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# Red-Throated Diver Energetics Project: 2021 Field Season Report

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# Summary


Offshore wind development around Europe is increasing to meet the demands for renewable energy production to help meet climate change targets. It is known that marine birds such as red-throated divers (*Gavia stellata*) are highly sensitive to disturbance caused by the construction and operation of offshore wind farms and are subsequently displaced from areas used in the non-breeding season. But the physiological, energetic and demographic consequences of such effective habitat loss is currently unknown.

This report details the fourth and final field season of the Red-throated Diver Energetics Project (https://jncc.gov.uk/our-work/rtde-project/). During 2018-2021, archival geolocator (GLS) and time depth recorder (TDR) tags were deployed and retrieved from red-throated divers breeding in Scotland, Finland and Iceland to quantify foraging behaviour and approximate non-breeding season locations. This empirical data will provide insight into the time divers spend foraging, thus providing insight into whether divers potentially have the capacity to accommodate displacement effects of offshore wind development.

During 2021, fieldwork was carried out in both Scotland and Finland. In Orkney, two tagged birds were resighted, but none were trapped. In Shetland, two tagged birds were resighted and one recaptured. A tagged bird from Shetland was also found dead in Northern Ireland in autumn 2020. In Finland, five tagged birds were resighted and two were recaptured. No tags were deployed in 2021.

Breeding success was calculated as the total number of nests producing at least one fledged chick (¾ grown) divided by the number of nests of known fate. Breeding success during summer 2021 was somewhat similar between sites, ranging from 51% in Shetland to 63% in Orkney. The success rate in Orkney was akin to the previous year, and for Shetland the success rate was comparable to that in 2018 and 2019. Breeding success metrics for Finland were unavailable at the time of writing.

If leg-mounted tags have a negative impact on divers, e.g., by increasing drag on divers' legs when diving for prey, then we would expect body condition of tagged birds to be lower in 2021, compared with when they were first tagged, after having carried tags for up to three years. Using body mass as a proxy of body condition, repeated weighing of the same individuals allows assessment of any change in body condition after carrying tags for one or more years. The mass of birds caught in 2021 was compared with the mass of when they were previously caught and tagged in either 2018 or 2019. The average difference between the two most recent years of capture was -63g, although the body mass for each bird was still above average and was well within the recorded range for this species. Detailed analysis of tagging effects was not carried out due to the small sample size of three, however it should be noted that various other factors are known to influence body mass, including sexual dimorphism, age, stage of the breeding season (and therefore date of capture) and potentially clinal variations.

From the four birds recovered dead or recaptured during the 2020/21 winter and 2021 summer, a total of three TDR and two GLS tags were retrieved. One TDR and one GLS tag had been lost, and the GLS tag was not retrieved from the dead bird. Of the three TDR tags retrieved, two recorded data into mid- or late-October and one recorded into mid-January. There was evidence of damage to two tag casings, one with subsequent water ingression, however the data was still retrievable. The cause of damage was not clear but appears to have occurred after the tags were deployed, possibly due to divers attempting to remove the tags.

GLS tag data for two consecutive years are available for two birds and one TDR tag was redeployed for two consecutive years, allowing for further novel insight into interannual variation in location and foraging behaviour.

Year 2021 was the final year of fieldwork for the RTDE project. With all data now collected, further analysis into the effects of trapping and tagging will be undertaken to inform future research with red-throated divers.

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# 1 Introduction

Recently, the UK Prime Minister set an ambitious target of 40GW of electricity generation from offshore wind in UK waters by 2030 (GOV.UK 2020). With other European countries also relying on substantial increases in offshore wind power development, offshore wind production in the North Sea is likely to reach 70GW by 2030 (WindEurope 2017). Whilst renewable energy is a vital contributor in mitigating the effects of climate change by reducing global carbon emissions, the impacts of large-scale deployment of offshore wind on marine wildlife remains unclear (Masden *et al*. 2015). Red-throated divers (*Gavia stellata*) are sensitive to disturbance caused by offshore wind farms, which leads to displacement from their foraging areas (Furness *et al.* 2013; Halley & Hopshaug 2007; Heinänen *et al.* 2020; Mendel *et al.* 2019; Percival 2014; Petersen *et al.* 2006; Welcker & Nehls 2016). However, the energetic costs and demands of this displacement on both individuals and populations are unknown. This study aims to obtain the first ever empirical evidence on red-throated divers' foraging behaviour during the non-breeding season, which will enable inference about the energetic consequences of displacement.

It is important to quantify any detrimental effects of attaching biologging devices to wild animals, particularly if the devices have not been used or their effects quantified on a species previously. As this project is the first to attach time depth recorder (TDR) devices to red-throated divers, and as the effects of attaching leg-mounted geolocator (GLS) tags to divers have not been previously quantified, we attempted to measure the effects that carrying tags may have on the divers (tag effects). Additionally, red-throated divers are highly sensitive to disturbance, so we also investigated whether there were any noticeable effects of trapping and handling the birds (trapping effects).

In 2018 and 2019, breeding red-throated divers were tagged in Scotland, Finland and Iceland with GLS and TDR tags to obtain empirical evidence on birds' locations and foraging activity during the non-breeding season. These data will allow us to infer whether red-throated divers are able to accommodate the increased energetic costs of displacement and barrier effects from offshore wind farms.

This report details the 2021 field season of the Red-throated Diver Energetics (RTDE) Project, in particular describing red-throated diver breeding success, the recapture and resighting rates of tagged divers in 2021, and it also briefly describes tag effects by looking at changes in body mass of tagged divers over multiple years of capture. For further information and for details of previous field seasons, see O'Brien *et al*. (2018), O'Brien *et al.* (2020) and Thompson *et al*. (2020).

# 2 Methods

## 2.1 Breeding success

Breeding success was monitored at nest sites of both tagged and untagged birds in Shetland (n=67) and Orkney (n=43) using methods detailed in O'Brien *et al.* (2020). Breeding success was also monitored at sites in Finland, but the data were unavailable at the time of writing. A breeding attempt was recorded at each of the monitored nest sites, i.e. at least a nest scrape was noted even if no eggs or chicks were seen. Breeding success was calculated as the total number of nests producing at least one fledged chick divided by the number of nests of known fate. A chick was assumed to have fledged once it was ¾ grown (approximately three weeks old), although further follow-up checks were not carried out to minimise disturbance.

Analysis of trapping effects on breeding success was not performed as there was no contracted fieldwork to recapture tagged birds or to monitor control nests in Finland nor Iceland in 2021, therefore the spatial coverage of this year's data is insufficient for meaningful analysis.

## 2.2 Tag deployment and retrieval

### 2.2.1 Tag deployment in 2018 and 2019

In total, 89 (Finland n=32; Scotland n=38; Iceland n=19) individual red-throated divers have been fitted with leg-mounted time depth recorder (TDR) tags (Cefas G5 Standard Time Depth Recorder) and global location sensor (GLS) tags (Biotrack/Lotek MK4083 Geolocator). Of these 89 birds, 18 individuals were caught and tagged in both 2018 and 2019 to obtain information on inter-annual variation. The 9-month TDR battery life required birds to be trapped and tags replaced each summer in order to collect data over multiple winters. Once tagged birds were caught, tags were quickly removed and morphometrics taken in line with current ringing standards to assess body condition and to determine the sex of the birds (Baker 2016): culmen length, tarsus length, wing length and body mass (see O'Brien *et al.* 2018 for more information). No tags were deployed in 2020 or 2021.

For information on tag deployment during the 2018 and 2019 breeding seasons and for details on tag retrieval methods used in 2021, see O'Brien *et al.* (2018) and O'Brien *et al.* (2020). Information on the choice of study areas and details of deployment methods are also detailed within the previous reports.

## 2.3 Tag effects

### 2.3.1 Resighting

Resighting refers to the number of divers tagged in 2018 or 2019 which were also seen in 2021. Tagged birds were first searched for at the lakes where they were previously tagged. If they were not seen at this initial breeding site, then other suitable lakes within the area were searched. Red-throated divers exhibit high survival rates (Hemmingsson & Eriksson 2002; Schmutz 2014) and typically show strong interannual nest site fidelity (Okill 1992) so we would expect the number of resightings to be high.

### 2.3.2 Tag effects on body mass

Leg-mounted tags are not thought to have a negative impact on the foraging performance of foot-propelled foragers over short time periods, however the impacts may differ when tags are attached for periods greater than one year (Ropert-Coudert *et al.* 2009). If leg-mounted tags have a negative impact on divers, e.g. by increasing drag on divers' legs when diving for prey, then we would expect body condition of tagged birds to be lower in 2021 compared with when they were first tagged, after having carried tags for up to three years (Elliott *et al.* 2012; Geen *et al.* 2019). Using body mass as a proxy of body condition, repeated weighing of the same individuals allows assessment of any change in body condition after carrying tags for one or more years.

Body mass in 2021 was compared with the body mass of each tagged bird's previous capture in either 2018 or 2019. The average and range residual of body mass was calculated for the sample (n=3). Due to the small sample size, it was not possible to perform more detailed analyses as in O'Brien *et al.* 2020 and Thompson *et al.* 2020.

# 3 Results

## 3.1 Breeding success

Breeding success was similarly good across the two sites during 2021, ranging from 51% in Shetland to 63% in Orkney (Table 1). Previously, breeding success in Orkney was 66%, 48% and 32% during 2020, 2019 and 2018 respectively, while Shetland had breeding success of 35%, 47% and 53% during 2020, 2019 and 2018 respectively (see O'Brien *et al.* 2018, O'Brien *et al.* 2020 and Thompson *et al*. 2020 for more details).

A high proportion (71.4%) of failed nesting attempts in Shetland were due to predation. Nests are deemed predated if there is evidence of either a dead chick or broken eggshell containing blood (unlike successfully hatched eggshells).

**Table 1.** Breeding success (number of successful nests (producing at least one ¾ grown chick) divided by the number of nests of known fate) in Shetland and Orkney in 2021.

| Sites | No. of nests monitored | No. of failed nests | No. of successful nests | No. nests of unknown fate | Breeding success (%) |
|---|---|---|---|---|---|
| Orkney | 43 | 14 | 24 | 5 | 63% |
| Shetland | 67 | 21 | 22 | 24 | 51% |

## 3.2 Recapture of tagged birds in 2021

The focus of this year's fieldwork was to recapture birds tagged in 2018 and 2019, in both Scotland and Finland, and retrieve any tags. One bird originally tagged in 2019 in Shetland was recovered dead on the east coast of Northern Ireland during late autumn 2020. Two birds with tags deployed in 2018 were retrapped in 2021 from Finland (n=1) and Shetland (n=1), and one bird with tags deployed in 2019 was recaptured in Finland (n=1).

## 3.3 Tag effects

### 3.3.1 Resighting

In Finland, five tagged birds were resighted and two of these were recaptured. Nest trapping attempts were not possible at the other three sites; chicks had already hatched at two sites and the third nesting site was on a raft unsuitable for placing a trap. Two tagged birds were resighted in Shetland and one was recaptured; the failed capture attempt was due to a particularly challenging site with chicks already present. In Orkney, two tagged birds were present at their original nesting sites, but recapture attempts using wader nets were unsuccessful; one nest had become an island due to erosion making trapping difficult, and at the second site an off-duty bird flushed during net-setting and neither bird returned within a suitable timeframe, so the attempt was abandoned. Adhering to NatureScot permissions, only single trapping attempts were made at each site in Orkney.

### 3.3.2 Tag effects on body mass

During 2021, three tagged birds were retrapped in Shetland (n=1) and Finland (n=2). For these three birds, the average residual of body mass in 2021 compared to their previous capture in either 2018 or 2019 was -63g (range -180g to 30g) (Table 2). For more detailed results obtained from larger sample sizes from previous years, see O'Brien et al. 2020 and Thompson et al. 2020.

**Table 2.** Body mass in 2021 and in years of previous capture. The residual of body mass is calculated as an indicator of change.

| Site | Ring no. | Sex | Date of first capture | Mass (g) | Date of second capture | Mass (g) | Date of recent capture | Mass (g) | Residual of body mass (g) |
|---|---|---|---|---|---|---|---|---|---|
| Shetland | 1173680 | F | 31/05/2018 | 1710 | - | - | 12/07/2021 | 1671 | -39 |
| Finland | GS0822 | M | 02/06/2018 | 2250 | 03/06/2019 | 2235 | 22/05/2021 | 2055 | -180 |
| Finland | GS0817 | F | 30/05/2018 | 1750 | - | - | 05/06/2021 | 1780 | 30 |

## 3.4 Tag data retrieved

Of the four tagged birds recaptured or recovered during autumn 2020 and summer 2021, one bird had retained both tags, one had lost a TDR tag, and another had lost a GLS tag. Only the TDR tag was retrieved from the dead bird, resulting in a total of two GLS and three TDR tags retrieved this season (Table 3).

**Table 3.** Tags retrieved in autumn 2020 and summer 2021. Location, unique metal ring number, year of tagging and whether birds were tagged for consecutive years, number of days from deployment that each tag continued collecting data for each year and whether the bird was trapped alive or dead are shown. Where birds were tagged and retrapped for two consecutive years, two sets of duration data have been provided. Tags which recorded for a sufficient duration to provide information on winter location/foraging behaviour of that bird are indicated by a "*". Where tags were lost, failed to record data or were not retrieved, these have been labelled as such.

| Country | Ring No. | Year of tagging | GLS duration (days) | TDR duration (days) | Trapped alive or found dead? |
|---|---|---|---|---|---|
| Shetland | 1173680 | 2018 | 672* | 152* | Alive |
| Shetland | 1173676 | 2018+2019 | Fail + not retrieved | 225*+215* | Dead |
| Finland | GS0822 | 2018+2019 | 2+716* | 220*+lost | Alive |
| Finland | GS0817 | 2018 | lost | 138* | Alive |

To provide an idea of tag duration, of the four sets of tags retrieved during the 2020 autumn and 2021 summer, those deployed in 2018 were done so during late May and those deployed in 2019 were done so in June.

Of the two GLS tags retrieved, both recorded for just under two years from deployment. Of the three TDR tags retrieved, two recorded data into mid- or late-October and one recorded into mid-January. There was evidence of damage to two TDR tag casings, one with subsequent water ingression, however the data was still retrievable. The cause of damage was not clear but appears to have occurred after the tags were deployed, possibly due to divers attempting to remove the tags.

Two birds of the total either recovered or recaptured in autumn 2020 and summer 2021 were fitted with two sets of tags over two consecutive winters (2018/19 and 2019/20). One of the birds had TDR tags that provided foraging behaviour data from each of two winters. The GLS tags from both of these birds recorded continuously for two years. Whilst a small sample size, this is further novel information on inter-annual variability in red-throated diver foraging behaviour and location that has never been obtained previously.

# 4 Discussion

## 4.1 Breeding success

Without further analysis, limited conclusions can be drawn from this season's breeding success data alone, however it is worth noting that Orkney's breeding success rate in 2021 (63%) was similar to that in 2020 (66%) which means the most recent two years have been consistently higher than both 2019 (48%) and 2018 (32%). The breeding success rate in Shetland in 2021 (50%) was considerably higher than in 2020 (35%) and more in line with the rates recorded for 2018 (47%) and 2019 (53%). A long-term average for both sites is not currently available for comparison.

Trapping effort was markedly lower in 2021, and completely absent in 2020, compared to 2018 and 2019. It could be considered that this lower rate of disturbance is a possible contribution to the higher breeding success observed during 2020 and 2021 in Orkney. However, this pattern in breeding success is not reflected in Shetland – the year of lowest breeding success was the year in which there were no trapping attempts – suggesting that either populations respond uniquely to levels of disturbance, or breeding success is more greatly influenced by other factors. Further investigation is therefore required to draw any conclusions on the impacts of trapping on breeding success.

## 4.2 Tag effects

### 4.2.1 Resighting

Red-throated divers are long-lived species, with an adult survival rate of at least 84% (Hemmingsson & Eriksson 2002; Schmutz 2014). It is also known that red-throated divers exhibit high inter-annual breeding site fidelity (Okill 1992). Therefore, we would expect the quantity of resightings of tagged birds to be similarly high. However, quantity of resightings does not necessarily represent survival rate as there are many reasons why a tagged bird may not be resighted in a given year, including asynchronous breeding phenology, moving nesting sites, skipping a breeding season (Giudici *et al*. 2010), and practical difficulties in resighting tagged birds due to both terrain and sensitivity of the species to disturbance (for further details see O'Brien *et al.* 2020). In other words, a low quantity of resightings does not necessarily equate to a low survival rate.

Seven tagged birds have been found dead during the period June 2018 to October 2020 (Finnish ringed birds n=4; Scottish ringed birds n=3). Given that a total of 89 divers were tagged during this period, this gives a very coarse estimate of mortality of 7.8% or an adult survival rate of 92.2%, which would be as expected for a long-lived species such as red-throated divers. This survival rate is a crude measure as it does not account for the actual numbers of live birds carrying tags at the point when each individual was reported dead. It also does not account for birds that died and were not found. For example, no tagged birds have been reported dead from Iceland, but this is likely due to corpses not being found rather than an absence of mortality. We have insufficient evidence to conclude whether low numbers of resightings are due to tagged birds being alive but not being seen or to higher mortality rates of tagged birds.

### 4.2.2 Body mass

Analysis in previous years suggested that there was no apparent effect of tags on body condition of red-throated divers (O'Brien *et al*. 2020; Thompson *et al.* 2020). Although there was an average residual of -63g from birds caught in 2021 after having carried tags for three years, the body mass for each bird was still above average and was well within the recorded range for this species; average body mass of a red-throated diver is around 1680g (range 1430g - 2030g) (Robinson 2005), but note that males are larger than females and clinal variations have also been observed in similar species (Gray *et al.* 2014). Other factors likely to influence body mass include age and stage of the breeding season; variation in the date of recapture between years could therefore result in apparent fluctuation in body mass. With three years of data, bird GS0822 provides an interesting insight as the first two captures were within a day of each other and body mass was very similar, however the most recent capture was a month earlier and recorded a lower body mass than the previous two years. Although inconclusive, it is suggestive of the potential importance of consistency in timing when weighing birds for comparison between years.

# 5 Conclusions and Recommendations

During this final field season, a third of all tagged birds resighted during 2021 were recaptured, bringing the total number of recaptured and recovered birds to 54 (50.47% of all birds tagged in the lifetime of the project), ten of which had been tagged over two consecutive years. This figure reflects both a phenomenal effort by field teams as well as the challenges brought about by working with red-throated divers.

This tagging study is the first of its kind to gather empirical evidence on foraging activity of red-throated divers (see Duckworth *et al.* 2020a, 2020b, 2021). Analysis on interannual variation in both winter foraging behaviour and wintering location will be performed as part of the PhD associated with the project. Unfortunately, due to small sample sizes and unavailability of data, it was not possible to perform robust statistical analyses to identify any tagging or trapping effects on the birds in this report. However, next steps are to utilise the entire dataset to identify any potential tagging or trapping effects on red-throated divers to inform future research projects with red-throated divers.

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