Red-throated diver marine SPA identification:
Data collection and analysis

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1. Background and overview

The red-throated diver (*Gavia stellata*) is listed as rare or vulnerable on Annex I of the EC Birds Directive and thus is subject to special conservation measures including the classification of Special Protection Areas (SPAs). The entire UK breeding population of red-throated diver which exists of 10 breeding territory SPAs (terrestrial) occurs in Scotland. Red-throated divers forage almost exclusively at sea during the breeding season but at present no associated marine areas are included within the SPA network.

JNCC and SNH undertook a programme of survey and data collection to establish red-throated diver use of the marine environment for foraging during the breeding season in order to inform possible marine SPA identification work. Since resource and time constraints prevented detailed surveys around all breeding areas across Scotland, a statistical modelling approach was taken which used data collected from a sub-sample of breeding areas to a) characterise the types of marine environment that is used by foraging red-throated divers, and b) use this information to identify important feeding areas around breeding locations for the species, by creating habitat models. This summary document gives an overview of the survey and analytical work carried out between 2003 and 2013. A detailed description of the analysis can be found in 'Identification of important marine areas in the UK for red-throated divers (Gavia stellata) during the breeding season'.

2. Data collection

Boat-based survey data (see Box 1 for more details) were collected over five years (2003 to 2007) around representative red-throated diver breeding territories in Shetland, Orkney, and the Outer Hebrides (North Uist). All surveys were conducted during the chick rearing period between July and August. Three study areas were defined as the seas around the breeding/nest site aggregations. Surveys aimed to record all divers present in the study areas at the time.

Box 1: Boat-based surveys

Two types of survey route were used, each designed to maximise coverage of areas expected to be used by divers based on what was known about their foraging behaviour and preferences at the time. During the surveys, two observers (one port, one starboard) used both naked eye and binoculars to detect divers to the side of the boat. The latter was used to make sure that divers reacting to the boat at larger distances were not missed. The maximum distance from the boat where observers could reliably detect divers on the water was estimated to be approximately 750m.

Survey routes covered a range of environmental conditions including depths ranging from 0 to 100m. All red-throated divers (on the water as well as in flight) were recorded alongside information on time of sighting, estimated range and bearing of the bird in relation to the boat, whether the bird was sitting or flying, and whether it was foraging or carrying a fish. The typical dive duration of red-throated divers is < 90 seconds (Cramp and Simmons, 1977), so in order to maximise the probability of detecting birds between dives the speed of the boat was maintained at approximately 14 km/h (7 – 8 knots).

The position of the boat was recorded using a Geographical Positioning System (GPS).

Information on habitat conditions across the marine area of interest was subsequently gathered from various sources to act as ‘environmental covariates’ in the habitat models. Different types of environmental data were chosen for their potential to explain the observed diver distribution. Due to a lack of information on actual prey distributions (e.g. sandeels, gadoids, or clupeids such as herring and sardine), environmental covariates which could relate to the occurrence or availability of these prey species were used instead. Examples of covariates include water depth, temperature, sediment type and distance to nearest coast (as a proxy for energetic costs of flying to a foraging area). Radio telemetry data was also collected from selected breeding individuals in the same study areas as the boat-based surveys were undertaken. Individual birds were caught in mist nets and radio-transmitter tags were attached to the bird’s tail feathers. Radio tagged birds were monitored during foraging trips and their locations at sea recorded.

3. Data preparation and analysis

Prior to analysis within the habitat models, data was prepared and processed into a suitable format. The marine area around red-throated diver breeding areas was divided into grid cells of $1km^2$. Each grid cell through which the boat survey had passed and observers had ‘looked’ for divers was included in the model. These cells were scored according to presence or absence of divers during surveys. The value of each of the environmental covariates (such as depth, temperature etc) within the grid cell was also included within the dataset.

The analysis (more detail in Box 2) compared the environment at observed diver presence locations with the environment at absence locations to characterise the kind of environment used by the divers. Once the environment that the divers use has been characterised by the analysis, we can then ‘reverse’ the analysis to search for similar environmental conditions or habitats around important diver breeding areas. In other words, based on the analysis of observed diver locations, we predict areas that other divers are likely to use, as shown in Figure 1.

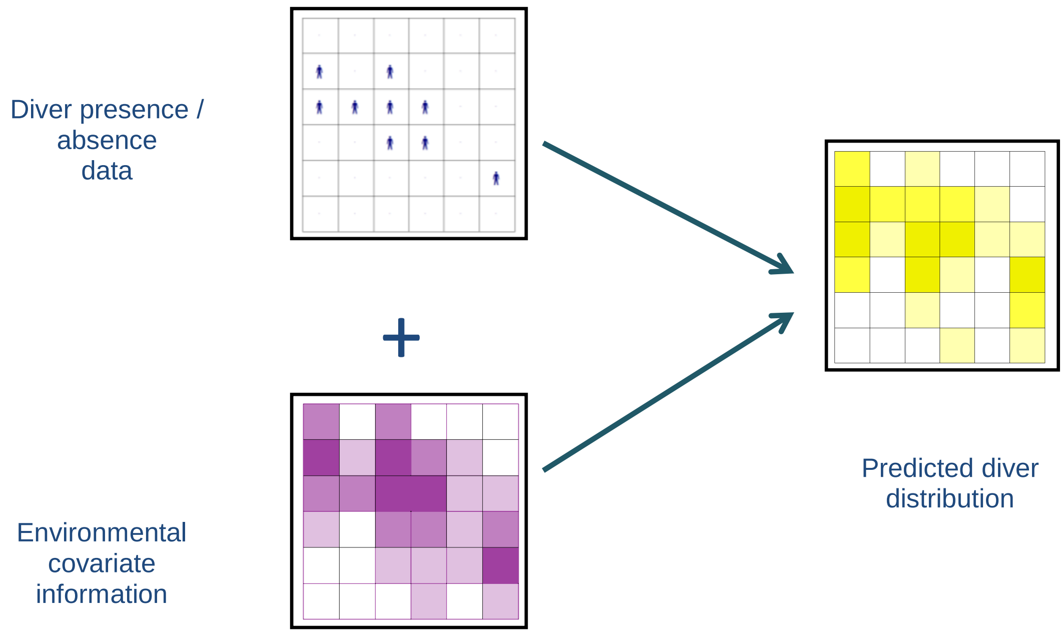

Figure 1: Simplified process of modelling diver distributions based on environmental information. The actual analysis used several different environmental covariates simulteaneously.

Box 2: Generalised Additive Modelling

Generalised Additive Modelling (GAM) was the analysis method used. Each $1km^2$ cell that was surveyed was assigned a value of either 1 (presence, diver(s) observed) or 0 (absence, no diver observed). This is the response, or dependent variable in the model. Only grid cells which were included in the boat survey observation transects were used in this part of the analysis. The analysis characterises the environment of the observed foraging locations.

A single logistic presence-absence GAM was created which used all of the survey data from all of the study areas across five years (2003-2007). Selection of which environmental covariates were included in the final model was based on a standard statistical approach which trades-off model complexity with goodness-of-fit to the underlying data. Predictions of foraging likelihood were then made across a gridded map of Scotland's marine areas based on the environmental conditions at the centre points of each 1x1km grid cell.

The final model was applied to all $1km^2$ cells in the study area in order to predict the probability of red-throated divers being present in each cell, based on the recorded values of the environmental predictor variables at those cells.

The maps created from the modelling outputs are essentially a series of grid squares, each with an associated measure of how likely the area within that square is to be used by feeding red-throated divers compared to other squares (we can call this measure a relative usage, ranging from 0-1, where 0 represents an area which is unlikely to be used by foraging red-throated divers, and 1 represents an area which is very likely to be used).

In some areas, we have knowledge about where the red-throated divers are nesting, and we know that red-throated divers tend not to forage further than 10km away from the nest site. Thus, in the areas where we have nest site information, we can measure for each grid cell at sea, how many nests are within foraging range of that grid cell. If we multiply that by the predicted relative usage for that grid cell, we can get a number which is essentially a predicted number of breeding red-throated diver pairs likely to be using that grid cell for foraging. For example, a grid cell with a relative usage value of close to 1 is expected to be used by all of the diver pairs whose nests are within 10km range of that cell. We can call this measure the nests-usage, i.e. the number of nesting birds we estimate to use a certain grid cell for foraging.

4. Boundary Delineation

There is no clear threshold in either of these values (relative-usage or nests-usage) to distinguish between 'important' and 'not important'. This kind of problem occurs in most of the marine SPA analysis JNCC has undertaken and more details on how we solved this problem can be found in 'Defining SPA boundaries at sea'. In order to identify important foraging areas for red-throated divers during the breeding season and draw a boundary around them, a cut-off or threshold value had to be found and only those grid squares with a value above this cut-off would be included within an SPA boundary. An objective and repeatable method called maximum curvature identifies such a threshold value. It indicates at what point disproportionately large areas would have to be included within the boundary to accommodate any more increase in foraging diver numbers.

As the maximum curvature technique is sensitive to the size of the area it gets applied to, the maximum curvature analysis was applied to only those grid cells which were within foraging range of at least one nest site (in areas where nest site information was known).

Finally, boundaries were then drawn around the cells exceeding the maximum curvature threshold, in as simple a way as possible. In some cases, draft SPAs will be composite sites where the most suitable territories for foraging red-throated divers have been combined into an area which is also important for other bird species, like terns or inshore wintering waterbird aggregations for example.