£0	£12,005	£12,545	£13,110	£13,700	£14,316	£65,676
Professional Waste Disposal	£6,300	£6,584	£6,880	£7,189	£7,513	£7,851	£42,316
Small Equipment < £1,000	£138,475	£0	£0	£0	£0	£0	£138,475
Water Rates/Charges	£0	£3,135	£3,276	£3,423	£3,578	£3,739	£17,151
Ringling/Tagging	£0	£55,000	£56,925	£58,917	£60,979	£63,114	£294,936
ANNUAL TOTAL FOR NOMINAL	£551,934	£112,692	£117,213	£121,919	£126,816	£131,913	£1,162,487
Staff - Rearing and release	£204,101	£533,207	£551,869	£571,184	£591,176	£611,867	£3,063,403
Staff - Ringing and tagging	£0	£4,107	£4,250	£4,399	£4,553	£4,712	£22,022
Staff - Monitoring at selected ICAs	£0	£118,064	£122,196	£126,473	£130,900	£135,481	£633,114
ANNUAL TOTAL FOR STAFF	£204,101	£655,377	£678,315	£702,056	£726,628	£752,060	£3,718,539
OVERALL TOTAL	£756,034	£768,069	£795,529	£823,975	£853,444	£883,973	£4,881,026

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