BSc (HONS) GEOGRAPHY, BA (HONS) GEOGRAPHY, BSc (HONS) MARINE ENVIRONMENTAL SCIENCE, BSc (HONS) ENVIRONMENTAL SCIENCE
SCHOOL OF THE ENVIRONMENT, GEOGRAPHY & GEOSCIENCES, UNIVERSITY OF PORTSMOUTH.

MODERATION BOX / OFFICE USE

COURSEWORK COVERSHEET DISSERTATION

Student Number: 926470

Title of Dissertation: The spatio-temporal distribution of common dolphin *(Delphinus delphis)* and white-beaked dolphin *(Lagenorhynchus albirostris)* within UK waters in relation to environmental change

Personal Tutor: Dr Michelle Hale

Word count: 9142

Separate Supporting document uploaded: ☐ YES ☒ NO

PLAGIARISM IS AN OFFENCE AND WILL BE PENALISED

Declaration

I, the undersigned, declare that this Independent Study, including any supporting documents also submitted, is exclusively my own work (except where the work of others is acknowledged). I give permission for this work to be photocopied, archived and made available for inter-library loan. Ethical issues associated with the research have been considered and appropriate procedures adhered to.

Electronic Signature*: Emma Chappell

** Please type your First and Last Name*

☒ I understand that checking this box constitutes a legal signature confirming that I acknowledge and agree to the above declaration.

The spatio-temporal distribution of Common dolphin *(Delphinus delphis)* and White-beaked dolphin *(Lagenorhynchus albirostris)* within UK waters in relation to environmental change

Emma Chappell

Student ID Number: 926470

BSc Marine Environmental Science

Year of Submission: 2022

School of the Environment, Geography and Geosciences

University of Portsmouth

Acknowledgements

I would like to sincerely thank my supervisor at university, Dr Michelle Hale for guiding me along the dissertation process and helping me with the challenging statistics. I would also like to send my gratitude to my external supervisor from the Sea Watch Foundation, Dr Peter Evans who provided me with the knowledge and expertise to be able to conduct this research. In addition, I would like to thank Dr Chiara Bertulli for providing me with Sea Watch's extensive datasets. I would also like to take this opportunity to thank Nuria from the GIS department who taught me the principles of mapping. Lastly, I would like to thank my family and friends for helping me through the hurdles of writing a dissertation.

Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Description
CD	Common Dolphin
WBD	White-beaked Dolphin
SST	Sea-surface Temperature
SCANS	Small Cetacean Abundance in the North Sea
SWF	Sea Watch Foundation

1. Abstract

Understanding a species' spatio-temporal distribution is a crucial part in the conservation effort of that species and the habitat in which it resides. In this study, geographical distribution maps were produced for the Common dolphin *(Delphinus delphis)* and White-beaked dolphin *(Lagenorhynchus albirostris)* in UK waters over a period of 30 years between 1990-2020. This was done in an effort to analyse if any spatial range shifts have occurred with the two species, and to what extent sea-surface temperatures have an influence on the number of sightings and individuals seen in particular regions of the UK. The result of this study confirms that spatial shifts have occurred, with decreasing White-beaked dolphins' sightings in the northern North Sea and west coast of Scotland but an increase in the number of Common dolphin sightings in the same regions. There were approximately 345 White-beaked dolphin individuals in the northern North Sea between 1995-99, whereas in 2015-20 only 77 were sighted. The habitat expansion of Common dolphins is seen along the northern coast of Scotland, as only 50 individuals were observed during 1990-2000, however, during 2015-20 there were 970 individuals in the same region. Numerous significant differences were observed between sightings and individuals with regions and years ($p<0.001$). This study's data coincides with previous literature on the possible linkage of observed individuals and increased sea-surface temperatures around the UK. It is highly likely that increased Common dolphin sightings in the North Sea are the result of habitat expansion, while the increased White-beaked dolphin sightings in the northern North Sea is due to habitat contraction amid warmer water elsewhere in the UK, with the fear of local extirpation if seawater temperature continues to rise.

2. Introduction

2.1 Cetacean species in UK waters

The United Kingdom provides habitat for an array of diversified species, including whales and dolphins, and is home to approximately 28 different species of cetaceans that have been recorded in British waters by observation programmes since 1973 (Evans and Hammond, 2004). These species include both the Odontoceti (toothed whales) and Mysticeti (baleen whales) suborders. Within those 28 species, only 15 are thought to be resident or annual visitors to the UK, and the short-beaked common dolphin *(Delphinus delphis)* and white-beaked dolphin *(Lagenorhynchus albirostris)* are two of those species (Evans et al., 2003). The other 13 commonly sighted species include 8 whales, the Humpback *(Megaptera novaeangliae)*, Fin *(Balaenoptera physalus)*, Minke *(Balaenoptera acutorostrata)*, Sperm *(Physeter macrocephalus)*, Long-finned Pilot *(Globicephala melas)*, Sei *(Balaenoptera borealis)*, Northern Bottlenose *(Hyperoodon ampullatus)* and the Killer whale *(Orcinus orca).* It also encompasses 4 dolphin species, the bottlenose *(Tursiops truncates)*, Atlantic white-sided *(Lagenorhynchus acutus)*, Risso's *(Grampus griseus)* and the Striped dolphin *(Stenella coeruleoalba)*, as well as one porpoise species, the Harbour porpoise *(Phocoena phocoena)* (Evans et al., 2003).

The UK has seen an increase in pressure for better practise of conservation management of both cetacean populations and the different habitats in which they occupy. It is therefore imperative to understand past cetacean distributions across the UK to detect if any changes in their spatial extent and habitat type have occurred, and to see if such changes are related to environmental variables such as sea-surface temperature (SST). For the purpose of this study, only the short-beaked common dolphin (hereafter referred to as common dolphin) and white-beaked dolphin sightings will be examined to distinguish their spatial and temporal distribution across the UK.

2.2. Global Distributions

The common dolphin (CD) (*Delphinus delphis*, Linnaeus, 1758) has a wide geographic range of distribution that encompasses the tropical, sub-tropical, and cool temperate waters of the Atlantic and Pacific oceans, as depicted in Figure 1 (Whale and Dolphin Conservation [WDC], *n.d*). Common dolphins are an offshore species, inhabiting the pelagic open oceans as well as coastal shelf-edge waters in both hemispheres (Perrin, 2009). They occupy waters of depths between 200-2000m and temperatures of 5-24°C, and their presence is often associated alongside continental slopes and geologic features, such as underwater seamounts and ridges (Chavex-Rosales et al, 2019; NOAA Fisheries, *n.d.*). Their persistent presence in such areas which have been modified by geological processes indicate this species prefers areas of high biological productivity relating to the upwelling of nutrients (Forcada & Hammond, 1998).

The white-beaked dolphin (WBD) (*Lagenorhynchus albirostris,* Gray 1846) is an offshore pelagic species that has a limited range of distribution which is restricted to the cold temperate and sub-arctic waters of the North Atlantic ocean in the northern hemisphere, which is shown in Figure 2 (Reid et al., 2003). Their confined geographic range extends from the shelfs off the Labrador Sea in Canada to the North Sea, and neighbouring waters to the north and west of the British Isles (Reeves et al., 1999). Their habitat preference tends to follow the continental shelf and they thrive in water that is less than 200m in depth (WDC, *n.d.*). As WBD are a cold-water species, they are only found in water temperatures <18°C but are most commonly reported in water temperatures below 13°C across areas of the North Atlantic ocean, such as the Barents Sea (MacLeod et al., 2007). Because of this, the WBD has become the most dominant neritic delphinid species found in cooler waters of the North Atlantic (MacLeod, 2013).

Figure 1 - *Global distribution of the Common dolphin (D. delphis) (WDC, n.d.)*

Figure 1- *Global distribution of the White-beaked dolphin (L. albirostris). (WDC, n.d.)*

2.3. Threats to Cetaceans

2.3.1. Rising Sea Temperatures

Worldwide, cetaceans are faced by anthropogenically induced issues and are at risk due to fluctuations in the marine ecosystems which can disrupt their normal environmental conditions. Temperature is an important component in determining global cetacean distribution, especially since all species have genetically evolved to live comfortably within their tolerable temperature regimes (Simmonds & Eliott, 2009). Although some cetacean species that are cosmopolitan with their distribution range have the ability to shift to different marine environments, this will not be possible for other cetacean species that possess a restricted geographic range (Learmonth et al., 2007). This can be said for many cold-water or subpolar cetacean species such as the Bowhead whale *(Balaena mysticetus)*, Narwhal *(Monodon monoceros)*, and White-beaked dolphin (*L. albirostris*), which all have the least opportunity for range expansion if circumstances such as temperature exceeds their natural threshold (Chambault et al., 2018; Chambault et al., 2020; Simmonds & Eliott, 2009).

2.3.2. Marine Litter

Plastic accounts for the majority of total marine litter found in the world's oceans and cetaceans are greatly affected by the global plastic crisis, approximately 66% are adversely affected by plastic pollution (Barnes et al., 2009; Fossi et al., 2018). The interactions of plastic with cetaceans are diverse due to complex paths plastics are carried across the aquatic environment, and the biochemical processes to which the plastic may be subjected (Arcangeli et al., 2021). This results in many different forms of plastic in the marine environment, from large mega plastics floating along the sea surface to bioavailable micro-sized particles of plastic (<5mm) that are inevitably ingested throughout the marine food web (Eisfield-Pierantonio et al., 2022). Mysticetes (baleen whales) are filter-feeders, such as the Blue whale *(Balaenoptera musculus)* and because they engulf large volumes of water during feeding, they are particularly prone to direct microplastic ingestion and contamination via plastic-associated toxins (Alava, 2020). Whereas Odontocetes, such as the common dolphin *(D. delphis)* ingest larger sized plastic debris because of their deep diving behaviour and feeding strategies, as well as through trophic transfer (Di Beneditto & Oliveira, 2019). Plastic ingestion could give rise to the leaching of toxic pollutants found inside the components of plastic waste, which can be fatal (Parsons et al., 2012). Entanglement by plastic affects both cetacean suborders, however, most entanglement records detail discarded fishery gear (ghost nets) as the causation (Laist, 1997). Entanglement among cetacean species can directly impair their locomotion and foraging ability which can lead to starvation in individuals (Cassoff et al., 2011). The entanglement itself can result in lethal injuries on the organism, reducing its survivability through physical trauma, physiological stress, and reduced manoeuvrability, resulting in compromised health and reproductivity, reduced energy assimilation and circulation, and entailing mortality (Senko et al., 2020).

2.3.3. Bycatch

Bycatch is defined as the unintentional catch of non-target marine species while trying to catch another type of commercially valuable fish (Marine Stewardship Council, *n.d.*). Bycatch appears to be one of the main threats that critically endangered cetacean species face in the 21st century, and it heavily contributed to the extinction of the Baiji dolphin *(Lipotes vexillifer)* and the near extinct Vaquita porpoise *(Phocoena* *sinus)* (Brownell et al., 2019). Although bycatch causes detrimental effects to numerous marine faunae, it is concerning for cetacean species due to their specific life history strategies. Their low fecundity, late maturity and slow population growth signals that cetacean species would be adversely impacted by this anthropogenically induced issue (Peltier et al., 2016). In terms of the two delphinids this study is focusing on; bycatch rates vary considerably between the species. In the North-Eastern Atlantic ocean, more than 1000 common dolphins *(D. delphis)* are bycaught annually in pelagic trawl nets (Mannocci et al., 2012). Whereas with White-beaked dolphins *(L. albirostris)*, there is little evidence to suggest large numbers are being bycaught in North Atlantic fisheries (Morizur et al., 1999).

2.4. The Sea Watch Foundation and Citizen Science

The Sea Watch Foundation (https://www.seawatchfoundation.org.uk) is a national marine environmental charity dedicated to the conservation of cetacean species around the UK. Their mission is to monitor the quantity and localities of whales and dolphins sighted in the UK to gain knowledge of the health of the marine environment. They achieve this from their continuous research programmes and active monitoring which delivers vital information on changes to the status and distribution of many cetacean populations and the conditions of their habitats. Their network of volunteer scientists (citizen scientists) allows Sea Watch to raise awareness of any potential concerns and prompt environmental change to aid in the conservation of marine mammals in the UK. Large amounts of sightings data have been previously collected by Sea Watch volunteers, of which contains both effort related sightings and presence-only sightings, which both fall under the umbrella of citizen science.

Citizen science can be defined as the commitment of volunteers who participate in scientific research by collecting and recording data, it is also commonly referred to as community science. It enlists the public, who are not formally trained scientists with assembling large quantities of raw data across a given period (Bonney et al., 2009; Roy et al., 2012). Citizen science has been used in an array of research projects and has been successful in advancing scientific knowledge on certain topics (Bonney et al., 2009). In terms of biodiversity science, it has become a useful tool due to its ability to equip data at broad spatio-temporal scales (Burgess et al., 2017) needed to address global conservation issues, and allows the public to engage with decision-makers (see Appendix 1). An array of ecological criteria can be measured efficiently with citizen science programmes which have gathered large-scale data on species distribution and population abundance (Chandler et al., 2017). Citizen science plays a key educational role in communities, whereby the active participation in scientific surveys by volunteers increases their scientific literacy and encourages communities to learn and engage with their local environment (Conrad & Hilchey, 2011). Citizen science allows opportunities to collect information that would otherwise by unlikely to gather due to limitations on time and resources (Kobori et al., 2016). It's cost-effective approach with potential for large volumes of data to be produced entices decision makers and non-government organisations (NGOs) to use such programmes to enhance their capability with managing and monitoring natural resources.

Although volunteer-based surveying programmes can yield successful data, especially in data-poor regions, there can be limitations involved with using citizen science. Firstly, a main challenge is the quality of the data generated by volunteers can be questionable, with an emphasis on the accuracy and validity of the data (Thornhill et al., 2016). In addition, some citizen science programmes are opportunistic and are therefore not specifically aimed at closing knowledge gaps (Amano et al., 2016). A limiting factor of successful citizen science could be the capability of volunteers to meaningfully contribute to scientific research, as some projects require extensive specialised knowledge, methods and equipment that make using citizen science an impractical approach. The inclusion of citizen science data can cause inconsistencies associated with sampling bias; however, this can be reduced if observers are using standardised protocols e.g., defined route transects on a vessel survey (Mueller et al., 2019).

3. Literature Review

To fully understand the dynamics of Common dolphin *(D. delphis)* and White-beaked dolphin *(L. albirostris)* in the UK, it is imperative to investigate past studies which have added to the cumulative pool of knowledge about these two species. This section will therefore aim to set this research project in the context of wider literature by reviewing key information about the fundamental genetics, morphology, and behaviour and feeding ecology of both delphinid species. As the study area of this project is UK waters, species distribution and habitat preference will be synthesised along with human activity and sea-surface temperature in relation to both species' distribution. This section will finish with a concluding summary of the key information that has been deuced from the literature used.

3.1 Common Dolphin (*Delphinus delphis*, Linnaeus, 1758)

3.1.1 Taxonomy

The Common dolphin *(D. delphis)* is from the order Cetacea and belongs in the suborder Odonoceti which denotes the 'toothed' whales and dolphins. This suborder comprises of 10 families, the largest of which is the Delphinidae which includes 37 species (The Society for Marine Mammalogy, *n.d.*). There has been prior controversy over the taxonomic classification of species within the Delphinus genera. During the 1990s, it was thought that there were two distinct species of common dolphin, the short-beaked *(D. delphis)* and long-beaked *(D. capensis)* (Heyning and Perrin, 1994). Heyning and Perrin's (1994) theory was based on the species' external morphological characteristics e.g., body size and skeletal features such as rostrum length and tooth counts. However, their theory has been heavily challenged among geneticists who now believe both *D. delphis* and *D. capensis* are not sufficiently differentiated to be coherently recognised as two separate species, and that the putative *D. capensis* is polyphyletic and their differing regional ecology to *D. delphis* caused their dissimilar features e.g., a longer rostrum (Evans, 2020; Natoli et al., 2005; The Society of Marine Mammalogy, *n.d.).* There are three other subspecies of Common dolphin, the Indo-Pacific (*D. d. tropicalis),* the Eastern North Pacific long-beaked (*D. d.*

bairdii) and the Black Sea *(D. d. ponticus* (The International Whaling Commission [IWC], *n.d.*).

3.1.2 Morphology

The Common dolphin is a small sized delphinid with a fusiform and streamlined shaped body that allows them to travel fast when swimming. They range in lengths between 2.1 – 2.4 metres and can weigh up to 85 kg (Sea Watch Foundation, 2007). There is sexual size dimorphism between sexes, with males typically measuring longer and heavier than females (Murphy and Rogan, 2006). CDs are slender and have a dark grey colouration with a white underside and the distinctive hourglass pattern on its lower flank, with a yellow-tan shade that stretches from the face to the dorsal fin, and grey behind (Sea Watch Foundation, 2007; The Wildlife Trusts, *n.d.*). They have dark patches surrounding each eye and a well-defined crease between its forehead and beak (Figure 3).

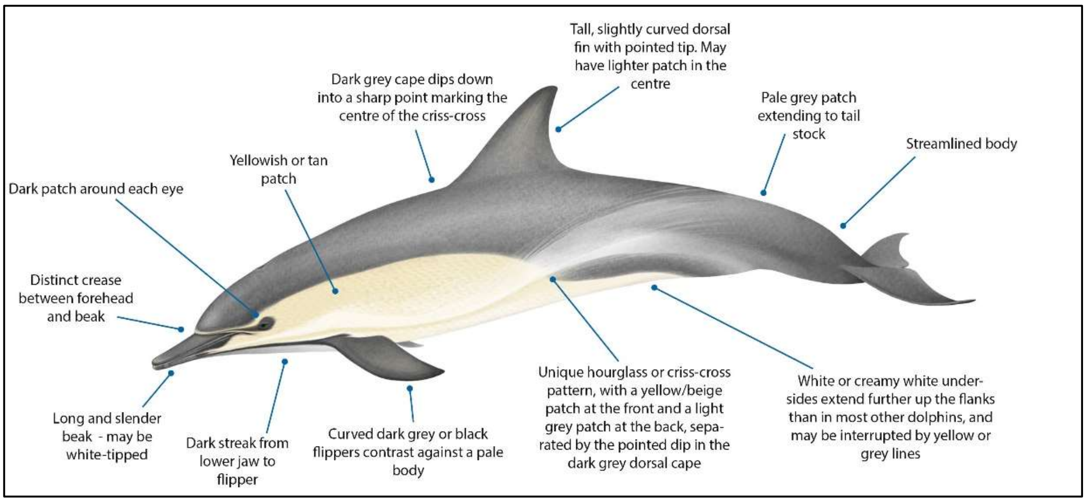


Figure 2*- An illustration of the morphological features of a D. delphis (IWC, n.d.)*

3.1.3 UK Distribution and abundance

Common dolphins have become the most numerous cetacean species in the North-East Atlantic and can be seen all-year round in the temperate waters of the British Isles. Their distribution is mainly concentrated around the continental slopes in the Celtic and Irish Sea but are seen further south-west towards the Bay of Biscay and Iberian Peninsula. CDs have also been repeatedly reported in the Hebrides Sea during summer seasons and occasional sightings in the North Sea (Reid et al., 2003). There have been numerous cetacean abundance surveys across the North-East Atlantic, such as the Small Cetacean Abundance in the North Sea and adjacent waters survey (SCANS) which combine aerial and vessel observations. The fist SCANS survey (Appendix 2) was undertaken in 1994 by Hammond et al., (2002) and recorded an abundance of 75,450 *D. delphis,* which were found exclusively in the Celtic Sea. SCANS II survey in 2005 (Appendix 3) carried out by Hammond et al., (2013) observed an estimated abundance of 56, 221 of *D. delphis.* The most recent SCANS III survey (Appendix 4) was conducted in 2016 by Hammond et al., (2017) and had an estimated abundance of 468,000 *D. delphis*. These results indicate an increasing abundance of CDs; however, SCANS surveys are conducted on a decadal scale and take place in July. It should be recognised that SCANS surveys only facilitate a snapshot of cetacean distribution (Hague et al., 2020).

3.1.4 Diet and Feeding Ecology

Common dolphins are opportunistic feeders and have a wide-ranging diet (Sea Watch Foundation, 2007). Their prey focuses on small aggregating species in the epipelagic layer, usually this entails groups of schooling fish e.g., mackerel and hake. Brophy et al., (2009) from analysing the stomach contents of stranded neritic *D. delphis*, found that teleost fish are the most important prey taxa and comprised 95% of their diet, followed closely by cephalopods e.g., the European Squid *(Loligo vulgaris)* which incorporated 5% of their stomach content. In contrast, similar studies with stranded oceanic *D. delphis* found that they consumed migrating mesopelagic myctophids e.g., Madeira lantern fish (*Ceratoscopelus maderensis*) (Spitz et al., 2010). Although both exhibit similar prey profiles, their diet content reflects the local availability and abundance of different prey species in their habitat (Young and Cockcroft, 1994).

Common dolphins exhibit an array of feeding strategies used to prey upon shoals of fish and other aquatic fauna. Techniques can involve cooperative feeding whereby a pod will energetically herd fish to cause panic and confusion, allowing for easy prey selection (Sea Watch Foundation, 2007). CDs can pertain in high-speed pursuits chasing down species, and other feeding strategies can consist of 'kerpluncking' meaning high velocity tail movement on the water's surface, and 'fish whacking', whereby prey is hit with their powerful fluke (Murphy et al., 2013). Other adapted foraging abilities include highly coordinated incursions such as line abreast, carouselling, synchronous diving and bubble-blowing which startles and confuses shoaling fish (Murphy et al., 2013). Many of the CDs feeding strategies attracts other cetacean species. Evans, (1982) argued that the herding of shoaling fish into compact bait balls increases inter-specific aggregations of other cetacean species and diving seabirds such as gannets because of concentrated shared prey at the surface.

3.1.5 Behavioural Ecology and Sociability

Common dolphins can be in large active groups that can consist of hundreds of individuals, however in the British Isles, CDs are mostly observed in groups of less than 30 (Evans, 1994). They can occur both solitarily and in pairs, although this increases during mid- summer and mid-winter and linked to prey species advancing inshore (Forcada et al., 1990; Sea Watch Foundation, 2007). CDs are highly sociable and energetic marine mammals, their various feeding strategies stipulates a high degree of behavioural plasticity among groups (Neumann and Orams, 2010). They rely on echolocation to detect prey whereby short-burst clicks ranging from 23-100 kHz are emitted from nasal passages which are passed through their melon and allows effective hunting and navigation in low visibility conditions (Henderson et al., 2011). Vocalisations e.g., whistles are frequency modulated and are used for communicational purposes between and within pods, some variations of whistles may have harmonic structure (Richardson et al., 1995). CDs have an average lifespan on 35 years, and individuals become sexually mature between 5-12 years. Their gestation period is 10-11 months and after birth, the calf is dependent on its mother for a year (NOAA Fisheries, *n.d.*).

3.2 White-beaked Dolphin (*Lagenorhynchus albirostris),* Gray 1846)

3.2.1 Taxonomy

The white-beaked dolphin *(L. albirostris)* is also from the order Cetacea and suborder Odonoceti, and likewise to *D. delphis,* are taxonomically in the same family of Delphinidae. The white-beaked dolphin belongs to the genera of *Lagenorhynchus,* of which there are 7 different species. Other than *L. albirostris,* it includes Fraser's dolphin *(L. hosei)*, Atlantic white-sided dolphin *(L. actus)*, Hourglass dolphin *(L. cruciger)*, Peale's dolphin *(L. australis)*, Dusky dolphin *(L. obscurus)* and the Pacific white-sided dolphin *(L. obliquidens)* (The Society of Marine Mammalogy, *n.d*.).

3.2.2 Morphology

White-beaked dolphins are a medium sized delphinid, with lengths ranging between 2.5-3.1 metres and can weigh from 180-350 kg (NOAA Fisheries, *n.d.*; Sea Watch Foundation, *n.d*.). Likewise to CDs, adult males are sexually dimorphic as they are typically larger in size than females, however both sexes have a streamlined torpedo shaped body shape (Kinze, 2002). WBDs have black colouration with a distinct light grey swathe extending from their flanks to their tail stock (Figure 4). As their name suggest, they usually have a short 5-8cm white beak, however some species naturally lack this feature (WDC, *n.d*.). Both fins are large and robust, their dorsal fin is centrally positioned and described as sickle-shaped (The Mammal Society, *n.d*).

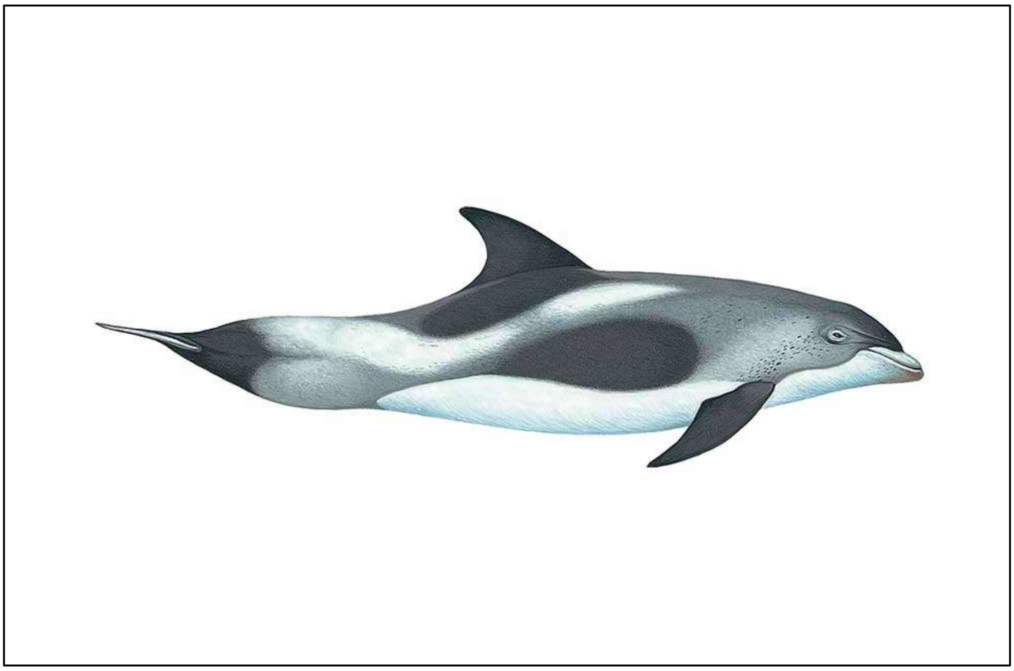


Figure 3- *Illustration of a White-Beaked dolphin (L. albirostris) (The Hebridean Whale & Dolphin Trust [HWDT], n.d.)*

3.2.3 <u>UK Distribution and Abundance</u>

The white-beaked dolphin is the most customary delphinid species of the northern European continental shelf. European waters alone accommodate between 50% to 75% of the global population of WBD (MacLeod, 2013). In the British Isles, they are predominantly seen in the northern and central North Sea with frequent sightings around the Shetland and Orkney Islands (Reid and Evans, 2003). Although WBDs can be seen year-round in the UK, peak numbers are observed between June-October, with highest abundance recorded during the month of August (Sea Watch Foundation, 2007). Brereton et al., (2013) discovered a small rare WBD population off Lyme Bay, Dorset in the western English Channel. Sightings data collected by MARINElife indicated ~200 individuals present which allows Lyme Bay to be nationally recognised as an important hotspot for WBDs. Large abundance surveys such as SCANS gave decadal estimations of White-beaked dolphins across the North Sea and surrounding continental shelf waters. In the first SCANS (1994) (Appendix 2) there were 7,856 reported WBD individuals found in the North Sea and northern Scotland (MacLeod, 2013). SCANS II (2005) (Appendix 3) generated an estimated abundance of 22,664 WBD individuals, with more occurring off the west of Scotland (Hammond et al., 2013). SCANS III (2016) recorded 36,287 individuals across the survey area (Appendix 4) (Hammond et al., 2021). Although large surveys like SCANS provide valuable abundance information about our native cetacean species in the UK, there are some uncertainties over this data. This can be said with SCANS II whereby abundances for WBDs were overestimated and produced invalid results relating to off the west of Scotland (MacLeod, 2013).

3.2.4 Diet and Feeding Ecology

White-beaked dolphins consume a variety of prey and are flexible predators when it comes to prey selection (Fall and Skern-Mauritzen, 2014). Carrying out a post-mortem on stranded WBDs along the British coast allows scientists to determine different factors, one of which is stomach content analysis. Canning et al., (2008) conducted dietary analysis on 22 WBDs that became stranded on the east and west coasts as well as on the northern isles of Scotland. Similarly to CDs, WBDS are opportunistic feeders and teleost fish represent more than 95% of WBDs diet. The most important prey taxa were identified as Haddock *(Melanogrammus aeglefinus)* comprising 43% of weight and Whiting *(Merlangius merlangus)* with 24% (Canning et al., 2008). Other than bottom-dwelling fish, WBDs also like to consume schooling fish e.g., Greater Sandeels *(Hyperoplus lanceolatus)*, cephalopods, benthic crustaceans, and some molluscs (NOAA Fisheries, *n.d.*). Compared to epipelagic predators like CDs, WBDs primarily for demersal species, consuming prey that live near or on the seabed (Weir et al., 2009). WBDs demonstrate different foraging strategies to CDs due to the nature of their prey's habitat. Pods will repeatedly dive to the bottom seabed in varying directions in one location (Bearzi, 2007).

3.2.5 Behavioural Ecology and Sociability

White-beaked dolphins can be seen in pod sizes exceeding several hundred individuals, however in UK waters it is common for pods to be made up of 10 or less individuals (Sea Watch Foundation, 2007). Although somewhat elusive, WBDs are likely to bow ride vessels and are extremely active fast swimmers with an average swim rate of 1.69 m/s (Simard and Gowans, 2008). WBDs have been observed interacting with other groups of cetaceans such as White-sided dolphins *(L. actus)* and feeding in the same area as baleen whales (NOAA Fisheries, *n.d.*). Haelters and Everaarts, (2011) discussed that the object-orientated playfulness and investigative behaviour of WBDs could be the cause of rake marks witnessed on other small cetacean species such as the Harbour porpoise *(Phocena phocena)* in the south North Sea. Little information is known about the life history or lifespan of WBDs, mating is thought to occur during spring and summer months and calves arriving 11 months later (Sea Watch Foundation, 2007). Canning et al., (2008) proposed the notion that female WBDs move inshore to give birth as coastal waters provide greater protection to the mothers with plentiful prey available, and male WBDs follow the females to mate after they have calved (Canning et al., 2008). WBDs, like CDs are highly sociable with each other and produce whistles with frequencies of 35kHz, and clicks of 115kHz (Rasmussen and Miller, 2002).

3.3 Human Activity

Although there are numerous anthropogenic issues affecting both species, the following issues will be examined:

- Underwater noise
- Sea-surface temperatures

3.3.1 Underwater Acoustic Pollution

Underwater noise pollution has become an increasing problem and a dangerous threat to cetaceans. All cetaceans have a heavy reliance on acoustics for navigation, communication, hunting, and reproduction due to their other senses e.g., vision being severely limited (Simmonds et al., 2014). Each year more than 60,000 vessels contribute to underwater noise and global vessel traffic has shown a fourfold increase since 1992 (Nabi et al., 2018; Tournadre, 2014). In addition, prior to the COVID-19 lockdowns, the tourism cruise ship industry was receiving millions of new passengers every year (Figure 5). Underwater noise from human activity is a new concept within the marine ecosystem, and its increasing pressure on the marine environment makes it challenging for cetacean species to genetically adapt to these new changes (Nabi et al., 2018). Underwater noise sources such as military sonar and wind farm construction can disrupt the behaviour of cetaceans, and the potential of chronic exposure can induce hearing impairment or loss (Harris et al., 2017; Madson et al., 2003). In terms of delphinid species, Erbe et al., (2019) suggests that vessel noise alters movement patterns with species increasing their speed or changing direction when approached by vessels. This in turn causes a shift in the species' behavioural budget, as more time is spent travelling with a decrease in resting and socialising (Erbe et al., 2019). Underwater acoustic noise has also caused dolphin whistle characteristics to alter, increased cortisol (stress) levels, changes in dive duration and surfacing, as well as avoiding or abandoning areas (ASCROBANS, 2018; Nabi et al., 2018). The operational and planned offshore wind farms in the UK are concentrated in the North Sea (Figure 6), covering the habitat range of WBDs. Long-term, it is thought that persistent exposure to ambient noise can suppress reproduction in marine mammals (Wright et al., 2007).

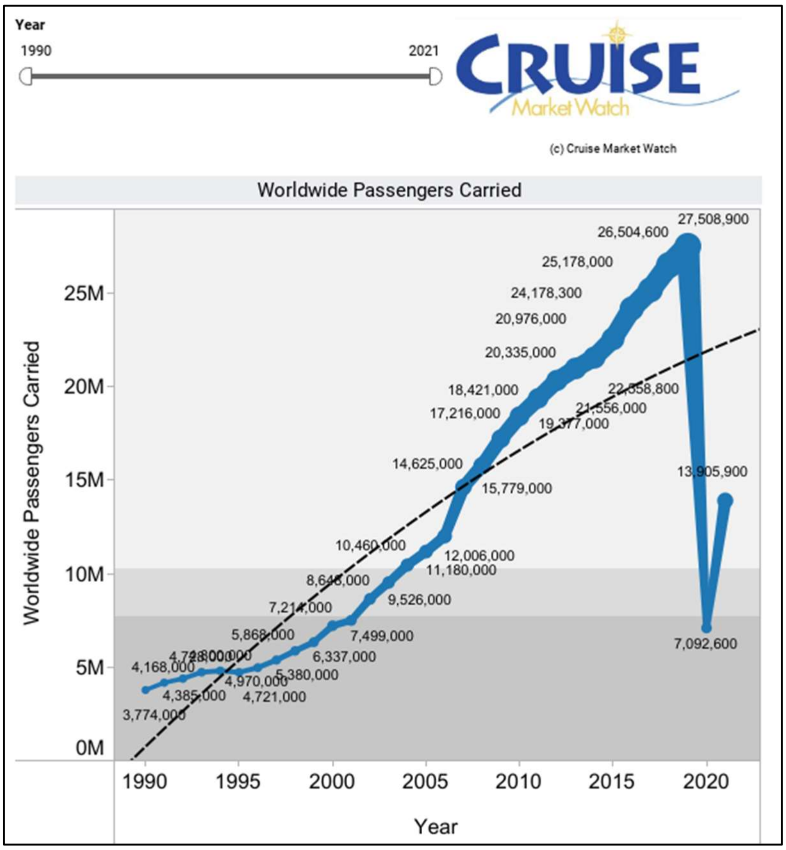


Figure 5- The number of worldwide passengers carried on cruise ships since 1990-2021 (Cruise Market Watch, n.d.)

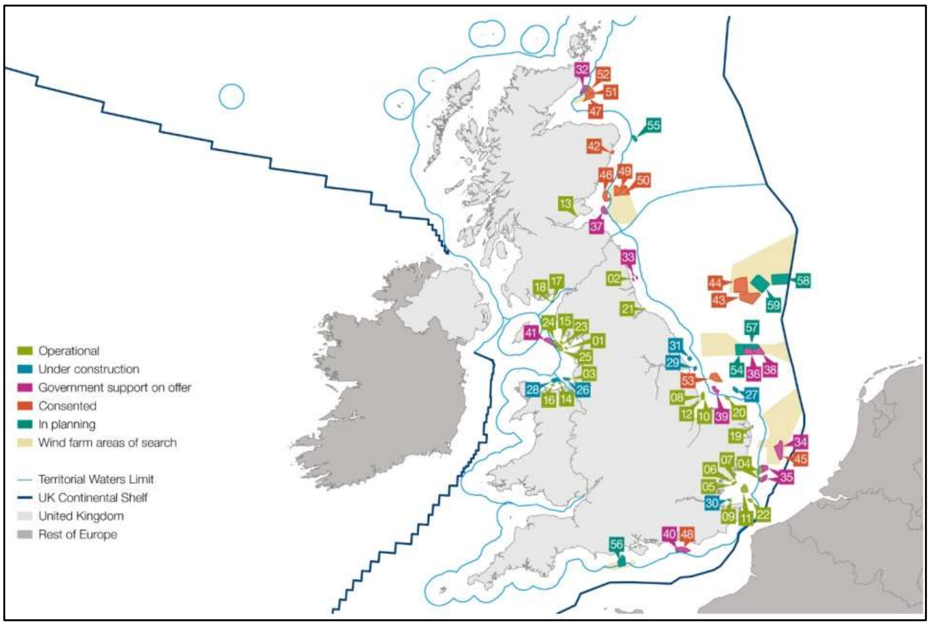


Figure 6- *UK map of operational and proposed planned offshore wind farms (Department for International Trade, 2015).*

3.3.2 <u>Sea-Surface Temperatures</u>

Global sea-surface temperatures (SST) have risen by 0.13°C per decade over the last century (International Union for Conservation of Nature [ICUN], *n.d.*). In UK waters, there is a consistent warming trend and SST have increased by 0.8°C since 1870 (Genner et al., 2017). These climate change induced SST, if continuous with rising, will cause shifts in species' range of distribution (Weelden et al., 2021). This has been observed with WBDs and CDs in the UK. Evans and Waggit, (2020) found that there has been a downward trend of WBD abundance over the last 30 years, whereas CD abundance has increased. MacLeod et al., (2005) examined the changes in the relative strandings and sighting frequencies of both species along northwest Scotland and determined that both are consistent with the hypothesised outcome in cetacean community changes with increased sea-surface temperatures. Therefore, due to the increased warming of the seas, there has been a decline in the occurrence of cold-water species and a subsequent increase in the occurrence of warm-water species (MacLeod et al., 2005). Increased SST has also caused the addition of new cetacean species e.g., the striped dolphin (*Stenella coeruleoalba*) that are expanding their shelf sea range into the northern North Sea (Evans and Bjørge, 2013).

To summarise, this project has acknowledged and synthesised the key literature that is relevant to this study. The fundamental background information of both species was examined in depth, and the understanding of how human activities effect the species, their behavioural ecology, and the marine environment in which they live in was explored. It is clear that both species are prevalent in UK waters from SCANs survey results and exhibit different spatial ranges to one another. In addition, both species have similar diets, however their feeding strategies differ slightly to one another. It is also evident from the literature that SST has some effect on both species and can be possibly linked to their distributional range.

4. Hypotheses and Aims

The main research hypothesis of this project is that the total number of sightings and individuals of a species is an effective method of determining its spatio-temporal distribution and relative abundance over time.

The primary aim of this study is to quantify and map the distribution of CD & WBD in the UK between 1990-2020 in order to determine if both species exhibit consistently different spatial ranges over a 30-year temporal scale.

Other project aims:

- ❖ To determine temporal changes in the distribution and abundance of CD & WBD between 1990-2020.
- ❖ To understand if there is a relationship between total effort watch hours and the total number of CD & WBD sightings.
- ❖ To determine by comparative literature if sea-surface temperatures influence CD & WBD presence in UK waters.
- ❖ To identify areas that may be of interest to conservation where noticeable shifts in CD & WBD distribution have occurred.

5. Rationale of the Study

The use of geographical distribution models is imperative for understanding where certain species are inhabiting and to what extent their spatial range covers. The mapping of species sightings over a large temporal scale can highlight if there are any differences in their frequency or abundance. Although these geographical models are sensitive to the survey approach, they can be a good representative of species distribution for a set time period in space which can go on to help inform decisions-making processes about designating protected areas and influence UK policy.

6. Methodology

6.1 Data Selection

The citizen science data used for my project was supplied on behalf of the Sea Watch Foundation [SWF]. Their sightings database contained a variety of information associated with each sighting of a particular species, however for this project only WBD and CD sightings from 1990-2020 were chosen with their relating latitude and longitude values, in addition to estimated group size (individuals). The database contains both effort related sightings and presence-only sightings. Effort sightings are those collected from a coordinated scientific timed effort watch e.g., land or vessel surveys, and allow corrections for biases of coverage. At each sighting, the time, date, latitude, longitude, descriptions, and environmental conditions (e.g., Beaufort Sea state) are recorded (Appendix 8). Presence-only sightings which are the ‘casual’ sightings are those that contain no effort.

For this project, only effort-related sightings with the unit of effort will be used for the data and statistical analysis, however due to the patchiness associated with the data in determining long-term spatio-temporal trends, the casual sightings of both species will be used to support and back up the effort sightings data in the form of ratios and maps. The potential biases surrounding the inclusion of casual sightings are minimised due to the large size of the data, and only casual sightings with a definite for species ID by the observer (public) was used.

6.2 <u>Data Organisation</u>

The data was cleaned and organised into a format that would allow for GIS maps to be generated and for statistical testing to be undertaken. Sightings that contained anomalies were removed, e.g., coordinates that were outside of UK waters or on land. Repetitions of sightings were also removed to improve the validity of the results.

6.3 <u>Study Area</u>

The study area consisted primarily of continental shelf waters around the British Isles, between latitudes of 48°N and 61°N. The data was categorised into six regional boundaries based on the existing SWF regions, as listed below, and shown in Figure 7.

- ❖ Region 1= Celtic Deep
- ❖ Region 2= Irish Sea
- ❖ Region 3= North-East Atlantic
- ❖ Region 4= North Sea (N)
- ❖ Region 5= North Sea (S)
- ❖ Region 6= English Channel

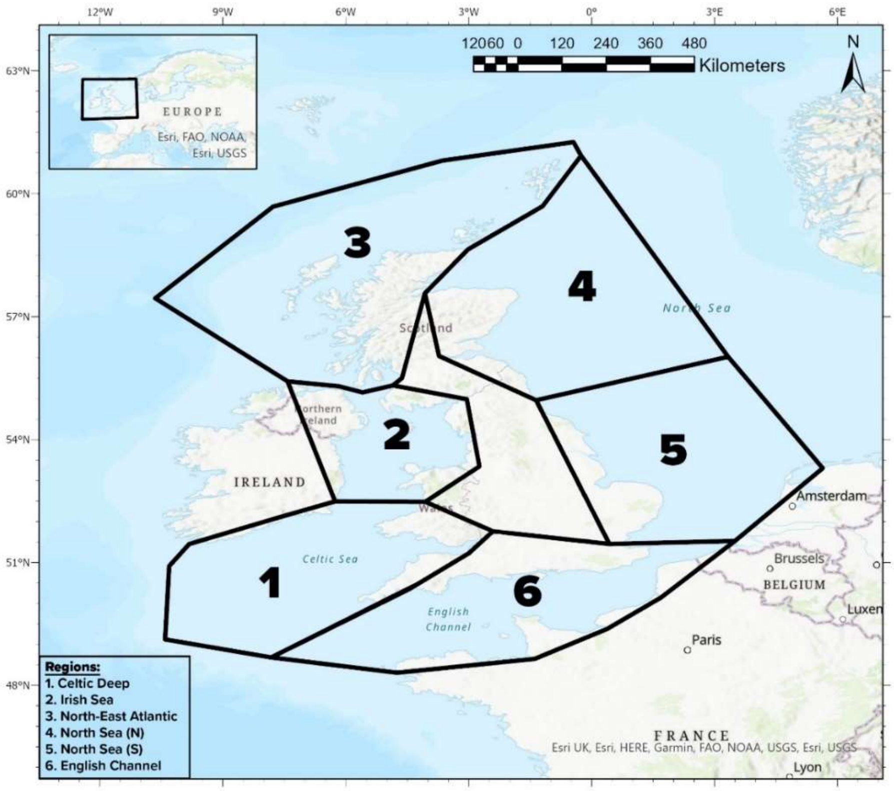


***Figure 7**- Regional boundaries map (created in ArcGIS Pro).*

6.4 Data Analysis

Due to the size of the dataset, the 30-year sightings (1990-2020) were split into 6-year bin codes for every 5 years, except year bin 6 which has 6 years (2015-2020). This was done so that during analyses, it would be easier to read the results and draw conclusions. The 30-year data was grouped into the following.

Year Bin Codes:

- 1 = 1990 – 1994
- 2 = 1995 – 1999
- 3 = 2000 – 2004
- 4 = 2005 – 2009
- 5 = 2010 – 2014
- 6 = 2015 – 2020

The total sightings of both species and number of individuals were quantified in respect to the regions and years, with their associated medians and ranges. The total minutes of effort watch was calculated and converted into hours so that a sighting per hour could be calculated for each species, for each year of the study (1990-2020). A total of ten GIS maps was be produced to illustrate both CD & WBD distributions around the UK. Six of these maps will contain the effort sightings for both species for each year bin, and another map with the total effort sightings for all years. In addition, the other three maps will contain the casual sightings to support the effort data findings, as well as casual sighting ratio for both species. External literature will be used to compare the sightings data with SST values for the UK.

6.5 Statistical Testing

Statistical testing was carried out in SPSS v.28 and the data was tested for normality with a Kolmogorov- Smirnoff test, and the use of a non-parametric test was best suited to statistically analyse the data. A Kruskal Wallis test was undertaken to see if there were any differences between all the variables. In addition, post-hoc testing with Mann Whitney-U tests was carried out to see where the differences were from pairwise comparisons with both species' number of sightings, number of individuals with years and regions. Because non-parametric tests do not generate as powerful results as parametric tests do, the significance value was automatically adjusted with Bonferroni corrections to minimise this gap (Appendix 9). The relationship between total effort watch (hrs) and sighting per hour was examined by running a Spearman's' correlation coefficient. Descriptive statistics were conducted to get the mean, median and ranges of the species analysed.

7. Results

7.1 GIS Effort Distribution Maps

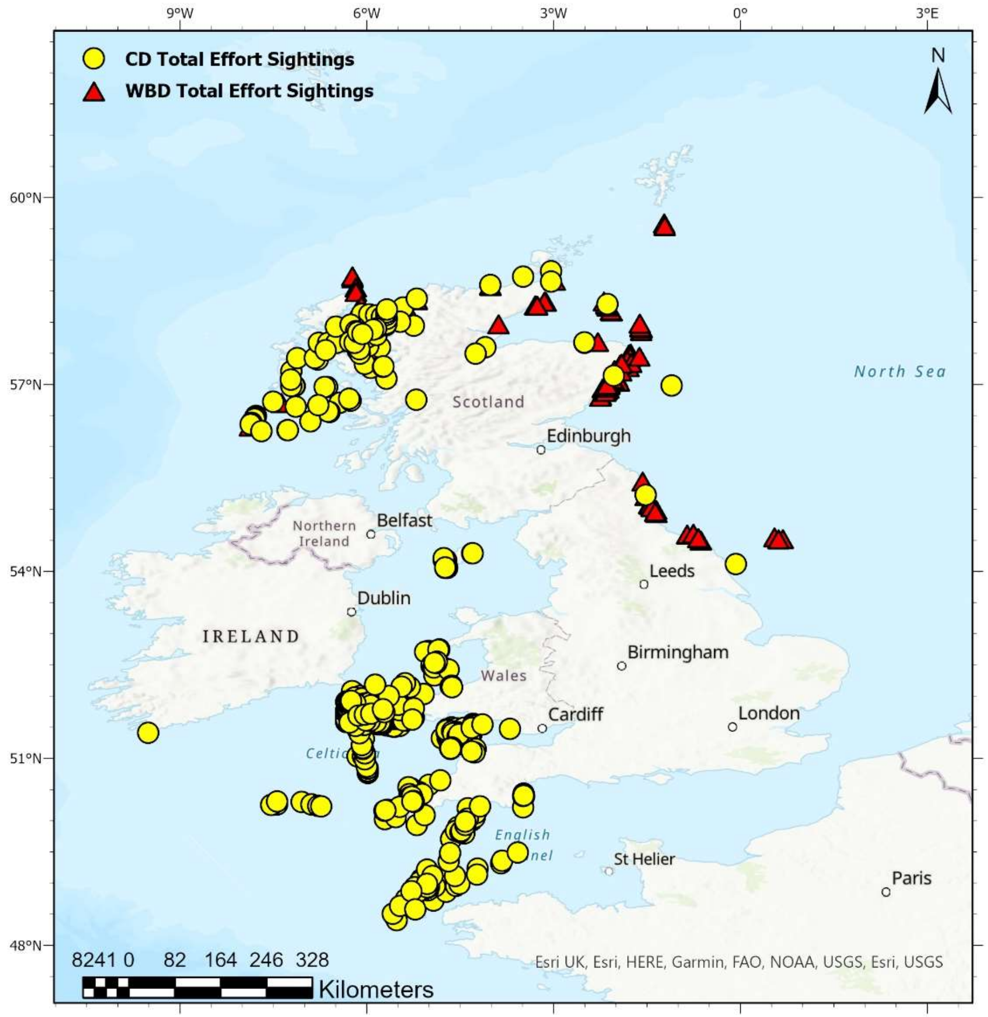


Figure 8- *Total effort sightings for both species between 1990-2020.*

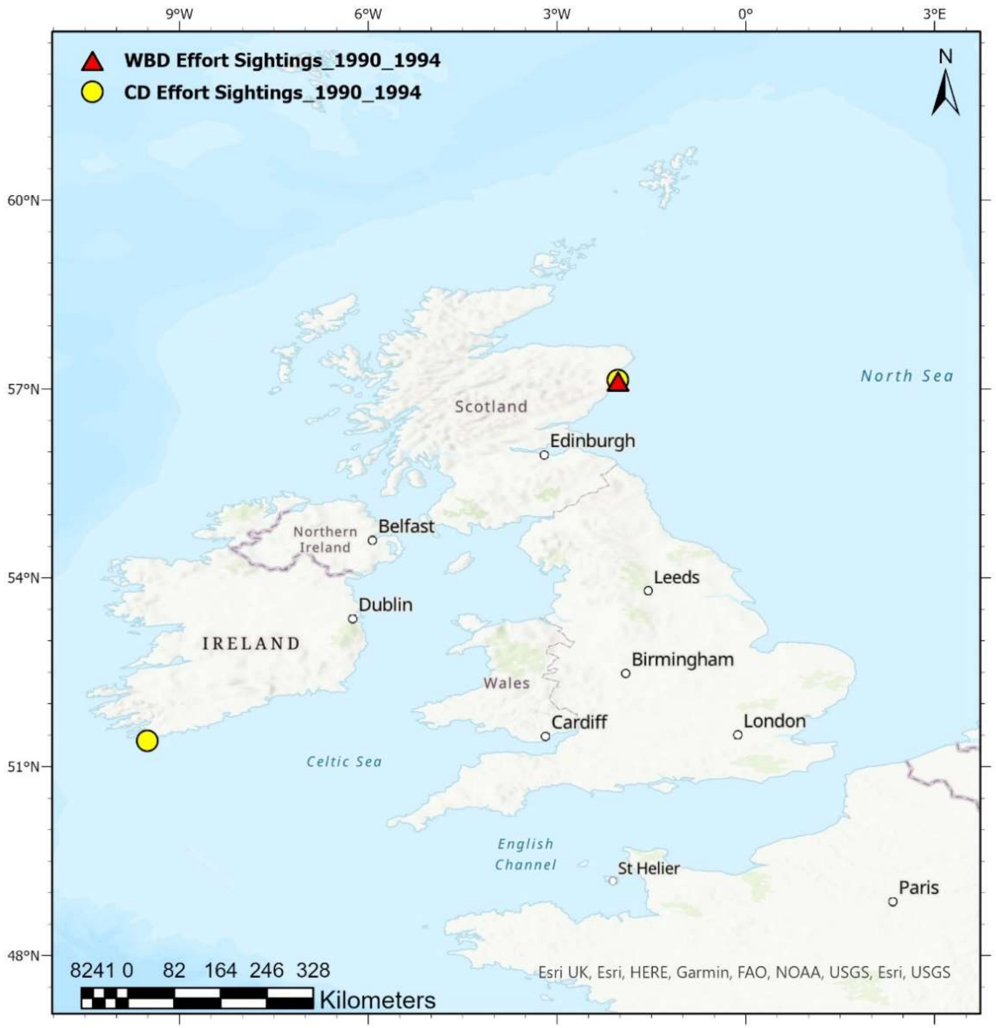


Figure 9- *Effort sightings for both species between 1990-1994.*

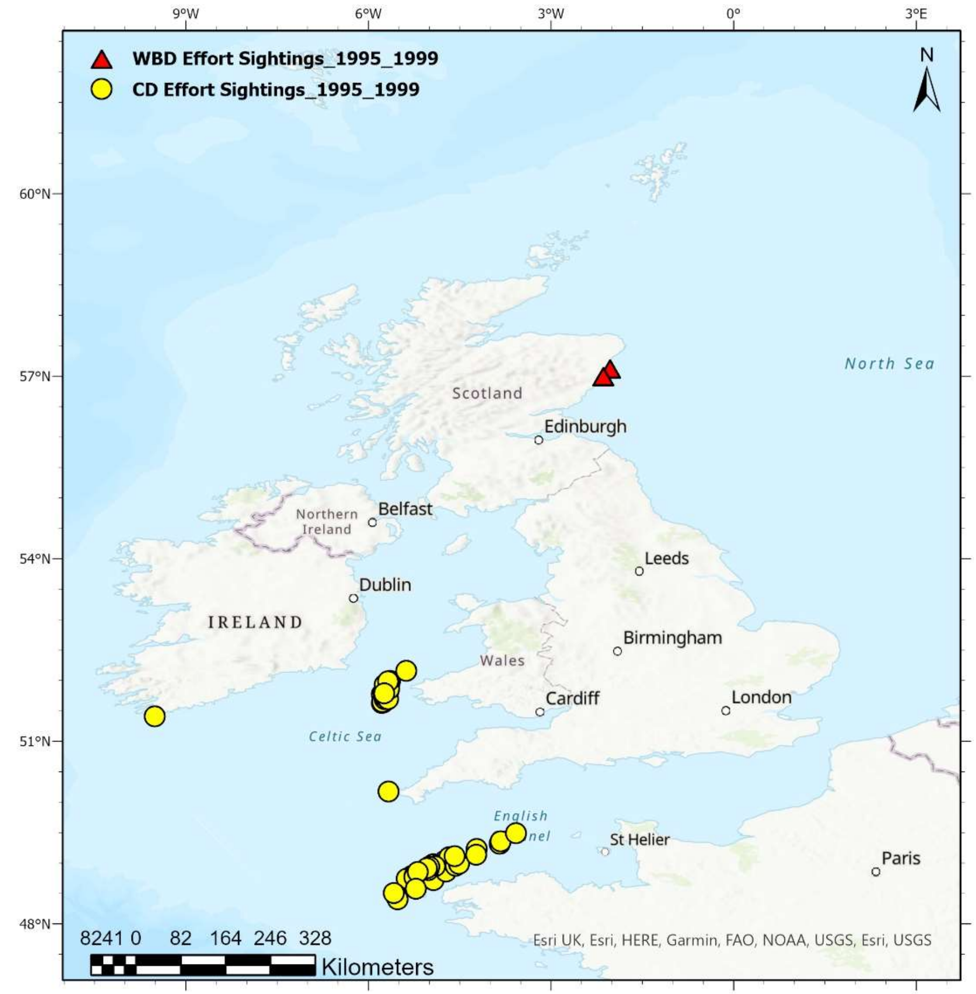


Figure 10*- Effort sightings of both species between 1995- 1999.*

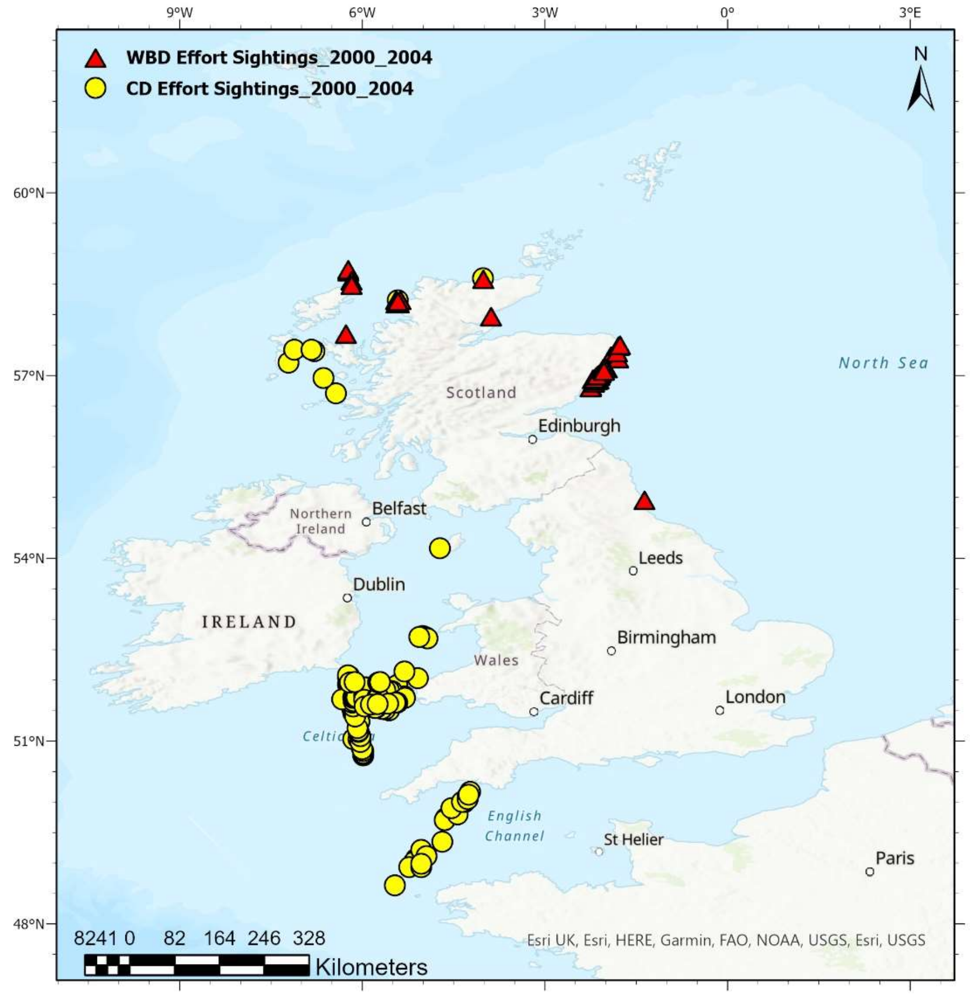


Figure 11*- Effort sightings of both species between 2000- 2004.*

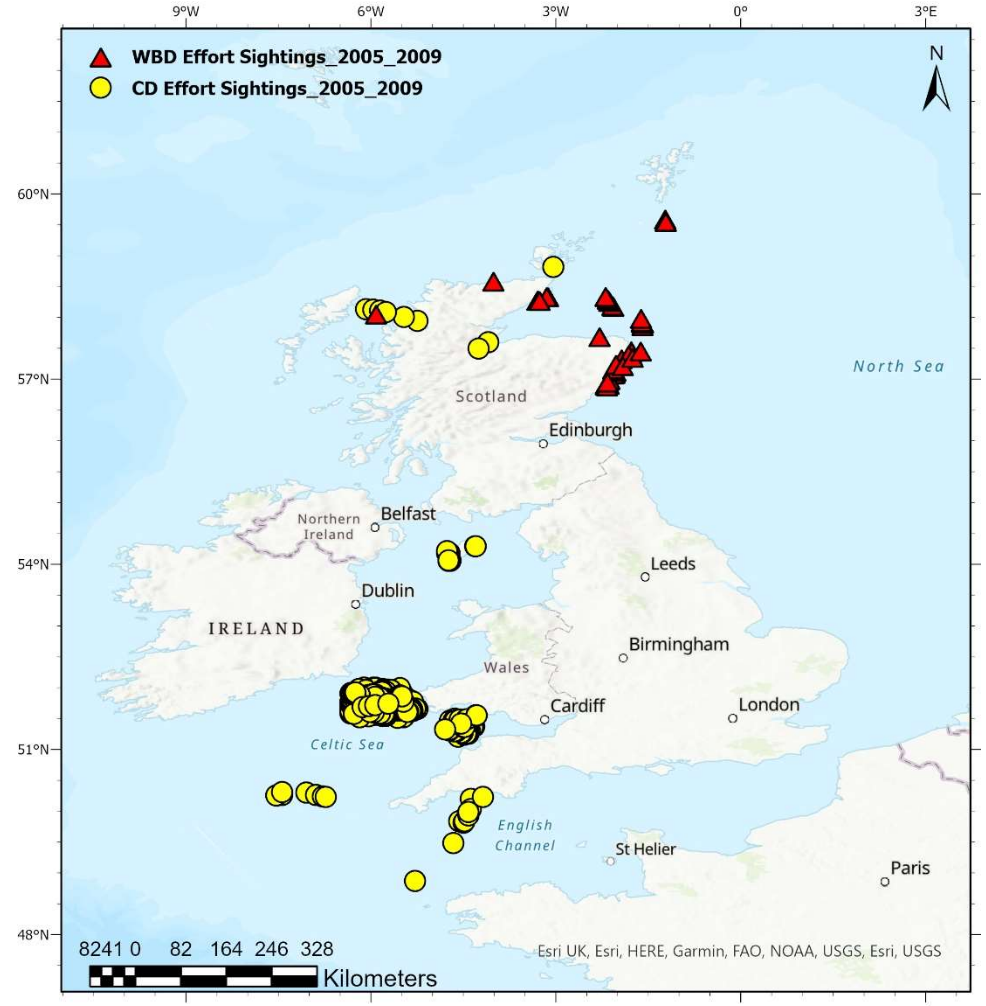


Figure 12*- Effort sightings for both species between 2005- 2009.*

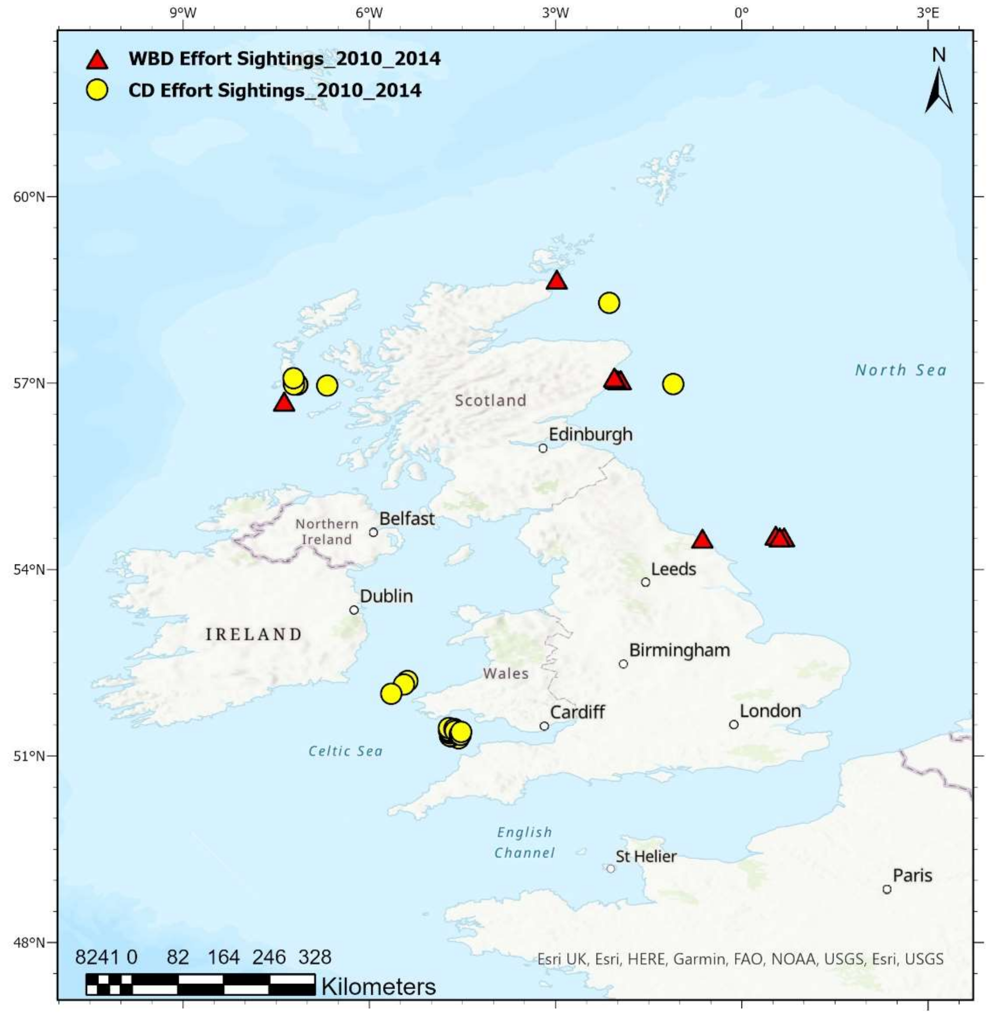


Figure 13*- Effort sightings for both species between 2010- 2014.*

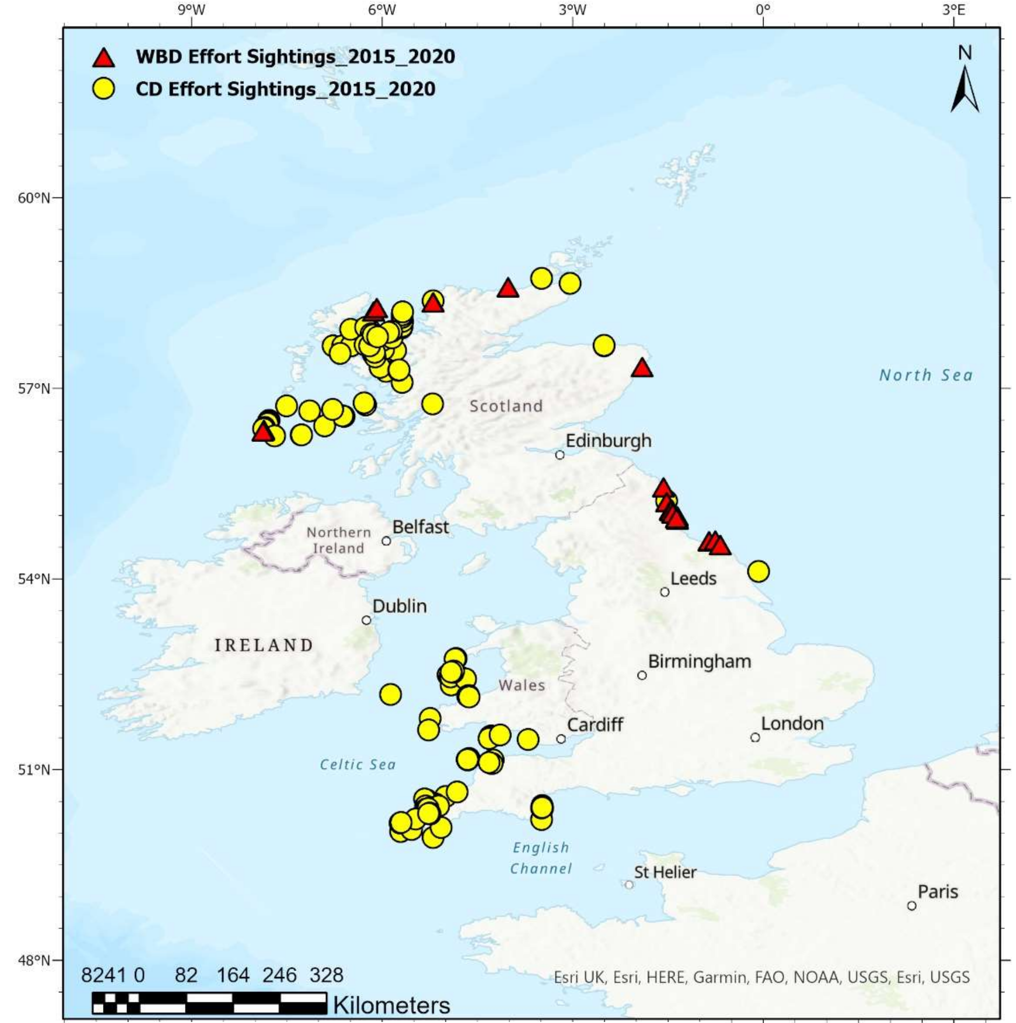


Figure 14*- Effort sightings for both species between 2015- 2020.*

7.1.1. Temporal Sightings

Table 1*- Total no. of effort sightings and individuals for both species for each year (1990-2020).*

	Total Sightings		**Total Individuals**	
Year	**CD**	**WBD**	**CD**	**WBD**
1990	1	0	8	0
1991	0	0	0	0
1992	0	0	0	0
1993	1	0	2	0
1994	1	1	1	2
1995	6	2	311	15
1996	27	0	579	0
1997	10	2	186	330
1998	10	0	265	0
1999	0	1	0	18
2000	19	55	219	435
2001	20	28	318	221
2002	40	34	559	242
2003	15	21	426	101
2004	48	33	490	125
2005	193	23	2207	67
2006	221	24	1620	133
2007	14	4	329	21
2008	9	0	102	0
2009	26	14	329	95
2010	14	0	242	0
2011	1	5	3	28
2012	0	2	0	2
2013	6	3	188	44
2014	3	3	133	14
2015	28	5	380	37
2016	2	0	21	0
2017	31	0	427	0
2018	32	10	227	33
2019	46	8	752	48
2020	23	4	315	19
Total	847	282	10639	2030

Table 2*- Median and range of total effort sightings and individuals for both species for each year bin code.*

Year Bin Code	1		2		3		4		5		6	
Year Period	1990 - 1994		1995 - 1999		2000 - 2004		2005 - 2009		2010 - 2014		2015 - 2020	
Average	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**
CD Sightings	0	1	0	18	0.5	42	0.5	189	0	14	0	23
WBD Sightings	0	1	0	2	0	51	0	20	0	5	0	10
CD Individuals	0	8	0	361	2.5	338	1	2180	0	242	0	343
WBD Individuals	0	2	0	330	0	424	0	92	0	28	0	45

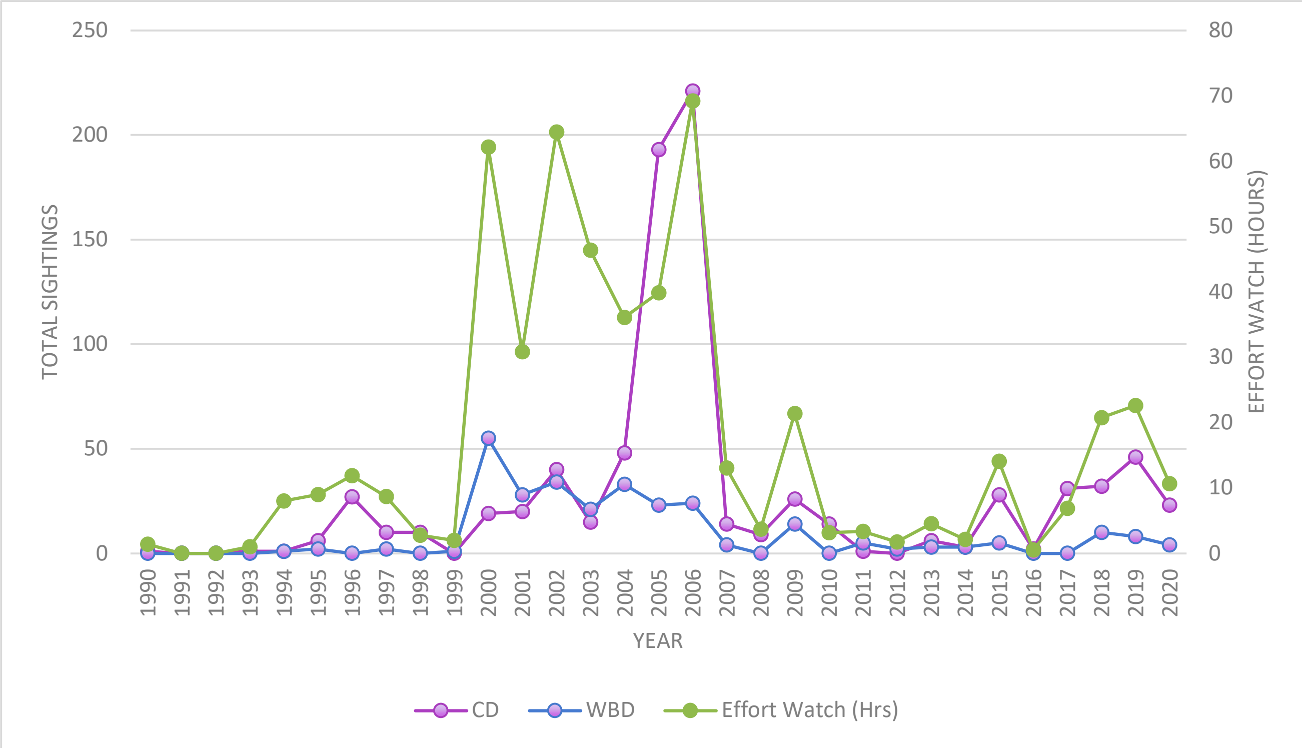


Figure 15- *Total number of effort sightings for both species from 1990-2020 with the correlating effort watch duration (hrs).*

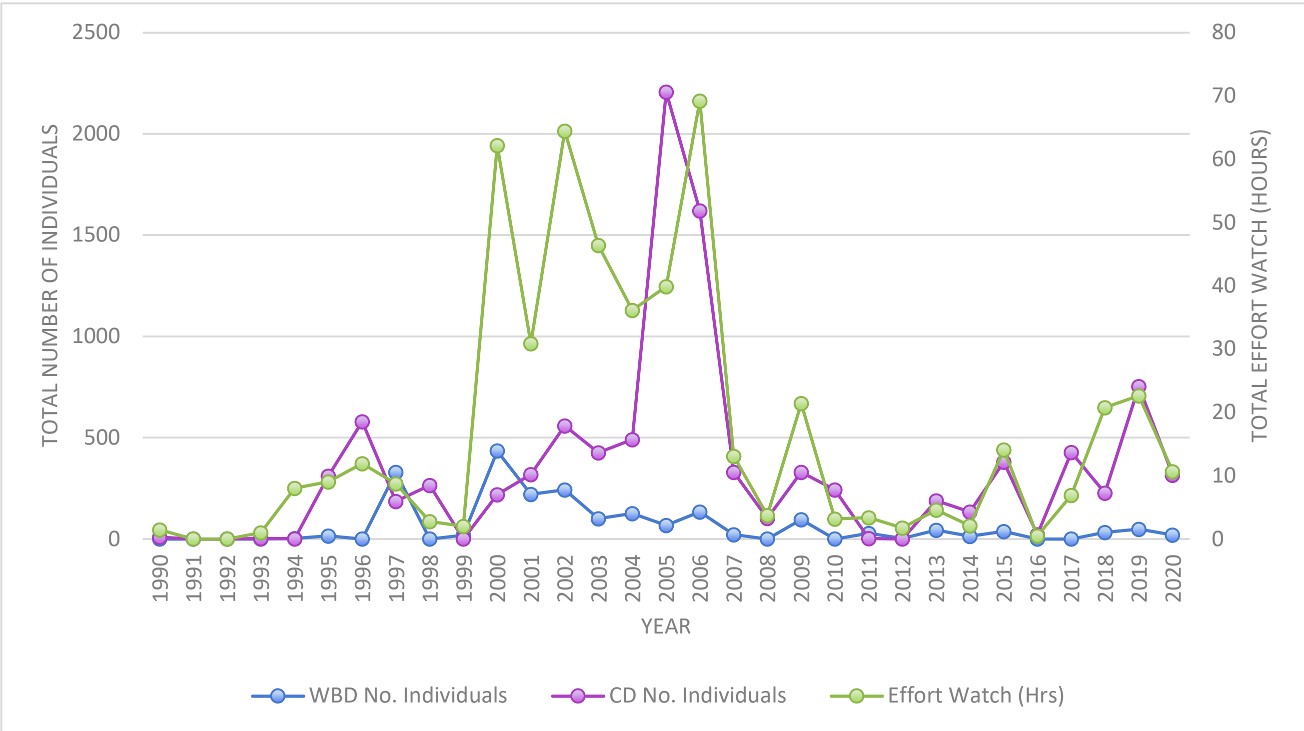


Figure 16- *Total number of individuals for both species from 1990-2020 with the correlating effort watch duration (hrs).*

In figures 9-14, the number of sightings and the region in which they occur changes over the 30-year time period. From table 1, there was a total of 1,129 effort sightings and a total of 12,669 individuals for both species between 1990-2020. Years with 0 sightings assumes the absence of species. There were approximately 565 more CD sightings which is 3x more than the total WBD sightings. The same can be said with total no. of individuals in which CD had over 5x the amount with 8609 more individuals than WBD. Between 1990-2020 the average pod size was 343 and 65 individuals for CD and WBD respectively. Total sightings and pod size (individuals) vary each year with each species (see figures 15-16), however the highest number of sightings for CD was in 2006 with 221 and 2000 for WBD with 55 sightings. In contrast to the lowest number of sightings which for CD was zero in 1991, 1992, 1999 and 2012, and zero in 1990-93, 1996, 1998, 2008, 2010 and 2016-17 for WBD. The highest amount of CD individuals was in 2005 with 2207, and 2000 with 435 for WBD individuals. From table 2, year bin code 4 (2005-09) had the biggest range with CD sightings, and year bin code 3 (2000-04) for WBD.

7.1.2. Spatial Sightings

Table 3*- Total sightings and individuals for both species in each regional boundary from 1990-2020.*

	Total Sightings		Total Individuals	
Region	**CD**	**WBD**	**CD**	**WBD**
1	621	0	6736	0
2	38	0	298	0
3	82	73	1816	800
4	10	214	89	1504
5	0	2	0	6
6	89	0	1620	0

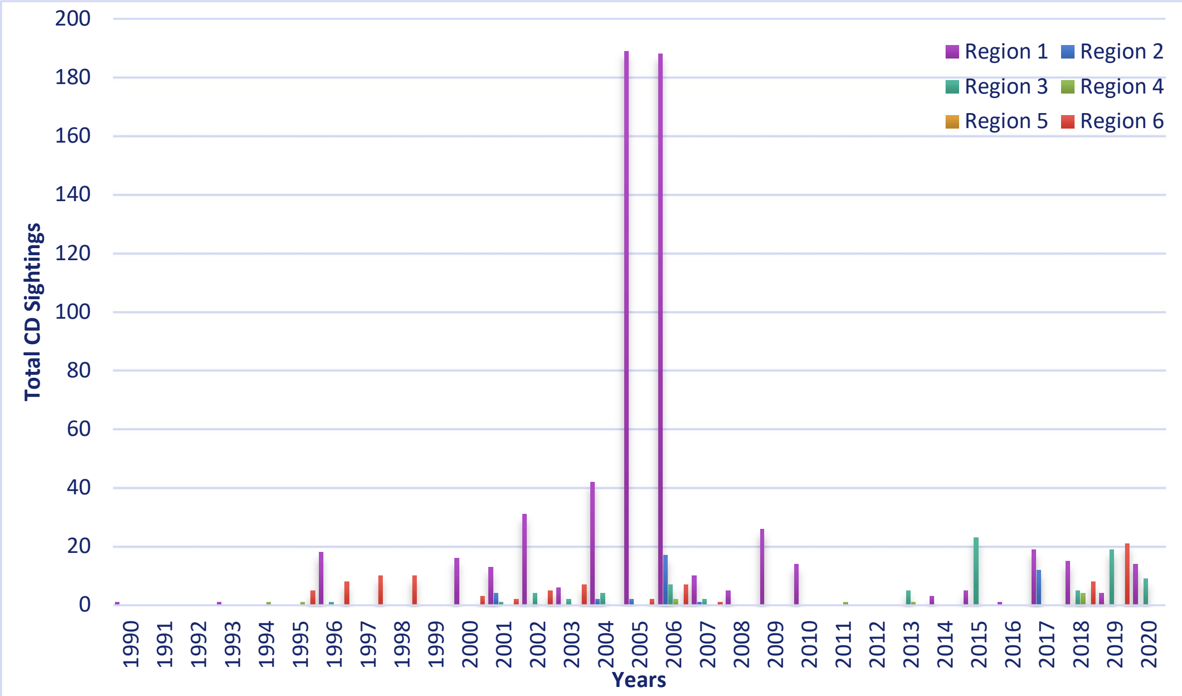


Figure 17- *Total CD sightings in each region between 1990-2020.*

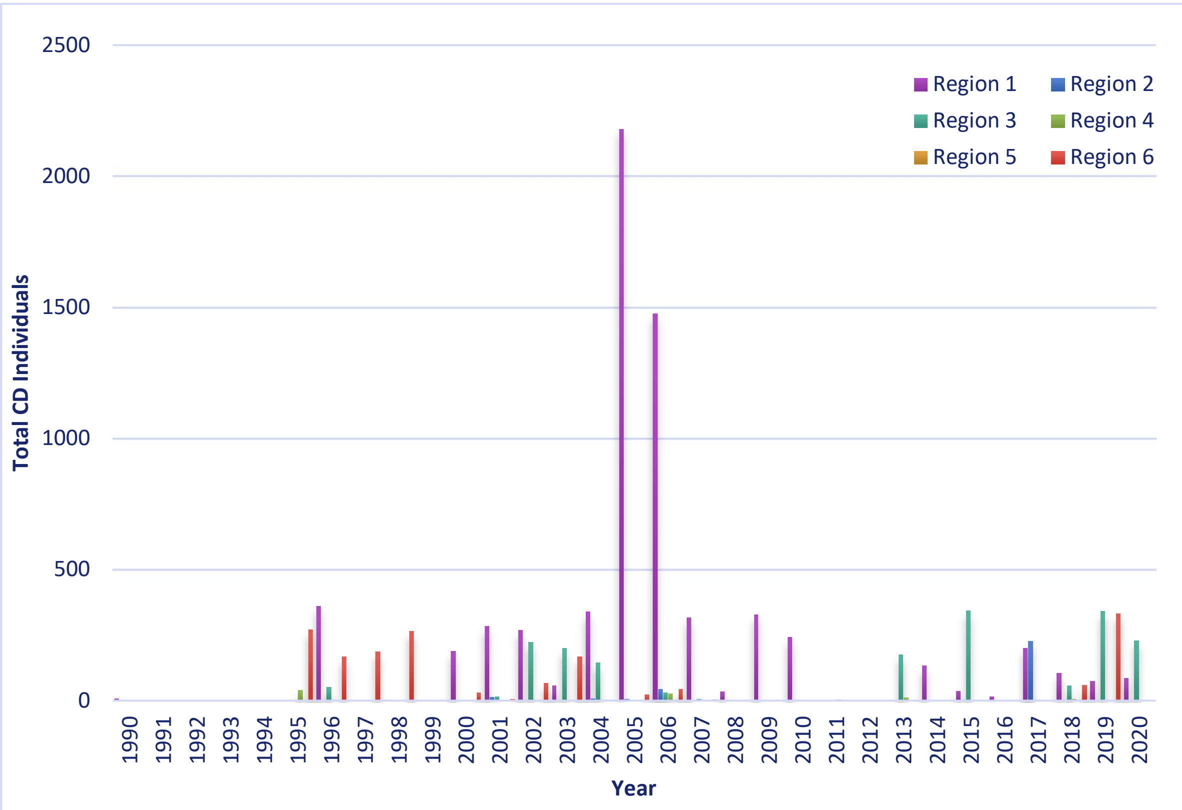


Figure 18- *Total CD individuals in each region between 1990-2020.*

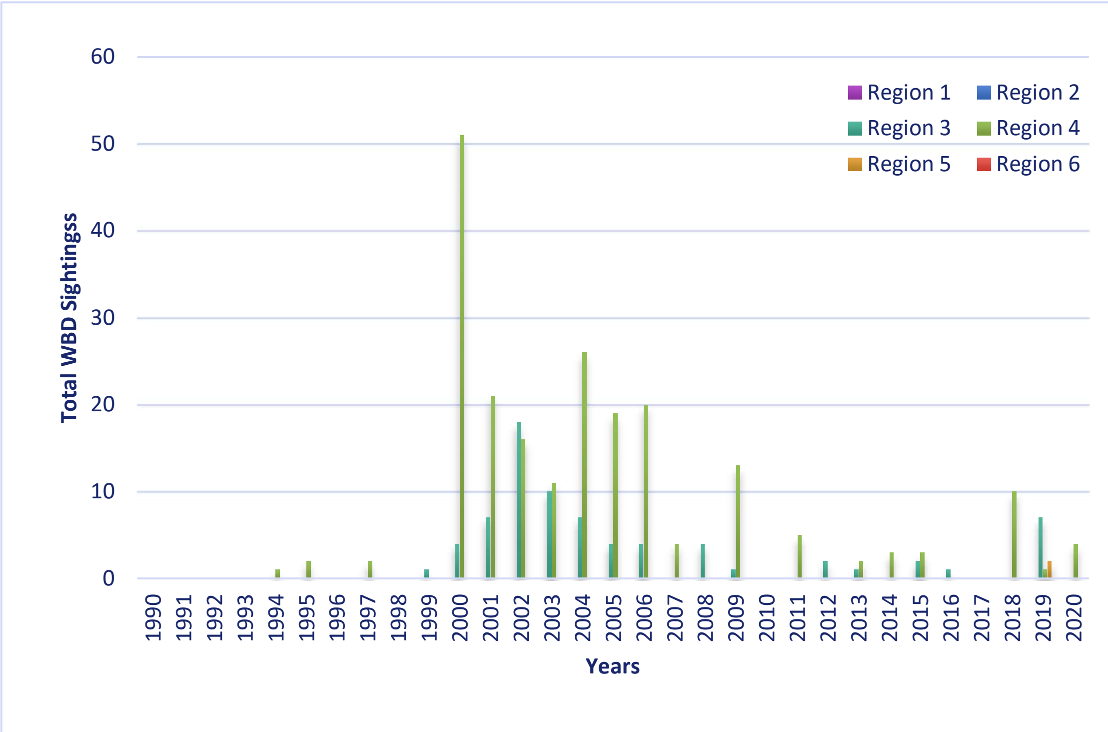


Figure 19- *Total WBD sightings in each region between 1990-2020.*

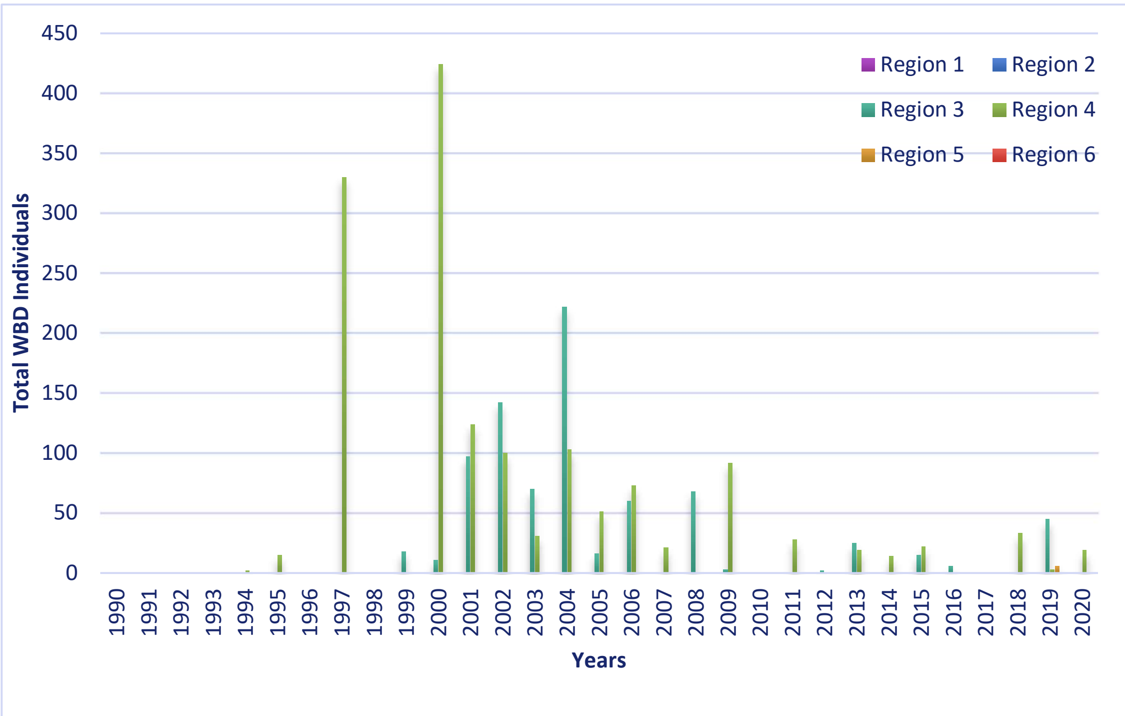


Figure 20- *Total WBD individuals in each region between 1990-2020.*

From table 3, it is evident that both species have strongly differed spatial distributions. Region 1 had the highest number of CD sightings and corresponding number of individuals in a pod, whereas for WBD, this was observed with region 4. CDs also had high sightings and abundances for region 1 and 3 respectively, however, had no appearance in region 5 between 1990-2020. The only other region containing high abundances for WBD was region 3 with 800 individuals, and similarly with CDs, the least number of sightings was in region 5.

The discrepancy with species sightings or abundance and regions between 1990-2020 is clearly visible in figures 17-20. The tabular format regional data for both species in each year can be seen in Appendix 5-6. Region 1 was extremely abundant with CD between 2005-06 with a combined total of 3,656 individuals, however this decreases to 86 individuals in 2020. In region 3, CD abundance also varies temporally, between 2002-04 the combined CD abundance was 568 individuals, however between 2015-20 it increased to 970 individuals. Additionally, region 6 only had 390 CD individuals between 2017-20. This is different to prior 2000 where there were 890 CD individuals in region 6 between 1995-98. WBD were only seen in regions 3, 4 and 5. Region 4 had the highest abundance of WBD individuals between 1990-2020, for example in 1997 with 330 and 2000 with 424. Post 2000, region 4 had a total of 733 WBD individuals. Large abundances of WBD in region 3 are only seen before 2010, with a total of 689 individuals between 2000-2010, and only 93 individuals post 2010.

7.2. Casual Sightings

7.2.1. GIS Casual Distribution Maps

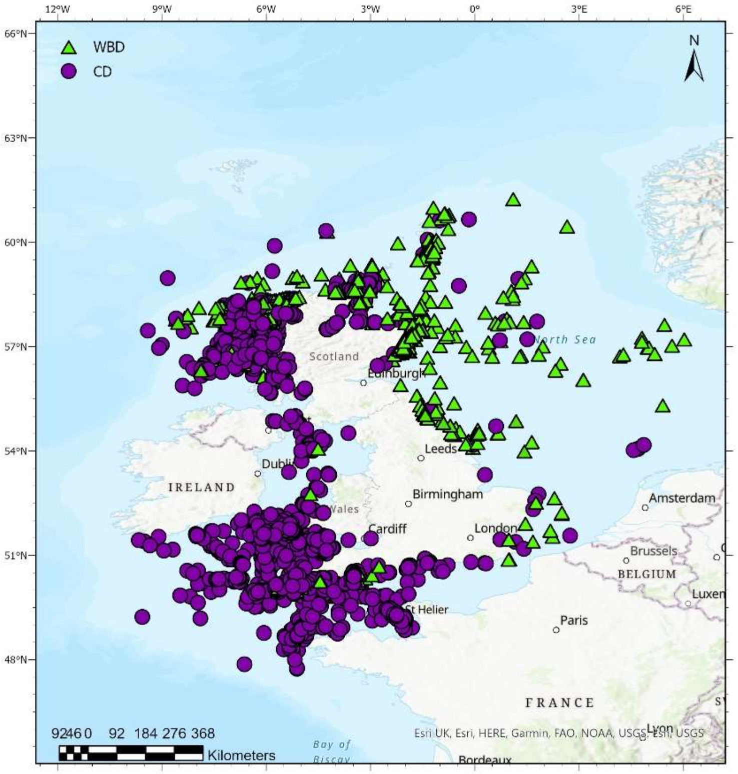


Figure 21- *Total casual sightings for both species between 1990-2020.*

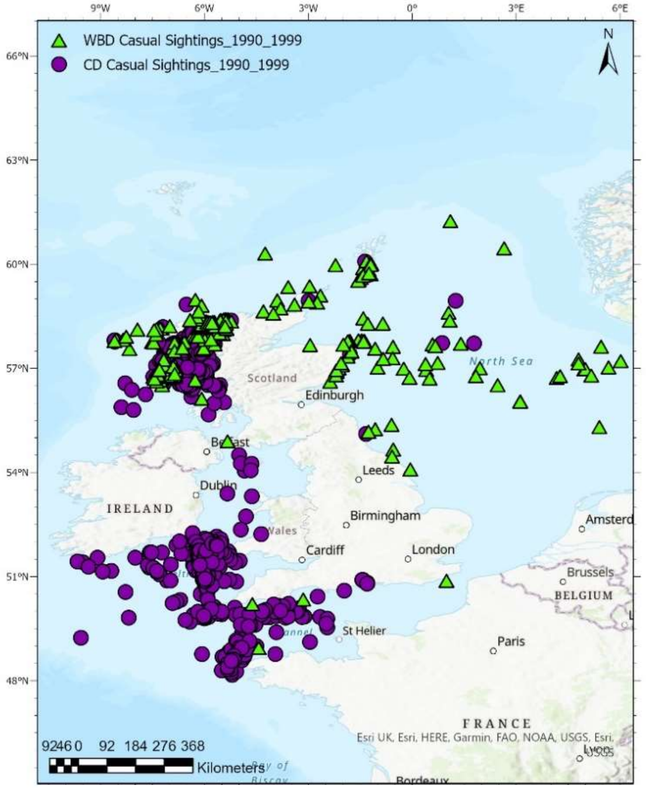


Figure 22- *Casual sightings for both species between 1990-1999.*

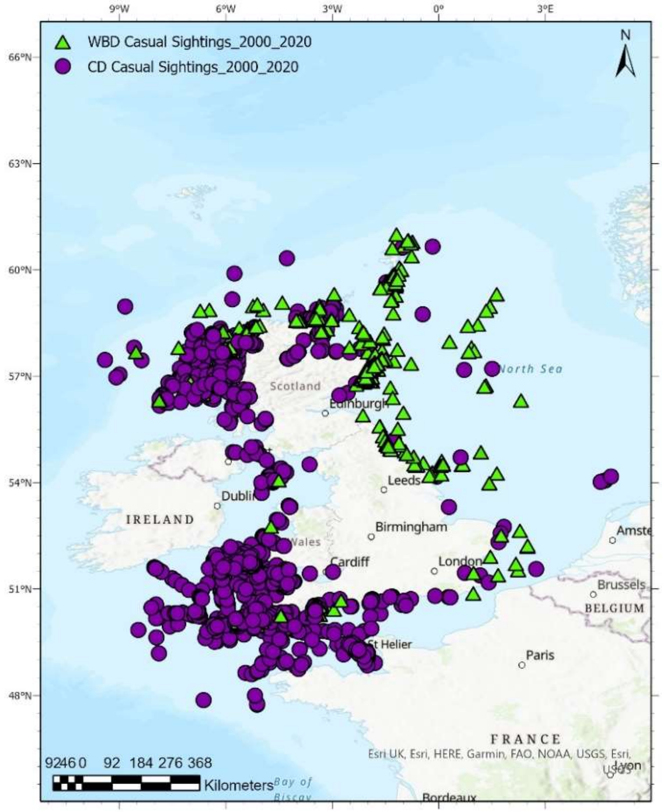


Figure 23- *Casual sightings for both species between 2000-2020.*

Table 4- *Total casual sightings of CD and WBD between 1990-2020.*

Year	Region	CD	WBD	Ratio
1990-94	1	196	0	196 - 0
	2	5	0	5 - 0
	3	162	150	162 - 150
	4	1	22	1 - 22
	5	0	1	0 - 1
	6	107	4	107 - 4
1995-99	1	317	3	317 - 3
	2	6	1	6 - 1
	3	153	149	153 - 149
	4	4	34	4 - 34
	5	0	0	0 - 0
	6	64	0	64 - 0
2000-04	1	317	5	317 - 5
	2	2	1	2 - 1
	3	197	84	197 - 84
	4	5	154	5 - 154
	5	2	6	2 - 6
	6	45	2	45 - 2
2005-09	1	347	4	347 - 4
	2	100	1	100 - 1
	3	319	73	319 -73
	4	53	202	53 - 202
	5	8	1	8 - 1
	6	65	8	65 - 8
2010-14	1	6	0	6 - 0
	2	5	0	5 - 0
	3	2	0	2 - 0
	4	0	3	0 - 3
	5	0	0	0
	6	1	0	1 - 0
2015-20	1	89	0	89 - 0
	2	2	0	2 - 0
	3	38	9	38 - 9
	4	1	10	1 - 10
	5	1	1	1 - 1
	6	77	0	77 - 0

The total amount of casual sightings between 1990-2020 was 2697 for CD and 928 for WBD. From table 4, the year segment with the most sightings was 2005-09 with a total of 892 CDs and 289 WBDs, and the lowest was 2010-14 with 14 CDs 3 WBDs. Similarly to the effort sightings, from figures 21-23, there were consistently more CDs than WBDs in region 3, and WBDs being sighted mostly in region 4. Regions 1 and 6 were routinely dominated by CDs. It can be summarised that the casual sightings support the effort related data findings. However, contrastive to the effort sightings, 12 WBDs were spotted in region 1 when only CDs were seen in the same region for effort sightings. In addition, 14 WBD was also reported in region 6 and 3 in region 2.

7.3. Statistical Tests

7.3.1. Spatial Analyses

Table 5*- Mann- Whitney U pairwise comparisons with regions and both species' sightings.*

Regions	CD SIGHTINGS		WBD SIGHTINGS	
1-2	MEAN	10.629	MEAN	0.000
	±STDEV	33.842	±STDEV	0.000
	P	X	P	X
1-3	MEAN	11.339	MEAN	1.177
	±STDEV	33.766	±STDEV	3.033
	P	X	P	<0.001
1-4	MEAN	10.177	MEAN	3.452
	±STDEV	33.878	±STDEV	8.565
	P	X	P	<0.001
1-5	MEAN	10.016	MEAN	0.032
	±STDEV	33.921	±STDEV	0.254
	P	X	P	X
1-6	MEAN	11.452	MEAN	0.000
	±STDEV	33.684	±STDEV	0.000
	P	X	P	X
2-3	MEAN	1.935	MEAN	1.177
	±STDEV	4.683	±STDEV	3.033
	P	X	P	X
2-4	MEAN	0.774	MEAN	3.452
	±STDEV	2.700	±STDEV	8.565
	P	X	P	X
2-5	MEAN	0.613	MEAN	0.032
	±STDEV	2.670	±STDEV	0.254
	P	X	P	X
2-6	MEAN	2.048	MEAN	0.000
	±STDEV	4.309	±STDEV	0.000
	P	X	P	X
3-4	MEAN	1.484	MEAN	4.629
	±STDEV	4.048	±STDEV	8.620
	P	X	P	X
3-5	MEAN	1.323	MEAN	1.210
	±STDEV	4.056	±STDEV	3.031
	P	X	P	X
3-6	MEAN	2.758	MEAN	1.177
	±STDEV	5.082	±STDEV	3.033
	P	X	P	X
4-5	MEAN	0.161	MEAN	3.484
	±STDEV	0.606	±STDEV	8.556
	P	X	P	X
4-6	MEAN	1.597	MEAN	3.452
	±STDEV	3.624	±STDEV	8.565
	P	X	P	X
5-6	MEAN	1.435	MEAN	0.032
	±STDEV	3.638	±STDEV	0.254
	P	0.007	P	X

Table 6*- Mann- Whitney U pairwise comparisons with regions and number of individuals of both species.*

Regions	CD INDIVIDUALS		WBD INDIVIDUALS	
1-2	MEAN	113.452	MEAN	0.000
	±STDEV	338.141	±STDEV	0.000
	P	X	P	X
1-3	MEAN	137.935	MEAN	12.903
	±STDEV	338.139	±STDEV	37.391
	P	0.003	P	<0.001
1-4	MEAN	110.081	MEAN	24.258
	±STDEV	338.033	±STDEV	71.229
	P	<0.001	P	X
1-5	MEAN	108.645	MEAN	0.097
	±STDEV	338.445	±STDEV	0.762
	P	<0.001	P	X
1-6	MEAN	134.774	MEAN	0.000
	±STDEV	337.504	±STDEV	0.000
	P	X	P	X
2-3	MEAN	34.097	MEAN	12.903
	±STDEV	82.655	±STDEV	37.391
	P	X	P	X
2-4	MEAN	6.242	MEAN	24.258
	±STDEV	29.671	±STDEV	71.229
	P	X	P	X
2-5	MEAN	4.806	MEAN	0.097
	±STDEV	29.255	±STDEV	0.762
	P	X	P	X
2-6	MEAN	30.935	MEAN	0.000
	±STDEV	75.733	±STDEV	0.000
	P	X	P	X
3-4	MEAN	30.726	MEAN	37.161
	±STDEV	78.837	±STDEV	76.389
	P	X	P	X
3-5	MEAN	29.290	MEAN	13.000
	±STDEV	79.134	±STDEV	37.365
	P	X	P	X
3-6	MEAN	55.419	MEAN	12.903
	±STDEV	99.203	±STDEV	37.391
	P	X	P	X
4-5	MEAN	1.435	MEAN	24.355
	±STDEV	6.208	±STDEV	71.199
	P	X	P	<0.001
4-6	MEAN	27.565	MEAN	24.258
	±STDEV	71.395	±STDEV	71.229
	P	X	P	<0.001
5-6	MEAN	26.129	MEAN	0.097
	±STDEV	71.658	±STDEV	0.762
	P	0.005	P	X

The independent-sample Kruskal Walls test indicated that CD and WBD sightings and individuals had a significant difference with the regions ($p<0.001$) as detailed in Appendix 9. The Mann Whitney- U pairwise comparisons were carried out to see where those differences lie between the variables which are shown in tables 5 & 6. CD sightings between regions 1-6 had the highest mean of 11.452, and the lowest mean of 0.161 between regions 4-5. The highest standard deviation was between regions 1-5 with 33.921, and the lowest between regions 4-5 with 0.606. The only significance difference was between regions 5-6 ($p=0.007$). WBD sightings between regions 3-4 had the highest mean of 4.629 and regions 1-2 had the lowest mean with 0. The highest standard deviation (STDEV) existed between regions 3-4 with 8.620 and the lowest between 1-2 with 0. A significant difference was obtained between regions 1-3 and 1-4 ($p<0.001$).

CD individuals had the highest mean between regions 1-3 with 137.935, and lowest with 1.435 between regions 4-5. The highest STDEV was 338.445 between regions 1-5, and lowest of 6.208 between regions 4-5. The only significance difference was observed between regions 1-3 ($p=0.003$), 1-4 ($p<0.001$), 1-5 ($p<0.001$), and 5-6 ($p=0.005$). WBD individuals had the highest mean between regions 3-4 with 37.161, and lowest between regions 1-2 with 0. Likewise, between region 3-4 had the highest STDEV of 76.389 and 0 with regions 1-2. The only significant difference was initiated between regions 1-3, 4-5, and 4-6 ($p<0.001$). Although tables 5 & 6 indicate differences in species distribution across regions, there must be consideration that the results are highly dependent on the sightings effort in a particular region. Therefore, there is a likelihood that the total sightings and individuals are higher in regions that contain the most effort watches.

7.3.2. <u>Temporal Analyses</u>

***Table 7**- Mann- Whitney U pairwise comparisons with years and both species' sightings.*

Year Bins	Years	CD SIGHTINGS		WBD SIGHTINGS	
1-2	1990-1994/ 1995-1999	MEAN	0.933	MEAN	0.100
		±STDEV	3.097	±STDEV	0.399
		P	X	P	X
1-3	1990-1994/ 2000-2004	MEAN	2.417	MEAN	2.867
		±STDEV	7.110	±STDEV	8.378
		P	0.003	P	X
1-4	1990-1994 / 2005-2009	MEAN	7.767	MEAN	1.100
		±STDEV	34.116	±STDEV	3.922
		P	X	P	X
1-5	1990-1994/2010-2014	MEAN	0.450	MEAN	0.233
		±STDEV	1.943	±STDEV	0.831
		P	X	P	X
1-6	1990-1994/ 2015-2020	MEAN	2.500	MEAN	0.424
		±STDEV	5.658	±STDEV	1.608
		P	X	P	X
2-3	1995-1999/ 2000-2004	MEAN	3.250	MEAN	2.933
		±STDEV	7.492	±STDEV	8.362
		P	X	P	X
2-4	1995-1999/ 2005-2009	MEAN	8.600	MEAN	1.167
		±STDEV	34.065	±STDEV	3.919
		P	X	P	X
2-5	1995-1999/ 2010-2014	MEAN	1.283	MEAN	0.300
		±STDEV	3.561	±STDEV	0.889
		P	X	P	X
2-6	1995-1999/ 2015-2020	MEAN	3.258	MEAN	0.485
		±STDEV	6.082	±STDEV	1.629
		P	X	P	X
3-4	2000-2004/ 2005-2009	MEAN	10.083	MEAN	3.933
		±STDEV	34.326	±STDEV	8.910
		P	X	P	X
3-5	2000-2004/ 2010-2014	MEAN	2.767	MEAN	3.067
		±STDEV	7.252	±STDEV	8.348
		P	X	P	X
3-6	2000-2004/ 2015-2020	MEAN	4.606	MEAN	3.000
		±STDEV	8.246	±STDEV	8.056
		P	X	P	X
4-5	2005-2009/ 2010-2014	MEAN	8.117	MEAN	1.300
		±STDEV	34.090	±STDEV	3.950
		P	0.002	P	X
4-6	2005-2009/ 2015-2020	MEAN	9.470	MEAN	1.394
		±STDEV	32.548	±STDEV	3.980
		P	X	P	X
5-6	2010-2014/ 2015-2020	MEAN	2.818	MEAN	0.606
		±STDEV	5.815	±STDEV	1.744
		P	X	P	X

***Table 8**- Mann- Whitney U pairwise comparisons with years and number of individuals of both species.*

Year Bins	Years	CD INDIVIDUALS		WBD INDIVIDUALS	
1-2	1990-1994/ 1995-1999	MEAN	22.533	MEAN	6.083
		±STDEV	72.546	±STDEV	42.632
		P	X	P	X
1-3	1990-1994/ 2000-2004	MEAN	33.717	MEAN	18.767
		±STDEV	80.638	±STDEV	62.528
		P	0.003	P	X
1-4	1990-1994 / 2005-2009	MEAN	76.633	MEAN	5.300
		±STDEV	339.456	±STDEV	17.954
		P	0.001	P	X
1-5	1990-1994/2010-2014	MEAN	9.617	MEAN	1.500
		±STDEV	41.559	±STDEV	5.583
		P	X	P	X
1-6	1990-1994/ 2015-2020	MEAN	32.318	MEAN	2.106
		±STDEV	83.272	±STDEV	7.750
		P	X	P	X
2-3	1995-1999/ 2000-2004	MEAN	55.883	MEAN	24.783
		±STDEV	101.290	±STDEV	74.150
		P	X	P	X
2-4	1995-1999/ 2005-2009	MEAN	98.800	MEAN	11.317
		±STDEV	342.129	±STDEV	45.560
		P	X	P	X
2-5	1995-1999/ 2010-2014	MEAN	31.783	MEAN	7.517
		±STDEV	81.061	±STDEV	42.790
		P	X	P	X
2-6	1995-1999/ 2015-2020	MEAN	52.470	MEAN	7.576
		±STDEV	102.191	±STDEV	41.110
		P	X	P	X
3-4	2000-2004/ 2005-2009	MEAN	109.983	MEAN	24.000
		±STDEV	341.405	±STDEV	63.505
		P	X	P	X
3-5	2000-2004/ 2010-2014	MEAN	42.967	MEAN	20.200
		±STDEV	87.178	±STDEV	62.340
		P	0.011	P	X
3-6	2000-2004/ 2015-2020	MEAN	62.636	MEAN	19.106
		±STDEV	104.693	±STDEV	59.730
		P	X	P	X
4-5	2005-2009/ 2010-2014	MEAN	85.883	MEAN	6.733
		±STDEV	339.883	±STDEV	18.388
		P	0.004	P	X
4-6	2005-2009/ 2015-2020	MEAN	101.652	MEAN	6.864
		±STDEV	327.895	±STDEV	18.307
		P	X	P	X
5-6	2010-2014/ 2015-2020	MEAN	40.727	MEAN	3.409
		±STDEV	89.228	±STDEV	9.111
		P	X	P	X

The Kruskal Wallis test confirmed that CD sightings and individuals had a significant difference with the years 1990-2020 ($p<0.001$) (Appendix 9). However, WBD sightings and individuals were not significant with the years ($p=0.076$, $p=0.084$). The Mann Whitney-U yearly comparisons can be seen in tables 7 & 8 (Appendix 9). For CD sightings, the highest mean was observed between year bin 3-4 with 10.083, and highest STDEV of 34.326. The lowest mean was between year bin 1-5 with 0.450, and lowest STDEV of 1.943. The only significant difference was between year bin 1-

3 (p=0.003) and 4-5 (p=0.002). The highest mean with WBD sightings with years was between year bins 3-4 with 3.933 and highest STDEV of 8.910. The lowest mean was recorded with year bins 1-2 with 0.100 and lowest STDEV of 0.399.

The highest mean for CD individuals was also between year bins 3-4 with 109.983, and similarly to the sightings, the lowest mean existed between year bins 1-5 with 9.617, and lowest STDEV with 41.559. The highest STDEV was between year bins 2-4 with 342.129. There was a significance difference between year bins 1-3, likewise to the CD sightings (p=0.003), also 1-4 (p=0.001), 3-5 (p=0.011) and 4-5 (p=0.004). The highest mean existed between year bins 2-3 with 24.783 for WBD individuals, and highest STDEV with 74.150. The lowest mean was between year bins 1-5 with 1.500, and lowest STDEV of 5.583.

7.3.3. Correlation Analyses

Table 9*- Sighting and individual per hour for both species each year with the coordinating total effort watch (hours) from 1990-2020.*

Year	Total_Minutes_EffortWatch	Total_Hours_EffortWatch	CD_Sightings_Per_Hour	WBD_Sightings_Per_Hour	CD_Indiv_Per_Hour	WBD_Indiv_Per_Hour
1990	85	1.416666667	0.705882353	0	5.647058824	0
1991	0	0	0	0	0	0
1992	0	0	0	0	0	0
1993	60	1	1	0	2	0
1994	480	8	0.125	0.125	0.125	0.25
1995	540	9	0.666666667	0.222222222	34.55555556	1.666666667
1996	713	11.88333333	2.272089762	0	48.72370266	0
1997	523	8.716666667	1.147227533	0.229445507	21.33843212	37.8585086
1998	166	2.766666667	3.614457831	0	95.78313253	0
1999	120	2	0	0.5	0	9
2000	3730	62.16666667	0.305630027	0.884718499	3.522788204	6.997319035
2001	1851	30.85	0.648298217	0.907617504	10.30794165	7.1636953
2002	3866	64.43333333	0.620796689	0.527677186	8.67563373	3.755819969
2003	2782	46.36666667	0.323508267	0.452911574	9.187634795	2.178289001
2004	2166	36.1	1.329639889	0.914127424	13.5734072	3.462603878
2005	2392	39.86666667	4.841137124	0.576923077	55.35953177	1.680602007
2006	4152	69.2	3.193641618	0.346820809	23.41040462	1.921965318
2007	784	13.06666667	1.071428571	0.306122449	25.17857143	1.607142857
2008	222	3.7	2.432432432	0	27.56756757	0
2009	1284	21.4	1.214953271	0.654205607	15.37383178	4.439252336
2010	190	3.166666667	4.421052632	0	76.42105263	0
2011	202	3.366666667	0.297029703	1.485148515	0.891089109	8.316831683
2012	104	1.733333333	0	1.153846154	0	1.153846154
2013	273	4.55	1.318681319	0.659340659	41.31868132	9.67032967
2014	127	2.116666667	1.417322835	1.417322835	62.83464567	6.614173228
2015	845	14.08333333	1.98816568	0.355029586	26.98224852	2.627218935
2016	30	0.5	4	0	42	0
2017	413	6.883333333	4.503631961	0	62.03389831	0
2018	1245	20.75	1.542168675	0.481927711	10.93975904	1.590361446
2019	1358	22.63333333	2.032400589	0.353460972	33.22533137	2.120765832
2020	638	10.63333333	2.163009404	0.376175549	29.62382445	1.786833856

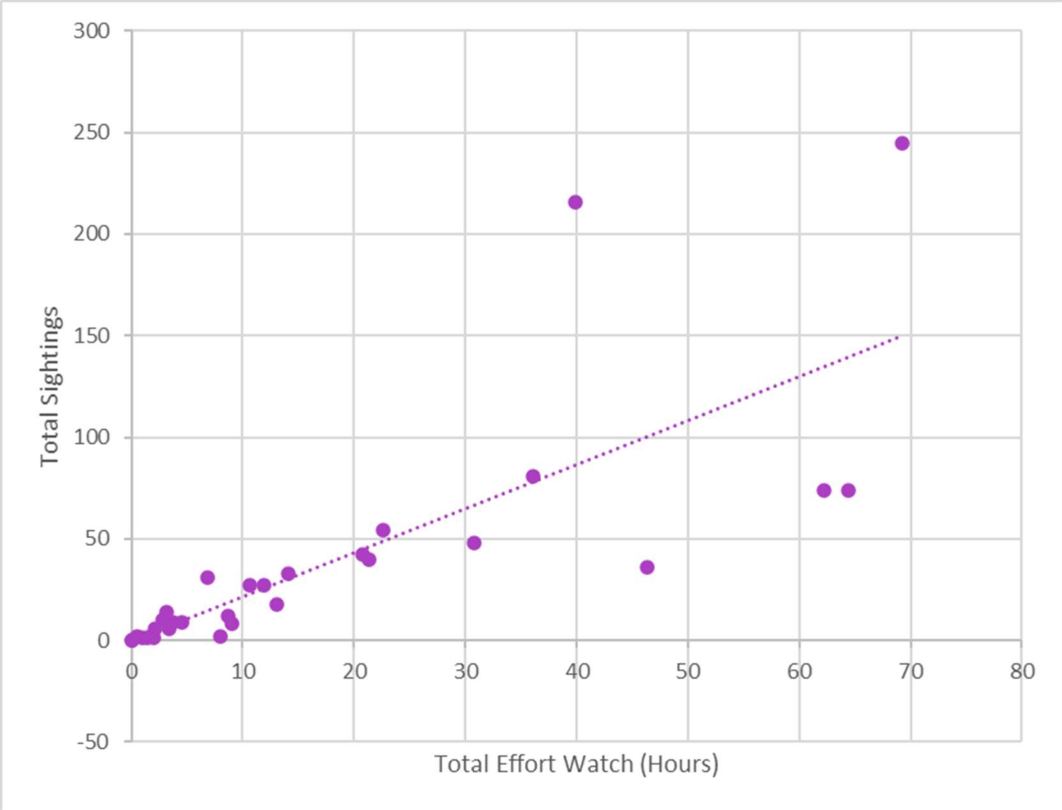


Figure 24- *Correlation graph of total effort watch conducted (hours) and combined total sightings for both species.*

Table 9 demonstrates that both species sightings and individuals per hour vary each year. The highest sighting per hour for CD was 2005 with 4.84/hr, and 2011 for WBD with 1.48/hr. Additionally, 1998 experienced the most CD individuals per hour with 95.78/hr whilst the most WBD individuals per hour was during 1997 with 37.56/hr. In figure 24, the relationship between total effort watch and the number of sightings is explored. There is a strong correlation between the two variables, exhibiting a Spearman's correlation coefficient of 0.937 (Appendix 10). However, there are some anomalies either side of the trend line e.g., there are longer effort watches that produce less sightings.

8. **Discussion**

8.1 Key Findings

8.1.1 Spatio-temporal distributions

This research aimed to quantify and map sightings of CDs and WBDs to determine their spatio-temporal distributions in the UK across a 30-year period and highlight if there are areas where shifts in spatial range have occurred. It is evident that both species exhibit different spatial ranges with varying abundances each year between 1990-2020. The findings of this study suggest that overall, the number of WBDs have decreased since 1990, whereas CDs remain a balanced population, but in last recent years (2017-20) have shown an increase in abundance.

For CDs, between 1990-94 there were minimal sightings, but the data, accompanied by the presence-only ratios suggests regions 1,3 and 6 on the UK's west coast experienced the most sightings and abundance. Figures 17-18 and Appendix 5-6 suggest that between 1995-99 there were high abundances of CDs (890 individuals) in the English Channel, but this declines post 2000 with a total of 730 individuals between 2000-20. The Celtic Deep consistently receives prominent abundances of CDs after 1999, with 6365 individuals between 2000-20, in addition to the inclusion of more individuals being sighted in north-east Atlantic. CDs have gradually expanded north over 30 years, with a significant difference observed with CD individuals between regions 1-3 (p=0.003). This is demonstrated with region 3 experiencing high abundances in year bin 6 (2015-20) with 970 individuals. However, prior to that CDs were seen much less in region 3, with only 50 individuals between 1990-2000, 583 individuals between 2000-04, 37 individuals between 2005-09 and 176 between 2010-14. Although CDs are predominantly seen along the UK's west coast, there have been fluctuations in number of sightings in the northern North Sea (region 4) (figures 9-14), with 10 effort sightings and 89 individuals between 1990-2020, and 64 casual sightings. However, 2018 had the highest effort sightings (4) of CDs in region 4. Although, the data suggests that WBDs are still the dominant delphinid in the North Sea.

For WBDs, although the lack of data for 1990-94, the casual sightings ratios along with the rest of effort sightings confirm that regions 3 and 4 on the UK's east coast experience the most sightings and abundance (table 3, maps 9-14). From figures 19-20, the quantity of WBD sightings and individuals has decreased in region 4 since 1990. For example, between year bin 2 (1995-99), there were approximately 345 WBD individuals in the northern North Sea, this increased by 437 to 782 individuals between year bin 3 (2000-04), however decreases post 2004. This is shown with year bin 4 (2005-09) experiencing 237 individuals, year bin 5 (2010-14) having 61 and year bin 6 (2015-20) detailing 77 individuals in region 4. Similarly, WBDs have declined in region 3 at the same time CDs exhibit greater presence in the north-east Atlantic. Within year bin 3 there were 542 individuals in region 3, however this progressively decreases to 147 individuals during year bin 4, and a total of 93 individuals between 2010-20. The casual sighting ratio demonstrates the same trend with region 3 and 4, with 150 WBDs during year bin 1 occurring in region 3, to only 9 individuals in year bin 6. The effort data suggest that WBD are absent from regions 1, 2, and 6, with a significant difference of WBD individuals between region 1-3 ($p<0.001$). However, there have been a handful of WBD casual sightings (24) in the English Channel which is supported by the studies of Brereton et al., (2013).

The data from this study supports the findings from other literature. The decrease of WBDs and their prominent range in region 4 was also discovered by Canning et al., (2008) in which the rate of strandings were increasing for north-east Scotland, amid decreasing levels elsewhere in the UK. The decline in WBD abundance on the west coast of Scotland (region 3) was also previously discovered by MacLeod et al., 2005), and declines of strandings in the southern North Sea (region 5), and the fact that WBDs are predominantly residing in northern parts of the North Sea are supported by Ijsseldijk et al., (2018). The increase of CDs along the east coast of the UK, specifically in the northern North Sea e.g., Moray Firth was reported by Robinson et al., (2011) and supports the CDs findings from this study.

8.1.2 Environmental Change

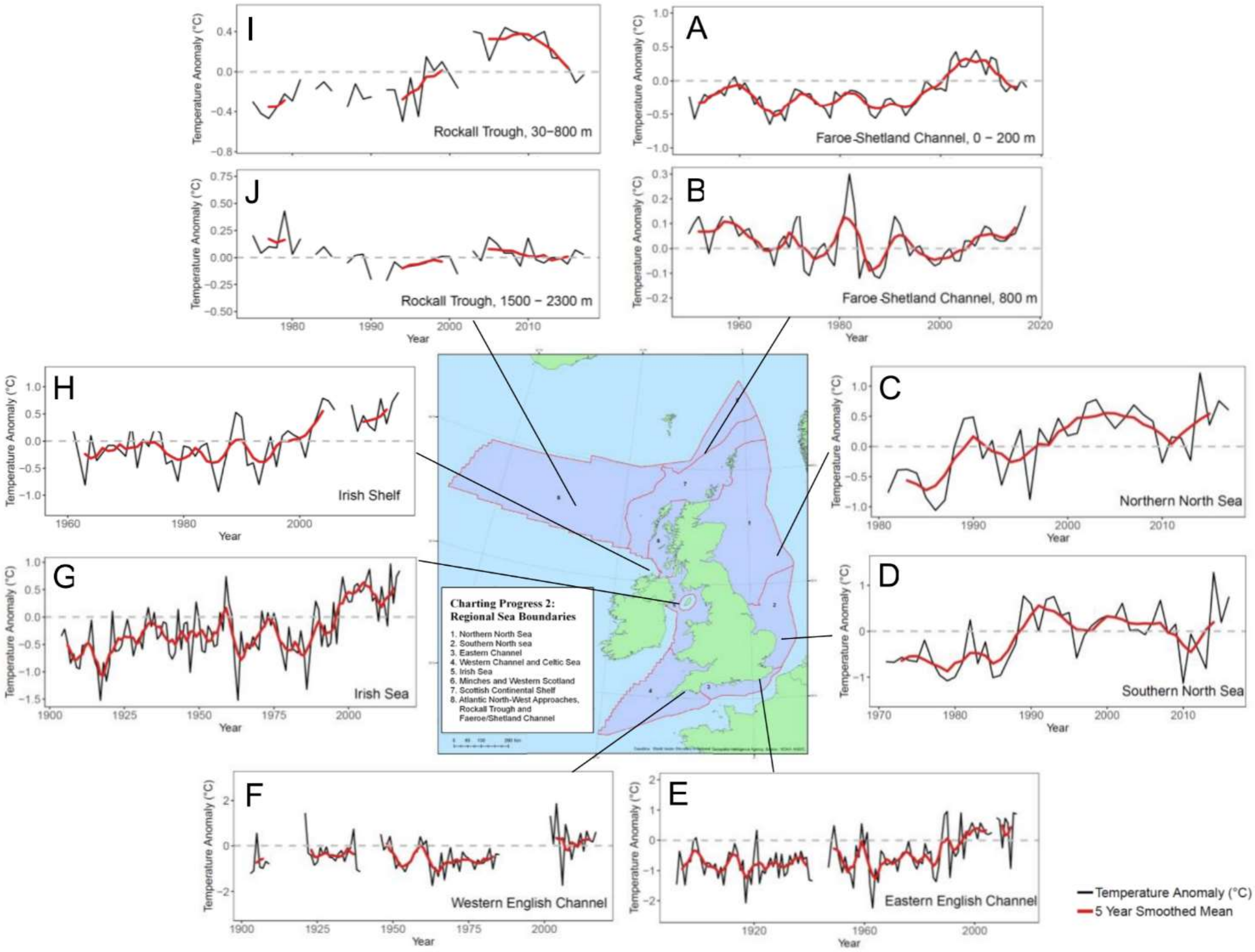


Figure 25*- SST anomalies in regions throughout the UK (Tinker et al., 2020).*

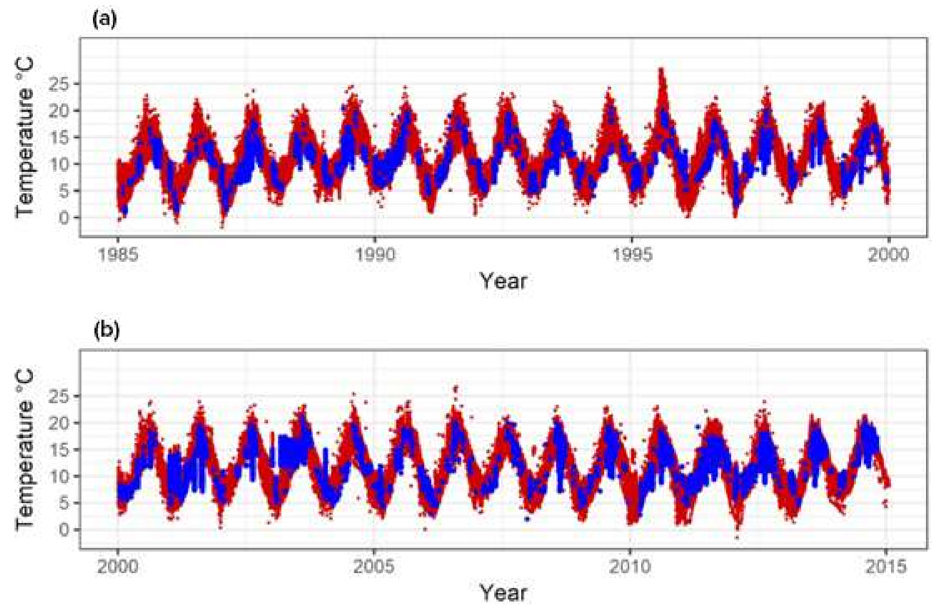


Figure 26*- SST cycles for 2-year periods: (a) 1985-1999, (b) 2000-2015. The surveyed area of sea in which these graphs are produced from is in Appendix 7. The red represents near surface waters (0-5m), and blue represents 20-25m depth (Morris et al., 2018)*

As shown in figures 25-26, the seawater temperature around the British Isles fluctuates. Tinker et al., (2020) used time-series data from the IROC [Report on Ocean Climate] 2017 to produce a map depicting SST anomalies around the UK. Morris et al., (2018) used open access CEFAS data on UK SST to produce temperature variants graphs in figure 25, the total surveyed area where SST was collected by CEFAS can be seen in Appendix 7. SST observed in the North Sea (region B, figure 25) has shown a steadily warming since the 1980s. Between 2003-14, SST increased by 0.3°C and was at its warmest since 1981. Although 2015 was cooler than previous years, the SST observed were still above the average SST for the time-series data obtained by IROC. SST have been steadily increasing post 2015. In addition, figure 26 highlights that in the water column, depths <25m are warming at a steadily rate.

Although the data from this study cannot directly show if SST has caused the spatial range shifts exhibited by CDs and WBDs, comparing the findings against other literature can highlight if SST has become a spatial limiting factor in the UK. The causes of the observed spatial shifts from this study are supported by MacLeod et al., (2008), who found that temperature was the most vital variable for separating the occurrence of CDs and WBDs and that to reduce competition for resources, it has been observed that both species partition their shared niche. This was determined due to only WBDs were present below 13°C, whereas CDs were only seen when temperature was above 14°C. As the northern North Sea tends to be colder than elsewhere in the UK, region 4 might reflect a displacement of WBDs from other UK regions, and therefore would provide a reason for the observed spatial range shifts and increased abundance of WBDs over the 30-year period (Canning et al., 2008). Given the information presented, it is thought that with increasing SST in the future, the range of WBD will contract and even become isolated or extirpated from the North Sea, losing this cetacean community from UK waters (MacLeod et al., 2008; MacLeod et al., 2005).

On the other hand, warmer local ocean temperatures off Scotland would facilitate larger spatial range for CDs, which are a warm-water species. This is due to SST influencing the distribution of their prey, which in turn affects the extent of CDs movements (Neumann, 2000). This theory was initiated due to an increased occurrence of common dolphin strandings along the coast of Scotland (MacLeod et al., 2005). Therefore, it is reasonable to argue that region 4 in this study should be identified as a current WBD hotspot or refugia from to the analysis of their spatial range shifts, and that conservation methods surrounding the global issue of climate change should be prioritised across the North Sea to prevent the loss of sub-polar species like the white-beaked dolphin.

8.2 Critical Reflection

8.2.1 Successes and limitations of the study

The strength of this study is that its findings proved the research hypothesis which denotes that the total number of sightings and individuals of certain species is an effective method of determining its spatio-temporal distribution and relative abundance in regions over a given period of time. Although this study was able to recognise and examine CD and WBD spatio-temporal distribution in UK waters from citizen science, there was minimal data for years 1990-94 which was a weakness with this study. Conducting the same study but with a larger pool of sightings data e.g., SCANS Surveys including those from historical observations would allow for more concrete findings to be established with comparing past spatial trends to current.

Additionally, all aims were successfully achieved, and the data originated from a trustworthy and reliable source (SWF). The method was well executed and the sightings with biases belonging to an effort watch were corrected for effort which improves the accuracy of the results obtained from this study. The inclusion of presence-only ratios aided in resolving the patchiness nature of the effort sightings. Drawing all sightings data (including presence only) into spatio-temporal analyses could yield more conclusive results, however the biases surrounding presence only data would have to be examined.

The findings with this study were not able to quantifiably distinguish if SST is the factor causing the observed spatial range shifts in CD and WBD distributions across the UK, which is another weakness of this study. However, the comparative literature used enabled possible links to be made between global warming and its effect on cetacean communities.

8.2.2 Recommendations for future research

Further research is needed to establish if SST is the only environmental variable causing the limited spatial extent of WBD in the UK, and the subsequent habitat expansion of CD. Other environmental factors should be taken into consideration to show what extent these have on determining spatial distribution e.g., running correlation analyses on sightings data and environmental variables. Furthermore, Maximum Entropy Modelling software such as MAXENT can predict species occurrences by using its distribution variances whilst acknowledging the environmental variables of an area. This could be a useful tool for conservationists to use when understanding the effect increased global climate change will have on different organisms and their distributions.

9. Conclusion

This research primarily aimed to quantify and map the distribution of CD and WBD in the UK between 1990-2020 in order to determine if both species exhibit consistently different spatial ranges over a 30-year temporal scale. Upon exploring this research using various method techniques, and by examining past literature, it can be concluded that white-beaked dolphins and common dolphins exhibit different spatial ranges and that it has changed on a temporal scale. WBD was found to have become restricted with spatial range in region 4 (northern North Sea) over a 30-year period, whilst CDs are shown to have expanded their habitat to encompass the spatial ranges previously utilised by WBDs. CDs have a dominance over the whole west coast of the UK, where high frequencies of sightings and individuals are observed throughout the Celtic Deep, English Channel, Irish Sea, and north-west Scotland. In a world that is faced with the increasing pressures of anthropogenic activities, the likelihood of WBDs sustaining a population off the north-east of the UK in the North Sea becomes doubtful. Therefore, it is of the utmost importance to prevent rising SST in the UK to protect local cold-water cetacean communities.

10.References

Alava, J.J. (2020). Modelling the Bioaccumulation and Biomagnification Potential of Microplastics in a Cetacean Foodweb of the Northeastern Pacific: A Prospective Tool to Assess the Risk Exposure to Plastic Particles. *Frontiers in Marine Science, 7*. DOI=10.3389/fmars.2020.566101.

Amano,T., Lamming, J.D.L., Sutherland, W.J. (2016). Spatial Gaps in Global Biodiversity Information and the Role of Citizen Science, *BioScience, 66*(5), (pp393–400). https://doi.org/10.1093/biosci/biw022.

Ana Paula Madeira Di Beneditto, A.P.M, and Ariane da Silva Oliveira, A. da. S. (2019). Debris ingestion by carnivorous consumers: Does the position in the water column truly matter? *Marine Pollution Bulletin, 144.* (pp134-1399). https://doi.org/10.1016/j.marpolbul.2019.04.074.

Arcangeli, A, Santini, E, and Cadiou, F.S. (2021). Report on the risk induced by floating litter. Assessment of risk exposure areas. MEDREGION Project D6.5.

ASCROBANS [Agreement on the Conservation of Small Cetaceans of the Baltic, Northeast Atlantic, Irish and North Seas]. (2018). Underwater Noise. Available at: https://www.ascobans.org/en/species/threats/underwater-noise. Accessed 12th February 2022.

Barnes, D.K.A., Galgani, F., Thompson, R.C, and Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of The Royal Society Biological Sciences 364*(1526). https://doi.org/10.1098/rstb.2008.0205

Bonney, R., Cooper, C.B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K.V, and Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience 59*(11), (pp. 977–984). https://doi.org/10.1525/bio.2009.59.11.9.

Brereton, T., Lewis, K, and MacLeod, C. (2013, August 27-19). Lyme Bay: A recently discovered hotspot for white- beaked dolphins in the English Channel. (pp39-58). [Paper presentation]. AC20/Doc.4.1.c. Proceedings of the ECS / ASCOBANS / WDC Workshop Towards a Conservation Strategy for White-beaked Dolphins in the Northeast Atlantic, The Casa da Baía, Setúbal, Portugal.

https://www.ascobans.org/sites/default/files/document/AC20_4.1.c_ECSWorkshop_White-beakedDolphin.pdf.

Brophy, J.T., Murphy, S, and Rogan E. (2009). The diet and feeding ecology of the common dolphin (Delphinus delphis) in the northeast Atlantic. Report to the International Whaling Commission. SC/61/SM14.
https://www.researchgate.net/publication/233385844_The_diet_and_feeding_ecology_of_the_common_dolphin_Delphinus_delphis_in_the_northeast_Atlantic.

Brownell, R.L., Reeves, R.R., Read, A.J., Smith, B.D., Thomas, P.O., Ralls, K., Amano, M., Berggren, P., Chit, A.M., Collins, T., Currey, R., Dolar, M.L.L., Genov, T., Hobbs, R.C., Kreb, D., Marsh, H., Zhigang, M., Perrin, W.F., Phay, S., ...Wang, J.Y. (2019). Bycatch in gillnet fisheries threatens Critically Endangered small cetaceans and other aquatic fauna. *Endangered Species Research, 40,* (pp285-296). DOI: https://doi.org/10.3354/esr00994.

Canning, S., Santos, M., Reid, R., Evans, P., Sabin, R., Bailey, N., and Pierce, G. (2008). Seasonal distribution of white-beaked dolphins (Lagenorhynchus albirostris) in UK waters with new information on diet and habitat use. *Journal of the Marine Biological Association of the United Kingdom 88*(6), (pp1159-1166). Doi:10.1017/S0025315408000076.

Cassoff, R.M., Moore, K.M., McLellan, W.A., Barco, S.G., Rotstein, D.S, and Moore, M.J. (2011). Lethal entanglement in baleen whales. *Diseases of Aquatic Organisms, 96.* (pp 175-185). doi: 10.3354/dao02385.

Chambault P, Tervo O, Garde E, Hansen R.G, Blackwell S.B, Williams T.M, Dietz R, Albertsen C.M, Laidre K.L, Nielsen N.H, Richard P, Sinding M.H.S, Schmidt H.C, Heide-Jørgensen P.M. (2020). The impact of rising sea temperatures on an Arctic top predator, the narwhal. *Scientific Reports, 10*(1):18678. Doi: 10.1038/s41598-020-75658-6.

Chambault, P., Albertsen, C.M., Patterson, T.A., Hansen, R.G., Tervo, O., Laidre, K.L., and Heide-Jørgensen, P.M. (2018). Sea surface temperature predicts the movements of an Arctic cetacean: the bowhead whale. *Scientific Reports 8*(9658). https://doi.org/10.1038/s41598-018-27966-1

Chandler, M., See, L., Copas, K., Bonde, A.M.Z., López, B.C., Danielsen, F., Legind, J.K., Masinde, S., Miller-Rushing, A.J., Newman, G., Rosemartin, A., and Turak, E., (2017). Contribution of citizen science towards international biodiversity monitoring. *Biological Conservation 213*, (pp. 280-294). 10.1016/j.biocon.2016.09.004.

Chavez-Rosales, S., Palka, D.L., Garrison, L.P., Josephson, E.A. (2019). Environmental predictors of habitat suitability and occurrence of cetaceans in the western North Atlantic Ocean. *Scientific Reports 9*(5833). https://doi.org/10.1038/s41598-019-42288-6.

Committee on Taxonomy. (2018). List of marine mammal species and subspecies. Society for Marine Mammalogy. Available at www.marinemammalscience.org. Accessed 20th March 2022.

Conrad, C.C, and Hilchey, K.G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment, 176,* (pp 273-291). DOI 10.1007/s10661-010-1582-5.

Cruise Market Watch, n.d. Growth of the cruise line industry. Available at: https://cruisemarketwatch.com/growth/. Accessed 12th February 2022.

Department for International Trade (2015, July 2). UK Offshore Wind: Opportunities for trade and investment. GOV.UK. https://www.gov.uk/government/publications/uk-offshore-wind-opportunities-for-trade-and-investment/uk-offshore-wind-opportunities-for-trade-and-investment.

Dickinson, K.H., J.L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., Kitamura, W., Takagawa, S., Koyama, K., Ogawara, T., and Miller-Rushing, A.J. (2016). Citizen science: a new approach to advance ecology, education, and conservation. *Ecological Research 31*(1), (pp1-19). https://doi.org/10.1007/s11284-015-1314-y.

Eisfield-Pierantonio, S.M., Pierantonio, N, and Simmonds, M.P. (2022). The impact of marine debris on cetaceans with consideration of plastics generated by the COVID-19 pandemic. *Environmental Pollution, 300*(118967). https://doi.org/10.1016/j.envpol.2022.118967.

Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E, and Embling, C.B. (2019). The Effects of Ship Noise on Marine Mammals – A Review. *Frontiers Marine Science 6.* https://doi.org/10.3389/fmars.2019.00606.

Evans, P. G. H., Anderwald, P., and Baines, M. E. (2003). UK cetacean status review. English Nature and Countryside Council for Wales Report. (160p). https://www.seawatchfoundation.org.uk/wp-content/uploads/2012/08/28.-UK-cetacean-status-review-2003.pdf.

Evans, P.G.H and Waggitt, J.J. (2020) Impacts of climate change on marine mammals, relevant to the coastal and marine environment around the UK. *MCCIP Science Review* (pp421–455). https://www.seawatchfoundation.org.uk/wp-content/uploads/2020/01/Evans-and-Waggitt-2020.pdf.

Evans, P.G.H. (1982). Associations between seabirds and cetaceans: a review. *Mammal Review 12* (4). (pp187-206). https://doi.org/10.1111/j.1365-2907.1982.tb00015.x

Evans, P.G.H. (2020). European Whales, Dolphins, and Porpoises. *Marine Mammal Conservation in Practise*. Academic Press, London & New York (306pp).

Evans, P.G.H., and Bjørge, A. (2013). Impacts of climate change on marine animals. *MCCIP Review.* https://www.seawatchfoundation.org.uk/wp-content/uploads/2015/05/Evans-Bj%C3%B8rge_2013.pdf

Evans, P.G.H., and Hammond, P.S. (2004). Monitoring cetaceans in European waters. *Mammal Review, 34*(1), (pp. 131-156). DOI:10.1046/j.0305-1838.2003.00027.x.

Evans, W. (1994). Common dolphin, white-bellied porpoise Delphinus delphis Linnaeus, 1758. In: Ridgway S, Harrison R (eds). *Handbook of marine mammals 5*. Academy, London, pp 191–214

Fall, J, and Skern-Mauritzen, M. (2014). White-beaked dolphin distribution and association with prey in the Barents Sea. *Marine Biology Research, 10*(10), (pp957-971). https://doi.org/10.1080/17451000.2013.872796.

Forcada J, Aguilar A, Evans P, Perrin W. (1990). Distribution of common and striped dolphins in the temperate waters of the eastern north Atlantic. In: Evans P, Aguilar A, Smeenk C (eds). European Research on Cetaceans: *Proceedings of the Fourth Annual Conference of the European Cetacean Society 4*, (pp 64–65).

Forcada, J and Hammond, P. (1998). Geographical variation in abundance of striped and common dolphins of the western Mediterranean. *Journal of Sea Research, 39* (3-4), 313-325. https://doi.org/10.1016/S1385-1101(97)00063-4.

Fossi,M.C., Baini, M., Panti, C and Baulch, S. (2018). Impacts of Marine Litter on Cetaceans: A Focus on Plastic Pollution. *Marine Mammal Ecotoxicology 6*, (pp147-184). Academic Press. https://doi.org/10.1016/B978-0-12-812144-3.00006-1.

Genner, M.J., Freer, J.J., and Rutterford, L.A. (2017). Future of the Sea: Biological Responses to Oceans Warming. *Foresight- Government Office for Science*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/639430/Ocean_warming_final.pdf.

Haelters, J and Everaarts, E. (2011). Two Cases of Physical Interaction Between White-Beaked Dolphins (Lagenorhynchus albirostris) and Juvenile Harbour Porpoises (Phocoena phocoena) in the Southern North Sea. *Aquatic Mammals, 37*(2). (pp.198-201). DOI 10.1578/AM.37.2.2011.198.

Hague, E.L., Sinclair R.R, and Sparling, C.E. (2020). Regional baselines for marine mammal knowledge across the North Sea and Atlantic areas of Scottish waters. *Scottish Marine and Freshwater Science 11*(12). Doi:10.7489/12330-1.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide- Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. & Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology 39*, (pp361–376). https://doi.org/10.1046/j.1365-2664.2002.00713.x

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Boerjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M., Scheidat, M. & Teilmann, J. (2021). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANSIII aerial and shipboard surveys. Final Report. (39pp). https://synergy.standrews.ac.uk/scans3/category/researchoutput/.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D. & Gordon, J. (2013). Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation 164*, (pp107-122). https://doi.org/10.1016/j.biocon.2013.04.010

Harris, C.M., Thomas, L., Falcone, E.A., Hildebrand, J., Houser, D., Kvadsheim, P.H., Lam, F-P.A., Miller, P.J.O., Moretti, D.J., Read, A.J., Slabblekoorn, H., Southall, B.L., Tyack, P.L., Wartzok, D., and Janik, V.M. (2017). Marine mammals and sonar: Dose-response studies, the risk-disturbance hypothesis and the role of exposure content. *Journal of Applied Ecology 55*(1). (pp. 396-404) https://doi.org/10.1111/1365-2664.12955.

Henderson, E.E., Hildebrand, J.A., Smith, M.H, and Falcone, E.A. (2011). The behavioural context of common dolphin (Delphinus sp.) vocalisations. *Marine Mammal Science, 28*(3), (pp439-460). https://doi.org/10.1111/j.1748-7692.2011.00498.x.

Heyning, J. E., & W. F. Perrin. (1994). Evidence for two species of common dolphins (genusDelphinus) from the eastern North Pacific. Natural History Museum of Los Angeles County Contributions. *Science, 442*, (pp1-35). https://doi.org/10.5962/p.226804.

ICUN (International Union for Conservation and Nature), n.d. Ocean Warming. Available at: https://www.iucn.org/resources/issues-briefs/ocean-warming. Accessed 14th February 2022.

Ijsseldijk, L.L., Brownlow, A., Davidson, N.J., Deaville, R., Haelters, J., Keijl, G., Siebert, U., and Ten-Doeschate, M.T.I. (2018). Spatiotemporal trends in white-beaked dolphin strandings along the North Sea coast from 1991–2017. *Journal of the Dutch Mammal Society [LUTRA] 61*(1), (pp 153-163). https://www.researchgate.net/publication/328283036_Spatiotemporal_trends_in_white-beaked_dolphin_strandings_along_the_North_Sea_coast_from_1991-2017.

International Whaling Commission n.d. Common Dolphin (Delphinus delphi) [online]. Available at: https://wwhandbook.iwc.int/en/species/common-dolphin. Accessed on 12th January 2022.

Kinze, C.C. (2002). White-beaked Dolphin: Lagenorhynchus albirostris. *Encyclopedia of Marine Mammals (2nd edition)*. In Perrin, W.F., Würsig, B and Thewissen, J.G.M. (eds.) (pp1332–1334). Academic Press, London, UK. https://doi.org/10.1016/B978-0-12-373553-9.00285-6.

Laist, D.W. (1997). Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records. In: Coe J.M., Rogers D.B. (eds). *Marine Debris. Springer Series on Environmental Management* (pp 99-139). Springer, New York, NY. https://doi.org/10.1007/978-1-4613-8486-1_10.

Learmonth, J.A., Macleod, C.D., Santos, M.B., Pierce, G.J., Crick, H.Q.P. and Robinson, R.A. (2007). Potential effects of climate change on marine mammals. *Oceanography and Marine Biology: An Annual Review 44*, (pp431–464). DOI:10.1201/9781420006391.ch8.

MacLeod, C., Weir, C., Santos, M., Dunn, T. (2008). Temperature-based summer habitat partitioning between white-beaked and common dolphins around the United Kingdom and Republic of Ireland. *Journal of the Marine Biological Association of the United Kingdom 88*(6), (pp1193-1198). Doi:10.1017/S002531540800074X.

MacLeod, C.D. (2013, August 27-19). White-beaked Dolphins in the Northeast Atlantic: A brief review of their ecology and potential threats to conservation status. (pp26-35). [Paper presentation]. AC20/Doc.4.1.c. Proceedings of the ECS / ASCOBANS / WDC Workshop Towards a Conservation Strategy for White-beaked Dolphins in the Northeast Atlantic, The Casa da Baía, Setúbal, Portugal. https://www.ascobans.org/sites/default/files/document/AC20_4.1.c_ECSWorkshop_White-beakedDolphin.pdf#page=28.

MacLeod, C.D., Bannon,S.M., Pierce, G.J., Schweder, C., Learmonth, J.A., Herman, J.S., Reid, R.J. (2005). Climate change and the cetacean community of north-west Scotland. *Biological Conservation 124*(4). (pp. 477-483). https://doi.org/10.1016/j.biocon.2005.02.004.

MacLeod, C.D., Weir, C.R., Pierpoint, C. and Harland, E. (2007). The habitat preferences of marine mammals west of Scotland (UK*). Journal of the Marine Biological Association of the United Kingdom 87*(1), (pp157-164). https://doi.org/10.1017/S0025315407055270.

Maddalena Bearzi (2005) Dolphin sympatric ecology, *Marine Biology Research, 1*(3), (pp165-175). DOI: 10.1080/17451000510019132.

Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K., and Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Marine Ecology Progress Series 309*. (pp. 279-295). Doi:10.3354/meps309279.

Mannocci, L., Dabin, W., Augeraud-Véron, E., Dupuy, J-F., Barbaud, C, and Ridoux, V. (2012). Assessing the Impact of Bycatch on Dolphin Populations: The Case of the Common Dolphin in the Eastern North Atlantic. *PLoS ONE, 7*(2). https://doi.org/10.1371/journal.pone.0032615.

Marine Stewardship Council, n.d. What is bycatch and how can it be managed? [online]. Available at: https://www.msc.org/en-au/what-we-are-doing/our-collective-impact/what-is-a-fishery/what-is-bycatch-and-how-can-it-be-managed. Accessed on 9th January 2022.

McKinley, D.C., Miller-Rushing, J.A., Ballard, H.L., Bonney,R., Brown, H., Cook-Patton, S.C., Evans, D.M., French, R.A., Parrish, J.K., Phillips, B.T., Ryan, S.F., Shanley, L.A., Shirk, J.L., Stepenuck, K.F., Weltzin, J.F., Wiggins, A., Boyle, O.D., Briggs, R.D., Chapin., ...Soukup, M.A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation, 208*. (pp15-28). https://doi.org/10.1016/j.biocon.2016.05.015.

Morizur, Y., Berrow, S.D., Tregenza, N.J.C., Couperus, A.S. and Pouvreau, S. (1999). Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. *Fisheries Research, 41*(3), (pp297-307). https://doi.org/10.1016/S0165-7836(99)00013-2.

Morris, D.J., Pinnegar, J.K., Maxwell, D.L., Dye, S.R., Fernand, L.F., Flatman, S., Williams, O.J., and Rogers, S.L. (2018). Over 10 million seawater temperature records for the United Kingdom Continental Shelf between 1880 and 2014 from 17 Cefas (United Kingdom government) marine data systems. *Earth System Science Data Discussions 10*(1), (pp 1-42). DOI:10.5194/essd-10-27-2018.

Mueller, M.A., Drake, D, and Allen, M.L. (2019). Using citizen science to inform urban canid management. *Landscape and Urban Planning, 189*. (pp362-371). https://doi.org/10.1016/j.landurbplan.2019.04.023.

Murphy, S., and Rogan, E. (2006). External morphology of the short-beaked common dolphin, Delphinus delphis: growth, allometric relationships and sexual dimorphism. *Acta Zoologica, 87*(4), (pp315-329). https://doi.org/10.1111/j.1463-6395.2006.00245.x.

Murphy, S., Pinn, E.H, and Jepson, P.D. (2013). The short-beaked common dolphin (Delphinus delphis) in the northeast Atlantic: distribution, ecology management and conservation status. In R.N. Hughes, D.J. Hughes, and I.P. Smith (Eds.). *Oceanography and Marine Biolog*y (pp193- 280). CRC Press.

Nabi, G., McLaughlin, R.W., Hao, Y., Wang, K., Zeng, X., Khan, S., Wand, D. (2018). The possible effects of anthropogenic acoustic pollution on marine mammals' reproduction: an emerging threat to animal extinction. *Environmental science and pollution research international 25*(20), (pp19338-19345). DOI: 10.1007/s11356-018-2208-7.

Natoli, A., Cañadas, A., Peddemors, V.M., Aguilar, A., Vaquero, C., Fernández-Piqeuras, P, and Hoelzel, A.R. (2005). Phylogeography and alpha taxonomy of the common dolphin

(Delpinus sp.). *Journal of Evolutionary Biology, 19*(3), (pp943-954). https://doi.org/10.1111/j.1420-9101.2005.01033.x

Neumann, D., and Orams, M. (2010). Feeding behaviours of short-beaked common dolphins, Delphinus delphis in New Zealand. *Aquatic Mammals 29*(1), (pp137-149). 10.1578/016754203101023997.

Neumann, D.R., Leitenberger, A., and Orams, M.B. (2002). Photo-identification of short-beaked common dolphins (Delphinus delphis) in north-east New Zealand: A photo-catalogue of recognisable individuals. *New Zealand Journal of Marine and Freshwater Research 36*(3), (pp593-604). https://doi.org/10.1080/00288330.2002.9517115.

NOAA Fisheries n.d. White-Beaked Dolphin. Available at: https://www.fisheries.noaa.gov/species/white-beaked-dolphin. Accessed on 3rd February 2022.

NOAA Fisheries, n.d. Short-Beaked Common Dolphin. Available at: https://www.fisheries.noaa.gov/species/short-beaked-common-dolphin#:~:text=Short%2Dbeaked%20common%20dolphins%20prefer,with%20the%20Gulf%20Stream%20curren . Accessed on 8th January 2022.

Parsons, E.C.M., Clark, J., Warham, J, and Simmonds, M.P. (2012). The Conservation of British Cetaceans: A Review of the Threats and Protection Afforded to Whales, Dolphins, and Porpoises in UK Waters, Part 1. *Journal of International Wildlife Law & Policy 13*(1), (pp1-62). https://doi.org/10.1080/13880291003705145.

Peltier, H., Authier ,M., Deaville, R., Dabin, W., Jepson, P.D., Canneyt, van, O., Daniel, P, and Ridoux, V. (2016). Small cetacean bycatch as estimated from stranding schemes: The common dolphin case in the northeast Atlantic. *Environmental Science & Policy, 63*, (pp 7-18). https://doi.org/10.1016/j.envsci.2016.05.004.

Perrin, W.F. (2009). Common dolphins: Delphinus delphis and D. capensis. *Encyclopedia of Marine Mammals*. (pp255-259). DOI:10.1016/B978-0-12-373553-9.00063-8.

Rasmussen, M.H, and Miller, L.A. (2002). Whistles and clicks from white-beaked dolphins (Lagenorhynchus albirostris), recorded in Faxaflói Bay, Iceland. Aquatic Mammals, 28(1). (pp. 78-79). https://www.researchgate.net/publication/266883602_Whistles_and_clicks_from_white-beaked_dolphins_Lagenorhynchus_albirostris_recorded_in_Faxafloi_Bay_Iceland.

Reeves, R., Smeenk, C., Kinze, C.C., Brownell, R.L. and Lien, J. (1999) White-beaked dolphin Lagenorhynchus albirostris, Gray 1846. In: *Handbook of Marine Mammals 6*, (pp. 1-30). Academic Press.

Reid, J., Evans, P. G. H. & Northridge, S. P. (2003) Cetacean Distribution Atlas. Joint Nature Conservation Committee, Peterborough. https://data.jncc.gov.uk/data/a5a51895-50a1-4cd8-8f9d-8e2512345adf/atlas-cetacean-distribution-web.pdf.

Richardson, W., C. J. Greene, C. Malme and D. Thomson. (1995). *Marine Mammals and Noise* (p208). Academic Press, San Diego, CA.

Robinson, Kevin & Eisfeld-Pierantonio, Sonja & Costa, Marina & Simmonds, Mark. (2011). Short-beaked common dolphin (Delphinus delphis) occurrence in the Moray Firth, north-east Scotland. *Marine Biodiversity Records. 3*. DOI:10.1017/S1755267210000448.

Roy, H.E., Pocock, M.J.O., Preston, C.D., Roy, D.B., Savage, J., Tweddle, J.C, and Robinson, L.D. (2012). Understanding citizen science and environmental monitoring: final report on behalf of UK Environmental Observation Framework. Wallingford, NERC/Centre for Ecology & Hydrology, 173pp.
https://www.ceh.ac.uk/sites/default/files/citizensciencereview.pdf.

Sea Watch Foundation (2007). The White-Beaked Dolphin in UK waters. Sea Watch Foundation, New Quay, Wales. https://seawatchfoundation.org.uk/wp-content/uploads/2012/07/White-beaked_Dolphin.pdf.

Sea Watch Foundation, n.d. White-beaked dolphin. Available at:
https://www.seawatchfoundation.org.uk/white-beaked-dolphin/. Accessed on 3rd February 2022.

Sea Watch Foundation. (2007). The Short-Beaked Common Dolphin in UK Waters. Sea Watch Foundation, New Quay, Wales. https://seawatchfoundation.org.uk/wp-content/uploads/2012/07/Common_Dolphin.pdf.

Senko, J.S., Nelms, S.E., Reavis, J.L., Witherington, B., Godley, B.J, and Wallace, B.P. (2020). Understanding individual and population-level effects of plastic pollution on marine megafauna. *Endangered Species Research, 43*, (pp234-252). DOI:
https://doi.org/10.3354/esr01064.

Simard, P, and Gowans, S. (2008). Group movements of White-beaked dolphins (Lagenorhyncus albirostris) near Halifax, Canada. *Aquatic Mammals, 34*(8). (pp.331-337). DOI 10.1578/AM.34.3.2008.331.

Simmonds, M., & Eliott, W. (2009). Climate Change and cetaceans: Concerns and recent developments. *Journal of the Marine Biological Association of the United Kingdom, 89*(1), (pp203-210). Doi:10.1017/S0025315408003196.

Simmonds, M.P., Dolman, S.J., Jasny, M., Parsons, E.C.M., Weilgart, L., Wright, A.J., and Leaper, R. (2014). Marine Noise Pollution- Increasing Recognition but need for more practical action. *The Journal of Ocean Technology 9*(1). (pp. 71-90). https://www.wellbeingintlstudiesrepository.org/acwp_ehlm/9/.

Spitz, J., Mourocq, E., Leauté, J.P., Ouéro, J.C., and Ridoux, V. (2010). Prey selection by the common dolphin: Fulfilling high energy requirements with high quality food. *Journal of Experimental Marine Biology and Ecology, 390*(2). (pp73-77). https://doi.org/10.1016/j.jembe.2010.05.010.

The Hebridean Whale & Dolphin Trust, n.d. White-Beaked Dolphin. Available at: https://hwdt.org/whitebeaked-dolphin. Accessed 5th February 2022.

The Mammal Society, n.d. Species- White-Beaked Dolphin. Available at: https://www.mammal.org.uk/species-hub/full-species-hub/discover-mammals/species-white-beaked-dolphin/. Accessed 5th February 2022.

The Wildlife Trusts n.d. Common Dolphin. [online]. Available at: https://www.wildlifetrusts.org/wildlife-explorer/marine/marine-mammals-and-sea-turtles/common-dolphin. Accessed on 14th January 2022.

Thornhill, I., Loiselle, S., Lind, K, and Ophof, D. (2016). The Citizen Science Opportunity for Researchers and Agencies. *BioScience, 66*(9), (pp720–721). https://doi.org/10.1093/biosci/biw089.

Tinker, J.P., Howes, E.L., Wakelin, S., Menary, M., Kent, E., Berry, D., Hindson, J., Ribeiro, J., Dye, S., Andreas, O., Lyons, K., and Smyth, T. (2020). The Impact of climate change on temperature (air and sea), relevant to the coastal and marine environment around the UK. *MCCIP Science Review*, (pp 1-30). DOI:10.14465/2020.arc01.tem.

Tournadre, J. (2014) Anthropogenic pressure on the open ocean: the growth of ship traffic revealed by altimeter data analysis. *Geophysical Research Letters 41*(22), (pp7924–7932). https://doi.org/10.1002/2014GL061786.

Weelden, van-C., Towers, J.R., and Bosker, T. Impacts of climate change on cetacean distribution, habitat, and migration. (2021). *Climate Change Ecology 1*(100009). https://doi.org/10.1016/j.ecochg.2021.100009.

Weir, C., Macleod, C., Calderan, S. (2009). Fine-scale habitat selection by white-beaked and common dolphins in the Minch (Scotland, UK): Evidence for interspecific competition or coexistence*? Journal of the Marine Biological Association of the United Kingdom 89*(5), (pp951-960). Doi:10.10117/S0025315408003287.

Whale and Dolphin Conservation, n.d. Short-Beaked Common Dolphin [online]. Available at: https://au.whales.org/whales-dolphins/species-guide/short-beaked-common-dolphin/. Accessed on 7th January 2022.

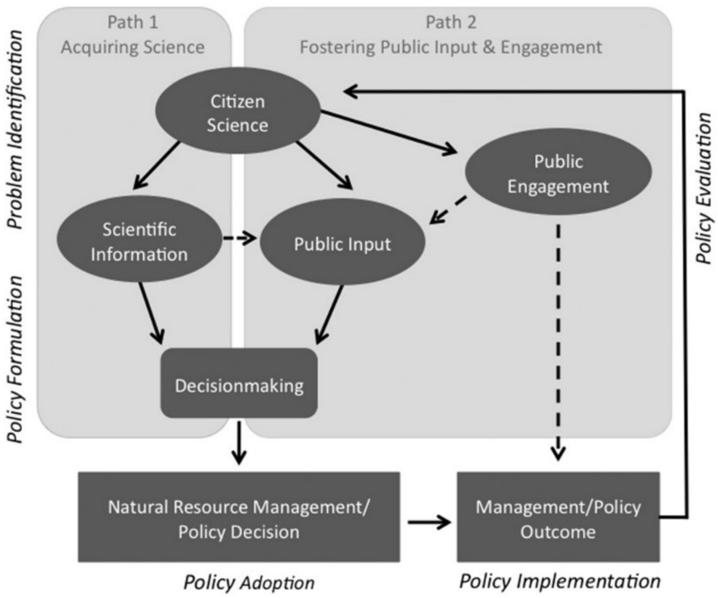
Whale and Dolphin Conservation, n.d. White-Beaked Dolphin [online]. Available at: https://uk.whales.org/whales-dolphins/species-guide/white-beaked-dolphin/. Accessed on 7th January 2022.

Wright AJ, Soto NA, Baldwin AL, Bateson M, Beale CM, Clark C et al (2007) Do Marine mammals experience stress related to anthropogenic noise? *International Journey of Comparative Psychology 20*(2), (pp274–316). https://www.researchgate.net/publication/284463826_Do_marine_mammals_experience_stress_related_to_anthropogenic_noise.

Young, D.B, and Cockcroft, V.G. (1994). Diets of common dolphins (Delphinus delphis) off the south coast of Africa: opportunism or specialisation? *Journal of Zoology, 234*(1), (pp41-53). https://doi.org/10.1111/j.1469-7998.1994.tb06055.x.

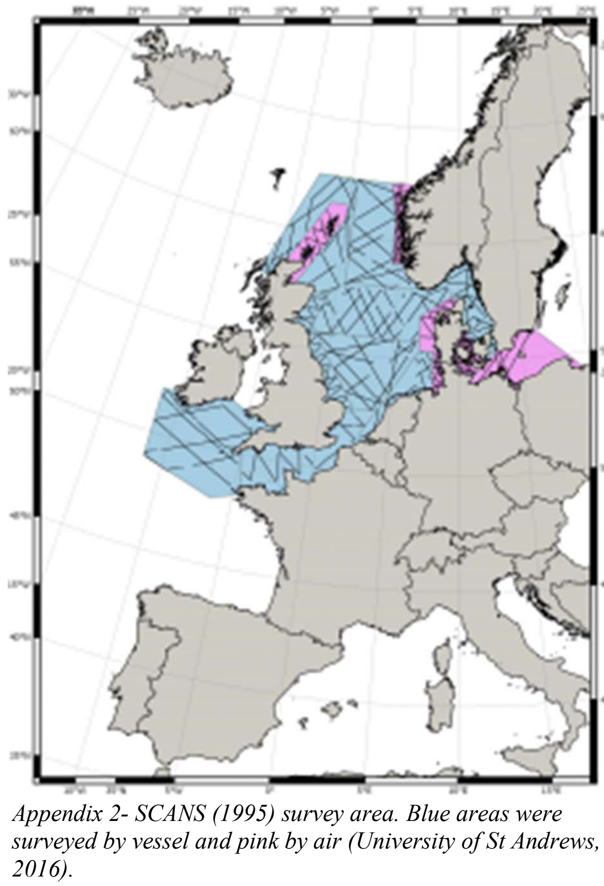
11.Appendix

Appendix 1



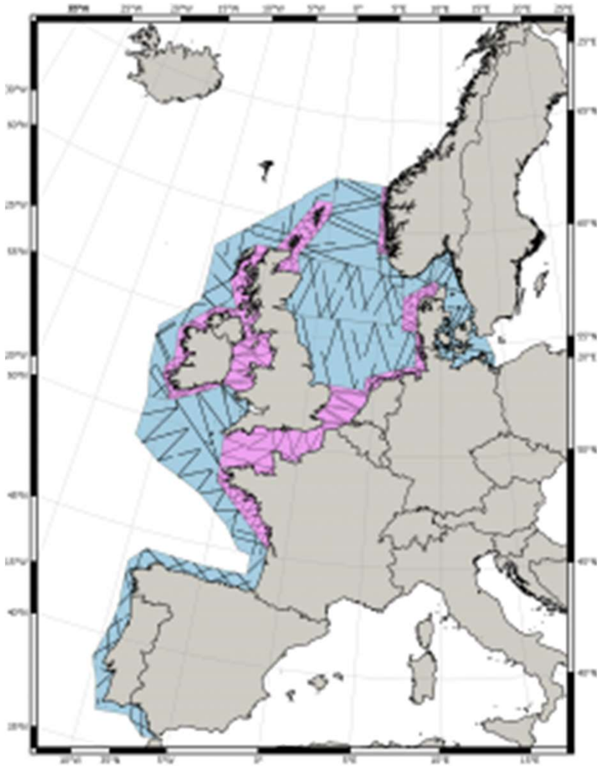
Appendix 1- Flow chart detailing the ways in which citizen science can take to inform decision-makers (McKinley et al.,2017).

Appendix 2



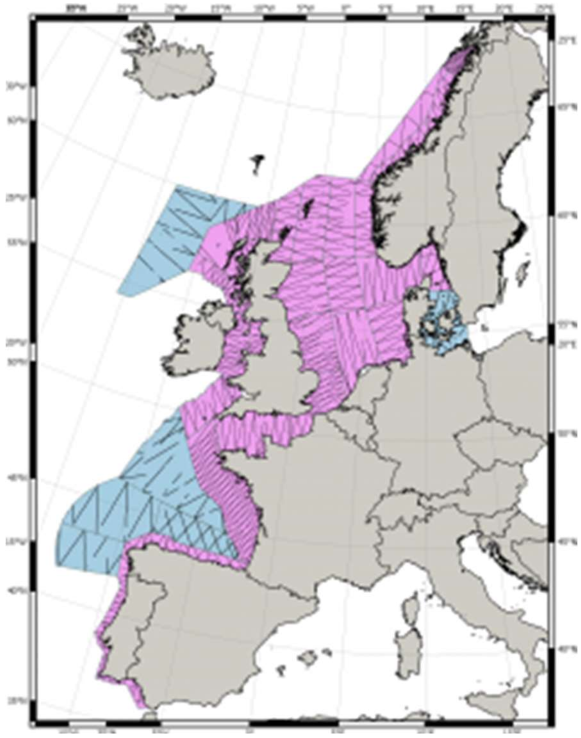
Appendix 2- SCANS (1995) survey area. Blue areas were surveyed by vessel and pink by air (University of St Andrews, 2016).

Appendix 3



Appendix 3- SCANS II (2005) survey area. Blue areas were surveyed by vessel and pink by air (University of St Andrews, 2016).

Appendix 4



Appendix 4- SCANS III (2016) survey area. Blue areas were surveyed by vessel and pink by air (University of St Andrews, 2016).

Appendix 5

Year	Region	Total_Sighting_CD	Total_Sighting_WBD	Total_Individuals_CD	Total_Individuals_WBD
1990	1	1	0	8	0
1991	1	0	0	0	0
1992	1	0	0	0	0
1993	1	1	0	2	0
1994	1	0	0	0	0
1995	1	0	0	0	0
1996	1	18	0	361	0
1997	1	0	0	0	0
1998	1	0	0	0	0
1999	1	0	0	0	0
2000	1	16	0	189	0
2001	1	13	0	285	0
2002	1	31	0	269	0
2003	1	6	0	58	0
2004	1	42	0	338	0
2005	1	189	0	2180	0
2006	1	188	0	1476	0
2007	1	10	0	316	0
2008	1	5	0	34	0
2009	1	26	0	329	0
2010	1	14	0	242	0
2011	1	0	0	0	0
2012	1	0	0	0	0
2013	1	0	0	0	0
2014	1	3	0	133	0
2015	1	5	0	37	0
2016	1	1	0	15	0
2017	1	19	0	200	0
2018	1	15	0	104	0
2019	1	4	0	74	0
2020	1	14	0	86	0
1990	2	0	0	0	0
1991	2	0	0	0	0
1992	2	0	0	0	0
1993	2	0	0	0	0
1994	2	0	0	0	0
1995	2	0	0	0	0
1996	2	0	0	0	0
1997	2	0	0	0	0
1998	2	0	0	0	0
1999	2	0	0	0	0
2000	2	0	0	0	0
2001	2	4	0	13	0
2002	2	0	0	0	0
2003	2	0	0	0	0
2004	2	2	0	8	0
2005	2	2	0	5	0
2006	2	17	0	43	0
2007	2	1	0	2	0
2008	2	0	0	0	0
2009	2	0	0	0	0
2010	2	0	0	0	0
2011	2	0	0	0	0
2012	2	0	0	0	0
2013	2	0	0	0	0
2014	2	0	0	0	0
2015	2	0	0	0	0
2016	2	0	0	0	0
2017	2	12	0	227	0
2018	2	0	0	0	0
2019	2	0	0	0	0
2020	2	0	0	0	0
1990	3	0	0	0	0
1991	3	0	0	0	0
1992	3	0	0	0	0
1993	3	0	0	0	0
1994	3	0	0	0	0
1995	3	0	0	0	0
1996	3	1	0	50	0
1997	3	0	0	0	0
1998	3	0	0	0	0
1999	3	0	1	0	18
2000	3	0	4	0	11
2001	3	1	7	15	97
2002	3	4	18	224	142
2003	3	2	10	200	70
2004	3	4	7	144	222
2005	3	0	4	0	16
2006	3	7	4	30	60
2007	3	2	0	7	0
2008	3	0	4	0	68
2009	3	0	1	0	3
2010	3	0	0	0	0
2011	3	0	0	0	0
2012	3	0	2	0	2
2013	3	5	1	176	25
2014	3	0	0	0	0
2015	3	23	2	343	15
2016	3	0	1	0	6
2017	3	0	0	0	0
2018	3	5	0	57	0
2019	3	19	7	341	45
2020	3	9	0	229	0

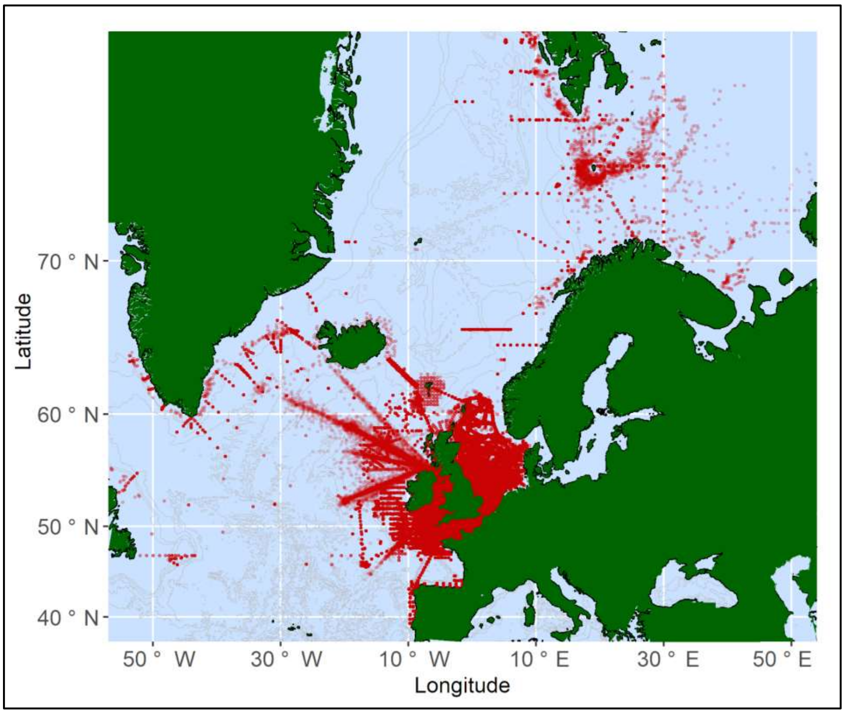
Appendix 5- *Total sightings and individuals for both species in each region (1-3) between 1990-2020.*

Appendix 6

Year	Region	Total_Sighting_CD	Total_Sighting_WBD	Total_Individuals_CD	Total_Individuals_WBD
1990	4	0	0	0	0
1991	4	0	0	0	0
1992	4	0	0	0	0
1993	4	0	0	0	0
1994	4	1	1	1	2
1995	4	1	2	40	15
1996	4	0	0	0	0
1997	4	0	2	0	330
1998	4	0	0	0	0
1999	4	0	0	0	0
2000	4	0	51	0	424
2001	4	0	21	0	124
2002	4	0	16	0	100
2003	4	0	11	0	31
2004	4	0	26	0	103
2005	4	0	19	0	51
2006	4	2	20	26	73
2007	4	0	4	0	21
2008	4	0	0	0	0
2009	4	0	13	0	92
2010	4	0	0	0	0
2011	4	1	5	3	28
2012	4	0	0	0	0
2013	4	1	2	12	19
2014	4	0	3	0	14
2015	4	0	3	0	22
2016	4	0	0	0	0
2017	4	0	0	0	0
2018	4	4	10	7	33
2019	4	0	1	0	3
2020	4	0	4	0	19
1990	5	0	0	0	0
1991	5	0	0	0	0
1992	5	0	0	0	0
1993	5	0	0	0	0
1994	5	0	0	0	0
1995	5	0	0	0	0
1996	5	0	0	0	0
1997	5	0	0	0	0
1998	5	0	0	0	0
1999	5	0	0	0	0
2000	5	0	0	0	0
2001	5	0	0	0	0
2002	5	0	0	0	0
2003	5	0	0	0	0
2004	5	0	0	0	0
2005	5	0	0	0	0
2006	5	0	0	0	0
2007	5	0	0	0	0
2008	5	0	0	0	0
2009	5	0	0	0	0
2010	5	0	0	0	0
2011	5	0	0	0	0
2012	5	0	0	0	0
2013	5	0	0	0	0
2014	5	0	0	0	0
2015	5	0	0	0	0
2016	5	0	0	0	0
2017	5	0	0	0	0
2018	5	0	0	0	0
2019	5	0	2	0	6
2020	5	0	0	0	0
1990	6	0	0	0	0
1991	6	0	0	0	0
1992	6	0	0	0	0
1993	6	0	0	0	0
1994	6	0	0	0	0
1995	6	5	0	271	0
1996	6	8	0	168	0
1997	6	10	0	186	0
1998	6	10	0	265	0
1999	6	0	0	0	0
2000	6	3	0	30	0
2001	6	2	0	5	0
2002	6	5	0	66	0
2003	6	7	0	168	0
2004	6	0	0	0	0
2005	6	2	0	22	0
2006	6	7	0	45	0
2007	6	1	0	4	0
2008	6	0	0	0	0
2009	6	0	0	0	0
2010	6	0	0	0	0
2011	6	0	0	0	0
2012	6	0	0	0	0
2013	6	0	0	0	0
2014	6	0	0	0	0
2015	6	0	0	0	0
2016	6	0	0	0	0
2017	6	0	0	0	0
2018	6	8	0	59	0
2019	6	21	0	331	0
2020	6	0	0	0	0

Appendix 6 - *Total sightings and individuals for both species in each region (4-6) between 1990-2020.*

Appendix 7



***Appendix** 7- CEFAS surveyed area for SST data (Morris et al., 2018).*

Appendix 8

Sea Watch Foundation Vessel-Based Sightings Recording Form

WF/RF 5 Apr 2006 Page .... of ....

VESSEL-BASED EFFORT RECORDING FORM

RECORD AS MUCH INFORMATION AS POSSIBLE, BUT REMEMBER THAT EVEN PARTIAL DATA MAY BE HELPFUL! CONTINUE ON SEPARATE SHEET IF NECESSARY.

Date (dd/mm/yyyy): .... **Vessel:** .... **Contact Name/Address:** ....

Tel/E-mail: .... **Observer names:** ....

Start Time .... **GMT / BST** **End Time** .... **Total Time** .... **Observer Height Above Sea Level (m)** .... **Field of View:** 180° fwd; 90°L; 90°R; 360° (tick)

TIME GMT/BST	LATITUDE (degrees, decimal minutes)	LONGITUDE (degrees, decimal minutes)	BOAT COURSE	SPEED (knots)	EFFORT TYPE	SEA STATE	SWELL HEIGHT	VISIBILITY	BOAT ACTIVITY	SIGHT. REF.

DATA DEFINITIONS: *Use categories provided below where possible*
Time: 24-hour clock; specify GMT or BST. **Location:** Record latitude and longitude (deg., decimal min. preferred) every 15 minutes or when course changes, if lat/long unavailable, note location in relation to local landmarks. **Boat course:** Record course as vessel heading not course over ground (as deg. magnetic). **Speed:** Record in knots, if available. **Effort Type:** OFF = end of effort or not watching; CASW = casual watching; DEDS = dedicated search; LINE = line transect. **Sea State:** 0 = mirror calm; 1 = slight ripples, no foam crests; 2 = small wavelets, glassy crests, but no whitecaps; 3 = large wavelets, crests begin to break, few whitecaps; 4 = longer waves, many whitecaps; 5 = moderate waves of longer form, some spray; 6 = large waves, whitecaps everywhere, frequent spray; 7 = sea heaps up, white foam blows in streaks; 8 = long, high waves edges breaking, foam blows in streaks; 9 = high waves, sea begins to roll, dense foam streaks. **Swell Height:** Light = 0-1 m; Moderate = 1-2 m; Heavy = >2 m. **Visibility:** <1 km; 1-5 km; 6-10 km; >10 km. **Boat Activity:** Record No of each and type: NB = No boats, VE = unspecified vessel, YA = yacht, RB = row boat or kayak, JS = jet ski, SB = speed boat, MB = motor boat, FI = fishing boat, FE = ferry, LS = large ship , SV = seismic vessel, WS = warship. **Sighting Reference:** Refer to number(s) on Sighting Record Form.
Please return to Sea Watch Foundation, Paragon House, Wellington Place, New Quay SA45 9NR or to your Regional Group Co-ordinator
For more info contact info@seawatchfoundation.org.uk or call 01545 561227 or visit www.seawatchfoundation.org.uk

Codes for the Sea Watch Foundation Effort Database

Field Name	Code	Variable
Effort_ID	Text	Unique identifier for effort records, e.g. eCW000123
Effort_type	LINE	Line transect effort with bearing and distance data collected for each sighting; at least one dedicated cetacean observer on watch.
	BOAT	Mobile watch with start and end positions and times; at least one dedicated cetacean observer on watch. Used for dedicated effort from any moving vessel, including ships and smaller boats.
	SKIP	Mobile watch from a vessel with start and end positions and times, but where the observer was not continuously dedicated, e.g. because they had other duties, such as navigating or driving (the SKIPper).
	WILD	Mobile watch from a wildlife operator's vessel, which maximises sightings opportunities by visiting known or assumed cetacean hot-spots.
	BIRD	Mobile watch from a vessel with start and end positions and times, but where the observer was primarily recording other taxa, especially seabirds.
	STAT	Static watch with one position, start and end times. Most land-based watches fall in this category, but also includes watches from fixed platforms at sea. May also include estimated range and bearing data.
	DIST	Point DISTANCE data, where effort was from a static platform, usually on land, and for which bearing and distance data were collected for each sighting, using a theodolite, compass or sightings board.
	SCAN	Watches carried out using a scan sampling protocol, in which the number of animals seen is recorded at regular intervals (e.g. every 15 minutes) without necessarily indicating whether or not the same animals have been counted in consecutive time periods.
	AERO	Mobile watch from an aircraft with start and end positions and times.
	CASW	Casual watch – typically associated with a sighting with no or inadequate recorded effort.
Day	Dd	Day in which record was made
Month	mm	Month in which record was made
Year	yyyy	Year in which record was made
Start_time	hh:mm	GMT time at start of watch/leg
End time	hh:mm	GMT time at end of watch/leg
Duration	Numeric	Duration of watch or leg in minutes
Lat_start	Numeric	Latitude at start of watch/leg expressed in decimal degrees (usually to 4 decimal places).
Long_start	Numeric	Longitude at start of watch/leg expressed in decimal degrees (usually to 4 decimal places).
Lat_end	Numeric	Latitude at end of watch/leg expressed in decimal degrees (usually to 4 decimal places).
Long_end	Numeric	Longitude at end of watch/leg expressed in decimal degrees (usually to 4 decimal places).
Geog_accuracy	5	Accurate to within 50km (only general area known)
	4	Accurate to within 5km (e.g. estimated from time along ferry route)
	3	Accurate within 1.5km (position estimated from land marks or by dead-reckoning)
	2	Accurate within 150m (pre1999 GPS)
	1	Accurate within 50m (e.g. post 1999 GPS recorded in DMS or degrees and decimal minutes)
	0	Not known
Observer	Integer	Link to Observer table

Platform_type	LAND	Any land based platform, including headlands, islands, piers and towers.
	RIGS	A static platform at sea, including oil rigs and moored vessels.
	AERO	Aircraft, including fixed wing, helicopters, microlites and baloons.
	SAIL	Vessel under sail, not including yachts running on engine power.
	KYAK	Canoes, rowing boats and anything paddled, e.g. wave skies.
	MOBO	Small motorboat, less than 15 m length.
	MEMO	Medium sized motor powered vessel, from 15 m to 30 m.
	SHIP	Ship, a motor vessel more than 30 m in length.
	FERY	Ferry of conventional type.
	CATS	High speed ferry.
	UNVE	Vessel of unknown size or type.
	NOPL	Platform type unknown.
Platform_code	Text	Link to Platform table
Wind_force	0 – 10	Beaufort scale
	-1	Not recorded
Wind_direction	N, NE	Compass points
	VAR	Variable
	NR	Not available
Sea_state	0 – 10	Beaufort scale (Intermediate values permissable if range given, e.g. if 2 – 3 recorded, enter 2.5).
	-1	Not recorded
Swell_height	N	None 0
	L	Low < 1 m
	M	Medium 1 to 2 m
	H	High > 2 m
	NR	Not recorded

Precip_type	N	None
	R	Rain
	SN	Snow
	F	Fog/mist
	H	Hail
	SL	Sleet
	NR	Not recorded
Precip_intensity	CL	Continuous light
	CH	Continuous heavy
	IL	Intermittent light
	IH	Intermittent heavy
	CM	Continuous moderate
	IM	Intermittent moderate
	NR	Not recorded
Visibility	0	Not recorded
	1	Less than 1km/at night
	2	
	3	1-10 km (moderate/fair)
		More than 10 km (good/excellent)

Boat_activity	NB	None – no boats in the area
	YA	Yacht / sailing boat
	RB	Rowing boat, kayak etc
	JS	Jet ski
	SB	Speed boat / RIB / small fast motorboat
	MB	Motorboat
	FI	Fishing boat
	FE	Ferry
	LS	Large ship (> 30m in length)
	VE	Unspecified vessel
	SV	Seismic survey vessel
	WS	Warship
	NR	Not recorded
		NB Prefix code with number without a space between, e.g. 3YA. If more than 1 type of boat, make a list with comma followed by space between codes, e.g. 3YA, 1LS
Additional_ information	Text	Comments or link to other recorded information.

Codes for the Sea Watch Foundation Sightings Database

Field Name	Code	Variable
Sighting_ID	Text	Unique identifier for sighting record, e.g. sCW000123
Assoc_effort_ID	Text	Link to effort record, e.g. eCW002545
Observer	Integer	Link to Observer table
Day	dd	Date of observation
Month	mm	Month of observation
Year	yyyy	Year of observation
Time_start	hh:mm	Time of observation
Time_end	hh:mm	Time last seen. Same as Time_start if not recorded as end time of sighting.
Species	Text	Link to Species code table
Best_est_group	Integer	Best estimate of number of animals – median value if range given (round up if necessary).
	-1	Not recorded
Min_no	Integer	Minimum estimate of number of animals
	-1	Not recorded
Max_no	Integer	Maximum estimate of number of animals
	-1	Not recorded
No_calves	Integer	Number of calves within the group
	-1	Not recorded
No_juveniles	Integer	Number of juveniles within the group
	-1	Not recorded
Latitude	Numeric	Decimal degrees (usually to 4 decimal places)
Longitude	Numeric	Decimal degrees (usually to 4 decimal places)
Geog_accuracy	7	Accurate to within 50km (only general area known).
	6	Accurate to within 10km (e.g. estimated from time along ferry route).
	5	Accurate to within 5km (e.g. rough estimation of position or no distance and bearing to big whale).
	4	Accurate within 2km (e.g. from land but no distance and bearing).
	3	Accurate to within 1km (e.g. GPS of vessel; or from land estimated distance to animals > 1000m).
	2	Accurate within 500m (e.g. GPS of vessel + distance and bearing but animals > 1000m).
	1	Accurate within 50m (e.g. GPS + precise estimates of range and bearing).
	0	Not known.

Bearing	0 - 360	Compass bearing from observer to animal(s)
	-1	Not recorded
Distance	Numeric	Distance from observer to animal(s) in metres
	-1	Not recorded
Depth	Numeric	Depth in metres if recorded in the field.
	-1	Not recorded
Animal_ heading	N	N (340-22)
	NE	NE (23-67)
	E	E (68-112)
	SE	SE (113-157)
	S	S (158-202)
	SW	SW (203-247)
	W	W (248-292)
	NW	NW (292-339)
	VAR	Variableor no particular direction
	NR	Not recorded
Behaviour_1	SURF	Surfacing the only behaviour seen
	NORM	
	FAST	Swimming at normal speed.
	BLOW	Fast swimming or porpoising.
	FEED	Blow.
	JUMP	Feeding or foraging.
	SLAP	Breaching or jumping.
	HEAD	Tail or flipper slap.
	WAVE	Spy hopping or raising head above surface.
	REST	Bow riding or riding any wave created by boat.
	SEXY	Resting or lying still on the surface.
	AGRO	Sexual behaviour.
	NOTR	Aggressive behaviour.
		Behaviour was not recorded.
Behaviour_2	As above	As Behaviour_1
Reaction	POS	Attracted to the vessel, e.g. changed direction of movement towards the vessel or came to bow ride.
	NEG	
	NON	Avoided the vessel, e.g. seen to change heading away from the vessel.
	NR	
		No response seen, although there was a boat in the vicinity.
		Reaction was not recorded or no boats in the vicinity.
Assoc_birds	Text	Link to Birds code table
Repeat_ sighting	0	No – this is the first sighting of this group
	Sighting _ID	If this group has already been sighted, enter the sighting ID of the first time the group was sighted, e.g. sCW002545.
Additional _information	Text	Any relevant information not covered by above fields

Appendix 8- *Sea Watch Foundation effort sightings recording sheet accompanied by the effort watch data manual.*

Appendix 9

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of CD_Sightings is the same across categories of Region.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.
2	The distribution of WBD_Sightings is the same across categories of Region.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.
3	The distribution of CD_Individuals is the same across categories of Region.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.
4	The distribution of WBD_Individuals is the same across categories of Region.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

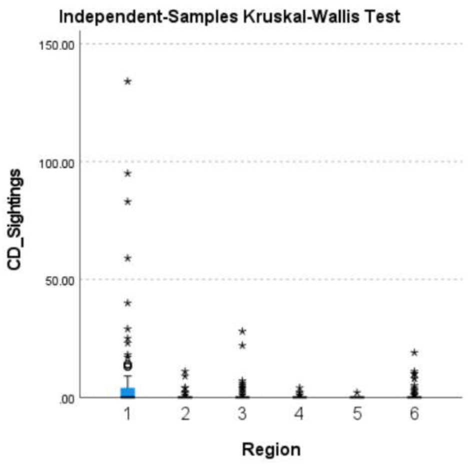
Independent-Samples Kruskal-Wallis Test

CD_Sightings across Region

Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	50.613[a]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.



Pairwise Comparisons of Region

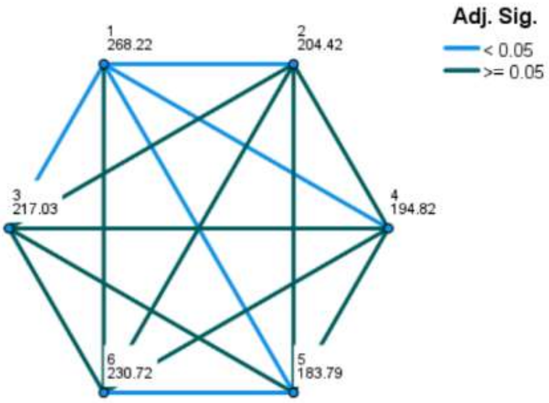
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
5.00-4.00	11.028	13.428	.821	.411	1.000
5.00-2.00	20.632	13.428	1.537	.124	1.000
5.00-3.00	33.236	13.428	2.475	.013	.200
5.00-6.00	-46.931	13.428	-3.495	<.001	.007
5.00-1.00	84.424	13.428	6.287	<.001	.000
4.00-2.00	9.604	13.428	.715	.474	1.000
4.00-3.00	22.208	13.428	1.654	.098	1.000
4.00-6.00	-35.903	13.428	-2.674	.007	.112
4.00-1.00	73.396	13.428	5.466	<.001	.000
2.00-3.00	-12.604	13.428	-.939	.348	1.000
2.00-6.00	-26.299	13.428	-1.959	.050	.752
2.00-1.00	63.792	13.428	4.751	<.001	.000
3.00-6.00	-13.694	13.428	-1.020	.308	1.000
3.00-1.00	51.188	13.428	3.812	<.001	.002
6.00-1.00	37.493	13.428	2.792	.005	.079

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Pairwise Comparisons of Region



Each node shows the sample average rank of Region.

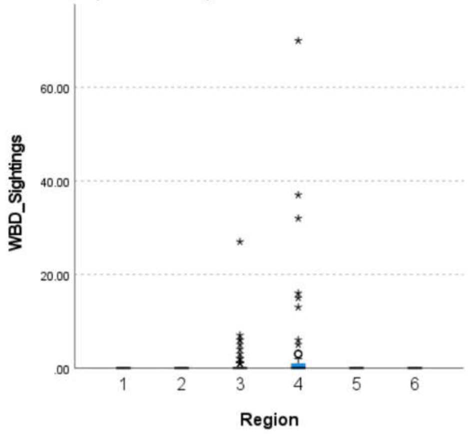
WBD_Sightings across Region

Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	81.673[a]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

Independent-Samples Kruskal-Wallis Test



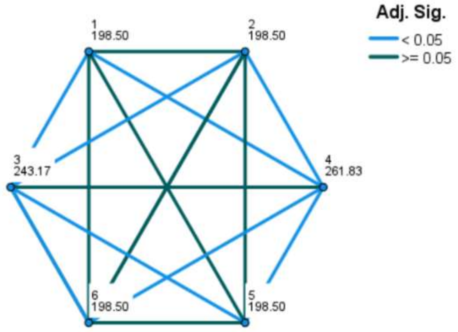
Pairwise Comparisons of Region

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
1.00-2.00	.000	9.973	.000	1.000	1.000
1.00-5.00	.000	9.973	.000	1.000	1.000
1.00-6.00	.000	9.973	.000	1.000	1.000
1.00-3.00	-44.674	9.973	-4.479	<.001	.000
1.00-4.00	-63.326	9.973	-6.350	<.001	.000
2.00-5.00	.000	9.973	.000	1.000	1.000
2.00-6.00	.000	9.973	.000	1.000	1.000
2.00-3.00	-44.674	9.973	-4.479	<.001	.000
2.00-4.00	-63.326	9.973	-6.350	<.001	.000
5.00-3.00	44.674	9.973	4.479	<.001	.000
6.00-3.00	44.674	9.973	4.479	<.001	.000
5.00-4.00	63.326	9.973	6.350	<.001	.000
6.00-4.00	63.326	9.973	6.350	<.001	.000
5.00-6.00	.000	9.973	.000	1.000	1.000
3.00-4.00	-18.653	9.973	-1.870	.061	.922

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Pairwise Comparisons of Region



Each node shows the sample average rank of Region.

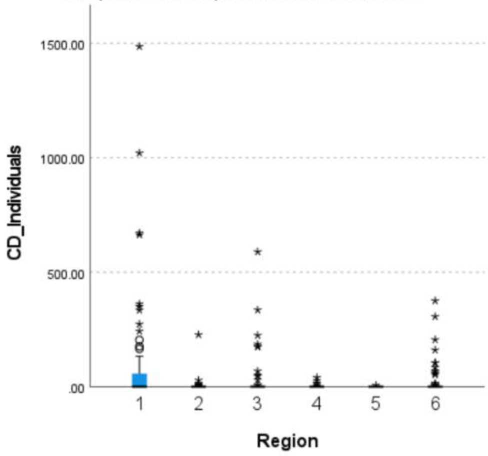
CD_Individuals across Region

Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	50.979[a]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

Independent-Samples Kruskal-Wallis Test



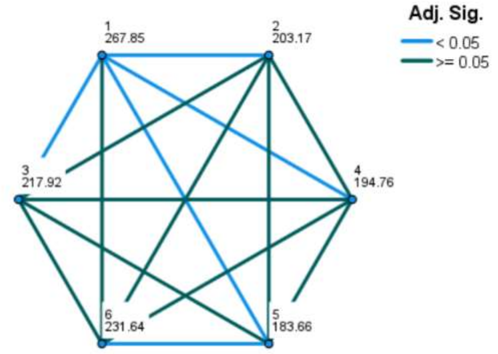
Pairwise Comparisons of Region

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
5.00-4.00	11.104	13.429	.827	.408	1.000
5.00-2.00	19.507	13.429	1.453	.146	1.000
5.00-3.00	34.264	13.429	2.552	.011	.161
5.00-6.00	-47.979	13.429	-3.573	<.001	.005
5.00-1.00	84.188	13.429	6.269	<.001	.000
4.00-2.00	8.403	13.429	.626	.531	1.000
4.00-3.00	23.160	13.429	1.725	.085	1.000
4.00-6.00	-36.875	13.429	-2.746	.006	.090
4.00-1.00	73.083	13.429	5.442	<.001	.000
2.00-3.00	-14.757	13.429	-1.099	.272	1.000
2.00-6.00	-28.472	13.429	-2.120	.034	.510
2.00-1.00	64.681	13.429	4.817	<.001	.000
3.00-6.00	-13.715	13.429	-1.021	.307	1.000
3.00-1.00	49.924	13.429	3.718	<.001	.003
6.00-1.00	36.208	13.429	2.696	.007	.105

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Pairwise Comparisons of Region



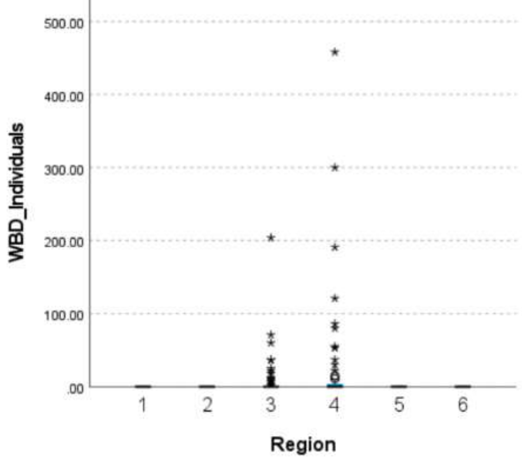
Each node shows the sample average rank of Region.

WBD_Individuals across Region

Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	81.561[a]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

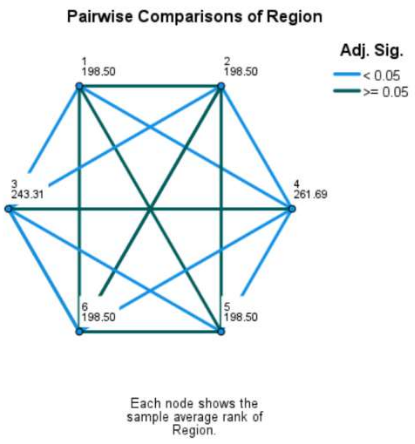


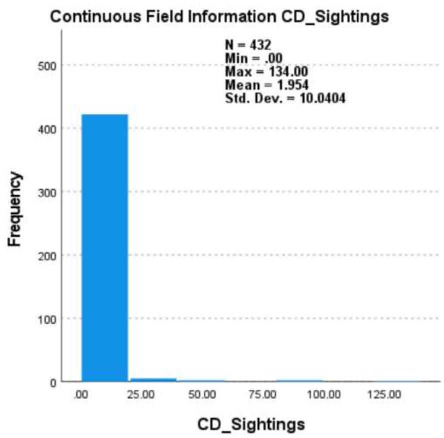
Pairwise Comparisons of Region

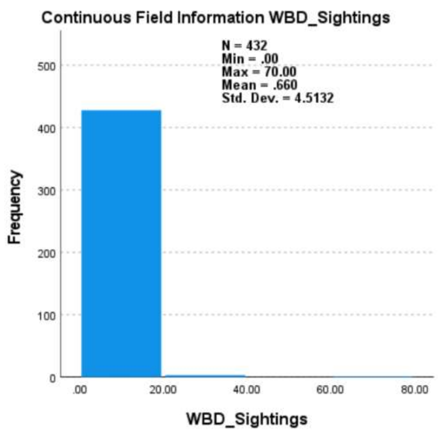
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
1.00-2.00	.000	9.974	.000	1.000	1.000
1.00-5.00	.000	9.974	.000	1.000	1.000
1.00-6.00	.000	9.974	.000	1.000	1.000
1.00-3.00	-44.812	9.974	-4.493	<.001	.000
1.00-4.00	-63.187	9.974	-6.335	<.001	.000
2.00-5.00	.000	9.974	.000	1.000	1.000
2.00-6.00	.000	9.974	.000	1.000	1.000
2.00-3.00	-44.812	9.974	-4.493	<.001	.000
2.00-4.00	-63.187	9.974	-6.335	<.001	.000
5.00-3.00	44.813	9.974	4.493	<.001	.000
6.00-3.00	44.813	9.974	4.493	<.001	.000
5.00-4.00	63.188	9.974	6.335	<.001	.000
6.00-4.00	63.188	9.974	6.335	<.001	.000
5.00-6.00	.000	9.974	.000	1.000	1.000
3.00-4.00	-18.375	9.974	-1.842	.065	.981

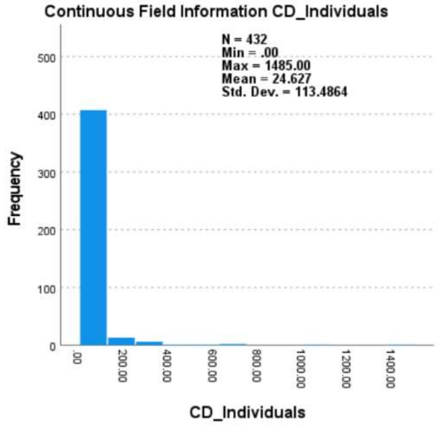
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

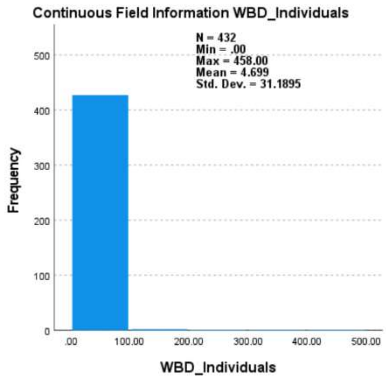
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

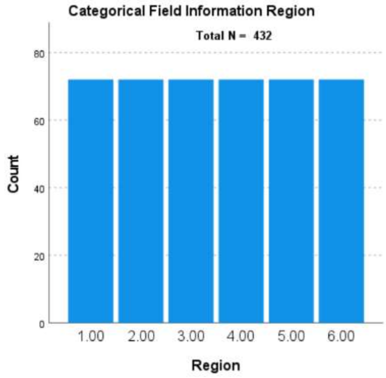

Pairwise Comparisons of Region
Adj. Sig.
< 0.05
>= 0.05
1
198.50
2
198.50
3
243.31
4
261.69
5
198.50
6
198.50
Each node shows the sample average rank of Region.


Continuous Field Information CD_Sightings
N = 432
Min = .00
Max = 134.00
Mean = 1.954
Std. Dev. = 10.0404
Frequency
CD_Sightings


Continuous Field Information WBD_Sightings
N = 432
Min = .00
Max = 70.00
Mean = .660
Std. Dev. = 4.5132
Frequency
WBD_Sightings


Continuous Field Information CD_Individuals
N = 432
Min = .00
Max = 1485.00
Mean = 24.627
Std. Dev. = 113.4864
Frequency
CD_Individuals





Nonparametric Tests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of CD_Sightings is the same across categories of Years.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.
2	The distribution of WBD_Sightings is the same across categories of Years.	Independent-Samples Kruskal-Wallis Test	.076	Retain the null hypothesis.
3	The distribution of CD_Individuals is the same across categories of Years.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.
4	The distribution of WBD_Individuals is the same across categories of Years.	Independent-Samples Kruskal-Wallis Test	.084	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

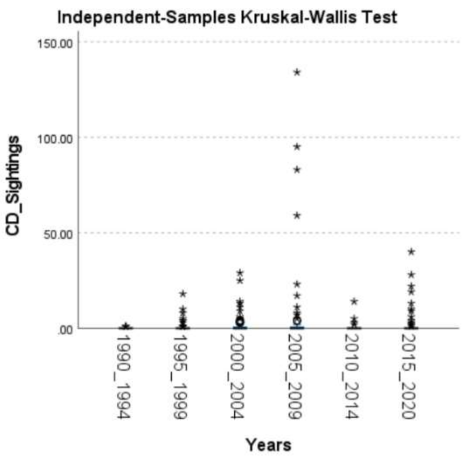
Independent-Samples Kruskal-Wallis Test

CD_Sightings across Years

Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	28.981[a]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.



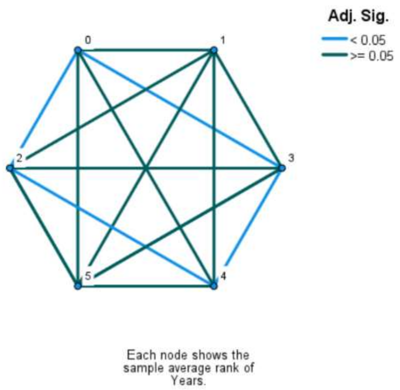
Pairwise Comparisons of Years

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
1990_1994-2010_2014	-4.215	13.428	-.314	.754	1.000
1990_1994-1995_1999	-23.924	13.428	-1.782	.075	1.000
1990_1994-2015_2020	-32.583	13.428	-2.427	.015	.229
1990_1994-2000_2004	-49.576	13.428	-3.692	<.001	.003
1990_1994-2005_2009	-55.576	13.428	-4.139	<.001	.001
2010_2014-1995_1999	19.708	13.428	1.468	.142	1.000
2010_2014-2015_2020	-28.368	13.428	-2.113	.035	.519
2010_2014-2000_2004	45.361	13.428	3.378	<.001	.011
2010_2014-2005_2009	51.361	13.428	3.825	<.001	.002
1995_1999-2015_2020	-8.660	13.428	-.645	.519	1.000
1995_1999-2000_2004	-25.653	13.428	-1.910	.056	.841
1995_1999-2005_2009	-31.653	13.428	-2.357	.018	.276
2015_2020-2000_2004	16.993	13.428	1.266	.206	1.000
2015_2020-2005_2009	22.993	13.428	1.712	.087	1.000
2000_2004-2005_2009	-6.000	13.428	-.447	.655	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Pairwise Comparisons of Years



WBD_Sightings across Years

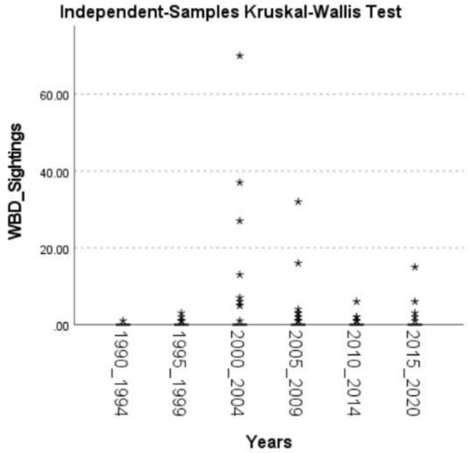
Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	9.961[a,b]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	.076

a. The test statistic is adjusted for ties.

b. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

Independent-Samples Kruskal-Wallis Test



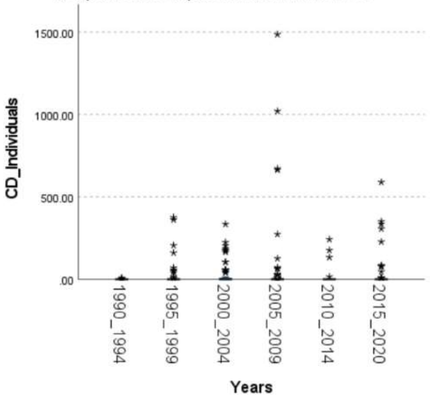
CD_Individuals across Years

Independent-Samples Kruskal-Wallis Test Summary

Total N	432
Test Statistic	27.838[a]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

Independent-Samples Kruskal-Wallis Test



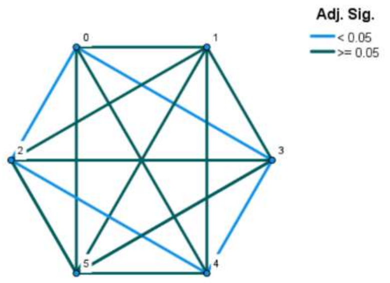
Pairwise Comparisons of Years

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
1990_1994-2010_2014	-4.743	13.429	-.353	.724	1.000
1990_1994-1995_1999	-25.444	13.429	-1.895	.058	.872
1990_1994-2015_2020	-32.049	13.429	-2.387	.017	.255
1990_1994-2000_2004	-50.028	13.429	-3.725	<.001	.003
1990_1994-2005_2009	-54.028	13.429	-4.023	<.001	.001
2010_2014-1995_1999	20.701	13.429	1.542	.123	1.000
2010_2014-2015_2020	-27.306	13.429	-2.033	.042	.630
2010_2014-2000_2004	45.285	13.429	3.372	<.001	.011
2010_2014-2005_2009	49.285	13.429	3.670	<.001	.004
1995_1999-2015_2020	-6.604	13.429	-.492	.623	1.000
1995_1999-2000_2004	-24.583	13.429	-1.831	.067	1.000
1995_1999-2005_2009	-28.583	13.429	-2.129	.033	.499
2015_2020-2000_2004	17.979	13.429	1.339	.181	1.000
2015_2020-2005_2009	21.979	13.429	1.637	.102	1.000
2000_2004-2005_2009	-4.000	13.429	-.298	.766	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Pairwise Comparisons of Years



Each node shows the sample average rank of Years.

WBD_Individuals across Years

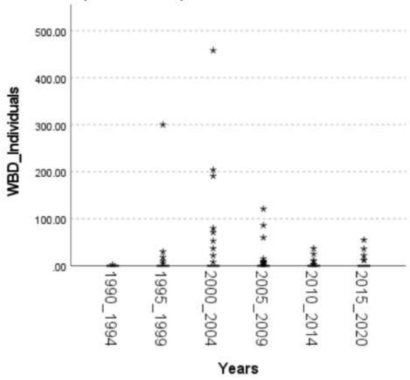
Independent-Samples Kruskal-Wallis Test Summary

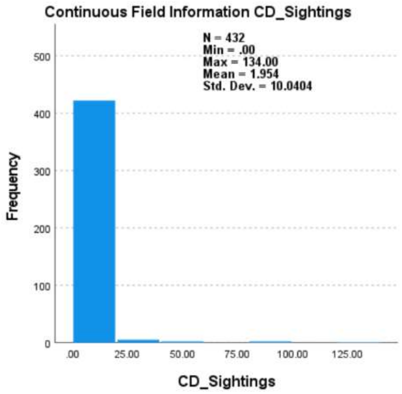
Total N	432
Test Statistic	9.703[a,b]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	.084

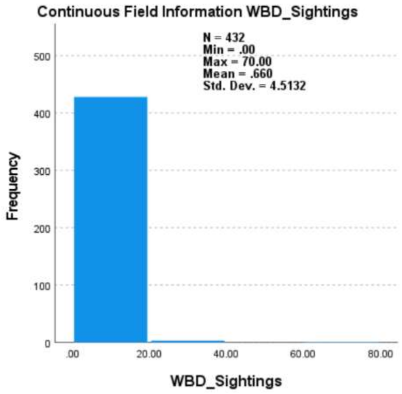
a. The test statistic is adjusted for ties.

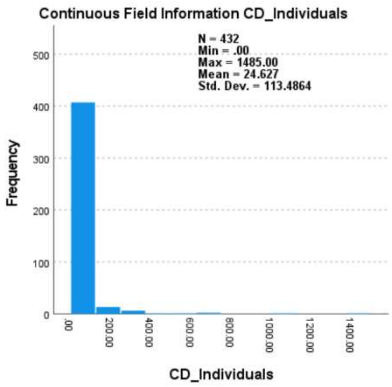
b. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

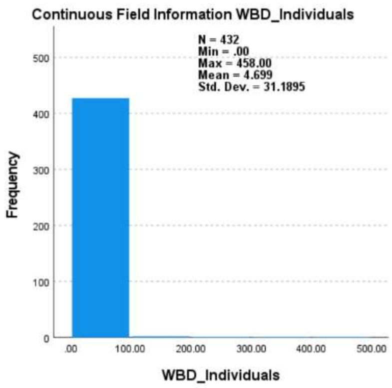
Independent-Samples Kruskal-Wallis Test

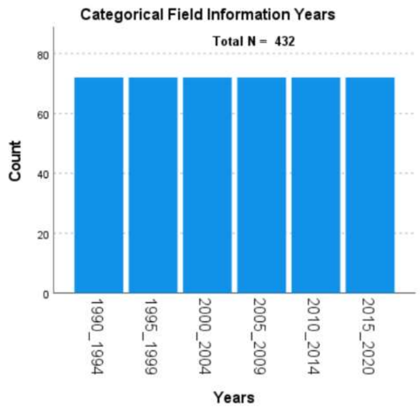



Continuous Field Information CD_Sightings
N = 432
Min = .00
Max = 134.00
Mean = 1.954
Std. Dev. = 10.0404
Frequency
CD_Sightings


Continuous Field Information WBD_Sightings
N = 432
Min = .00
Max = 70.00
Mean = .660
Std. Dev. = 4.5132
Frequency
WBD_Sightings


Continuous Field Information CD_Individuals
N = 432
Min = .00
Max = 1485.00
Mean = 24.627
Std. Dev. = 113.4864
Frequency
CD_Individuals


Continuous Field Information WBD_Individuals
N = 432
Min = .00
Max = 458.00
Mean = 4.699
Std. Dev. = 31.1895
Frequency
WBD_Individuals



Appendix 9- SPSS output for the Independent-sample Kruskal Wallis test and the pairwise comparisons of Mann Whitney-U tests.

Appendix 10

Correlations

			TotalSightings	TotalEffortWatch
Spearman's rho	TotalSightings	Correlation Coefficient	1.000	.937**
		Sig. (2-tailed)	.	<.001
		N	31	31
	TotalEffortWatch	Correlation Coefficient	.937**	1.000
		Sig. (2-tailed)	<.001	.
		N	31	31

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 10- SPSS output of Spearman's Correlation Coefficient.