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Migratory bird connections between Europe and Canada

By

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Abstract

Many bird migration movements are undertaken annually with millions of birds migrating from breeding to non-breeding areas. Some birds migrate a short distance, while others fly for thousands of kilometers within a defined flyway. Regarding worldwide-scale migration journeys, only 52 species of migratory birds are identified as performing migration movements on the Eastern Atlantic Flyway between North America and mainland Europe. Seabirds and waterfowl outnumber other migratory birds with, respectively, 44% and 25% of total migrants, whereas shorebirds and landbirds are the least common group, at 17% and 13%, respectively. In addition, at least 17% of migrants found in the Eastern Atlantic Flyway undertake atypical migration journeys by shifting en route from their normal migration ranges and by changing or extending migration grounds. The Eastern Atlantic Flyway includes the large Atlantic Ocean which counts approximately 5,119 km wide between mainland Europe and North America, and that distance of relatively inhospitable water would act as an ecological barrier, particularly to non-seabirds. However, various islands, such as Greenland, Iceland, and Spanish Canary Islands act as resting/staging areas, and functionally as stepping stones, for those individuals traversing the Ocean. In the end, this research recommends further research to assess the impact of climate change on migration phenomenon along the Eastern Atlantic Flyway. In addition, the lower number of migratory shorebirds present in this corridor, together with the limited migration movements of landbirds in Greenland and Iceland, are the fields of research. After analyzing various aspects of habitat management that include legal, technical, and feasibility frameworks together with the perspective of property rights, this research furthermore recommends that the integration of PES into migratory birds' habitat conservation initiatives would increase species and habitat management status along the migration flyway.

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Acronyms

1. **ES:** Ecosystem Services
2. **GT:** Geolocator Tracking
3. **Km:** Kilometer
4. **LR:** Literature Review
5. **NA:** Non-Applicable
6. **NAO:** Northern Atlantic Oscillation
7. **PES:** Payment of Ecosystem services
8. **RR:** Ringing/banding Recovery
9. **SHIA:** Stable hydrogen-isotope Analysis
10. **SM:** Simulation Model
11. **ST:** Satellite Tracking
12. **TO:** Telescopic Observation
13. **UK:** United Kingdom
14. **USA:** United States of America
15. **WTP:** Willingness to pay
16. **WTA:** Willingness to accept

Explanatory note

This report describes the research workflow and results of the study conducted to assess the connection of migratory birds between Canada and the European continent. The terms Canada and North America are frequently used interchangeably because any migrant bird identified to migrate both anywhere in North America and Europe through the Eastern Atlantic Flyway has to pass through Canadian grounds.

CHAPTER 1: INTRODUCTION

1.1. Study background

Many animal species annually travel distances ranging from a few to several thousands of kilometers (Dingle, 1996). While some animal species undertake natural dispersal movements, others do seasonal round-trip movements. In this context, natal dispersal refers to movement away from a place of birth, whereas seasonal migration refers to annual movements in search of seasonally variable conditions needed for survival (Hensz, 2015). In addition to seasonal migration, the round-trip movement involves whether individual or group, partial or whole population, where animal species relocate between two distant regions (Dingle & Drake, 2007). Furthermore, movement is considered migration when movement is relatively longer than normal daily motions of animal activities, and one region among migration areas could have favorable breeding conditions (Meretsky et al., 2011). Beside animal movement terminologies, the long distances covered amid migration are energetically demanding (Domer et al., 2021) and thus most migratory species, especially those using active movement such as birds, need a number of stopover/staging sites along their routes to refuel body energy in preparation for the next migratory leg (Hedenström & Ålerstam, 1997). However, ecological barriers such as long mountain ranges, deserts, or oceans might sometimes cover the distance between two migration areas whereas the stopover sites and refueling possibilities are limited. From the fact that migration is the most dangerous period of migratory birds' life cycles (Strandberg et al., 2010), only specific migrant species or well-equipped ones could perform migration movement over such migration routes (Smolinsky et al., 2013).

A significant seascape (Atlantic Ocean) separates Canada and Europe and this inhospitable waterbody would act as an ecological barrier, particularly to non-seabirds. Relatively less movement is believed to occur between Europe and Canada, but the subject has not been extensively addressed. Some amount of movement of mainly waterfowl exists in an arc northward from Canada to Greenland and Iceland, Scotland and Norway, with distances of 1,947 km between Canada and Greenland, 2,847 km between Greenland and Iceland, and distances of 2,711 km and 1,796 km from Iceland to Norway and Scotland, respectively. As well depicted in Figure 1, these distances are

much shorter than the straight line distance between Newfoundland and mainland Great Britain (5,119 Km) or Norway (7,044 km)¹. The objective of this report is to assess and synthesize evidence of typical and atypical bird migration with special concern for east-west movement between North America and Europe. The result is a report that synthesizes migration data and produces a theory that describes migration patterns in the Eastern Atlantic corridor between North America and Europe.

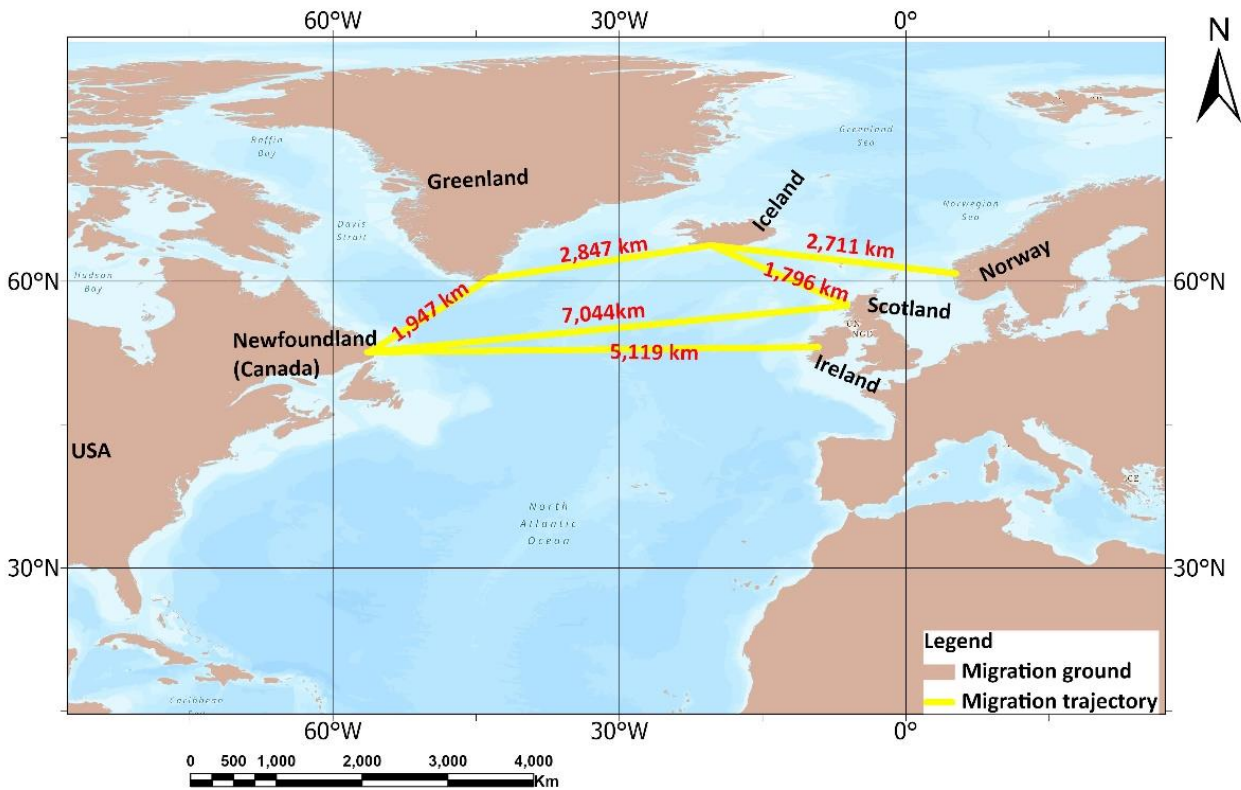


Figure 1: Proposed migration pathway and estimates of distances between Canada/North America and mainland Europe as well as the in-middle islands respective to continental areas (Designed by Philbert Raj Habiyakare)

In order to assist scholars, researchers, and decision-makers, this study adopts literature review techniques to investigate the phenomenon of bird migration that occurs between two continents to define the species of migratory birds and their migration strategy over a large ecological barrier that covers the flyway in this area.

¹ Distances are estimated through direct measurement of distance using ArcGIS pro 2.9.2 version

1.2. Problem statement

Migration is the most dangerous period of the life cycle of migratory birds since it is estimated that at least 85% of the annual mortality of birds is associated with migration dynamics (Strandberg et al., 2010). However, to emphasize the degree to which migration of birds is critical to the survival of migrant species, Jefferies & Drent (2006) revealed that failure of migration or migration through poor stopover sites and migration grounds increases reproduction failures in subsequent breeding seasons.

Birds are members of the ecosystem components and they are pretty important to the welfare of humans (Whelan et al., 2008) a fact that determines their protection needs. The International Convention on the Conservation of Migratory species acknowledged the importance of animal species and decided that range states should protect migratory species. Following this, the Member States agreed to take action for protection of migrant birds and their habitats to eliminate conservation threats ([UN, 1979](#)). Whilst the European and Canadian legal frameworks for bird conservation across territorial states consider migratory birds as a common heritage, In Canada, migratory bird species are protected under the Migratory Birds Convention Act ([Government of Canada, 2017](#)). Similarly, the European Union established legal frameworks conceived in Bird and Habitat directives that aim at protecting habitats and species of community interest ([Habitats 92/43/EEC](#) and [Bird 2009/147/EC](#)). Despite well-established legal aspects to protect migratory bird species both in Canada and Europe, the management framework of transcontinental species is less developed, and many marine migratory species, including 27% of seabirds, are still under threat from various pressures they encounter during their migration journey (Lascelles et al., 2014).

Migrant bird species that migrate between Europe and North America fly mainly through the East Atlantic Flyway, the corridor that connects a patchwork of arctic breeding areas stretching from Canada to central Siberia, progressing to wintering grounds in western Europe and West Africa (BirdLife International, 2019b). This corridor is mostly covered by the Atlantic Ocean, which acts as an ecological barrier for birds that migrate through it (Alerstam, 2001). On the other side, few birds from both sides including the peregrine falcon (*Falco peregrinus*) (Fuller et al., 1998) can progress

until they reach the adjacent Americas Atlantic Flyway, another corridor that links the Canadian Arctic Archipelago to the southernmost tip of United States of America (USA) and South America in general (BirdLife International, 2019). In general, migratory birds settling between Europe and sub-Saharan African grounds and those migrating between North and South American areas are encountering various problems related to habitat degradation, illegal trapping, and killing, as well as the residual effects of climate change, issues that cause a drastic decline of migratory birds in the said areas (Bairlein, 2016). To a high degree, the Breeding Bird Survey, which is a study conducted in the United States and some parts of Canada since 1966, showed that migratory birds are declining (URL, 1 C.E.). This widespread decline in migratory birds is, in most cases, attributed to the accumulated effects of anthropogenic activities on a local scale. In this sense, habitat fragmentation caused by agriculture, timber harvesting, and urban development leads to habitat degradation, and such activities are usually carried out both in wintering and breeding areas, and stopover sites as well (Faaborg et al., 2010). Discussing the effect of anthropogenic activities on migratory birds, a strong negative relationship has been identified between human activities and the needs of migratory birds in concentration areas, whereas the coasts and coastal forests as components of terrestrial habitats are fragmented (Bonter et al., 2009). Thus, to ensure that migratory birds are well protected, the issues of habitat degradation should be handled both on local and landscape scales (Rich et al., 2004). Regarding management strategies, the inadequate coordination of management practices across the European member states is frequently inducing the overharvesting of some migratory bird species such as ducks (Holopainen et al., 2018). Furthermore, migration-dependent mortality of migratory species is revealed to increase with migration distance (Sawyer et al., 2016), and following this, I was curious about the migration phenomenon of migratory birds that seasonally resettle between Europe and Canada, the movement that could probably be among the longest migration journeys, if not the first.

1.3. Aim and objectives of the study

This study seeks to achieve its general objective of acquiring knowledge from trans-continental migration processes by analyzing migration connections between the European continent and North America through a series of specific objectives:

- ❖ To identify species (birds) with migration habits between Europe and Canada;
- ❖ To define the most important flyway route and associated stopover used by migrants between two continents;
- ❖ To identify probable aberrant behavior throughout the migration corridor and;
- ❖ To propose management practices for the migration corridor between two continents focusing on terrestrial habitats located between the seashores and coastal forests.

1.4. Significance of the study

Several studies have been conducted to investigate bird migration along the East Atlantic Flyway, which is the area of my concern. Some of these studies were carried out for population counts and estimates; others were for studying migration grounds of targeted migratory birds while others were designed to understand migration routes for specified migrants. However, no complete study has tried to integrate all of the above aspects or has tried to combine them with consideration of conservational legal and technical frameworks. In addition, this study is important and needed since it also considers atypical migration movements and migration setbacks occurring over the concerned migration corridor.

1.5. Thesis Structure

This research report consists of several thousand words summarized in six chapters that are interconnected to address the objectives, needs, and overall result of the research. Chapter 2 (Literature Review) discusses general terms of animal migration with the emphasis placed on bird migration. This chapter provides a general background on bird migration ecology, a fact that facilitates understanding of the migration phenomenon in the study area. Furthermore, and more importantly, Chapter 2 analyses the existing literature conducted in the area and explains the importance of this research. Chapter 3

expands upon key methods used. From the start, Chapter 3 describes the study area and extends to data collection and analysis, and decision-making throughout the research. Chapters 4, 5, and 6 go with results, discussion and conclusion respectively. From the Chapter of results, several subjects including migratory bird species identified across the flyway, their type of movement and migration strategies, their migration grounds, and other subjects related are shown up whereas the Chapter of discussion puts an emphasis on everything identified pulling it together with commonalities and differences from previous studies. The conclusion mainly seems to be to provide additional subjects of consideration and provides recommendations according to the findings and discussion of the results. Furthermore, it emphasizes various factors that may indirectly influence migration behavior in the region.

CHAPTER 2: LITERATURE REVIEW

2.1. General background about bird migration

There are approximately 4,000 species of migratory birds. In the northern hemisphere, most of these species migrate to breeding sites at high latitudes during the summer and then migrate to lower latitudes to overwinter (Shaw, 2016). The opposite pattern often occurs in the southern hemisphere, for example, many seabirds nest on islands in the South Pacific but ‘overwinter’ in the Atlantic during the summer months of the northern hemisphere (Newton & Dale, 1996; Dingle, 2008; Chambers et al., 2013). In either movement, the birds are selecting abundant food during breeding and mild living conditions during non-breeding seasons. In equatorial regions, where mild conditions dominate throughout the year, many species do not migrate long distances but do undertake shorter movements (Gómez et al., 2016). Some tropical species undertake altitudinal migrations to breed at high elevations and then progress towards low elevations in order to seek refuge from seasonal storms (Boyle et al., 2010). Moreover, some bird species undertake refuge migration from breeding sites to safe, often isolated sites when unable to fly during the period of moulting flight feathers.

Generally, common flyway patterns exist for breeding and non-breeding purposes (Kirby et al., 2008). Migration movements between Europe and Africa, migration journeys between North and Central/South America, and migration connections between northeast Asia and Australasia are the most famous migration patterns among common migration routes (Hahn et al., 2020). In North America, many breeding birds migrate for wintering areas in temperate and tropical zones of Central and South America with major migration corridors passing through the Pacific and Atlantic coasts in South America and Mexico's western gulf, or via the Great Plains of North America (Willson, 1976; Myers et al., 1987). Although the corridor linking Europe and North America is uncommon, some evidence confirms the importance of this migration route in serving various migratory bird species that breed in northeast Canada, stage in Greenland, and then migrate to and from Europe and/or Africa (Lyngs, 2003).

At the interpretational point of view, animal migration has diverse definitions depending on the users and contexts. It changes across taxa and involves all animal

organizations from genetic to landscape units (Dingle & Drake, 2007). Dingle and Drake (2007) defined animal migration as a seasonal round-trip movement of animal species whether individual or group, partial or whole population, where animal species relocate between two distant regions. Furthermore, movement is relatively longer than normal daily motions of animal activities, and one region among migration areas might have favorable breeding conditions. Thus, optimum environmental conditions such as milder air, water, soil temperature, availability of food, lack of diseases or predators, suitable places for breeding or some combination of the above are considered major triggers of animal migration (Meretsky et al., 2011). For many animal species, food resources are reduced during winter periods, the competition increases between individuals, and poor competitors are forced to migrate toward food-rich locations (Smith & Nilsson, 1987).

The long distances covered by migrants during migration are energetically demanding (Domer et al., 2021). Most migratory species, especially those using active movement to which also birds belong, need a number of stopover/staging sites along their routes to refuel body energy in preparation for the next migratory leg (Hedenström & Ålerstam, 1997). Stopover and/or staging areas are locations along migration corridors where birds stop to feed en route and are critical to migration success (Myers, 1983). Although these terms are usually used interchangeably, the authors tend to separate them with consideration of different categories of migrants and migration routes. Notably, neither term is used for marine birds. Instead, terms such as hot stops are used for these migrants (Warnock, 2010). Numerous migrating birds overcome flight problems that may arise from natural barriers such as oceans, seas, deserts, and higher mountains and decide to face them only when they are fully equipped for crossing (Kranstauber et al., 2015). Therefore, long-distance migration and passage over substantial ecological barriers require that exceptional instructions regarding fuel storage and orientation changes in the face of a barrier are incorporated into the birds' endogenous spatiotemporal circannual program (Berthold, 2001; Bowlin et al., 2010; Gwinner, 1996).

Although migrant birds take staging sites as points where their lives could be saved, many flights terminate at these sites since stopover sites are usually highly populated and therefore, predator-prone areas (Ålerstam, 1979). Furthermore, anthropogenic activities such as the use of agro-pesticides on staging grounds, hunting, and fishing activities

increase the stochastic mortality of migrating birds (Aarif et al., 2021). In particular, there is an increased vulnerability for juveniles and the least experienced migrants, while adults and those with migration experience are more likely to overcome stopover-high-density associated effects around coastal areas towards safer and non-crowded sites (Alerstam, 1979). The actual energy stores and fuel deposition rate primarily determine takeoff from the stopover sites and birds with ability to lose fuel stores or those that increase fuel stores at a high rate would leave a site quickly (Schaub et al., 2008). Poor quality stopovers and susceptibility of migrant birds to disturbance at these sites increase reproduction failures (Jefferies & Drent, 2006), and thus migrating birds' conditions are improved by providing good quality stopover sites (Bowlin et al., 2010).

In addition to stopping-over-associated disturbances, climatic factors can also hamper bird migration travel when they occur independently or when they combine with each other unfavorably throughout the migration journey. Wind influences migrating bird's behavior in several ways including determining the costs and benefits of bird's transportation fuel and dictating the migration pathway pattern distance and flying altitude.

Migrating birds depend more on wind currents for their migration activity as energy costs for the migratory journey increase or decrease depending on wind characteristics (Newton, 2007). According to Newton (2007), head winds act as a considerable hazard to migrant birds with diverse extent of vulnerability depending on migrant type (seabirds and land birds) and geographical area at which head winds occur. Taking into account geographical characteristics, seabirds suffer more from headwinds when crossing long unwatery landscapes such as wilderness, while land birds are more vulnerable across seas and oceans as ecological barriers. Land birds are forced to fly long distances through headwinds over water bodies. Such flights are extremely energy-consuming, leading to exhaustion of the birds that can result in death when birds land on the water and fail to take off again. Small birds flying at lower heights are often at risk of being driven into the water, snatched, and swallowed by gulls. It is not uncommon for headwinds to cause the loss of many migrating land birds into oceans, while survivors of the migration arrive exhausted, failing to recover, or encountering unsuccessful breeding (Newton, 2007). In addition, aberrant headwinds and dust are the main factors that cause aberrant behaviors in deserts, associated with migration retreat in response to crossing difficulty (Strandberg et al., 2010). Adversely to headwinds, flight accompanied by a tailwind requires less

energy to cover a given distance while a headwind increases flight energy costs (Beason, 1978). Therefore, certain species are distinctly more selective than others of advantageous winds for their migration flight (Alerstam, 1979). Studies emphasized the role of a tailwind for a migrating bird to reduce energy costs and be able to cross a considerable ecological barrier, whereas it uses alternative migration routes in the absence of this support (Bulte et al., 2014). Considering climate factors encountered along the migration journey, a migrant bird responds through a diversity of specific behaviors (see Figure 2) to overcome critical conditions or to exploit advantages that may result from a given circumstance.

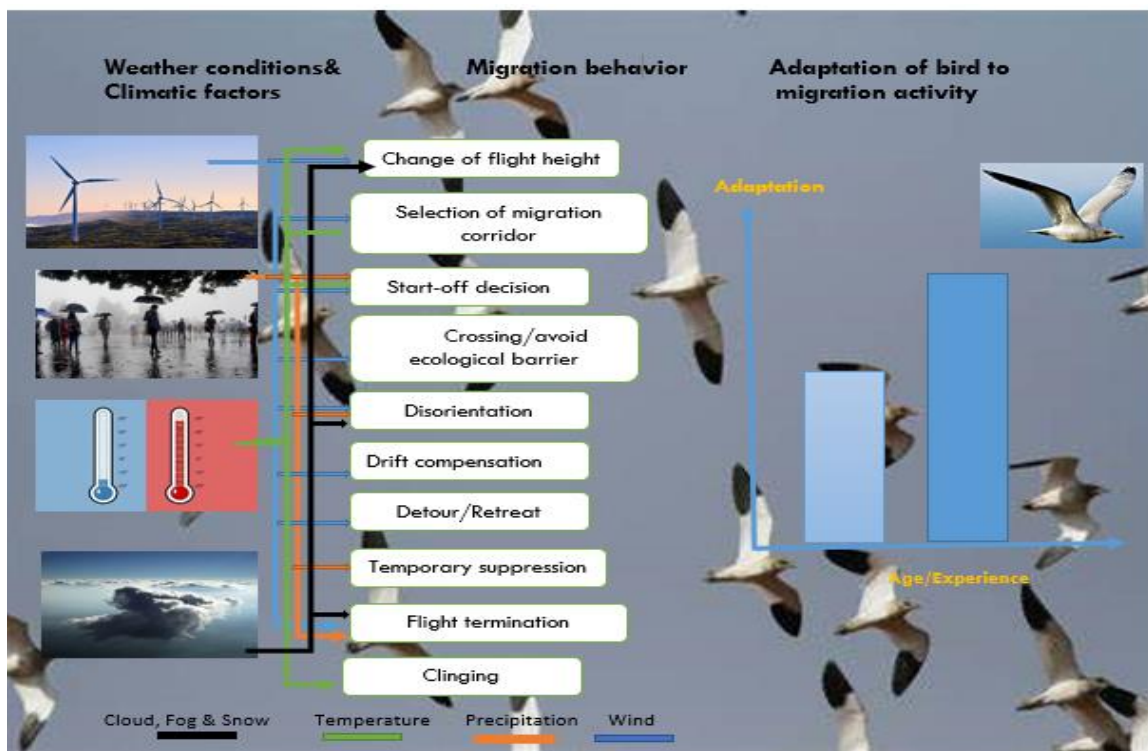


Figure 2: Summary of migrating birds' behavioral responses and bird's ability to migration phenomenon with respect to climatic and weather conditions. The figure is derived from synthesis of various literature discussing the effect of air currents (Designed by Philbert Raj Habiyakare).

Air temperature strongly affects bird's migration behavior in a variety of ways by influencing the airspeeds and related flight altitude (Panuccio et al., 2013) that both go together with the air density that varies in relation to altitude (Hedenström et al., 2002) and therefore, improved flight speed increases with altitude (Shamoun-Baranes et al., 2003). Air temperature also affects migration intensity depending on the season (Becciu

et al., 2019), including the survival rate at stopovers and breeding areas (Doyle et al., 2020). The temperature has gradually increased during the 20th century and this increase intensified during the last several decades (Zveryaev & Gulev, 2009). This change of temperature can influence migrating birds in terms of survival, reproduction, and therefore the population trend (Doyle et al., 2020). In this regard, it is highlighted that increased temperature favored the reproduction of adults and survival of juveniles of Arctic-breeding birds over the past 50 years, which has gradually increased the population of Greenland barnacle goose (*Branta leucopsis*) to the extent of tenfold in abundance since mid-20th century (Doyle et al., 2020).

In contrast to warm temperatures, lower temperatures have a significant impact on migrant birds including on-site, prior, and post-arrival effects. Snowfall, as a colder temperature-associated event kills migrant birds in their stopover and breeding sites, and triggers animal starvation by hiding ground feedings' food while aquatic feeders are subjected to a delayed melting or re-freezing of water surface. Snow induces a selective effect on the seasonal timing of migration and consequently, the reduced breeding intensity of migrant birds with an overall effect that becomes aggravated on juveniles and migrants compared to the adults and residents (Newton, 2007). Buss (1942) said that swallows do not fly but cling to their old nests when a sudden drop of temperature is accompanied by insects dormancy. Such an event killed many cliff swallows (*Petrochelidon pyrrhonota*) during 1996 across the north-central Great Plains.

Besides the climatic factors and stopover-associated dynamics, orientation and airspace navigation capability of migrating birds improve success of migration objectives (Emlen, 1975). For long-distance migration, birds and other animals navigate using several different compasses based on information from the sun and the related pattern of skylights polarization, Earth's magnetic field, and stars. The insolate compass is based on a time-compensation appliance while the rotation inwardness of the night sky indicated by the celestial system presents the instruction towards geographic poles (Alerstam et al., 2003). Besides the famous inclination compass that is based on radical-pair processes and admit course in the migratory line and acquired directions, birds have the additional iron-based system that – in addition to providing map-related information, affects orientation in fixed directions in the total absence of light and other abnormal light. However, this

iron-based system remains dormant when the radical-pair mechanism is working (Stapput et al., 2008). Moreover, migrant birds have endogenous daily (circadian) and annual (circannual) rhythms that serve as biological clocks to provide the major basis for their temporal orientation, initiation of activities such as breeding, migration, and molting, and determine spatial course of migration (Gwinner, 1996). Therefore, migrating invertebrates update the information along their migration course (Winkler et al., 2014).

Earth's magnetic field acts as an external cue that enables inexperienced migratory birds to select and recognize a suitable stopover where they need to replenish their body fat (Fransson et al., 2001) or their overwintering point (Peter et al., 1996; Guilford et al., 2011; Kranstauber et al., 2015). Furthermore, these external cues provide information about various aspects: remote conditions, local conditions, or individual state. Using this information, the bird must prepare to migrate by adjusting its physiological condition referring to the local weather phenomenon (Winkler et al., 2014) while natal dispersing birds use inadvertent social information and public information as location cues to detect suitable breeding habits (Nocera et al., 2006). However, the availability of navigational cues varies across migrants, either within or between species and/or within or between migrations (Guilford et al., 2011).

Studies (Alerstam, 2006; Holland, 2014; Mouritsen, 2012) discussed conflicting evidence of bird navigation systems, emphasizing that this field is scientifically uncontrollable hence, migrant birds are sometimes disoriented due to the diversity of facts (Guilford et al., 2011; Hiscock et al., 2017). Recently, the dominating opinion is that only experienced migrant birds are true navigators probably due to the fact that when a migrating bird establishes an optimal corridor successfully, it remembers it and copies it for the next several years of migration (Hadjikyriakou et al., 2020).

2.2. Literature analysis and inspiration of research

For some documents, several migration flyways are identified worldwide for migratory bird species with a focus on defined migratory taxa or with only background information about Eastern Atlantic Flyway (Kirby et al., 2008; URL, 2 C.E.). Furthermore, studies were designed to study the migration strategy of specific migrants (O'reilly & Wingfield, 1995), while others focused on surveying population

concentration sites and distribution (Boertmann et al., 2009), and the identification of migration routes (Fuller et al., 1998). However, none of the studies mentioned and other literature consulted provide detailed information about typical, atypical bird migration movements, and habitat management aspects across the migration flyway that links North America and Europe. While my focus is to provide scholars, administrative entities, and conservation agencies with complete information on bird migration pattern and habitat management aspects all along the Eastern Atlantic corridor connecting North America and Europe, existing studies have several deficiencies to answer the concerns of my research. Table 1 illustrates gaps from existing studies about the Eastern Atlantic Flyway compared to my work, and these gaps drove me to conduct this research.

Table 1: Analysis of literature that inspired my research

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
1	(Bird Life International, 2019)	This document provides a general description of the East Atlantic Flyway.	The document said that this corridor connects a patchwork of arctic breeding areas stretching from Canada to central Siberia, progressing until they reach the wintering grounds in western Europe and west. Every autumn, numbers of Arctic migrants, particularly waterbirds, converge in western Europe, including some from the far north, Arctic breeders from the western hemisphere (Canada, Greenland, and Iceland), and Eurasian migrants from the eastern hemisphere (Scandinavia, Arctic Russia, and northwest Siberia).	This document neither mentions any bird that flies from Europe to North America nor provides a migration strategy over the Atlantic Ocean.
2	(Boertmann & Frederiksen, 2022)	The author was studying the status of Greenlandic populations of great black-backed gull (<i>Larus marinus</i>), lesser black-backed gull (<i>Larus fuscus</i>), and	Citing Hallgrimson et al. (2011), the author said that an increasing number of lesser black-backed gulls are frequent along the Atlantic coasts of North America and recent sightings there of color-banded birds from Iceland and the Netherlands, he suggested that a	The document is concerned neither with other bird species of migratory birds that live in Greenland nor with birds from other regions outside Greenland.

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
		herring gull (<i>Larus argentatus</i>)	substantial part of the population spends the winter in Canada and the USA.	
3	(Branson et al., 1978)	Using ringing recovery records, the author was studying turnstone migrations in Britain and Europe.	He found that knots and most turnstones arriving in Europe and Britain come from breeding grounds of Greenland and high Arctic Canada, while doing a refueling staging of a few weeks in Iceland.	The study was not concerned with other bird species, and is in addition focused on inward migration movements without consideration of move-on journeys.
4	(Burnham et al., 2021)	This was an experimental study designed to study migration pathways of Atlantic puffin (<i>Fratercula arctica</i>) from high Arctic Greenland using a tagged geolocator.	Geolocator-emitted information showed that one female bird traveled 5,200km after crossing the southeast of Cape Farewell from the mid-Atlantic Ocean in the south of the Azores. The second migrant departed Baffin Bay in early October having sojourning time at Cape Farewell and southeast Greenland, progressing to an ultimate reach of Iceland where the geolocator stopped the emission.	The study focused only on one single migratory bird.
5	(Hallgrimsson et al., 2011)	The study was designed to work on records of European-banded lesser black-backed gulls	The author mentioned in his review that the lesser black-backed gulls reported in Florida, New Jersey, Virginia, and North Carolina could have been a migrant that arrived from	The study does not identify the proper migration route from Europe to North America and the species in

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
		<i>(Larus fuscus)</i> in America.	Europe or colonized Greenland. Banding efforts in Iceland and the Netherlands resulted two sightings in America. An unfledged chick banded at Gardaholt, southwestern Iceland, was seen and photographed at Rio Grande de Arecibo, Puerto Rico, while another juvenile banded at the Port of Rotterdam, the Netherlands, was resighted at Cold Spring Harbor, Long Island, and New York.	question was only lesser black-backed gulls.
6	(Lyngs, 2003)	This report discusses the wintering and breeding grounds of Greenlandic migratory birds using band recovery records.	The report reveals birds that enter the Greenland grounds for various migration purposes. In summary, Greenlandic birds have various migration targets, including North America, Iceland, and mainland Europe. Moreover, this report appears likely to define the Greenland region as a stepping-stone region for birds that use the Eastern Atlantic Flyway, notably long-distance migrants. For some migrants, it serves as a wintering area, while others use it for breeding and staging sites as well.	Although the report explores much about birds migrating over the Atlantic Ocean, it is based on ins and out movements of Greenland with a high probability of not capturing settlers that do not pass through Greenland when they are migrating to North America and mainland Europe. The migration strategies of migrant birds are also limited while

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
				conservation aspect is completely forgotten.
7	(Melfoite, 2017);	This report reviews the annual schedules of the waders in Greenland and estimates the population size of Greenlandic waders.	When estimating the population size of waders, the author integrates birds in both breeding and wintering areas. The report shows that the waders circle between North America, Greenland, and the old world in western Europe. Since the report was made for Greenlandic birds, it considers Greenland as the center point and home of most of these birds. Furthermore, he emphasizes that Iceland is a major staging site for birds migrating between Canada, Greenland, and Europe.	The document places emphasis on one group of migratory birds (waders), and the only focused region is Greenland.
8	(Morrison, 1975)	The study was intended to study the migration and morphometrics of the European knot and turnstone on Ellesmere island, Canada, using the banding method.	The records of the banding recoveries provided dramatic confirmation of the European wintering areas used by knots breeding in the Canadian high Arctic. These were the first banding records for the species between Canada and Holland, Iceland, and Norway, respectively. The consideration of weight changes during migration indicates that Iceland is an essential stopover point for	The study was limited to a smaller group of birds (waders). In the study, typical and atypical movement issues, together with conservation aspects, are ignored.

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
			knots migrating from Europe to breeding grounds in the Canadian high arctic. Based on Nettleship's (1974) study, the author also guessed that some knots may possibly migrate to and from Ellesmere Island via the northern parts of Greenland.	
9	(Boere et al., 2006)	This book describes the status of waterbirds from almost all of the world's migration flyways. It studies the conservation status, population, habitat, and others.	The study found that waterbirds are threatened around the world mainly due to climate change and the shrinkage of natural habitats. It calls for international co-operation for the conservation of migratory waterbirds	The book only pays attention to waterbirds and does not really demonstrate migration strategies in all flyways, especially in the zone of my concern. The book tends to handle things in a general way, and not many species of waterbirds are mentioned.
10	(Van Roomen et al., 2018)	This is the study conducted with the main objective of assessing the status of coastal waterbirds from the East Atlantic Flyway. The report includes the results of the 2017	Since the report compared the results of the actual total count with those from the 1975 total count report, the results caught from 72 species show positive population trends to the extent of twice. For bird populations breeding in the Wadden Sea, however, results show a disappointing message with no improvement detected. Additionally, pollution from various	Although the report explores much about birds migrating over the East Atlantic Flyway, it only focuses on waterbirds and little is discussed about migration strategy. In addition, the report considers the East

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
		<p>population total count, the basic monitoring results, and the results of the monitoring of environmental conditions and conservation measures. It eventually defines population trends over time.</p>	<p>sources, fishing, agriculture, and urbanization, was identified as the main sources of pressure across the flyway.</p>	<p>Atlantic Flyway without focusing on departures and end destinations; hence, the description of aberrant movements is ignored.</p>
11	(Newton & Dale, 1996)	<p>This study assesses the relationship between migration and latitude among west European birds.</p>	<p>Considering the move-ins and move-on, numbers of bird species vary with latitudes and seasons with evidence confirming that 3% of wintering specie totally leave western Europe in spring to breed elsewhere, some to the north-west in Iceland-Greenland-Canada and others to the north-east in northern Siberia. However, most of these birds both breed and winter in northern Europe but are also augmented by other birds from other</p>	<p>Migration strategy and conservation issues are not of great concern.</p>

S/N	Reference	Study parameter	General findings	Gap identified respecting my research objectives
			breeding areas of Iceland, Greenland, and Canada.	
12	(Alerstam et al., 1990)	This study aimed to survey the migration strategy of migrant birds specifically, knots, turnstones, and brant geese that migrate from Iceland during spring migration.	The study concluded that the overwhelming majority of knots, turnstones, and brant geese migrate from Iceland in spring to their breeding sites in northern Canada and northwest Greenland. Within the unfavorable winds, the waders decided to fly lower, while geese usually use lower-altitude flights. Generally, moreover, birds departed in flocks, and waders' starting time is afternoon or evening hours, whereas geese start during the morning or in late evening.	The study focuses on specific migrant birds (waders and geese) and although the migration strategies have been deeply discussed for every single migrant species in question, the conservation aspect does not make part of the study.
13	(Wilson, 1981)	This study discusses the migration strategy of waders from the high Arctic region to the west migration movement with a focus on assessing the ecological importance of Iceland amid their migration.	The findings show that birds breeding in northeast Canada and northwest Greenland stage in Iceland for at least three weeks while those breeding in north-east Greenland either overfly Iceland or stage there for a shorter time. In addition, birds (mainly turnstone and knot) staging for a longer time in Iceland winter principally in Europe, whereas those staging for a shorter time or overflying Iceland continue for West Africa.	The study is designed for waders only, and the conservation aspects are completely ignored.

CHAPTER 3: METHODOLOGY

3.1. Study area

In North America, my research work encompasses eastern Canada and Maine, and much of the Arctic region. I also include the various islands in the North Atlantic, between North America and Europe. In Europe, the study area includes mainland Europe and extends to parts of Russia (Figure 3). Considering the water-covered zone, the area consists mainly of the North Atlantic Ocean, where a greater number of migration movements occur in the Atlantic Ocean between two continents. The climate across Atlantic Ocean is often characterized by strong eastward airflow and dynamic stormtrack of weather systems, usually heading towards western Europe (Rodwell et al., 1999). The region is dominated by the Northern Atlantic Oscillation (NAO), which influences climatological and oceanographic variability in the lower troposphere (Van Loon & Rogers, 1978).

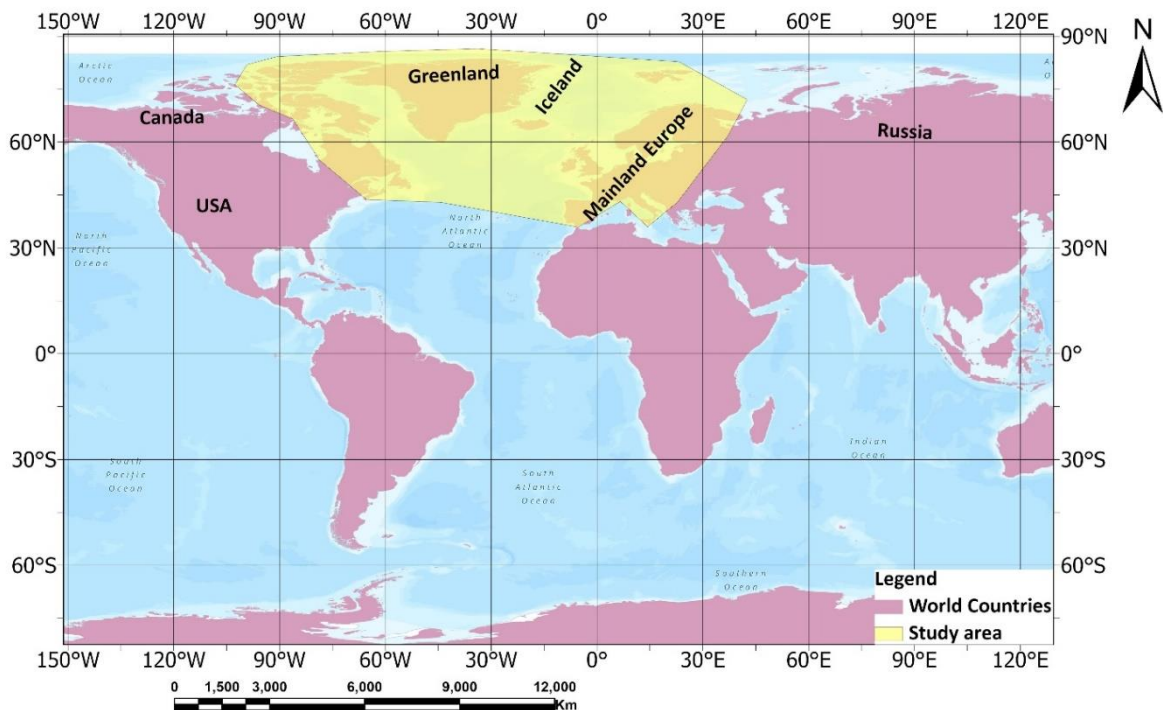


Figure 3: Boundaries of the study area (Designed by Philbert Raj Habiakare)

Human density is high in most of central and southern Europe but relatively less on the islands in the North Atlantic and much of eastern Canada. Human activities, exert severe pressure on wildlife and their habitats in parts of the study area, and less elsewhere

(Van Roomen et al., 2018). Activities that affect migratory birds in the area include fishing, pollution, disturbance, and conversion of coastal wetlands to alternative uses such as agriculture and urbanization (Van Roomen et al., 2018).

In terms of bird migration, the study area mainly is located in the Eastern Atlantic Flyway, the corridor that gathers a patchwork of Arctic breeding areas stretching from Canada to central Siberia progressing to birds' wintering grounds in western Europe and West Africa (BirdLife International, 2019). In this area, numbers of Arctic migrants, particularly waterbirds, converge on western Europe, including some from the far north, Arctic breeders from the Western Hemisphere (Canada, Greenland, and Iceland), and Eurasian migrants from the Eastern Hemisphere (Scandinavia, Arctic Russia, and northwest Siberia) (BirdLife International, 2019).

3.2. Data collection

This work relies on electronic scholarly databases and search engines for the collection of relevant articles, reports, books, and journals. To obtain the maximum information, I formulated relevant keywords related to bird migration across the Atlantic Ocean between North America and mainland Europe. (Lyngs, 2003) suggested Greenland and Iceland to be important transitory areas for birds migrating between Europe and North America. Therefore, I used various keywords (Table 2) that could provide information on bird migration in Greenland, Iceland, and in the Arctic region as well. To achieve the overall goal and objectives of the literature review, I created a literature review survey list that has further been transformed into a literature review matrix that enabled me to organize and analyze all relevant information collected. The matrix tool provided me with a means to ensure this work is not made of subjective ideas, or of unilateral references that only support my point of view while ignoring references that present contrary points of view.

Table 2: Keywords used during data collection

S/N	Formulated keywords
1	Trans-Atlantic bird migration
2	Bird migration between North America and Europe
3	Bird migration in Greenland

4	Bird migration in Iceland
5	Bird migration in the Arctic region
6	Migration flyways of Greenlandic and Icelandic population
7	Long-distance migratory bird species

3.3. Data analysis method

During this research, I performed a systematic literature review and non-statistical meta-analysis methods since the objective was to come up with a detailed theory describing migratory phenomenon occurring over Atlantic Ocean between mainland Europe and North America. Each document identified with relevant information was taken as a reference due to the fact that it provides additional information either on the migratory bird identified itself or it increases the reliability of the database, this because while monitoring a bird's migration strategy, the accuracy of results depends greatly on applied methods of collection (Fiedler, 2009; Sidney, 1996). Three methods were referred to for data analysis and also for the assessment of the quality of information. Method (1) was to compare the information provided by a given document with research questions. This work aims to evaluate and synthesize evidence of atypical bird migration with special concern for east-west movement between North America and Europe. To achieve this goal, it was crucial to split the main objective into smaller and specific goals so that the analysis of information and the consideration of quality information became factorial. The specific targets formulated amid this work in order to achieve my main goal include: first, the identification of migrant bird species that circulate in the area of concern whether or not they undertake regular or irregular migration movements, and try to understand their historical migration grounds and migration strategies. This information could help to provide a general overview of the migration and the ratio of atypical movements in the zone. Since the study area is mainly made up of waterbodies, I thought that there would probably be a particular migration strategy that should obviously be distinct from that of a migrant bird flying over a large landscape. Therefore, I formulated the second target to identify important stopover sites in the area, so that this together with the migration strategy of a given species helped me to judge whether a species is doing a

normal migration movement or an atypical movement when caught somewhere in the migration journey.

The second method applied to assess the quality of the information collected and analyze them is (2) putting into consideration the reliable accuracy of the methodology applied. Generally, ornithology uses various methodologies to monitor the bird's migration phenomenon to answer curious questions pertaining to migration behavior over a diversity of atmospheric conditions, migration routes, and migration grounds as well. The effectiveness and accuracy of every single technique depend on several factors although the combination of various tools is the most accurate to address a specific question (Fiedler, 2009; Sidney, 1996). Following this, having a diversity of methodologies to test migration strategy of a given migrant, application of more than one method, or using the latest advanced tracking technologies ensure that the data are valid and reliable. The last aspect considered to assess the quality of information is (3) prioritizing the approval process of a document and assessing whether or not it has passed through a review process, is published, or is internationally recognized. References that are journal-published or academically reviewed make a good reference whereas conference papers are usually considered "lower"-quality references (Bandara et al., 2015), thus, several unpublished and non-reviewed references were rejected.

Moreover, considering the quality of information and the research questions of concern, it does not necessarily mean that every single reference discusses migratory movement of a given migrant bird directly between North America and Europe, or defines movement type whether atypical or regular. Rather, a combination of two or more documents helped to define either migration between North America and Europe or characterize migration movements of various migrant bird species over the Atlantic Ocean. More clearly, a migrant bird might have for instance been identified in North America from mainland Europe without any fact that such settler has passed through Greenland to reach the North American grounds. However, from another document, I might also find the information saying that another migrant bird of the same species was recorded in North America possessing a ring (leg band) that had been attached in Greenland during the activity period, and exactly in the same areas where habitually the mainland European species are used to stay or to pass through. There is a higher

probability that these migrant bird species first pass through Greenland in their migration journey to North America although no typical evidence confirms this information. In this case, there is room to suggest that such migratory bird species probably use Greenland as a stopover site when migrating between mainland Europe and North America.

3.4. Justification of methods

The review was done using both systematic literature review and non-statistical meta-analysis methods, which entail a thorough, transparent, and replicable process for literature search and analysis. The systematic literature review has long been used and is described as a way to make sense of large amounts of information, asking questions about what works and what doesn't (Petticrew & Roberts, 2006). This method, therefore, aligns well with this study because my research questions require a quantitative and quantitative overview of existing literature that worked on bird migration across the area of concern. A systematic literature review aims to identify all the literature in the subject area with the intent of making sure that no existing understanding or knowledge is missed or overlooked (O'Gorman & MacIntos, 2014). Normally, several types of literature reviews have emerged over the years, but the four main types namely: traditional or narrative, systematic, meta-analytic, and meta-synthetic types of literature are the most dominant (O'Gorman & MacIntos, 2014). The main purpose of a traditional or narrative literature review is to analyze and summarize a collection of literature thereby presenting a comprehensive background of the literature within the topic of interest to highlight new research directions and identify gaps and contradictions. This type of literature survey helps refine, focus and shape new research questions and develop a theoretical and conceptual framework. In contrast, a systematic literature review targets a rigorous approach for a literature survey because it is often used to answer specific, highly structured research questions. Complementarily, the meta-synthesis approach is another non-statistical procedure that reviews and analyses qualitative study data in order to expand from earlier conceptualizations and interpretations. (O'Gorman & MacIntos, 2014). One of the main roles of literature surveys is that through a literature review, information gleaned from relevant, important, valid, and authoritative articles and studies can be compiled into a document (such as an article or a dissertation). This method can

provide a research rationale or reason that may include justification for a particular research approach (McGhee et al., 2007). Literature reviews also provide the researchers with a starting point to recognize and understand what is happening in their particular field. In addition, literature reviews do not only highlight knowledge gaps, but also imply that students, researchers, and administrators are not repeating previous work (O’Gorman & MacIntos, 2014).

While literature involves a three-stage paradigm (assembly, organizing, and assessing) to explore the interconnected processes, as well as practical recommendations and useful illustrations (Fernandez, 2019), the matrix tool provides a means to arrange the data collected (Goldman & Schmalz, 2004). Matrix tool also helps to ensure that work is not the result of subjective stitching of a patchwork quilt of references, or of the unilateral cherry that only picked references that support one's point of view while ignoring references that present contrary points of view (Goldman & Schmalz, 2004). In addition, the practical screening, quality appraisal, data extraction, synthesis of studies, and writing the review constitute a detailed methodological approach necessary to conduct any kind of systematic literature review including an academic thesis or dissertation (Okoli & Schabram, 2012). Following the principle of systematic literature review and non-statistical meta-analysis adhered to during my research, and taking into account the role of the matrix tool in the literature review, I can confirm that the methodology applied is adequate to achieve the overall goal of my research.

3.5. Limitation

A systematic literature review, as opposed to other literature surveys, examine and systematically summarizes existing information. Meta-analysis gives a more reliable and precise assessment of effect than individual research. This type of review is useful for establishing the methodologies to be used in subsequent studies, but, it is also biased since it is a retrospective research endeavor (Yuan & Hunt, 2009). It requires a rigorous research procedure and the amount of information to which scientific review processes are applied determines the quality of the work. In health science, when data is handled incorrectly, systematic reviews can be misleading, useless, or even destructive; meta-analyses can be abused when the difference between a patient seen in the clinic and those

included in the meta-analysis is not examined. Furthermore, systematic reviews cannot provide answers to all important problems, and their conclusions may be difficult to implement (Yuan & Hunt, 2009).

Specifically, the limitations during my work do not greatly differ from the theory aforementioned; it has mainly fallen in the shortage and imprecision of studies conducted in the area of my concerns. Generally, not many precise studies worked on the migration phenomenon undertaken by birds crossing or trying to cross the Atlantic Ocean between Europe and North America, and in addition, the intent of many of the available ones was not exactly focusing on my objectives. Some studies were designed for migration strategy of given specific migrants, whereas others focused on population estimation, distribution, and the identification of migration routes. Thus, it was time-consuming and a little complicated to identify relevant literature since it requires proper reading for almost every single document including even those showing minor signs of being providers of adequate information. However, my results would be validated and reliable since time limitation-associated errors were compensated by making extra time for working hours.

CHAPTER 4: RESULTS

4.1. Studies related to the field of concern

Numerous studies have focused on the migration phenomenon undertaken by birds crossing or trying to cross the Atlantic Ocean between Europe and North America, however, the intent of many of these studies was not to assess birds' migration movements across the Atlantic Ocean between North America and Europe. Using various keywords formulated earlier before the beginning of my research, I identified and analyzed 89 documents that were screened one by one and retained only quality references. Therefore, four dozen documents were retained as quality references that provided various information about bird migration that occurs between mainland Europe and North America, as well as associated 'in the middle islands,' mainly Iceland and Greenland. These documents include experimental and reviewed articles (60%), reviewed and published reports (21%), books (10%), journals (6%), and papers (2%). Of the literature considered, some studies were designed to study the migration strategy of given specific migrants, whereas others focused on population estimation, distribution, and identification of migration routes.

4.2. Trans-Atlantic migration movements

The review identified 52 species of migrant birds grouped into four various taxonomic groups: landbirds, seabirds, shorebirds, and waterfowl. The species include migrant birds that completely cross Atlantic Ocean and those that in some cases undertake a partial crossing of the Atlantic Ocean to settle on the in-the-middle islands between North America and mainland Europe. Migratory bird species undertake trans-Atlantic movements with distinctive migration strategies. The majority of these migrants use stopovers to migrate between North America and mainland Europe across the Atlantic Ocean whereas a fewer number of migratory bird species do a round-trip of non-stop trans-oceanic flight. Greenland is identified as an important stepping stone area for the majority of migrant birds that use the Eastern Atlantic Flyaway between mainland Europe and North America, with 98% of the total migrants reaching Greenland grounds. Given that the majority of migratory bird species that move between North America and

mainland Europe reach Greenland as an important stepping stone, some of them pass through Iceland. In addition, mainland Europe and Spanish Canary Islands serve as important refueling sites for long trans-oceanic migration flights when migrants are progressing to or coming from African wintering areas (Alerstam et al., 1990; Davidson & Wilson, 1992; Reneerkens et al., 2008; David et al., 2014). Although the identified migratory bird species circulate between North American and mainland European grounds, some of them are made up of various populations that reside in different ecological home ranges. Seabirds and waterfowl make up the majority of these migrant species to the extent of 44% and 25% respectively, while shorebirds and landbirds follow with a respective amount of 17% and 13% of total migrants in the area (Figure 4).

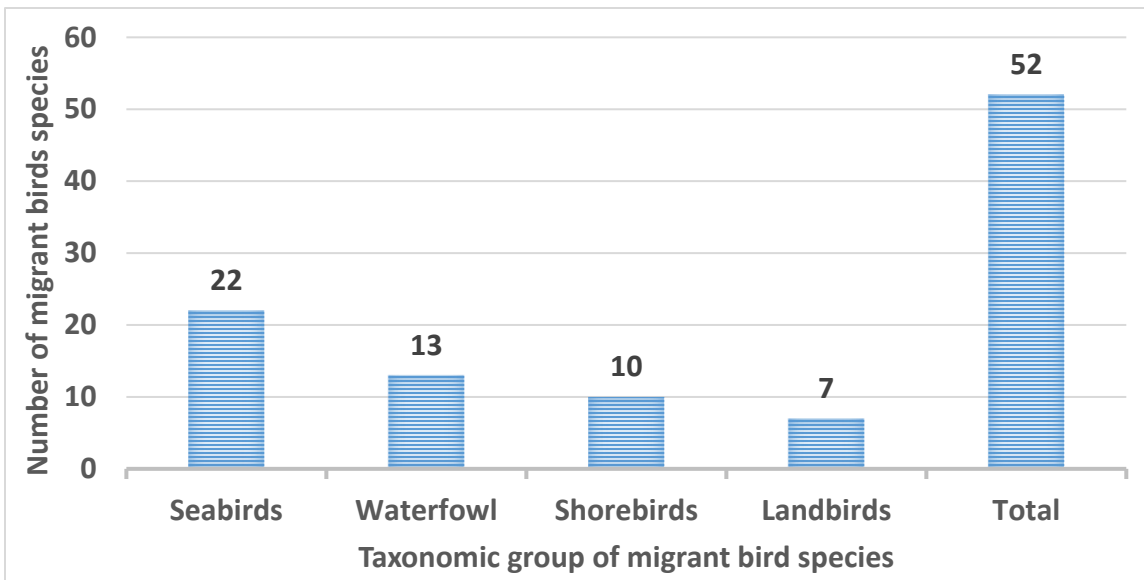


Figure 4: Migratory bird species identified as general migrants of the Eastern Atlantic Flyway across the Atlantic Ocean between Canada/North America and Europe. Source: The figure is designed from the synthesis of data appeared in Appendix A)

Most of the migrant species identified in the areas carry out typical migration movements, while approximately 17% of the total of migrants found in the Eastern Atlantic Flyway undertake atypical migration journeys (Figure 5) by shifting en route from their normal migration ranges and by changing or extending migration grounds. In this route, the majority of migrants make wintering and breeding migration movements, and a small number of migrants make irregular migration movements with journeys other than those expected. A migration movement is defined as irregular depending on various

circumstances in which migration journey is carried out (Cottee-Jones et al., 2015). An atypical movement becomes 'dispersive' if a species of migrant birds moves with fluctuating migration direction or distance from its breeding site (Baker, 1980; Newton, 2008), and the movement is 'irruptive' when migrants make seasonal migration movements with a variety of changes in the number of individuals, migration timing, migration direction, and distance traveled between years (Lack, 1968; Newton, 2008). In addition, the migration movement is atypical 'nomadic' if the species, respectively, move with no fixed spatial, temporal pattern or 'vagrant' when an individual bird appears in an area far beyond the limits of its normal range and migration routes (Newton, 2008).

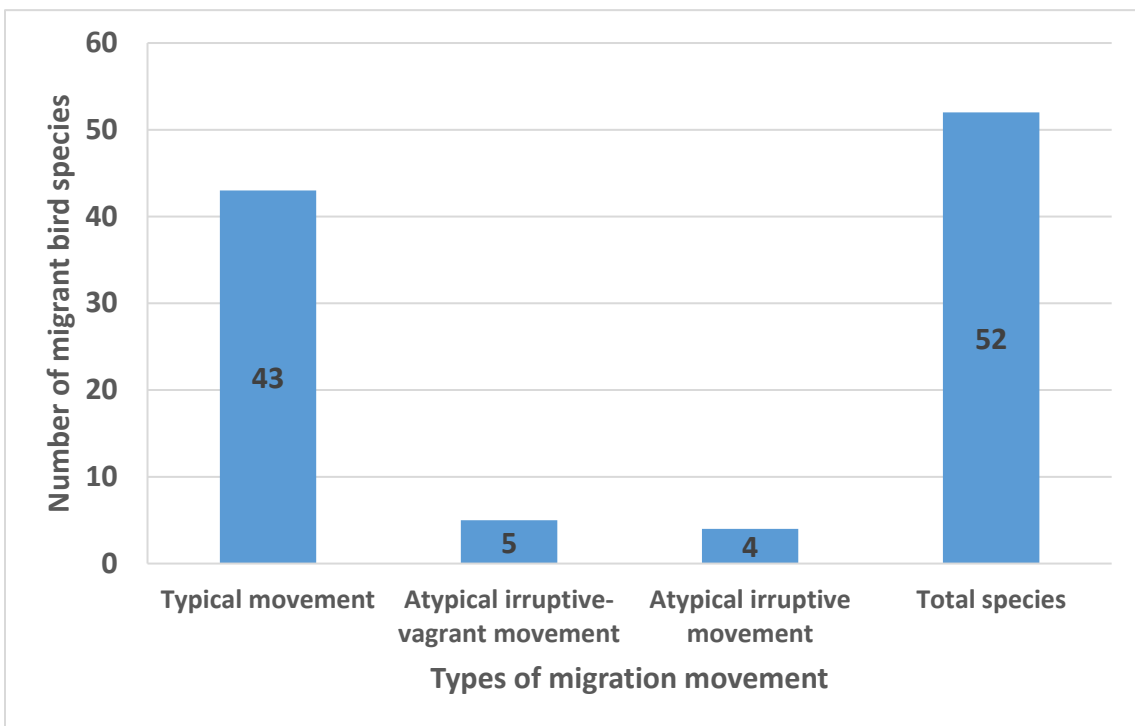


Figure 5: Comparison of different types of migration movements identified in the Eastern Atlantic Flyway

Regarding irregular migration movements, some migrants were identified as atypical migrants in some areas of the flyway, but let me talk a little about the irregular movements of Arctic terns and American bitterns. The Arctic tern (*Sterna paradisaea*) that starts migration in northern Canada typically heads south to the east coast of the United States before crossing the Atlantic Ocean to West Africa and sometimes Australia before progressing toward its Antarctic molting grounds. On the contrary, Arctic terns

that start migration in Greenland and Iceland first head to the European coast before crossing back toward South America until they reach the arctic cycle. However, it is found that the early return of Greenlandic Arctic terns induces an irruptive and vagrant movement that can bring them to North America (Lyngs, 2003). In his study on the reorientation of migrating birds in coastal areas and their ability to disperse toward suitable resting grounds, Alerstam (1978) suggested that migrating birds with small fuel reserve can go off the vicinity of their normal migration route and head towards a suitable ground for refueling before they continue the journey. In addition to guessing the exploratory movements that could perhaps be associated with an early return and without the rush to reach Greenland before the usual arrival time, Alerstam's theory like previously referenced in Alerstam (1978) pushes me to raise two additional reasons, suggesting why Arctic terns reach North American grounds while coming back from Antarctica. The first argument lies in the geographical position of Greenland (which is the breeding range) compared to other regions. Respecting the geographical location of Greenland, parts of Europe, Africa, and some zones of North America (Canada and USA) are closer for a migrant that is returning from the Antarctic region. With the statement of Alerstam (1978), I can guess that the presence of Arctic tern in North America, while it is coming back from Antarctica, could be associated with the refueling needs before progressing its returning movement to Greenlandic breeding grounds. The second argument for the presence of the turn in North America might be a direct effect of easterly winds that may be drifting the Arctic turn from the middle of the North Atlantic Ocean and overshoots from the normal route toward North America. This second suggestion is supported by various studies which have confirmed the existence of strong winds over the Atlantic Ocean (Bagg, 1967; Alerstam, 1990b).

In addition to the atypical movement of Arctic terns, in general, American bittern (*Botaurus lentiginosus*) winter along the southern American coastal states, the temperate pacific coasts of British Colombia, and along the North Atlantic coast at Virginia, Delaware, and sometimes New Jersey. However, records showed that post-breeding dispersal moments in late summer make American bitterns reach Greenland and mainland Europe (Huschle et al., 2013). This dispersive journey might be initially governed by post-breeding resting needs of bitterns like other many migrants do

(Alerstam, 1978) but its occurrence in Greenland and mainland Europe was attributed by Cramp (1977) to being caught up in westerly storm tracks during post-fledging dispersal.

Although many species use western Atlantic areas during breeding and eastern zones during the winter period (Lyngs, 2003), special movements were identified that are undertaken toward North America during the winter (Newton & Dale, 1996b). According to Newton and Dale (1996b), species such as great skua (*Catharacta skua*), lesser black-backed gull (*Larus fuscus*), black-headed gull (*Larus ridibundus*), Eurasian wigeon (*Anas penelope*), and little auk (*Alle alle*) move on from Iceland and northwestern Europe to pass wintertime on North American grounds. In the context of atypical migration, these migrants do irregular irruptive or vagrant movements since it is revealed that these migrants (great skua, lesser black-backed gull, black-headed gull, and Eurasian wigeon) also pass the winter elsewhere in Europe. Alternative wintering areas suggested in Europe include Russia, eastern Europe, and northeast Africa (Cantos et al., 1994; Atkinson et al., 2006, p.343; van Roomen et al., 2018) and no evidence was found confirming fidelity to their wintering areas in North America.

The Eastern Atlantic Flyway is characterized by many vagrant movements mostly observed in young passerine landbirds relatively accompanied by few adults on the coasts of North America (Ralph, 1978). The vagrancy of American land birds appearing in western Europe has been ascribed to strong westerly winds across the Atlantic Ocean (Alerstam, 1990). In terms of specific migrant species, I failed to identify a failed or lost migrant species in the Eastern Atlantic Flyway but what is known is that except for insectivorous and seed-eating migrants which occasionally survive trans-Atlantic movements, several birds of various sizes get lost and fall down as a result of unfavorable weather conditions and ship-induced disorientation (Elkins, 1979). Along the North American Atlantic coasts, the air currents act as a serious migration setback that even sometimes leads to reversal movements when migrant birds moved from far west of Nova Scotia toward Newfoundland (Richardson, 1982). Whilst the fluctuation of westerly winds forces birds to do a migration u-turn, the easterly currents drift migrant birds from the European sides, pushing them farther west and causing vagrant movements toward North America (Bagg, 1967). In this regard, generally, the breeding areas of Eurasian lapwing (*Vanellus vanellus*) are in the open countries across the

Eurasian tundra while they spend wintertime in the south of their breeding ranges in Europe and northern parts of Africa (Pranty & Woolfenden, 2000; Leitao & Peris, 2004). However, Eurasian lapwing appeared in various regions of North America (Canada and USA)(Pranty & Woolfenden, 2000) and it is discussed that Eurasian lapwing immersed first in North America as a direct effect of easterly winds from Europe out into the Atlantic that made western birds overshoot western Europe and reach North America (Bagg, 1967).

4.2.1. Migratory species between Greenland and Canada/North America

As Table 3 shows, the majority of migrant birds that change grounds in this zone are made up of seabirds (40%), waterfowl (40%), and landbirds (20%) which are fewer compared to the aforementioned groups. This category of migrant bird species is composed of both Greenlandic and North American populations that undertake breeding migration in Greenland with subsequent winter migration to North American grounds. Although a diversity of typical migrant bird species were identified to migrate between Greenland and North America, no shorebird was identified as an endemic migratory species of Greenland (Table 3). Greenland as an island shares a considerable border of approximately 18,977 km with North America from the Lincoln Sea in the north to the Labrador Sea in the southeast slightly between North America and mainland Europe. The possible longest waterboard flight between two distinct grounds is approximately 2,300 km on the side of Atlantic Ocean whereas other parts are separated by narrower waterbodies, which can reduce down to 200 km distance. It is well understood how the geomorphological structure of the area (also consult to Figure 1) is hospitable for migrant birds of various distance bouts to migrate on either side and this might probably be the cause of my failure to find vagrant movements from typical migrants of the areas.

Table 3: List of migrant bird species that migrate between Greenland and Canada/North America.

S/N	Common name	Species/Scientific name	References
LANDBIRDS			
1	Peregrine falcon	<i>Falco peregrinus</i>	(Fuller et al., 1998; Lyngs, 2003)
2	Rock ptarmigan	<i>Lagopus mutus</i>	(Lyngs, 2003)
SEABIRDS			

S/N	Common name	Species/Scientific name	References
3	Ivory gull	<i>Pagophila eburnea</i>	(Lyngs, 2003)
4	Little auk/dovekie	<i>Alle alle</i>	(Newton & Dale, 1996b; Lyngs, 2003)
5	Razorbill	<i>Alca torda</i>	(Lyngs, 2003)
6	South polar skua	<i>Stercorarius maccormicki</i>	(Lyngs, 2003)
WATERFOWL			
7	Canada goose	<i>Branta canadensis</i>	(Lyngs, 2003)
8	Common teal	<i>Anas crecca</i>	(Lyngs, 2003)
9	Northern pintail	<i>Anas acuta</i>	(Lyngs, 2003)
10	Harlequin duck	<i>Histrionicus histrionicus</i>	(Lyngs, 2003)

4.2.2. Migration between Greenland, Iceland, and mainland Europe

This category has neither typical migrants that reach North American areas nor dispersive movements that could reach either ground. The category consists of migrants with almost regular migration movements between Greenland, Iceland, and mainland Europe (Table 4) although it is revealed that some vagrant movements are present in the area. The settler mentioned in Table 5 is found to be a species that sometimes undertakes Palearctic vagrant movement toward Greenland (Lyngs, 2003). Seabirds outnumber other migratory bird species in this category with 60% of total migratory bird species, while no landbird migrant was identified to restrict their migration movements in these areas. Citing various authors, Evans et al. (1992) note that landbirds inhabiting Oceanic islands are exposed to extinction dangers, the phenomena that occurred to landbirds from Seychelles and Mascarenes of the Indian Ocean and to the Hawaiian population in the Pacific Ocean. Therefore, I could think that landbirds prefer to use Greenland and Iceland as refueling sites on their way to continental areas or consider them as seasonal dwelling grounds to reduce the risks of extinction. In this category, some bird species, such as black guillemot (*Cephus grille*), migrate between Greenland and Iceland (Lyngs, 2003) whereas others such as Icelandic whimbrel (*Numenius phaeopus*) migrate anywhere from Greenlandic to mainland European (Gunnarsson & Guðmundsson, 2016)

Table 4: List of birds migrating between Greenland, Iceland, and mainland Europe

S/N	Common name	Species/Scientific name	References
SEABIRDS			
1	Black guillemot	<i>Cepphus grille</i>	(Lyngs, 2003)
2	Great skua	<i>Stercorarius skua</i>	(Lyngs, 2003)
3	Iceland gull	<i>Larus glaucoides</i>	(Newton & Dale, 1996a)
4	Northern fulmar	<i>Fulmarus glacialis</i>	(Lyngs, 2003)
5	Red-throated diver	<i>Gavia stellate</i>	(Lyngs, 2003; Boertmann et al., 2009)
SHOREBIRDS			
6	Dunlin	<i>Calidris alpine</i>	(Wilson, 1981; Greenwood, 1984; Ens et al., 2006; Meltofte, 1985; van Roomen et al., 2018)
7	Icelandic whimbrel	<i>Numenius phaeopus</i>	(Alves et al., 2016; Gunnarsson & Guðmundsson, 2016; Van Roomen et al., 2018)
WATERFOWL			
8	Pink-footed goose	<i>Anser brachyrhynchus</i>	(Lyngs, 2003; National Audubon Society, 2021)
9	Red-breasted merganser	<i>Mergus serrator</i>	(Lyngs, 2003)
10	White-fronted goose	<i>Anser albifrons flavirostris</i>	(BirdLife International, 2019a)

Table 5: Table: Migratory bird species identified as frequent undertakers of vagrant movements between Greenland, Iceland, and mainland Europe.

S/N	Common name	Species/Scientific name	Type of irregular movement	References
SHOREBIRDS				
1	Eurasian oystercatcher	<i>Haematopus ostralegus</i>	irruptive, vagrant	(Lyngs, 2003)

4.2.3. Migrating between mainland Europe, Iceland, Greenland, and Canada/North America

This category of migrants is made up of migratory bird species from various taxonomic groups that have populations dwelling in varied home ranges from mainland Europe to North America along the Atlantic coasts. In this category, some migratory bird species from different populations and home ranges migrate between North American and mainland European areas, as well as to the in-middle islands. Compositionally, this category is made up of most seabirds with 43% of total migratory birds followed by shorebirds and waterfowl that count 20% each, and few landbirds that hold slightly more than 16% of total migrants (Tables 6 and 7). Furthermore, this category includes the dominance (nearest 89%) of the total number of irregular migration travelers identified throughout the Atlantic Ocean (Table 7).

Table 6: List of migratory birds undertaking regular migration movements between mainland Europe, Iceland, Greenland, and Canada/ North America

S/N	Common name	Species/Scientific name	References
LANDBIRDS			
1	Gyrfalcon ^{**2}	<i>Falco rusticolus</i>	(Burnham & Newton, 2011)
2	Lapland bunting [*]	<i>Calcarius lapponicus</i>	(Lyngs, 2003)
3	Mealy redpoll [*]	<i>Carduelis flammea</i>	(Lyngs, 2003)
4	Snow bunting	<i>Plectrophenax nivalis</i>	(Lyngs, 2003)
5	Northern wheatear	<i>Oenanthe oenanthe</i>	(Newton & Dale, 1996; Lyngs, 2003; Bairlein et al., 2012; Bulte et al., 2014; Corman et al., 2014)
SEABIRDS			

¹.(**) means the North American species which do not have a population on the other side and this species doesn't overpass Iceland in its migration movements toward the eastern Atlantic areas;

2. (*) means movements where only Greenlandic and North American populations reach grounds on either side;

3. The remainders can reach mainland European, middle islands, and North American sites either directly or using refueling sites (appendix A).

S/N	Common name	Species/Scientific name	References
6	Atlantic puffin	<i>Fratercula arctic</i>	(Lyngs, 2003; Burnham et al., 2021)
7	Black-legged kittiwake*	<i>Rissa tridactyla</i>	(Lyngs, 2003)
8	Brünnich's guillemot*	<i>Uria lomvia</i>	(Lyngs, 2003)
9	Common guillemot	<i>Uria aalge</i>	(Lyngs, 2003)
10	Glaucous gull	<i>Larus hyperboreus</i>	(Huettmann & Diamond, 2000; Baak et al., 2021)
11	Great black-backed gull*	<i>Larus marinus</i>	(Lyngs, 2003; Van Roomen et al., 2018)
12	Great northern diver*/ Common loon	<i>Gavia immer</i>	(Newton & Dale, 1996a; Evers, 2004; Boertmann et al., 2009)
13	Herring gull*	<i>Larus argentatus</i>	(Lyngs, 2003)
14	Northern gannet	<i>Morus bassanus</i>	(David et al., 2014; Boertmann et al., 2020;)
SHOREBIRDS			
14	Common ringed plover	<i>Charadrius hiaticula</i>	(Taylor et al., 1980; Wilson, 1981; Newton & Dale, 1996; Lyngs, 2003; Meltofte, 1985; van Roomen et al., 2018)
16	Purple sandpiper	<i>Calidris maritima</i>	(Salomonsen, 1967; Morrison et al., 2001; Lyngs, 2003; LeBlanc et al., 2017; van Roomen et al., 2018)
17	Red knot	<i>Calidris canutus</i>	(Morrison, 1975; Branson et al., 1978; Clapham, 1979; Alerstam et al., 1990;; Davidson & Wilson, 1992; Meltofte, 1985)
18	Sanderling	<i>Calidris alba</i>	(Wilson, 1981; Newton & Dale, 1996a; Lyngs, 2003; Ens et al., 2006; Reneerkens et al., 2008; Meltofte, 1985; van Roomen et al., 2018)

S/N	Common name	Species/Scientific name	References
19	Ruddy turnstone	<i>Arenaria interpres</i>	(Morrison, 1975; Branson et al., 1978; Clapham, 1979; Fems, 1981; Wilson, 1981; Godfrey, 1986; Alerstam et al., 1990; Newton & Dale, 1996; Lyngs, 2003; Meltofte, 1985; van Roomen et al., 2018)
WATERFOWL			
20	Common eider*	<i>Somateria mollissima</i>	(Lyngs, 2003; Boertmann et al., 2009)
21	Light-bellied brent goose	<i>Branta bernicla hrota</i>	(Alerstam et al., 1990; Gudmundur et al., 1995; Lyngs, 2003; Van Roomen et al., 2018)
22	Long-tailed duck*	<i>Clangula hyemalis</i>	(Lyngs, 2003)
23	White-fronted goose	<i>Anser albifrons</i>	(Newton & Dale, 1996; Lyngs, 2003; National Audubon Society, 2021)

Table 7: List of migratory birds undertaking atypical migration movements between mainland Europe, Iceland, Greenland, and Canada/North America.

S/N	Common name	Species/Scientific name	Type of irregular movement	References
SEABIRDS				
1	Arctic tern	<i>Sterna paradisaea</i>	irruptive, vagrant	(Lyngs, 2003), https://www.americanocéans.org/facts/where-does-arctic-tern-migrate/
2	Barnacle goose	<i>Branta leucopsis</i>	irruptive, vagrant	(Lyngs, 2003; Boertmann et al., 2009; van Roomen et al., 2018; National Audubon Society, 2021)

S/ N	Common name	Species/Scientific name	Type of irregular movement	References
3	Black-headed gull	<i>Larus ridibundus</i>	Irruptive	(Cantos et al., 1994; (Newton & Dale, 1996b); Lyngs, 2003; van Roomen et al., 2018)
4	Lesser black-backed gull	<i>Larus fuscus</i>	Irruptive	(Newton & Dale, 1996b; Hallgrimsson et al., 2011; van Roomen et al., 2018; Zawadzki et al., 2021; Boertmann & Frederiksen, 2022)
5	Great skua	<i>Catharacta skua</i>	Irruptive	(Furness, 1978; Newton & Dale, 1996b)
SHOREBIRDS				
6	American bittern	<i>Botaurus lentiginosus</i>	irruptive, vagrant	(Cramp, 1977; Huschle et al., 2013)
7	Eurasian lapwing/northern lapwing	<i>Vanellus vanellus</i>	irruptive, vagrant	(Bagg, 1967; Pranty & Woolfenden, 2000; Leitao & Peris, 2004)
WATERFOWL				
8	Eurasian wigeon	<i>Anas penelope</i>	Irruptive	(Newton & Dale, 1996b; Atkinson et al., 2006, p.343)

Climatic factors greatly influence migration strategy in this area, whereas wind determines the flight altitude and flight speed of migrants (Alerstam et al., 1990). Being composed of various migrants flying over a considerable zone, birds in this category use various migration strategies during their migration journeys, where some of them use stopover sites to reach the migration grounds on the other side, whereas others perform a long trans-oceanic flight to connect themselves with grounds from different continents. For those migrants that do long-distance flights, I found the gannet and wheatear (see

their latin names in Appendix A and Table 6) to be the only migratory birds that can cross the Atlantic Ocean and directly migrate from North American breeding areas to European wintering grounds with a non-stop flight. Although these birds can cross the Atlantic Ocean in a single flight, they may also be using stopovers when migrating between North America and Europe (Corman et al., 2014; David et al., 2014). While this section discusses migratory bird species that migrate between mainland Europe, Iceland, Greenland, and North America, some European migrant species do not reach North American grounds as likely similar to other species from North America which do not arrive in mainland Europe. I categorized them in such a way just to provide notice about the diversity of some species that come from various populations of different home ranges and these species may to some extent reach varied migration grounds depending on their location or migration ability. In this case, I mention, for instance, mealy redpoll that comes from two distinctive Greenlandic populations where one population residing in western parts migrates only between Canada and Greenland, whereas the second breeding from eastern parts of Greenland heads towards Icelandic and mainland European grounds during the winter (Lyngs, 2003).

4.3. Threats of identified migrants along the flyway

Apart from Greenland and Iceland mentioned as important stopovers utilized by migrant birds connecting themselves with distant grounds between North America and the Europe continent, at least nine different sites were identified to be critical for settlers migrating between North America and mainland Europe. Six sites among these areas are located on the grounds of the Eastern Atlantic Flyway, whereas the other three are on the Atlantic Americas Flyway (BirdLife International, 2019a) and these sites provide migrants with breeding, wintering, and staging services. In contemporary bird migration, migrants face various threats that act as potential drivers of population decline. Stochastic factors such as illegal killing and taking, habitat degradation, and loss are emphasized, and it is discussed that climate change is causing a serious problem for settlers that reach African and European migration grounds (Bairlein, 2016). In addition, infrastructure and housing development, agricultural expansion, and unsustainable exploitation of water-based food, as well as the residual effects of climate change, the development of alternative energy generators (Wind farms) are negative additions to habitat degradation and amplify threats

encountered by migrants circulating through the flyways (BirdLife International, 2019a). Appendix C illustrates in detail the important international areas for migratory birds and potential threats encountered across the migration flyway.

4.3.1. Habitat Protection for trans-Atlantic migratory birds

4.3.1.1. Legal framework

The International Convention on the Conservation of Migratory Species recognized the importance of animal species and decided that range states should protect migratory species. Following this, the Member States agreed to take action for the protection of migrant birds and their habitats to eliminate conservation threats ([UN, 1979](#)). Through Environment and Climate Change Canada, migratory species are protected under the Migratory Birds Convention Act ([Government of Canada, 2017](#)). Similarly, the European Union established legal frameworks conceived in Bird and Habitat directives that aim at protecting habitats and species of community interest (Faulks, 2007; European Parliament and Council, 2010; Campagnaro et al., 2019) under which migratory bird species and their habitats are protected. On the other hand, The United States of America (USA) have historically had a migratory bird protection regulation at least since early 1913 when they established the Migratory Bird Act (Dorsey, 1998). While I found that some birds reach migration grounds in the USA from the European areas either by normal or vagrant migration movements, (Bagg, 1967; Pranty & Woolfenden, 2000; Lyngs, 2003) until recently, no recognized conservation treaty exists between the USA and the European Union. However, the regional conservation efforts engaged by the USA to protect migratory birds are explained by a multitude of international conventions they signed with various countries, for instance, the convention between USA and Canada, USA and Mexico, USA and Japan, and convention between the USA and the Soviet Union all signed respectively in 1916, 1936, 1972, and in 1976 (Anderson et al., 2018).

Although all established treaties and legal frameworks consider broader aspects that involve habitat and population protection, many marine migratory species, including 27% of seabirds (Lascelles et al., 2014), other for woodland and farmlands, including even bird species from protected areas such as Natura 2000 in Europe (Portaccio et al., 2021) are still under threat. The pressure encountered by migratory birds is on the one hand

attributed to the insufficient coordination between various states and countries (Holopainen et al., 2018) or unbalanced conservation efforts carried out in various conservation sectors. Portaccio et al.(2022) revealed that generally researchers have focused on terrestrial habitats, more particularly wetlands, while little effort has been put on conservation status for both species and habitat suitability and on marine environments. This might, on the other hand, explain what is going on from the investment and engagement points of view in the world of today that is highly driven by research in various decisions taken. Thus, existing conservational initiatives or those that may arise to protect trans-Atlantic migratory birds should strengthen and ensure a balanced harmonization for the legal and strategic implementation, monitoring, and throughout various conservation sectors to reduce migration-associated pressure that could be highly exercised over trans-continental migrants since this last increases with migration distance (Sawyer et al., 2016).

4.3.1.2. Technical framework: Management practices

During migration-related activities, migratory bird species of the Eastern Atlantic Flyway utilize various types of habitats grouped into 13 main groups (Davidson & Stroud, 1996). These habitats are mentioned in Appendix D with the addition of forest and woodland (native coniferous forest and mixed forest) not previously mentioned by Davidson & Stroud (1996) probably because he was discussing only habitat types for migratory shorebirds, seabirds, and waterfowl in this corridor. Taking into account various aspects, including but not limited to the deteriorating agent as mentioned in Appendix C, the quality of habitats and forage sites of migratory birds are susceptible to deterioration over time. While conflicts between anthropogenic economic activities and biodiversity conservation initiatives are continuously increasing in Europe (Young et al., 2005; Portaccio et al., 2022), many wetland habitats were converted in all developing countries whereas mangrove swamps disappeared throughout Africa and Asia (Turner, 1991). According to Turner (1991), 300,000 ha (67%) of the national mangrove stock are lost in the Philippines during the period 1920-1980, all as a result of agricultural land reclamation, construction of fishponds, mining, and waste disposal. On the other hand, however, afforestation and inadequate forest and grassland management degrade habitats

of ground-nesting birds, whereas breeding, roosting, and feeding services are interrupted due to predator proneness resulting from reduced management practices, as a matter of fact, open forests and managed grasslands change towards the closed vegetated areas (Thompson et al., 1988). Although forests and woodlands need management practice to provide adequate services to a diversity of bird species, the type of management practice and intensity vary and are, moreover, possible depending on several aspects that may include bird species, nesting and feed types, the type of woodland ownership, and others (Quine et al., 2007). In the Eastern Atlantic Flyway, migratory birds face serious threats related to habitat degradation and loss all as a result of increasing anthropogenic activities, particularly in non-breeding areas (Pearce-Higgins et al., 2017). The perspective of increased vulnerability of migratory birds across non-breeding grounds would obviously introduce an aspect of needed integrated habitat management with consideration of breeding and non-breeding areas including the stopover sites, with all efforts to be undertaken at various levels and scales including local, regional, landscape, and international spatial scale as well (Johnson, 1996). This section discusses technical habitat management practices with a focus on terrestrial habitats that involve seashores and coastal forests to propose adequate management practices to protect migratory birds that depend on the shore and coastal forests when traveling between North America and mainland Europe. Appendix D exhaustively describes the appropriate management practices for each habitat type identified to protect these migratory birds.

4.3.1.3. Feasibility and Tools for habitat management

Well-designed legal frameworks and better management practices are not enough to cover the protection, management, and conservation perspectives of bird habitats, since migratory birds do not have borders. They use a variety of countries, properties, and ownerships, and the protection and conservation of their habitat should be viewed at a broader scale in the environment. Although some sovereign parliaments around the world created a new legislation power that interfered with property right amid the 18th century, property right is still under consideration since laws set principles of compensation for any kind of property right interference (Sperling, 1997). Therefore, land use decision-making and land-based economic objectives are governed by the landowner's survival and livelihood objectives (Malek et al., 2019). In the forest industry, forest management

practices differ on temporal and spatial scales depending on the type of ownership (Artti et al., 2014). Consequently, industrial landowners and timber investment management organizations are likely to have similar management practices and they intensively manage their forestlands than the state and non-industrial private forest landowners (Artti et al., 2014). In the Finish forestry sector for instance, despite law-regulated management practices in the public forests, in private owned forests management decisions are made by individuals while the Forest Act is primarily aimed at renewing stands and protecting valuable sites for biodiversity without preservation of landscape and recreational values (Act on changes in Forest Act, 1085/2013). From these, the ownership-based variety of management practices complicates the integration of private properties into the scheme that provides public goods and services such as recreational and landscape services, and conservation objectives (Tyrväinen et al., 2014). An English philosopher 'Mr. John Locke' said that it is proper and necessary for property rights considerations to govern land use decisions. To complement his statement, certain legislations considered unnecessary to incorporate into common law the aspect of public interest consideration since they take it as basic and mandatory that the public interest works in harmony with the private interest (Sperling, 1997).

Although the economic value of birds for humans is yet to be quantified worldwide, birds are members of the ecosystem and are pretty important to humans (Whelan et al., 2008). They consume pests, pollinate flowers, disseminate seeds, scavenge carrion, cycle nutrients, and alter the environment to benefit other species. Millions of people around the world observe, feed, and use birds as creative and spiritual inspiration (Whelan et al., 2008,2015). When discussing the migratory species, it is emphasized that these species connect environmental processes and fluxes separated by large distances and time. Over the last two decades, the efforts to examine those ecosystem processes have increased, and now, the ecological values of birds are widely recognized (Whelan et al., 2008). The ecosystem services (ES) and natural capital are a collection of ecological system services and the natural capital stocks that provide them, both of which are vital to the operation of the Earth's life-support system, and they ensure human welfare both directly or indirectly, and hence add to the total economic value of the planet (Costanza et al., 1997). ESs are the circumstances and processes by which natural ecosystems and the

species that comprise them sustain and meet the needs of humans, and they include, but are not limited to, life-supporting functions such as cleaning, recycling, and renewal. They also offer many intangible aesthetic and cultural benefits (Daily et al., 1997).

A set of tools was developed to promote the conservation of the environment, taking into account the aspect of consideration of property rights to make the ESs provided more sustainable. The commercialization of an increasing variety of ES, the replication of the neoclassical economics paradigm, and the application of market logic to the solution of environmental issues have all helped to increase the political support for conservation (Gómez-Baggethun et al., 2009). While ES trading is emerging as an important part of the human economy (Kapsalis et al., 2019), payment for ecosystem services (PES) has proven to be a popular tool to promote the conservation of the environment (FAO, 2011). However, the participation of farmers in PES programs is influenced by the direct and indirect opportunity costs of providers' financial commitment to provide these services. According to the study by Seroa da Motta & Ortiz (2018), the willingness to accept (WTA) or the people's decisions to join the PES scheme is based not only on their opportunity costs, but also on their perceptions of specific issues such as environmental knowledge or awareness, the inertia to change production modes, fear of additional monitoring, and level of understanding of the program. This is also aggravated probably by the fact that the economic value of such services is rarely recognized in land-use decisions (Grieg-Gran et al., 2005).

Apart from commodification, monetization, and establishment of PES, the willingness to pay (WTP) is something very important to consider amid sustainable environmental conservation through PES since most often people with a higher socioeconomic standing have a more positive view of ecosystem services and therefore the higher WTP (Tian et al., 2020). Therefore, international communities and conservation agencies should play a key role in ensuring financial support to sustain the scheme. In conclusion, all tools identified for the protection and management of bird habitats and the ecosystem, in general, should be supported by analysis and strengthening of policy instruments (Campagnaro et al., 2019). In this context, the policy tool should govern the direct provision of environmental services and the exploitation of state resources, and analyze environmental regulations, political feasibility, institutional

framework and graduated sanctions to punish infringements (Sterner & Coria, 2013). The public engagement method should also be analyzed and enhanced to create more incentives for landowners rather than aiming to create jobs for trained personnel. I say this because, for instance, in the case of Natura 2000, even though this conservation initiative has been working on policy system and administration strengthening across the Member states (Campagnaro et al., 2019), breeding bird population is declining in Natura 2000 sites especially, within sites adjacent to private farmlands (Portaccio et al., 2021).

4.4. Quality of data

Nine different techniques were identified to be used in the collection of raw data that make up the overall database of my work (Figure 6 and Appendix B). Satellite Tracking (ST), Geolocator Tracking (GT), Ringing or Banding Recovery (RR), Literature Review (LR), Observation by Telescopic instruments (TO), Field Survey (FS), Simulation Models (SM), Stable Hydrogen-Isotope Analysis (SHIA), Radio Tracking (RT), and other documents that do not show methodologies here abbreviated as (NA) are the main technics used.

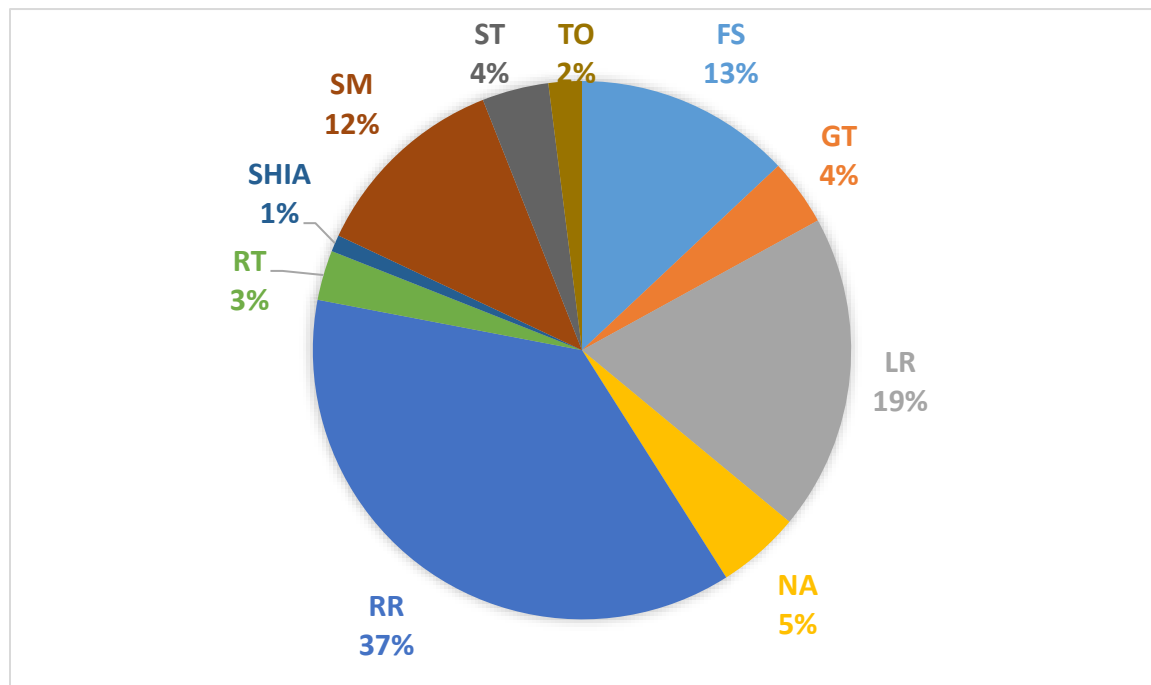


Figure 6: Techniques used in the collection of raw data that make up the overall database of this work

While 17 birds (32% of the total identified migratory bird species identified) were studied using at least three different methods, the ruddy turnstone is the migratory bird studied with many techniques where six different methods were applied. It is followed by light-bellied brent goose, northern wheatear, and northern gannet as well (see the scientific name in Appendix A) which were studied with five techniques each. The SM, SHIA, FS, and NA methods could trigger a skepticism about the quality of my data; however, the doubts that could arise from these methods are fortunately compensated by additional methods, since none of these techniques was applied alone to study a migrant bird (see also Appendix B). Having utilized various methodologies, the quality of data is also ensured by the fact that at least 98% of references used have passed through the review process, hence, higher reliability.

CHAPTER 5: DISCUSSION

5.1. General Discussion

Contrary to the global estimates of migrating birds that count thousands of migration movements, this work found that only a small number of migratory birds undertake migration movements crossing the Atlantic Ocean between North America and mainland Europe, with a majority of migratory birds flying via Iceland and Greenland. In some aspects, the findings of migration patterns support the arguments of other researchers, whereas, on the other hand, they raise curious wonders for further exploration fields. On the side of migration strategy performed by migrant birds, it is understandable a considerable number of identified migratory birds use refueling stops to connect themselves with migration grounds, recalling what long-distance migration journeys and ecological barriers entail during bird migration. It takes several days for a migrant bird to undertake a trans-Atlantic migratory journey directly from North America to Europe. For example, David et al. (2014) illustrate that it takes between 5-7 days of non-stop flight for a northern gannet to travel between 3,322-3,800 km-distance from Canadian shelf waters to European wintering grounds. However, not every migrant bird can travel such a distance in a row, since a long-distance migration requires considerable energy stores, and the capacity to store fuels varies with bird species (Pettersson & Hasselquist, 1985). Consequently, for long-distance migration travels, migrant birds with a lower capacity to accumulate fuel try to circumvent ecological barriers such as water bodies. Therefore, they prefer to use alternative migration routes that are sometimes longer than the straight line covered by these obstacles, provided that they offer the refueling possibilities (Agostini et al., 1994, 2007; Hedenström & Alerstam, 1997; Nourani et al., 2018), a strategy quite similar to the migration path depicted in Figure 1.

5.2. Migratory bird species identified

Another important note emphasized in this work is the fact that identified migrant birds (Appendix A) are considerably made up of seabirds and waterfowl, while shorebirds and landbirds come last. Considering the migration behavior, it is comprehensive that seabirds can adapt to a large seascape area since they are known to be sea harvesters. In addition, there are many sea stopovers in considerable water bodies

where migratory seabirds refuel their reserves, and these last are deemed functionally comparable to terrestrial staging sites (Guilford et al., 2009). Therefore, seabirds may be the most popular migratory birds to make migration journeys between mainland Europe and North America by flying over the Atlantic Ocean. The important presence of waterfowl in the Eastern Atlantic Flyway may also be explained by three main reasons: their body size (Ornis et al., 2017), the endogenous ability to adjust flight efforts for compensation of ground speed under atmospheric constraints (Society & Bulletin, 2018) and a high-value diet of waterfowl (Bishop & Vrtiska, 2008). According to Ornis et al. (2017), large-sized birds, to which most waterfowl identified belong, are generally more efficient flyers than smaller birds and can therefore partly compensate for their lower maximum fat deposition rates. Although the ground speed of migrating birds reduces into headwinds, some waterfowl can average the flight efforts exercised when they are flying against the wind (Society & Bulletin, 2018). Furthermore, it is revealed that vegetation-based food, including corn, seeds, and herbs, is a special diet that provides waterfowl with energy that helps them travel an extra distance (Bishop & Vrtiska, 2008).

In addition, the migration behavior of shorebirds is usually shaped by geography, food availability, and the diversity of abilities of some migrants in this category to adapt to various migration strategies. These birds perform various migration strategies, while they can either be short-distance bouts or long-distance bouts species, the status that allows them to fly between 100-5,000 km or more provided that they have intermittent food availability along the migration course (O'reilly & Wingfield, 1995). Additionally, many migratory shorebirds can exploit a variety of prey items by adopting various foraging strategies such as pecking, probing, or sweeping, depending on the type of food and availability. This adaptability in varied foraging strategies allows them to buffer against changes in natural feeding conditions and to take advantage of new man-made habitats (Lei et al., 2021). The last but not the least reason behind the ability of shorebirds to perform a tarns-Atlantic migration lies in their susceptibility to physio-morphological change which is proportionately greater and more rapid than those known in any other adult vertebrates. By accumulating fats as migration fuel, these birds can double their total body mass only within a 2-3 week period prior to their migration start-up (Scott et al., 1986). These arguments may probably be the reasons behind the migration pattern of

shorebirds identified in Table 3 where not even a single shorebird was identified as an endemic migrant between North America and Greenland. Adversely to advantageous conditions that allow shorebirds to travel long distances and have a wider migration range, it is somehow incomprehensible to have only ten species that fly over the area of concern whilst North America counts several tens of shorebirds within the interior plains of North America, especially during spring and fall migrations (Skagen et al., 1999).

It was noticed that landbirds are at lower number compared to other groups with only 13.4 % of total migratory birds identified. Furthermore, landbirds are made up of a majority of passerines (57.1%), falcons (28.5%), and one single galliform (rock ptarmigan) that migrate between North America and Greenland. There are convincing arguments that can help to understand the pattern behind the existence and lowered number of landbirds in the Eastern Atlantic flyway. Oceans act as ecological barriers for many landbirds that make an intercontinental migration, and this lowers the number of migratory bird species that migrate over large water bodies (Alerstam, 1990). Although a citation from Ehrlich et al. (1988) states that passerines flying over land interrupt their migration flights to almost everywhere to refuel where food is available (O'reilly & Wingfield, 1995), some warblers are, however, able to store the excess fuel reserve before migration journey as insurance to survive harsh environmental conditions even during their arrival. Thus, warblers such as blackpoll warblers (*Setophaga striata*) can breed anywhere they want with migration distance counted between 500-6,500 km (Meilgaard, M. et al., 2006). In addition, as I have exhaustively emphasized amidst this work, to a given degree, there is a straight correlation between long-distance migration and body size of migratory bird species with better performance for small-sized migratory birds compared to middle or large-sized migratory birds (Scott et al., 1986; Klaassen, 1996; Alerstam et al., 2003b).

Moreover, raptors are identified among migratory birds that mostly undertake long-distance migration without worries of considerable water bodies along the corridor, since these species are able to adjust their migration strategy according to the migration landscape encountered across the migration journey (López-López et al., 2010). From this aspect, I failed to make it understandable why this work identified only two raptors

that try to migrate between North America and Europe with restricted flights that do not go further beyond Iceland towards mainland European areas.

5.3. Atypical movements

The atypical migration movements identified in this work are associated with fluctuating climatic factors over the Atlantic Ocean. Weather over the North Atlantic Ocean is often characterized by strong eastward airflow between the Icelandic low and the Azores high, as well as a stormtrack of weather systems moving towards western Europe, especially in the winter (Rodwell et al., 1999). Additionally, it was revealed that the positive Northern Atlantic Oscillation (NAO) directs the flying capabilities of migrant birds at northern latitudes, as well as in central and northern Europe (Hüppop & Hüppop, 2003; Gordo, 2007; Pozo-Vazquez et al., 2011). The frequency of this NAO, moreover, dominates the regional teleconnection in the lower troposphere over the North Atlantic, where it influences the observable climatological and oceanographic variability in the area (Van Loon & Rogers, 1978). From all of this, the residual effects of NAO might be the potential cause of air currents apparent in the areas, responsible for irruptive and vagrant movements identified along the Eastern Atlantic corridor over the Atlantic Ocean, though convincing evidence is needed to confirm this statement.

Generally, wind is not the only suspected factor to direct unplanned migration behavior over Atlantic Ocean, but also other climatic factors such as frequent heavy rains, temperature-associated factors, and visibility issues caused by the strong overcast apparent in the study area (Alerstam, 1990). Regarding this, even though the values of the Northern Hemispheric snowfall fraction are lower compared to the Southern Hemisphere, the North Atlantic Ocean is characterized by snowfall fraction maxima exceeding 30%, especially in the southeastern coasts of Greenland (Kulie et al., 2016). Consequently, from his whole-year migration movement recording study conducted throughout the East Atlantic Flyway, more precisely, on the European side, Svårdson (1953) realized that reversal migration movements were frequent during cold months (March to April) while movements decline during the winter and on the overcast days. These unexpected movements were ascribed to snowfalls and winds (Svårdson, 1953; Alerstam, 1990), and this phenomenon might be frequent to migrants exchanging migration realms between Europe and North America.

CHAPTER 6: CONCLUSION

6.1. Factors influencing migration movements in the study area

Various factors influence the movements of species of migratory birds between North America and Europe. The important and most important factor is the Atlantic Ocean, which is a considerable ecological barrier, thereby limiting the number of migrant bird species that connect themselves between various home ranges from either side. The second influencer of movement is connected directly to the westerly and east wind of the Atlantic Ocean and fluctuating climatic factors in general. Generally, winds play an important role in the success and failure of migration movements depending on the ability of migrant species to navigate through the airspace dominated by various wind currents and direction of the wind (Newton, 2007) whereas some winds can be travel supporting and others may be migration setbacks. In addition, airspace visibility can affect navigation ability of migrant birds (Alerstam, 1990). In addition to external factors, there is an internal factor of a species that is based on the 'distinctiveness of the flying capacity of a specific species'. The diversity of species' navigation capacity over a considerable and inhospitable environment influences migration strategy over Atlantic Ocean, whereas some migratory birds such as North American shorebirds with limited capacity perhaps leave completely the migration movement along the Eastern Atlantic Flyway and probably head towards the interior plains of North America (Skagen et al., 1999). In addition to the diversity of species flying capacity, a considerable number of migratory birds choose to fly through various stopover sites, whereas others decide to perform a direct and non-stop trans-Oceanic migration flight.

6.2. Other Considerations

Considering various aspects including, but not limited to, global change and the fact that the quality of habitats and forage sites of migratory birds are susceptible to deterioration over time (Bairlein, 2016; BirdLife International, 2019a), one could wonder if no change has occurred in the area. This is because studies (Sutherland, 1998; Alerstam et al., 2003a; Huntley et al., 2007) emphasized the effect of climate change on shift of the spatio-temporal distribution of migration phenomenon. Bird migration corridors were nearly historically known for breeding and non-breeding migration purposes (Kirby et al.,

2008) whereas some migrant birds such as great reed warblers (*Acrocephalus arundinaceus*) and common reed warblers (*Acrocephalus scirpaceus*) migrate between Europe and Africa. Other species, such as Swainson's thrush (*Catharus ustulatus*), and ovenbirds (*Seiurus aurocapilla*) migrate between North and Central / South America, while bar-tailed godwits (*Limosa lapponica*) migrate between northeast Asia and Australasia (Hahn et al., 2020). However, contemporary interchange in the migration routes (Huntley et al., 2007) and migration ranges (Louchart, 2008) of birds occurred as a suggested response to climate change with several cases of populations having preserved their original, but now evidently other flyways are increasingly becoming sub-optimal corridors connecting breeding and winter ranges (Sutherland, 1998). Some migrant birds enlarge their breeding ranges without changing the initial migration route, while others do. For example, the red-necked phalarope (*Phalaropus lobatus*) breeds in Scandinavia and Scotland and flies southeasterly to the Persian Gulf, and the Amur falcon (*Falco amurensis*) breeds in Asia but flies across Asia to winter in the southern part of the continent (Sutherland, 1998).

The climate change model demonstrated a shift in both migration home ranges and usual bird distributions whereas non-migrant African residents appear in Europe during periods of global cooling and wintering areas being shifted towards the equator due to the decreasing winter temperatures (Louchart, 2008). This scenario was further confirmed by (Clairbaux et al., 2019) who identified 29 Arctic migratory bird species (which also belong to the area of my concern) that will shift their migration flyway to trans-Arctic migration corridor towards the Pacific Ocean, while the other 24 Arctic-breeding species could become all year-bound Arctic resident species. Despite the complexity in disentangling the causes of the northward winter vagrant movements that I identified from some migrants, those irregularities could also be facts confirming the theory of Clairbaux et al. (2019) previously discussed in this section. (Gómez et al., 2021) provided additional evidence demonstrating the breeding-origin-shift of blackpoll warbler with 600 km northward over a 45-year period.

6.3. Recommendations

This study recommends that researchers would implement contemporary experimental studies to assess the effect of climate change on the phenomenon of bird migration over the Eastern Atlantic flyway. The lower number of shorebirds identified in the Eastern Atlantic migration corridor, together with the limited movements and/or absence of landbirds in Greenland and Iceland, provide further exploration needs. In addition, it is confusing to disentangle whether some species (those identified as North American winterers) reach North America as a vagrancy effect, or as an extension of migration areas that eventually became migration naturalization.

Moreover, any harm that may arise from climate change threatens directly migrant birds or indirectly affects them through habitat degradation (Valiela & Bowen, 2003). Although management aspects have been strengthened around the world and over the years, it is marked that the management status for both species and habitats is conspicuously egregious, mainly in Europe where breeding settlers are declining in population even in protected areas (Portaccio et al., 2021). Following this, I would provide advice to conservation initiatives concerned with protection of migratory birds to strengthen harmonization for both legal and strategy implementation, and monitoring to reduce migration-associated pressure on trans-Atlantic migratory birds since it is revealed that this last increases with migration distance (Sawyer et al., 2016). Furthermore, considering the increased mobility of migratory birds and the perspectives of property rights, conservation initiatives would integrate and improve PES schemes along the migration corridor, especially in concentration areas where sites are adjacent or interact with private property rights.

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Appendix A: Matrix survey list of literature with taxonomic³ order of migrant bird species

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
I. LANDBIRDS			
1	(Burnham & Newton, 2011)	Gyr Falcon (<i>Falco rusticolus</i>)	<ul style="list-style-type: none"> The Greenlandic population of gyrfalcon winters in various parts of Canada and the United States whereas it breeds in Greenland. Fewer eastward movements were spotted during the winter making it to reach Iceland.
2	(Lyngs, 2003)	Lapland bunting (<i>Calcarius lapponicus</i>)	<ul style="list-style-type: none"> Citing (Francis et al. 1991, Schekkerman 1989), he mentioned that the Greenlandic population migrates divergently whereas some move on to North American (southern Canada and the northern parts of United States of America (USA) wintering areas and others towards mainland Europe, especially, in Britain and the Netherlands particularly in early autumn.
3	(Lyngs, 2003)	Snow bunting (<i>Plectrophenax nivalis</i>)	<ul style="list-style-type: none"> A great majority of the Greenlandic snow bunting population migrates to North America to winter in southern Canada and the northern USA. However, considerable numbers of snow buntings from Greenland were recovered on various grounds in mainland Europe mainly Norway, Great Britain, and Russia. On the other hand, foreigner settlers were found in Greenland including those from Iceland, Michigan, and New York

³ **References for categorization of taxonomic groups:** (Vladimir, 1967; Marburger, 2002; Third et al., 2004; Backues, 2015; Groups & Groups, 2016; Harkess, 2019).

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			(USA). In addition, a migrant snow bunting ringed in Shetland, United Kingdom (UK) has been recovered in Newfoundland (Canada).
4	(Fuller et al., 1998; Lyngs, 2003)	Peregrine falcon (<i>Falco peregrinus</i>)	<ul style="list-style-type: none"> The male of this Greenlandic bird winters in South America, females in the Caribbean and southern USA (Lyngs, 2003); In an experimental study to track routes and travel rates of migrating peregrine falcons, the satellite transmitters showed that this migrant moved from Padre Island, Texas to its target located in central West Greenland (Fuller et al., 1998).
5	(Lyngs, 2003)	Mealy redpoll (<i>Carduelis flammea</i>)	<ul style="list-style-type: none"> Mealy redpoll is a common breeder of Greenlandic grounds while it undertakes wintering migration towards southern Canada and the northern USA. Moreover, citing from (Salomonsen, 1967b), the author said that the western Greenland population migrates to southeast Canada while the eastern Greenland population flies to Iceland and sometimes reaches the British Isles.
6	(Newton & Dale, 1996; Lyngs, 2003; Bairlein et al., 2012; Bulte et al., 2014; Corman et al., 2014)	Northern wheatear (<i>Oenanthe oenanthe</i>)	<ul style="list-style-type: none"> The Canadian bird performs a trans-Atlantic migration traveling about 3400 km totaling the distance from Baffin Island through Greenland to the western British Isles. It progresses towards African wintering grounds and takes a

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>similar route during spring migration (Bairlein et al., 2012);</p> <ul style="list-style-type: none"> • Some northern wheatears may perform a transoceanic migration directly from southern Greenland to Africa, while others move to western Europe and then south to western Africa in one or two stops. The Greenland breeding population belongs to the subspecies leucorhoa, which also breeds in northeast Canada and Iceland. This migrant bird winters in tropical West Africa, supposedly from Senegal and Sierra Leone east to Mali. The autumn recoveries in western Europe suggest that the Greenland northern wheatears embark on a nonstop crossing of the Atlantic, reaching the European coast south of the British Isles (Lyngs, 2003; Bulte et al., 2014) • This bird comes from Greenlandic breeding grounds to winter in western Europe (Bird Life International, 2019); • The former subspecies reach their Scandinavian breeding areas after a short sea crossing, while the leucorhoa northern wheatears cross the North Atlantic towards Iceland, Greenland, or Canada (Corman et al., 2014)
7	(Lyngs, 2003)	Rock ptarmigan (<i>Lagopus mutus</i>)	The Rock ptarmigan is a common breeder throughout Greenland, with three dominant subspecies namely: rupestris in the south saturates in the northwest and captus in the north and northeast. The northernmost populations are migratory, presumably

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			wintering in southern Greenland and returning to their breeding areas. Moreover, recovery data confirmed migration from Ellesmere Island to Greenland (Lyngs, 2003).
II. SEABIRDS			
8	(Lyngs, 2003; Burnham et al., 2021)	Atlantic puffin (<i>Fratercula arctic</i>)	<ul style="list-style-type: none"> • Ringing recovery data recorded from eight migrants revealed that some birds from Iceland, Norway, Faeroes, and Great Britain could easily migrate towards southwest Greenland primarily during the summer whereas other birds, especially, young Icelandic and mainland European migrate towards northwest to winter off Newfoundland-Canadian grounds and in some years in southwest Greenland wintering areas. On the other hand, the Greenlandic population also inters Labrador and Nova Scotia (Canada) for winter purposes (Lyngs, 2003); • In his experiment aiming at assessing the migration pathways of Atlantic puffin, the geolocator-emitted information showed that one female bird traveled 5,200 km after crossing the southeast of Cape Farewell from the mid-Atlantic ocean in the south of Azores. The second migrant departed the Baffin Bay in early October having sojourning time at Cape Farewell and southeast Greenland, progressing for an ultimate reach of Iceland

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			where the geolocator stopped the emission (Burnham et al., 2021).
9	(Lyngs, 2003)	Black guillemot (<i>Cepphus grille</i>)	<ul style="list-style-type: none"> The black guillemot is the most widespread auk in Greenland and apparently, foreigner birds from Iceland move in for autumn and winter periods where many birds head to southeast Greenland with few birds that reach southwest and west Greenland.
10	(Lyngs, 2003)	Brünnich's guillemot (<i>Uria lomvia</i>)	<ul style="list-style-type: none"> It is well revealed that the west Greenland population winters off Newfoundland and Nova Scotia (Canada) whereas other ringed birds from Lancaster and Jones Sound in NorthWest Baffin Bay (Canada), Russia, Norway, and Iceland were recovered in Greenland.
11	(Lyngs, 2003)	Common guillemot (<i>Uria aalge</i>)	<ul style="list-style-type: none"> In a report that analyzed the migration and winter ranges of birds in Greenland, the banding recovery report showed that common guillemot from Funk Island and Newfoundland (Canada) migrates in farthest Greenland within 2200 km distance from the ringing site. Other migrants from the Barents Sea, Russia, and Iceland are found in Greenland after traveling several kilometers to reach the ground. In addition to foreigner recoveries, the report shows that the Greenlandic population also travels to settle off Canadian and Iceland coasts during the winter.
12	(Newton & Dale, 1996b; Lyngs, 2003)	Little Auk (<i>Alle alle</i>)	<ul style="list-style-type: none"> Recovery records showed that little auks from northwest Greenland primarily winter off Newfoundland, Canada whereas further data confirmed that migrant birds ringed

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>in Svalbard have been recovered in west Greenland (Lyngs, 2003);</p> <ul style="list-style-type: none"> This species also named Dovekie by (Newton & Dale, 1996b), heads to North America during the winter after spending considerable time in Greenland which seems to be its breeding area.
13	(Lyngs, 2003)	Razorbill (<i>Alca torda</i>)	<ul style="list-style-type: none"> A small part of Greenlandic population of razorbill winters off Newfoundland and Nova Scotia.
14	(Newton & Dale, 1996a; Evers, 2004; Boertmann et al., 2009)	Common loon/ Great Northern Diver (<i>Gavia immer</i>)	<ul style="list-style-type: none"> This bird migrates between Greenland and fjords (Denmark) of mainland Europe (Boertmann et al., 2009); These migratory bird species are widely distributed: They are found in North America, Greenland, Iceland, and Mainland Europe and their migration grounds vary depending on population location. The Greenlandic breeding population overwinters in Iceland and mainland Europe. The information about Icelandic breeders' that can move towards Europe is less known. North American population undertakes offshore and coastal Atlantic migration that links breeding populations from Canadian maritime, eastern Quebec, and Newfoundland to western Greenlandic grounds (Evers, 2004); However, these migrant species (<i>Gavia immer Briinnich</i>) sub-species do not typically breed in the area of western Europe but Icelandic migrants undertake a move-in migration during winter periods (Newton & Dale, 1996a)

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
15	(Lyngs, 2003; Boertmann et al., 2009)	Red-throated diver (<i>Gavia stellate</i>)	<ul style="list-style-type: none"> • This bird breeds in Europe especially in Denmark and Peary Land (Greenland) (Boertmann et al., 2009); • The red-throated diver winters in west European waters from the North Sea south to the Bay of Biscay (Lyngs, 2003).
16	(Lyngs, 2003), https://www.americanocéans.org/facts/where-does-arctic-tern-migrate/	Arctic tern (<i>Sterna paradisaea</i>)	<ul style="list-style-type: none"> • The Arctic tern visits many countries in various regions including parts of Greenland, Iceland, Norway, Sweden, Finland, Canada, Russia, and the United States (Alaska). The Arctic tern's general preferences are opposite regions of the earth mostly the upper zones of these countries; • The Arctic terns spend the winter in Antarctic regions as resting and molting places where they restore their feathers amid preparation for the journey heading northward. Migrants starting from upper Canada may fly down the eastern coast of the United States and parts of South America before crossing the Atlantic and flying down the coast of Africa or even Australia just before returning to Antarctica. On the other side, migrants starting in Greenland or Iceland follow the European coast before crossing the Atlantic and flying the coast of South America until reaching the arctic Circle. (https://.americanocéans.org/facts/here-does-arctic-tern-migrate/); • The evidence showed that the Greenlandic Arctic terns come back in their natal areas during the summer although

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			ringing recovery data confirmed a wider wandering movement that gets them to reach Canada and farthest Russia (Lyngs, 2003).
17	(Cantos et al., 1994; Newton & Dale, 1996b); Lyngs, 2003; van Roomen et al., 2018)	Black-headed gull (<i>Larus ridibundus</i>)	<ul style="list-style-type: none"> • The black-headed gull commonly breeds in European countries. In the western part of the European continent, species use the Eastern Atlantic Flyway to cover migration between mainland Europe Iceland and the southern tip of Greenland (van Roomen et al., 2018); • Marking recovery data showed that Icelandic birds very often reach Greenland whereas the Greenlandic population migrates towards the farthest Disko Bay in western Greenland and Danmark-shavn in eastern Greenland (Lyngs, 2003); • Black-headed gull does not breed in North America but birds from Iceland and northwestern Europe prefer to move in during the winter (Newton & Dale, 1996b); • However, black-headed gull breeds in European areas and winters on European or African grounds (Cantos et al., 1994).
18	(Lyngs, 2003)	Black-legged kittiwake (<i>Rissa tridactyla</i>)	<ul style="list-style-type: none"> • Ringing recovery data revealed that the foreigner black-legged kittiwake reaches Greenland for migration purposes. These include migrants ringed in the northwest European breeding range and Newfoundland (Canada) grounds.

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
19	(Lyngs, 2003; Van Roomen et al., 2018)	Great black-backed gull (<i>Larus marinus</i>)	<ul style="list-style-type: none"> The great black-backed gull has a considerable distribution range all over the Eastern Atlantic Flyway from northwest Russia to the African Atlantic coasts. It breeds mainly along the arctic region of Scandinavia, Iceland, Britain, Ireland, and French coasts. Migration movement frequently occurs amidst this region whereas the northern population moves on for winter in southern parts (van Roomen et al., 2018); Recovery data showed that a low number of Icelandic great black-backed gulls reach southeast and southwest Greenland during autumn and winter while young birds from Denmark and Russia probably were found in Greenland. On the other hand, the birds from North America can reach Greenland (Lyngs, 2003).
20	(Lyngs, 2003)	Herring gull (<i>Larus argentatus</i>)	<ul style="list-style-type: none"> Herring gulls migrate between Greenland, North America, and mainland Europe. Migrants ringed from Bass Rock and east Lothian (UK) and those ringed from Witless Bay, and Newfoundland (Canada) were found on Greenlandic grounds.
21	(Newton & Dale, 1996a)	Iceland gull (<i>Larus glaucoides</i>)	<ul style="list-style-type: none"> These migrants do not breed in the areas of Western Europe but they move in from Greenland during the winter.
22	(Lyngs, 2003)	Ivory gull (<i>Pagophila eburnean</i>)	<ul style="list-style-type: none"> Recovery data revealed at least nineteen birds that reached Greenland from Seymour (USA) and Ellesmere Island in the NE Canadian Arctic.

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
23	(Newton & Dale, 1996b; Hallgrimsson et al., 2011; van Roomen et al., 2018; Zawadzki et al., 2021; Boertmann & Frederiksen, 2022)	Lesser black-backed gull (<i>Larus fuscus</i>)	<ul style="list-style-type: none"> • Within the Eastern Atlantic Flyway, two distinguished migrant species are having overlapping wintering and breeding grounds. They mainly breed in Iceland, the British Isles, the Netherlands, France, Spain, and Portugal while they winter from southwest Europe to West Africa (van Roomen et al., 2018); • However, a recovery report citing Hallgrimsson et al. (2011) showed that a considerable number of lesser black-backed gull from the Netherland and Iceland spend the winter period in Canada and the United States (Boertmann & Frederiksen, 2022); • On the other hand, it is suggested that birds of lesser black-backed gull recovered in Florida, New Jersey, Virginia, and North Carolina might have been returning migrants that were heading back to their natal areas of Europe or from colonized Greenland. Settlers were found amid North American recoveries with bands ringed from Iceland and Netherlands. In addition, a juvenile bird banded at Gardaholt, southwestern Iceland was seen Rio Grande de Arecibo, Puerto Rico while another banded at Rotterdam was also found at Cold Spring Harbor, Long Island, and New York (Hallgrimsson et al., 2011); • However, lesser black-backed gull does not breed in North America but birds from Iceland and northwestern

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>Europe prefer to move in during the winter (Newton & Dale, 1996b)</p> <ul style="list-style-type: none"> • Although the lesser black-backed gull is almost considered an established winter migrant in North America, the frequentations have been assessed as grant movements for the last 30 years (Zawadzki et al., 2021).
24	(Lyngs, 2003)	Northern fulmar (<i>Fulmarus glacialis</i>)	<ul style="list-style-type: none"> • Northern fulmar from Greenland is a true pelagic bird of the outside-breeding season. It winters somewhere in the western part of the North Atlantic and occasionally reaches the coast of western Europe (Lyngs, 2003).
25	(Lyngs, 2003)	Great skua (<i>Stercorarius skua</i>)	<ul style="list-style-type: none"> • The great skua is a widespread visitor of Greenland whereas many birds ringed in Iceland and Great Britain have been recovered in Greenland.
26	(Furness, 1978; Newton & Dale, 1996b)	Great skua (<i>Catharacta skua</i>)	<ul style="list-style-type: none"> • Great skua does not breed in North America but birds from Iceland and northwestern Europe prefer move-in journeys during the winter (Newton & Dale, 1996b); • However, the study designed to monitor mortality and migration movements showed that Schotish ringed great skuas winter in European areas (Furness, 1978).
27	(Lyngs, 2003)	South polar skua (<i>Stercorarius maccormicki</i>)	<ul style="list-style-type: none"> • The age determines whether a south polar skua migrant could be a long-distance, short-distance, or dispersive migrant. Juvenile and immature birds from Greenland undertake long-distance migration to winter off the northern Pacific coast while others migrate to winter North Atlantic on the Grand Banks off Newfoundland.

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
28	(David et al., 2014; Boertmann et al., 2020)	Northern gannet (<i>Morus bassanus</i>)	<ul style="list-style-type: none"> The study shows that gannets from Funk Island (Canada) do a direct and long trans-Atlantic journey to Europe and sometimes use this continent as a major staging site while progressing towards western African wintering areas. Banding recoveries confirmed migration movements of North American gannet in Greenland, Iceland, and mainland Europe (David et al., 2014); On the other hand, it is suggested that western European northern gannets have earlier become new settlers breeding in southeast Greenland waters since it followed mackerel (<i>Scomber scombrus</i>) considered the preferred food of gannets that also moved on to settle in Greenland (Boertmann et al., 2020);
29	(Huettmann & Diamond, 2000; Baak et al., 2021)	Glaucous gull (<i>Larus hyperboreus</i>)	<ul style="list-style-type: none"> Generally, the glaucous gull species is widely distributed. The North American population breeds in western Greenland with wintertime in southern Labrador, and southeast Newfoundland (Huettmann & Diamond, 2000);
III. SHOREBIRDS			
30	(Cramp, 1977; Huschle et al., 2013)	American bittern (<i>Botaurus lentiginosus</i>)	<ul style="list-style-type: none"> American bitterns winter along the southern tier of coastal states, Mexico, and south to Panama, Cuba, Puerto Rico, Jamaica, Hispaniola, and the Bahamas. American bitterns again spend their wintertime on the far North Coast of the temperate Pacific zone of British

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>Columbia and along the Atlantic coast north to Virginia, Delaware, and occasionally New Jersey. It undertakes considerable dispersal movements that make it cross the Atlantic Ocean to European areas (Huschle et al., 2013);</p> <ul style="list-style-type: none"> American bitterns do a considerable amount of wandering or extensive post-breeding dispersal in late summer. This post-breeding dispersal is based on observation records in Greenland and Europe. This trans-Atlantic vagrancy was attributed to strong westerly storm tracks over the Atlantic Ocean (Cramp, 1977).
31	(Taylor et al., 1980; Wilson, 1981; Newton & Dale, 1996b; Lyngs, 2003; Meltofte, 1985; van Roomen et al., 2018)	Common ringed plover (<i>Charadrius hiaticula</i>)	<ul style="list-style-type: none"> This report discusses three subspecies of common ringed plovers namely <i>C. h. psammodytes</i>, <i>C. h. tundrae</i>, and <i>C. h. hiaticula</i> recognized within the East Atlantic Flyway, migrating between Canada, Greenland and Iceland, and mainland Europe for breeding purposes (van Roomen et al., 2018); The spring migration usually brings all Eurasian wintering migrants from Greenland together in northwestern parts of Europe where they start returning journey in late April until the first days of June to breed in their natal grounds using Iceland as a stopover (Meltofte, 1985); Common ringed plover, dunlins, and northern wheatears (see the latin names in this appendix) exclusively spend

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>their winter periods in west Africa. Some of these birds undertake a direct trans-Atlantic movement from southern Greenland to Africa, while others use one or two stops in Europe before reaching their African wintering areas (Lyngs, 2003);</p> <ul style="list-style-type: none"> • Common ringed plover species breed in eastern North America and leave the area completely for the winter, mostly moving to Africa (Newton & Dale, 1996b); • Common ringed plover (<i>C.h.hiaticula</i>) breeds in Iceland (whole country) Greenland (High Arctic in north-east, Thule District; erratic elsewhere) Northeast Canada (Ellesmere, Bylot & Baffin Is), and winters principally in West Africa (Wilson, 1981); • This report determined recoveries in Europe made of various birds including those ringed plovers from breeding sites in Greenland, Baffin Island, and Iceland (Taylor et al., 1980).
32	(Bagg, 1967; Pranty & Woolfenden, 2000; Leitao & Peris, 2004)	Eurasian lapwing/northern lapwing (<i>Vanellus vanellus</i>)	<ul style="list-style-type: none"> • The breeding areas of Eurasian lapwing are in the open country across Eurasia south of the tundra. Populations from the east zone append wintertime in the south of the breeding range. The majority of the western populations are migratory, moving to Europe and northern parts of Africa for the winter (Pranty & Woolfenden, 2000; Leitao & Peris, 2004)

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<ul style="list-style-type: none"> • However, Eurasian lapwing appeared in various regions of North America (Canada and USA)(Pranty & Woolfenden, 2000) and it is discussed that Eurasian lapwing appeared for the first time in North America as a direct effect of easterly winds from Europe out into the Atlantic that made European birds overshoot western Europe and reach North America (Bagg, 1967).
33	(Lyngs, 2003)	Eurasian oystercatcher (<i>Haematopus ostralegus</i>)	<ul style="list-style-type: none"> • Citing from (Boertmann,1994 and Petersen,1998), the author emphasized that the oystercatcher is usually an Icelandic breeder that rarely undertakes a Palearctic vagrant movement in Greenland. Its nearest breeding grounds are in Iceland from where the majority of the population move to northwest Europe for the winter, while a few stay.
34	(Wilson, 1981; Greenwood, 1984; Ens et al., 2006; Meltofte, 1985; van Roomen et al., 2018)	Dunlin (<i>Calidris alpina</i>)	<ul style="list-style-type: none"> • The spring migration usually brings all Eurasian wintering migrants from Greenland together in northwestern parts of Europe and from there they start returning journey in late April until the first days of June to breed in their natal grounds using Iceland as a stopover (Meltofte, 1985); • Marking recovery report showed that Greenlandic birds have a wider migration corridor worldwide including the Eastern Atlantic Flyway whereas some birds together with those coming from Iceland migrate through western British Isles stopovers sites where they progress towards

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>other European grounds and most of the time to north-west Africa (Greenwood, 1984);</p> <ul style="list-style-type: none"> • Morphometrics suggested that the migration route of Dunlin extends breeding areas in Iceland (whole country) and Greenland while it winters probably in West Africa (Wilson, 1981); • This bird winters in Africa (Mauritanie and Maroco) with a trans-Atlantic migration towards breeding areas in NE Greenland using various spring staging sites in Europe that are SW Portugal, W. France, Britain, Hebrides, and SW Iceland (Ens et al., 2006; Van Roomen et al., 2018).
35	(Salomonsen, 1967; Morrison et al., 2001; Lyngs, 2003; LeBlanc et al., 2017; van Roomen et al., 2018)	Purple sandpiper (<i>Calidris maritima</i>)	<ul style="list-style-type: none"> • Two populations of wintering sandpipers use predominantly the East Atlantic Flyway to migrate between North America, Greenland, and mainland Europe. One population breeds in Canada and Greenland while the other breeds in northern parts of Scandinavia and the Russian Arctic. These populations winter mostly in the North Sea, the Irish Sea, and the Atlantic coasts of Britain, Ireland, France, Spain, and Portugal. However, some birds winter in Greenland although migrants from East Greenland can also winter in Iceland and suspiciously in the British Isles (Salomonsen, 1967);

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<ul style="list-style-type: none"> • Citing (Cramp & Simmons, 1983), he said that Purple Sandpipers breeding in North Canadian and Greenlandic grounds, undertake the overwintering migration journey from these areas to the coasts of North America, southern Greenland, Iceland, and also along the coasts of northwest Europe (LeBlanc et al., 2017); • The Jun-recovery in QAT of a bird ringed on the British Isles could be of a bird en route to Canada/NW Greenland (Lyngs, 2003); • This report provides estimates of shorebird populations in North America. The estimate of birds is a summation of birds located in North America and those in wintering areas outside the continent. Purple sandpiper are suspected to undertake trans-Atlantic movement that gets them reaching North American, Greenlandic and European grounds (Morrison et al., 2001); • This is a multi-co-operational-drafted report that assessed the population status of waterbirds and shorebirds and their environmental conditions at their sites along the whole East Atlantic Flyway. Various organizations, field workers, and institutions were involved in order to have accurate and reliable information. The findings show how birds undertake migration from Canadian, Greenlandic, and

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			Scandinavian breeding areas to Europe where winter occurs along the North Sea, the Irish Sea, and the Atlantic coasts of Britain, Ireland, France, Spain, and Portugal (van Roomen et al., 2018).
36	(Morrison, 1975; Branson et al., 1978; Clapham, 1979; Alerstam et al., 1990;; Davidson & Wilson, 1992; Meltofte, 1985)	Red knot (<i>Calidris canutus</i>)	<ul style="list-style-type: none"> • Knots and most turnstones from European wintering areas stage for a few weeks in Iceland for "refueling" before the onward migration to the high arctic breeding grounds of Greenland and Canada (Branson et al., 1978); (Clapham, 1979; Fems, 1981); Citing (Smit and Piersma, 1989 and Meltofte, 1985) he emphasized that the northeastern Canadian high arctic and Greenland are potential breeding areas of <i>C. c. islandica</i> that generally winters in Europe (Meltofte, 1985); • On the other hand, these migrant bird species breed and winter in western Europe although their number is increased by migrants from Greenland and North America during the winter (Morrison, 1975); • It is concluded that the overwhelming majority of the birds are bound for breeding sites in northern Canada and northwest Greenland from Iceland (Alerstam et al., 1990); • The islandica subspecies of knots is the most extensively studied. They breed in high arctic Greenland and

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>Canadian arctic islands. Probably, the population reaches its moulting and wintering grounds in Britain, France, and the Wadden Sea in autumn via staging areas in western Iceland (in late July-early August), where they pause to refuel for one or two weeks (Davidson & Wilson, 1992).</p>
37	(Wilson, 1981; Newton & Dale, 1996a; Lyngs, 2003; Ens et al., 2006; Reneerkens et al., 2008; Meltofte, 1985; van Roomen et al., 2018)	Sanderling (<i>Calidris alba</i>)	<ul style="list-style-type: none"> • This bird does not breed in western Europe but moves in for the winter from Greenland(Newton & Dale, 1996a) • Two populations of the sanderling occur in the East Atlantic Flyway and breeding areas are mostly located in the high arctic tundra of Greenland and northeast Canada (van Roomen et al., 2018); • The wintering ground of sanderling is West Europe and West Africa and they use England Hebrides, and southwest Iceland as important staging sites connecting them with breeding grounds in Greenland and Canada (Ens et al., 2006); • Although the winter destinations of sanderling birds breeding in northwest Greenland and northeast Canada remain unclear available ringing and sighting data clearly indicate that sanderlings breeding in northeast Greenland migrate to European and African wintering areas (Reneerkens et al., 2008);

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<ul style="list-style-type: none"> • Available ringing and sighting data clearly indicate that sanderlings breeding in northeast Greenland migrate to European and African wintering areas (Lyngs 2003); • The spring migration initially brings all the Old World wintering populations together in northwestern Europe and from there they migrate during late April, May, and the first days of June to the Greenland breeding grounds with many birds making a stopover in Iceland (Meltofte, 1985); • Sanderling breeds in Greenland and northeast Canada while it winters probably in Britain to West Africa, but possibly some Canadian birds in New World (Wilson, 1981).
38	(Morrison, 1975; Branson et al., 1978; Clapham, 1979; Fems, 1981; Wilson, 1981; Godfrey, 1986; Alerstam et al., 1990; Newton & Dale, 1996a; Lyngs, 2003; Meltofte, 1985; van Roomen et al., 2018)	Ruddy turnstone (<i>Arenaria interpres</i>)	<ul style="list-style-type: none"> • Two races of ruddy turnstones breed in the North American Arctic. The <i>Arenaria i. interpres</i> breeds in the northeastern parts of the Canadian high Arctic and migrates to wintering areas in Europe (Godfrey, 1986); • Ruddy turnstones breed in Arctic Greenland and Canada and migrate some 3500 km to winter on predominantly rocky shorelines of western Europe (Branson et al., 1978); • The nominate subspecies <i>interpres</i> (to which all recoveries refer) is an abundant breeder in northeast Greenland, common in north Greenland, and it also

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>breeds abundantly on Ellesmere and Axel Heiberg islands in northeast Canada (Cramp 1998) (Lyngs, 2003);</p> <ul style="list-style-type: none"> • The ruddy turnstone is a high arctic breeding species with a cosmopolitan range. In the East Atlantic Flyway, two sub-populations of the nominate subspecies occur: a Nearctic population breeding in northeast Canada and Greenland that winters mainly in western Europe, and a Palearctic population breeding in northern Scandinavia and west Russia, including Svalbard and winters in western Africa (van Roomen et al., 2018); • This birds species breeds and winters in western Europe, but the same bird species come from eastern Canada and Greenland to increase the local population (Newton & Dale, 1996a); • Knots and most turnstones stay a few weeks in Iceland for "refueling" before the onward migration to the high arctic breeding grounds of Greenland and Canada (Branson et al., 1978; Clapham, 1979; Fems, 1981); • Turnstone (A.i.interpres) breeds in Greenland (whole High Arctic) and northeast Canada (Ellesmere & Axel Heiberg) while it winters) Iceland to Mauritania, mainly west Europe (Wilson, 1981); • Banding recoveries showed that knots and turnstones migrate between the Canadian high arctic and Europe.

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<p>These include the first records for knots and turnstones respectively between Canada and Holland, Iceland and Norway (Morrison, 1975);</p> <ul style="list-style-type: none"> • It is concluded that the overwhelming majority of knots, turnstones, and brant geese birds (latin names are mentioned in this appendix) migrate from Iceland in spring to their breeding sites in northern Canada and northwest Greenland; • Reviewing the Greenlandic waders' schedules and population estimates, he considered all birds in wintering and breeding areas whereas the report mentions Canada and Old-World areas' populations (Meltofte, 1985).
39	(Alves et al., 2016; Gunnarsson & Guðmundsson, 2016; Van Roomen et al., 2018)	Whimbrel (<i>Numenius phaeopus</i>)	<ul style="list-style-type: none"> • Two subspecies of the whimbrel use the East Atlantic Flyway. The whimbrel from <i>islandicus</i> subspecies breeds in Iceland and a small part of Greenland with further migration flight to African wintering compound (Van Roomen et al., 2018); • Using a geolocator, (Alves et al., 2016) revealed that the whimbrel performs a high-speed and non-stop flight of 11,000km for a round-trip migration between breeding and wintering areas of respectively Iceland and West Africa;

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<ul style="list-style-type: none"> • Generally, Icelandic whimbrel migrates anywhere in Europe from mainland European countries to Greenland (Gunnarsson & Guðmundsson, 2016).
IV. WATERFOWL			
40	(Lyngs, 2003; Boertmann et al., 2009; van Roomen et al., 2018; National Audubon Society, 2021)	Barnacle goose (<i>Branta leucopsis</i>)	<ul style="list-style-type: none"> • Barnacle goose has various breeding and wintering areas depending on initial residence. There is the population that breeds in Arctic Russia in the Baltic areas and spends their winter period in the Netherlands where other resident birds breed. There is another population that breeds in Svalbard with further migration through Norway to winter in southern parts of Scotland. Moreover, the Greenlandic breeding population move-in mainland European wintering grounds, especially, in Ireland and Britain (Boertmann et al., 2009; van Roomen et al., 2018); • The Greenlandic migrant birds winter in West Scotland and West Ireland (Lyngs, 2003); • Barnacle goose breeds in Greenland and northern Eurasia whereas it winters in northern Europe and the British Isles with an occasional vagrant movement in northeastern North America during the winter. In North

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			America, usually, a single individual is seen amid a flock of Canada geese (National Audubon Society, 2021).
41	(Lyngs, 2003)	Canada goose (<i>Branta canadensis</i>)	<ul style="list-style-type: none"> • Several Greenlandic species winter in North America with an increasing number of birds coming from West Greenland to winter in the USA.
42	(Lyngs, 2003; Boertmann et al., 2009)	Common eider (<i>Somateria mollissima</i>)	<ul style="list-style-type: none"> • In his aerial survey to count seabirds and marine mammals in northeast Greenland, he cited (Elander & Ericson 1994, Falk et al. 1997) saying that about 2500 common eiders have been previously counted from their pre-nesting areas in the northeast Norway waters (Boertmann et al., 2009); • The population residing in the Baffin Bay breeds in the west of Greenland and the eastern parts of the Canadian Arctic while the Icelandic population breeds in Iceland and eastern parts of North Greenland (Lyngs, 2003);
43	(Newton & Dale, 1996b; Atkinson et al., 2006, p.343)	Eurasian wigeon (<i>Anas penelope</i>)	<ul style="list-style-type: none"> • It is discussed that the population residing in Iceland and mainland Europe undertakes a migration journey during the winter heading to North America (Atkinson et al., 2006, p.343; Newton & Dale, 1996b); • Eurasian wigeon has wider wintering areas from western Europe, Russia, and Africa. Other Eurasian wigeon migrate to North America for wintering purposes (Atkinson et al., 2006, p.343)

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
44	(Lyngs, 2003)	Harlequin duck (<i>Histrionicus histrionicus</i>)	<ul style="list-style-type: none"> • Citing (Robert et al.1997 and Canadian Wildlife Service homepage), he emphasized that satellite telemetry studies and ringing activities conducted in Canada during 1997-99 showed that some Canadian birds molt and winter in southwest Greenland.
45	(Alerstam et al., 1990; Gudmundur et al., 1995; Lyngs, 2003; Van Roomen et al., 2018)	Light-bellied brent goose (<i>Branta bernicla hrota</i>)	<ul style="list-style-type: none"> • Geese birds of this species breed in low numbers in northeast Greenland while they winter in Denmark and northeast England (Lyngs, 2003); • Greenlandic population moves on to winter in Western Europe. The subspecies <i>B. b. hrota</i> belonging to the Svalbard-breeding population winter mainly in Denmark, while those breeding in Greenland and Northeast Canada winter in Ireland (van Roomen et al., 2018); • The big part of light-bellied” Brent Goose residing in Greenland and North America are mostly bound to their locations as breeding sites, especially, in northern Canada and northwest Greenland (Alerstam et al., 1990); • In the experimental research conducted to examine the limits of flight and orientation performance of brent goose, satellite transmitters showed that Icelandic brent goose has a long-distance migration status where it can fly across the high Greenland ice-cap to breeding destinations in North Canada (Gudmundur, A. Gudmundsson et al., 1995).

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
46	(Lyngs, 2003)	Long-tailed duck (<i>Clangula hyemalis</i>)	<ul style="list-style-type: none"> The ringing recovery report showed that the long-tailed duck migrant from Greenland grounds migrates between Canada, Iceland, and Denmark state.
47	(Lyngs, 2003; National Audubon Society, 2021)	Pink-footed goose (<i>Anser brachyrhynchus</i>)	<ul style="list-style-type: none"> The pink-footed geese breeding in Greenland, Iceland, and Svalbard have wintering areas in northern British isles and Netherland (Lyngs, 2003; National Audubon Society, 2021).
48	(Lyngs, 2003)	Northern pintail (<i>Anas acuta</i>)	<ul style="list-style-type: none"> Banding's recovery report confirmed that northern pintail migrates between Greenland and Canada where a full-grown male from Mackenzie, Canada was shot 3880 km away from the ringing area just near Issormiut, Greenland (Lyngs, 2003).
49	(Lyngs, 2003)	Red-breasted merganser (<i>Mergus serrator</i>)	<ul style="list-style-type: none"> Citing from (Salomonsen,1967b, Alerstam et al.,1986 and Petersen 1998), the author concluded that these migrant bird species migrate between Greenland, Iceland, and mainland Europe.
50	(Lyngs, 2003)	Common teal (<i>Anas crecca</i>)	<ul style="list-style-type: none"> Banding recovery data confirmed the migration of common teal between Maryland, USA, and Nanortalik (Greenland).
51	(Newton & Dale, 1996a; Lyngs, 2003; National Audubon Society, 2021)	White-fronted goose (<i>Anser albifrons</i>)	<ul style="list-style-type: none"> The North American population of white-fronted goose breeds in Greenland with further migration to winter in Ireland and Scotland (National Audubon Society, 2021; Lyngs, 2003);

S/N	Reference	Name of Migrant bird	Author's small note about migration movement of migrant bird
			<ul style="list-style-type: none"> The European population both breeds and winters in western Europe, but the same migrant species from Greenland and Canada move in during the winter to increase the number of local population (Newton & Dale, 1996a).
52	(BirdLife International, 2019a)	White-fronted goose (<i>Anser albifrons flavirostris</i>)	<ul style="list-style-type: none"> This bird comes from Greenlandic breeding grounds to winter in western Europe.

Appendix B: Raw data: Methodologies used to study each migrant bird species identified

S/N	Common name	Species/Scientific name	Raw-data collection method										Number of methods used on migrant	
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹		
I. LANDBIRDS														
1	Lapland bunting	<i>Calcarius lapponicus</i>					X							1
2	Snow bunting	<i>Plectrophenax nivalis</i>					X							1
3	Peregrine falcon	<i>Falco peregrinus</i>	X				X							2
4	Mealy redpoll	<i>Carduelis flammea</i>					X							1

¹ **ST**: Satellite tracking

² **GL**: Geolocator loggers

³ **RT**: Radio tracking

⁴ **SHIA**: Stable-hydrogen isotope analysis

⁵ **RR**: Ringing recovery

⁶ **LR**: Literature Review

⁷ **TO**: Telescopic Observation

⁸ **NA**: Non-Applicable

⁹ **SM**: Simulation Model

S/N	Common name	Species/Scientific name	Raw-data collection method											
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹	Number of methods used on migrant	
5	Northern wheatear	<i>Oenanthe oenanthe</i>		X		X	X			X			X	5
6	Rock ptarmigan	<i>Lagopus mutus</i>					X							1
7	Gyrfalcon	<i>Falco rusticolus</i>	X		X									2
II. SEABIRDS														
8	Atlantic puffin	<i>Fratercula arctic</i>		X			X							2
9	Black guillemot	<i>Cephus grille</i>					X							1
10	Brünnich's guillemot	<i>Uria lomvia</i>					X							1
11	Common guillemot	<i>Uria aalge</i>					X							1
12	Little auk	<i>Alle alle</i>					X	X					X	3
13	Razorbill	<i>Alca torda</i>					X							1

S/N	Common name	Species/Scientific name	Raw-data collection method										
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹	Number of methods used on migrant
14	Great northern diver/common loon	<i>Gavia immer</i>						X				X	2
15	Red-throated Diver	<i>Gavia stellate</i>					X		X				2
16	Arctic tern	<i>Sterna paradisaea</i>					X						1
17	Black-headed gull	<i>Larus ridibundus</i>					X	X	X			X	4
18	Black-legged kittiwake	<i>Rissa tridactyla</i>					X						1
19	Great black-backed gull	<i>Larus marinus</i>					X	X				X	3
20	Herring gull	<i>Larus argentatus</i>					X						1
21	Iceland gull	<i>Larus glaucooides</i>						X				X	2
22	Ivory gull	<i>Pagophila eburnea</i>					X						1
23	Lesser black-backed gull	<i>Larus fuscus</i>					X	X	X			X	4

S/N	Common name	Species/Scientific name	Raw-data collection method											
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹	Number of methods used on migrant	
24	Northern fulmar	<i>Fulmarus glacialis</i>					X							1
25	Great skua	<i>Stercorarius skua</i>					X							1
26	Great skua	<i>Catharacta skua</i>						X				X		2
27	South polar skua	<i>Stercorarius maccormicki</i>					X							1
28	Northern gannet	<i>Morus bassanus</i>		X	X		X	X	X					5
29	Glaucous gull	<i>Larus hyperboreus</i>						X				X		2
III. SHOREBIRDS														
30	American bittern	<i>Botaurus lentiginosus</i>	X		X							X		3
31	Common ringed plover	<i>Charadrius hiaticula</i>					X	X	X					3
32	Eurasian lapwing/northern lapwing	<i>Vanellus vanellus</i>					X	X						2

S/N	Common name	Species/Scientific name	Raw-data collection method										Number of methods used on migrant	
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹		
33	Eurasian oystercatcher	<i>Haematopus ostralegus</i>					X							1
34	Dunlin	<i>Calidris alpina</i>					X	X	X			X		4
35	Purple sandpiper	<i>Calidris maritima</i>					X	X	X		X			4
36	Red knot	<i>Calidris canutus</i>					X	X	X	X				4
37	Sanderling	<i>Calidris alba</i>					X	X	X			X		4
38	Ruddy turnstone	<i>Arenaria interpres</i>		X			X	X	X		X	X		6
39	Icelandic whimbrel	<i>Numenius phaeopus</i>		X				X	X					3
VI. WATERFOWL														
40	Barnacle goose	<i>Branta leucopsis</i>					X	X	X		X			4
41	Canada goose	<i>Branta canadensis</i>					X							1

S/N	Common name	Species/Scientific name	Raw-data collection method										Number of methods used on migrant	
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹		
42	Common eider	<i>Somateria mollissima</i>					X	X						2
43	Eurasian wigeon	<i>Anas penelope</i>						X				X		2
44	Harlequin duck	<i>Histrionicus histrionicus</i>	X				X							2
45	Light-bellied brent goose	<i>Branta bernicla hrota</i>	X				X	X	X	X				5
46	Long-tailed duck	<i>Clangula hyemalis</i>					X							1
47	Pink-footed goose	<i>Anser brachyrhynchus</i>					X				X			2
48	Northern pintail	<i>Anas acuta</i>					X							1
49	Red-breasted merganser	<i>Mergus serrator</i>					X							1
50	Common teal	<i>Anas crecca</i>					X							1
51	White-fronted goose	<i>Anser albifrons</i>					X	X			X	X		4

S/N	Common name	Species/Scientific name	Raw-data collection method											
			ST ¹	GL ²	RT ³	SHIA ⁴	RR ⁵	LR ⁶	Field Survey	TO ⁷	NA ⁸	SM ⁹	Number of methods used on migrant	
52	White-fronted goose	<i>Anser albifrons flavirostris</i>								X				1
	Overall times a given method is used		5	5	3	1	43	22	15	2	6	14		

Appendix C: Potential Areas of International Importance for Migratory Birds Migrating Between Europe and North America- Habitat Composition and Potential Threats

Bird migration sites of International importance serving migrants between North America and mainland Europe						Habitat/Site Characterization & Description	
S/ N	Important site	Potential Migrants species	Functions provided to migratory birds	Potential threats to migrant birds	Reference	Habitat composition	Reference
1	Shepody Bay West, Canada	Waterbirds and shorebirds	Internationall y important staging areas	Collision, unsustainable exploitation that leads to disturbance of the food system, effects of climate change and habitat degradation, birdwatching tourism, alternative energy generation, infrastructure, and housing development.	(Deppe, 1999; BirdLife International, 2019)	Intertidal mudflats, carboniferous sandstone	(Sprague, 2006; MacKinnon et al., 2008; MacDonald et al., 2012)
2	Great Plain of the Koukdjuak, Canada	Waterfowl, mainly snow geese.	Breeding areas	Collision, unsustainable exploitation leading to disturbance of the food system, effects of	(BirdLife International, 2019a)	-Wetlands, moist grasslands	(Johnston. & Pepper, 2009;

Bird migration sites of International importance serving migrants between North America and mainland Europe						Habitat/Site Characterization & Description	
S/ N	Important site	Potential Migrants species	Functions provided to migratory birds	Potential threats to migrant birds	Reference	Habitat composition	Reference
				climate change, and habitat degradation		-Vegetated uplands, heaths, drier grasslands -Sparsely vegetated uplands, barren areas, bare gravel - Mudflats	Johnston & Smith, 2012)
3	Fort Custer Training Center and Recreation Area, United States	Landbirds mainly warblers	Breeding areas	Collision, unsustainable exploitation leading to disturbance of the food system, effects of climate change, and habitat degradation	(BirdLife International, 2019a)	-Dry-mesic prairie -Sand-mesic prairie - Bur Oak plains -Wet-mesic Flatwoods prairie - Floodplain forests	(Thomas et al., 2009)

Bird migration sites of International importance serving migrants between North America and mainland Europe						Habitat/Site Characterization & Description	
S/ N	Important site	Potential Migrants species	Functions provided to migratory birds	Potential threats to migrant birds	Reference	Habitat composition	Reference
						<ul style="list-style-type: none"> - Hardwood swamps - Shrub-carr - Wet meadow - Prairie fens - Marsh 	
4	Wadden Sea, Netherlands	Waterfowl, mainly Eurasian oystercatchers, dunlin, black-tailed godwit, and Eurasian wigeons	Staging and wintering sites	Collision, unsustainable exploitation leading to disturbance of food system, effects of climate change and habitat degradation, expected demographic pressure leading to infrastructure and industry development, pollution,	(Deppe, 1999; Lotze et al., 2005; BirdLife International, 2019)	- Coastal habitat: Marsh plants, seagrass, mudflats, salt-marsh pioneers.	(Dijkema, 1991; Reise, 2005)

Bird migration sites of International importance serving migrants between North America and mainland Europe						Habitat/Site Characterization & Description	
S/ N	Important site	Potential Migrants species	Functions provided to migratory birds	Potential threats to migrant birds	Reference	Habitat composition	Reference
				eutrophication, species invasions			
5	Olonets plain, Russia Wet agricultural lands	Waterfowl (mainly geese) and waders	Stopover sites	Collision, unsustainable exploitation leading to disturbance of food system, climate change effects and habitat degradation, agricultural intensification/expansion, industrial extraction, and mass burning of after-grass in the field	(Adelstein, 2001; Zimin et al., 2002; BirdLife International, 2019)	- Forest and woodland (70%; native coniferous forest; mixed forest), -Wetland (raised bog), - Artificial landscape (100%; highly improved reseeded grassland; arable land; perennial crops/orchards/groves)	(Adelstein, 2001)

Bird migration sites of International importance serving migrants between North America and mainland Europe						Habitat/Site Characterization & Description	
S/N	Important site	Potential Migrants species	Functions provided to migratory birds	Potential threats to migrant birds	Reference	Habitat composition	Reference
6	Rock of Gibraltar, Gibraka (to the UK)	Many species, but mainly birds of prey (raptors) and warblers.	Bottleneck site for crossing an ecological barrier	Collision, unsustainable exploitation leading to disturbance of food system, effects of climate change, habitat degradation, and loss	(Garcia, 2010; BirdLife International, 2019)	Fixed coastal dunes with herbaceous vegetation	(European Commission, 2013)
7	Banc d'Arguin National Park, Mauritania	Waders (dunlin, black-tailed godwit, and red knot)	Wintering sites	Collision, Overfishing leading to disturbance of the food system, climate change effects, habitat degradation, and loss, illegal killing and taking	(Bairlein, 2016; BirdLife International, 2019; El-Hacen et al., 2020)	Intertidal flats	(Frederiksen et al., 2016; El-Hacen et al., 2020)
8	Djoudj wetlands, Senegal	Waterbirds including northern pintail, ruff garganey, and also	Internationall y important wintering sites	Collision, unsustainable exploitation leading to disturbance of food system, effects of climate change, habitat	(Bairlein, 2016; BirdLife International, 2019a)	Wetland vegetation made of spiny bushes of various species mainly <i>Acacia</i>	(Fall et al., 2003)

Bird migration sites of International importance serving migrants between North America and mainland Europe						Habitat/Site Characterization & Description	
S/ N	Important site	Potential Migrants species	Functions provided to migratory birds	Potential threats to migrant birds	Reference	Habitat composition	Reference
		warblers (sand martin)		degradation and loss, illegal killing and taking		<i>nilotica</i> , <i>Tamarix senegalensis</i> , <i>Phragmites australis</i> , <i>Salicornia spp.</i> , and <i>Pistia stratoites</i> .	
9	Arquipélago dos Bijagós, Guinea-Bissau	Waders (curlew sandpiper, bar-tailed godwit, little stint, and red knot).	Wintering sites	Collision, unsustainable exploitation leading to disturbance of food system, effects of climate change, habitat degradation and loss, illegal killing and taking, intentional wildfire, agriculture, possible touristic effects	(Salvig et al., 1994; Deppe, 1999; Bairlein, 2016; BirdLife International, 2019)	Mudflats and mangroves habitat	(Robertson, 1997; BirdLife International, 2019;)

Appendix D: Detailed management practices of typical habitats of birds

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS			HABITAT MANAGEMENT PRACTICES	
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
1	The arable land of perennial crops/ Rice fields	Feeding, roosting, and sometimes breeding where agroforestry is implemented (Martin & Finch, 1995; Davidson & Stroud, 1996)	<ol style="list-style-type: none"> 1) Protection and enhancement of key non-crop areas; 2) Modulated and controlled grazing of pasturelands; 3) Promote intercropping, crop association systems and diversification of crop regions; 4) Promote winter cropping and change soil conservation strategies to ensure both soil quality, integrity and to increase quality of winter shelter for birds; 5) Minimize and regulate the utilization of fertilizers and farm chemicals, both heavily used in industrial agriculture since they do not respect boundaries and can easily move away from areas of intensive agriculture to affect protected areas; 6) Promotion of agroforestry practices in cropping systems 	(Martin & Finch, 1995; Mineau & Mclaughlin, 1996)
2	Cliffs	Roosting (Davidson & Stroud, 1996)	<ol style="list-style-type: none"> 1. For stable and non-sloppy cliffs, it is necessary to manage cliff-top grasslands by regular and controlled grazing to 	(Doody, 2001)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			constrain habitat from conversion to closed vegetation or forests.	
3	Forest and woodland* ¹	Feeding, roosting, and breeding (Quine et al., 2007)	<p>I. FOOD REQUIREMENTS</p> <p>1) Invertebrates</p> <ul style="list-style-type: none"> • Leave deadwood to promote development of saproxylic invertebrates; • Maintain nectar foliage/producing trees that could attract flying insects; • Maintain field and shrub layer foliage for larval stages <p>2) Seeds and fruits</p> <ul style="list-style-type: none"> • Maintain mature/flowering tree species for tree seed production; <p>3) Vertebrates and other plant materials</p> <ul style="list-style-type: none"> • Promote corns and aboveground vegetation to attract prey animals <p>II. NESTING SITE REQUIREMENTS</p> <p>1) Holes-nesting</p>	(Quine et al., 2007)

¹ Additional habitat type note not mentioned in (Davidson & Stroud, 1996) who is taken as reference for other 13 habitat types.

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			<ul style="list-style-type: none"> • Preserve mature and dead trees; • Maintain specific tree species and dimension size; 2) Ground-nesting <ul style="list-style-type: none"> • Promote growth of ground layer 3) Shrub-nesting <ul style="list-style-type: none"> • Promote dense-foliage vegetation 4) Canopy/top tree-nesting <ul style="list-style-type: none"> • Tree dimension; surrounding openness <p>III. ROOSTING SITE REQUIREMENTS</p> <ol style="list-style-type: none"> 1) Sheltered site <ul style="list-style-type: none"> • Dense thicket trees 2) Canopy location <ul style="list-style-type: none"> • Trees of a specific height <p>Notes:</p> <ul style="list-style-type: none"> - There is no single activity/operation or system that accommodates all avian species; - Forest management practices may not provide necessary habitat features in the required timeframe of bird migration, in this case, the contingency plan may be 	

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			used. For instance, nesting boxes can be used in the forest in case trees of required dimensions are not present at the time.	
4	Lagoons		<ol style="list-style-type: none"> 1) Control of non-native vertebrate and invertebrate animal species that could displace native species and alter ecological functioning; 2) Control anthropogenic exploitation and pollution; 3) Manage lagoon water quality and water level by installing floodgates; 4) Manage water level especially during peak migration to dispose of adequate water level (shallow water) to shorebirds. 	(Beer & Joyce, 2013; Holm & Clausen, 2006)
5	Mangrove		<ol style="list-style-type: none"> 1) Limit the impact of offshore activities; 2) Establish the restricted-use system, especially in protected areas; 3) Control of production systems where the dependence on silvicultural practices is higher to meet basic subsistence needs; 4) Restoration of mangrove ecosystems and rehabilitation of mangrove forests where they were destroyed 	(Clough, 2013)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
6	Mudflats	Feeding, roosting, and nesting (Deppe, 1999)(Davidson & Stroud, 1996)	<ol style="list-style-type: none"> 1) Prohibition of hunting activities; 2) The prohibition of removing turtle eggs-hatchlings and adults, to avoid disturbance of nesting birds on the islands and that no garbage may be left behind in the sanctuary; 3) Regular surveillance of concentration mudflats 4) Establish a special permitting system for those who need to visit the area in the scheme of recreational activities 5) Draft an overall management strategy that combines census and monitoring strategies supported by specific site management plans 6) Habitat characterization, active management in the form of restrictive signage and fencing, 7) Protecting and improving wetland habitats for waterbirds and other fauna and flora, especially rare and endangered species 	(Deppe, 1999; Jaffe et al., 2011)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			<ul style="list-style-type: none"> 8) Strengthen environmental education, conservation-oriented recreation, and scientific research 9) Hunting and trapping of waterbirds are strictly controlled in accordance with Federal and State regulations; 10) The introduction of agricultural best management practices 11) Biological nutrient removal at wastewater plants and prohibition of industry-derived pollution, 12) promotion of cross-border management cooperation to ensure large-scale management; 13) It is especially important to know which levees will be retained and to incorporate this into future modeling of sea level rise effects on the availability of suitable water depths for foraging; 	
7	Rocky habitats	Feeding, roosting, and nesting (Davidson & Stroud, 1996)	1) Limitation of grazing activity since vegetation is often sparse and can be vulnerable to disturbance;	(URL, 3 C.E.)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS			HABITAT MANAGEMENT PRACTICES	
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			2) Recreational activities should not 'clean' vegetation for handholds; 3) Prohibit quarrying activities in rocky habitat areas.	
8	Salinas	Feeding, roosting, and nesting (Davidson & Stroud, 1996)	1) Maintain the status of emergent vegetation (Moderate to dense) to promote nesting suitability; 2) Limitation of or keep at a lower level the effect of human disturbance; 3) Cooperate with salt producers to maintain convenient water levels (more or less 20 cm depth) to influence the availability of food and safe nesting sites; 4) Since this habitat type is under disappearing threat due to the abandonment of salt production, restoration and conservation measures propose the introduction of new habitats under some form of legal protection; 5) Maintain flooding conditions in the evaporation pans throughout winter.	(Masero, 2003; Fonseca et al., 2014)
9	Saltmarshes	Feeding, roosting, and nesting (Davidson & Stroud, 1996)	1) Providing efforts with the intent of promoting the formation of the complexity of the plant community;	(Doody, 2001)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS			HABITAT MANAGEMENT PRACTICES	
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			<ul style="list-style-type: none"> 2) Control of invasive plant and animal species that can disturb the sustainable succession of a protective community; 3) Limit human activities that might be raised through land reclamation, drainage, agriculture, and infrastructure. 	
10	Sand dunes	Nesting (Davidson & Stroud, 1996)	<ul style="list-style-type: none"> 1. Limitation of human activities to speed up dune stability so that it can support heath, scrubs, and woodland; 2. Control of invasive plant and animal species that can disturb the sustainable succession of a protective community; 3. Construction of sand fences to limit human disturbance and stop mobile sand in mature sand dunes. 	(Doody, 2001)
11	Sandflats	Feeding and roosting, (Davidson & Stroud, 1996)	<ul style="list-style-type: none"> 1) Consider the location, height, construction material, and condition of levees to control changing hydrodynamics (Sea level) in nesting and forage areas; 2) Minimize anthropogenic ecological changes by improving the political coverage of areas to determine the 	(Joint Nature Conservation Committee, 2001; Jaffe et al., 2011; Chowdhury, 2012)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			<p>adherence to protective rules and regulations;</p> <p>3) Maintain sediment supply by controlling the presence of dams that block sediment flow across the watershed</p> <p>4) Minimize human disturbance and regulate recreational, hunting, egg, and chick collection;</p> <p>5) Sand mining activities should be controlled on the important site to preserve habitat suitability;</p> <p>6) Define conservation objectives that maintain the subtidal sandbank under favorable conditions, where the extent, range of biotopes, topography, and sediment characteristics do not change or deviate from baseline to worse status.</p>	
12	Shingle	Roosting, and nesting (Davidson & Stroud, 1996)	1) Establish a temporary fence to protect some species of nesting birds, such as terns and oystercatchers, which typically nest on beaches that are often frequented by walkers and their dogs;	(Randall, 2004)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			<ul style="list-style-type: none"> 2) Map and indicate public access areas along with explanations about why general access is not recommended; 3) Harrowing is sometimes necessary to execute a responsible removal of vegetation from some areas to favor bare ground-nesting species; 4) Control of alien plants that may damage the vegetation community. The establishment of a control area made up of vegetation that will remain untouched will help to manage alien species; 5) Restoration of lost habitat by establishing new shingle-vegetated areas across coastal grounds; 6) Maintain the age and diversity of the species of <i>Calluna vulgaris</i> heath by controlled grazing, but again, keep in mind that the shingle vegetation is highly sensitive to grazing due to the poor nutrient content of the areas; 7) Limit and control activities that may cause fire incidence in shingle habitat 	

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
13	Tidal waters	Feeding, roosting, and breeding (Davidson & Stroud, 1996; Saathoff & Klugkist, 2012)	<ol style="list-style-type: none"> 1) Creating adequate engineering structures such as dikes and culverts that serve to protect habitat from floods and inundations; 2) Develop and promote active actions leading to the creation of a balanced area composed of a diversity of habitats, including mudflats, shallow waters, and shallow and deep sublittoral; 3) Conserve and ensure the development of tidal floodplains made up of typical vegetation structures and biocoenosis and favorable tidal and flood dynamics; 4) Conservation of habitat functions for breeding and migrant birds especially as feeding grounds (also for bordering or networked areas); 5) Insure favorable water quality to increase bird reproduction, larval development, and viability of typical fish communities which serve as birds' feeds; 6) Conservation of typical breeding bird communities and associated habitats 	(Meire et al., 2005; Saathoff & Klugkist, 2012)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			(breeding birds of grasslands, reeds, and tidal floodplains).	
14	Wet grasslands	Feeding, roosting, and nesting (Davidson & Stroud, 1996)	<p>I. Grazing management</p> <ol style="list-style-type: none"> 1) Although livestock also provide a supply of dung, which is important for dung beetles and other species that serve as food providers to birds, grazing should be avoided or reduced when birds are nesting to prevent loss of nests; 2) Wet grasslands and the water features within them provide important habitat for amphibians and invertebrates, which in turn provide food for breeding waders and their chicks; <p>II. Managing water levels</p> <ol style="list-style-type: none"> 1) Maintaining high water levels throughout spring and summer to assist birds with their feeding by keeping soils soft and moist; 2) Create shallow sludge or deeper pools with muddy margins and sparse marginal vegetation to assist adult and 	(URL, 4 C.E.)

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			<p>young birds in finding food where fields are drier;</p> <p>3) Wherever possible, try to keep the quantity of water close to ground level across the year-round</p> <p>III. Rush Management</p> <p>1) Promote scattered rush cover to provide important nesting and shelter areas for breeding waders, amphibians, and invertebrates;</p> <p>2) Carry out a rotational rush-cutting and weed wiping to the outside of the bird-breeding season.</p> <p>IV. Management of ditches and ponds</p> <p>1) Ensure a controlled and careful use of fertilizer and pesticides in the vicinity of ditches and ponds;</p> <p>2) Undertake rotational management (conveniently during November–December) of ditches if they sludge and become choked with vegetation;</p> <p>3) Manage marginal vegetation around ditches and other water bodies by using well-controlled and managed grazing to</p>	

HABITATS AND ECOLOGICAL FUNCTIONS TO BIRDS		HABITAT MANAGEMENT PRACTICES		
S/N	Habitat Composition/habitat type	Typical ecological functions and reference	Management practices	reference
			provide a diversity of vegetation beneficial for spiders and damselflies and other invertebrates;	

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