COSEWIC
Assessment and Status Report

on the

Red Knot
Calidris canutus

islandica subspecies (*Calidris canutus islandica*)
roselaari subspecies (*Calidris canutus roselaari*)
rufa subspecies (*Calidris canutus rufa*)
Tierra del Fuego / Patagonia wintering population
Northeastern South America wintering population
Southeastern USA / Gulf of Mexico / Caribbean wintering population

in Canada

***islandica* subspecies – NOT AT RISK**
***roselaari* subspecies – THREATENED**
***rufa* subspecies (Tierra del Fuego / Patagonia wintering population) – ENDANGERED**
***rufa* subspecies (Northeastern South America wintering population) – SPECIAL CONCERN**
***rufa* subspecies (Southeastern USA / Gulf of Mexico / Caribbean wintering population) – ENDANGERED**
2020

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2020. COSEWIC assessment and status report on the Red Knot *Calidris canutus, islandica* subspecies (*Calidris canutus islandica*), *roselaari* subspecies (*Calidris canutus roselaari*) and *rufa* subspecies (*Calidris canutus rufa*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxxv + 173 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Previous report(s):

COSEWIC 2007. COSEWIC assessment and status report on the Red Knot *Calidris canutus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 58 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC would like to acknowledge Guy Morrison for writing the status report on Red Knot, *Calidris canutus*, in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by Richard Elliot, Co-chair of the COSEWIC Birds Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
www.cosewic.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Bécasseau maubèche (*Calidris canutus*) sous-espèce *islandica* (*Calidris canutus islandica*), sous-espèce *roselaari* (*Calidris canutus roselaari*) et sous-espèce *rufa* (*Calidris canutus rufa*) au Canada.

Cover illustration/photo:
Red Knot — Photo credit: Jan van de Kam (with permission).

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COSEWIC
Assessment Summary

Assessment Summary – November 2020

Common name
Red Knot - *islandica* subspecies

Scientific name
Calidris canutus islandica

Status
Not at Risk

Reason for designation
This medium-sized shorebird breeds in the northeastern Canadian High Arctic and migrates across the North Atlantic Ocean to overwinter in coastal Europe. About 120,000 birds breed in Canada and make up 40% of the global population. Winter surveys in Europe indicate that populations have been stable or fluctuating slightly over the past three generations. Individuals congregate at many sites in winter, where they may be exposed to threats such as disturbance and effects of shoreline stabilization. Risks from exposure to storms and severe weather during trans-oceanic migratory flights may increase with climate change. However, as past population declines have been halted, and former threats from shellfish harvesting in Europe are much reduced, the status of this population has improved since the last assessment.

Occurrence
Nunavut, Northwest Territories

Status history
Designated Special Concern in April 2007. Status re-examined and designated Not at Risk in November 2020.

Assessment Summary – November 2020

Common name
Red Knot - *roselaari* subspecies

Scientific name
Calidris canutus roselaari

Status
Threatened

Reason for designation
This medium-sized shorebird breeds in northwestern Alaska and on Wrangel Island in the eastern Russian Arctic, overwintering on the Pacific coast of the Americas. The global population numbers about 22,000 mature individuals, most of which likely migrate through Canadian airspace, although only small numbers are recorded annually on coastal islands of British Columbia on spring migration and in winter. Migration and winter counts indicate a long-term population decline of 39-64% over three generations, although trend estimates have low precision. Habitat quality is declining in areas used throughout the year. Population and habitat declines are anticipated to continue. Individuals congregate at key sites on migration in Alaska, Washington, and California, making them vulnerable to localized threats. Threats include disturbance from recreational activities, coastal development, aquaculture, and shoreline stabilization, as well as over-fishing of grunion (small fish whose eggs are an important food source) in coastal Mexico. Exposure to storms and severe weather during long migratory flights may increase with climate change.

Occurrence
British Columbia, Yukon

Status history
The species '*roselaari* type' was considered a single unit (which included three groups) and designated Threatened in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies (Northeastern South America wintering population, Southeastern USA / Gulf of Mexico / Caribbean wintering population). The remaining unit now includes only the *roselaari* subspecies. The *roselaari* subspecies was designated Threatened in November 2020.

Assessment Summary – November 2020

Common name
Red Knot - *rufa* subspecies (Tierra del Fuego / Patagonia wintering population)

Scientific name
Calidris canutus rufa

Status
Endangered

Reason for designation
This medium-sized shorebird breeds in the central Canadian Arctic and overwinters in Tierra del Fuego at the southern tip of South America, with migratory round-trips of over 30,000 km each year. Annual winter surveys indicate that the population of about 7,500 mature individuals has declined by 73% over the past three generations. Habitat quality is declining in areas used for breeding, migration stopovers and in winter. Population and habitat declines are anticipated to continue. The population congregates at a few key sites on migration on the east coasts of North and South America, and on the wintering grounds, making it highly vulnerable to threats. Threats include human harvesting of Horseshoe Crab (whose eggs are an essential food source for northbound migrants) in Delaware Bay, disturbance and predation from recovering falcon populations, oil development, and disturbance from recreational activities. Risks from exposure to storms and severe weather during very long trans-oceanic migratory flights may increase with climate change.

Occurrence
Nunavut, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador

Status history
The *rufa* subspecies was considered a single unit (consisting solely of southern wintering birds from Tierra del Fuego / Patagonia) and designated Endangered in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies (Northeastern South America wintering population, Southeastern USA / Gulf of Mexico / Caribbean wintering population). The Tierra del Fuego / Patagonia wintering population of the *rufa* subspecies was designated Endangered in November 2020.

Assessment Summary – November 2020

Common name
Red Knot - *rufa* subspecies (Northeastern South America wintering population)

Scientific name
Calidris canutus rufa

Status
Special Concern

Reason for designation
This medium-sized shorebird breeds in the central Canadian Arctic and migrates long distances to overwinter on the northeastern coast of South America, centred in northern coastal Brazil. Overall numbers appear to be stable, with an estimated wintering population of about 19,800 mature individuals. During migration, the population congregates at key sites on the eastern seaboard of the United States, where it is vulnerable to threats from human harvesting of Horseshoe Crab (whose eggs are an essential food source for northbound migrants) in Delaware Bay, disturbance and predation from recovering falcon populations, and disturbance from recreational activities. Risks from exposure to storms and severe weather during long migratory flights may increase with climate change.

Occurrence
Nunavut, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador

Status history
The species '*roselaari* type' was considered a single unit (which included three groups) and designated Threatened in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies. The Northeastern South America wintering population of the *rufa* subspecies was designated Special Concern in November 2020.

Assessment Summary – November 2020

Common name
Red Knot - *rufa* subspecies (Southeastern USA / Gulf of Mexico / Caribbean wintering population)

Scientific name
Calidris canutus rufa

Status
Endangered

Reason for designation
This medium-sized shorebird breeds in the central Canadian Arctic and overwinters along the coasts of southeastern United States, Gulf of Mexico and islands in the Caribbean Sea. Migration and wintering surveys indicate that the population has experienced steep declines, in the range of 33-84% over three generations, with no evidence of recovery. The current population is estimated to be about 9300 mature individuals. During migration it congregates at a few key sites on the eastern seaboard of the United States, making it vulnerable to threats from human harvesting of Horseshoe Crabs (whose eggs are an essential food source for northbound migrants) in Delaware Bay, disturbance and predation from recovering falcon populations, and disturbance from recreational activities. Risks from exposure to storms and severe weather during fall and winter may increase with climate change.

Occurrence
Nunavut, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador

Status history
The species '*roselaari* type' was considered a single unit (which included three groups) and designated Threatened in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies. The Southeastern USA / Gulf of Mexico / Caribbean wintering population of the *rufa* subspecies was designated Endangered in November 2020.

COSEWIC
Executive Summary

Red Knot
Calidris canutus

Wildlife Species Description and Significance

Red Knot (*Calidris canutus*) is a medium-sized shorebird with a typical "sandpiper" profile: medium-long bill and smallish head, longish legs, and long tapered wings giving the body an elongated streamlined profile. In breeding plumage, the face, neck, breast and much of the underparts are rufous red. The upperparts are dark brown or black spangled with rufous and grey. In winter plumage, knots (used throughout to refer to Red Knots in general) have white underparts and pale grey back.

Six subspecies of Red Knot are currently recognized worldwide, each with distinct biogeographical populations that differ to varying degrees in distribution, in scheduling of the annual cycle, and genetically. Three subspecies occur in Canada: *C. c. islandica*, *C. c. roselaari*, and *C. c. rufa*. The taxonomy of North American Red Knot populations has been revised since the 2007 COSEWIC Status Report, with the populations wintering in Tierra del Fuego, as well as those wintering in northern Brazil and in southeastern USA / Gulf of Mexico / Caribbean, which were formerly assigned to *C. c. roselaari*, all now regarded as part of *C. c. rufa*. These three populations of *rufa* are also treated here as separate designatable units (DUs). The following five Red Knot DUs are considered here:

- DU1 – *islandica* subspecies (*C. c. islandica*): breeds in the northeastern Canadian High Arctic, and winters on the European Atlantic seaboard.

- DU2 – *roselaari* subspecies (*C. c. roselaari*): breeds in northwestern Alaska and on Wrangel Island in the Russian Eastern Arctic, migrates through Canadian airspace to overwinter on the Pacific coast of the Americas, and occurs in small numbers in coastal British Columbia on migration and in winter.

- DU3 – Tierra del Fuego / Patagonia wintering population (*C. c. rufa* in part): breeds in the central Canadian Arctic, and winters at the southern tip of South America, in Patagonia, Argentina, and Tierra del Fuego.

- DU4 – northeastern South America wintering population (*C. c. rufa* in part): breeds in the central Canadian Arctic, and winters on the northeastern coast of South America, centred in the Maranhão district of northern Brazil.

- DU5 – southeastern USA / Gulf of Mexico / Caribbean wintering population (*C. c. rufa* in part): breeds in the central Canadian Arctic, and winters along the coasts of the southeastern United States, Gulf of Mexico, and Caribbean Sea.

Red Knot is a "flagship" species for shorebird conservation, with long, inter-continental migrations and high vulnerability to threats, as it concentrates in large numbers at a few key sites on migration and in winter. It crosses many international boundaries and is symbolic of the need for international cooperation for successful conservation. Conservation of sites used by knots also benefits many other shorebird species.

Distribution (see **Wildlife Species Description and Significance** above)

Habitat

Red Knot nests in barren habitats in the Arctic, such as windswept ridges, slopes, or plateaus, with little vegetation cover. On migration and wintering areas, knots use coastal areas with extensive sandflats, mudflats and rocky flats, where birds feed on bivalves and other invertebrates. Along the mid-Atlantic coast of the eastern United States, they use sandy beaches and feed on high-energy Horseshoe Crab eggs. They also use salt marshes, brackish lagoons, mangrove areas, mussel beds, peat banks, rocky intertidal platforms, inland saline lakes, and agricultural fields.

Biology

Red Knot is monogamous, with pairs usually laying a single clutch of four eggs in the latter half of June, and the eggs hatching about mid-July. Females depart soon thereafter, leaving the males to accompany the young until they fledge. Breeding success varies considerably, depending on weather and the abundance and impacts of predators. Red Knot has comparatively high adult annual survival, ranging from 0.62-0.92 (mean 0.80), which varies in response to foraging and weather conditions on wintering grounds and during migration. Red Knot has a generation time of about 7 years, and most individuals start breeding at age two years.

Red Knot undergoes significant physiological changes during migration, to increase flight efficiency and permit rapid accumulation of body stores after reaching the breeding grounds. Organs and tissues involved in flight increase in size, while digestive organs and leg muscles decrease. Stores of fat and protein remaining on arrival on the breeding grounds are then used to regrow the latter organs in preparation for the breeding attempt.

Population Sizes and Trends

- DU1 - *islandica* subspecies. Recent counts and mark-resighting estimates of *C. c. islandica* birds wintering in Europe suggest a Canadian population of about 128,000 mature individuals. Annual winter surveys in coastal Europe show a stable or slightly fluctuating population trend over the past three generations.

- DU2 - *roselaari* subspecies. Mark-recapture studies on the US Pacific coast suggest a population size of about 22,000 mature individuals of *C. c. roselaari*, including birds that breed in both northwest Alaska and on Wrangel Island. Very small numbers are seen in Canada in most years, although satellite tracking suggests that most of the population migrates through Canadian airspace on spring migration, and many may stop briefly on the British Columbia coast. Repeated migration and winter surveys in the United States indicate that this DU has experienced a long-term population decline, equivalent to about 39-64% over three generations, with no evidence of recovery.

- DU3 - Tierra del Fuego / Patagonia wintering population. The *C. c. rufa* population wintering in Tierra del Fuego numbered over 50,000 birds in 1982 and 2000, including mature individuals, subadults and juvenile birds, but declined by over 80% to <10,000 birds in 2011 and 2018. This reflects an actual population reduction rather than a redistribution of birds to different areas, as few knots now winter at peripheral sites along the Patagonia coast which formerly held up to 21% of the wintering count. The Tierra del Fuego / Patagonia wintering population (DU3) is now estimated to be about 7,500 mature individuals and is estimated to have declined by about 73% over three generations (1999-2020), with no evidence of recovery.

- DU4 - northeastern South America wintering population. Some 32,500 Red Knots of all ages were found on the northeastern coast of Brazil during aerial surveys in 2019. This total was considerably higher than on previous surveys, although the difference likely reflects improved methodology designed specifically for Red Knots. Numbers overall appear to be relatively stable or fluctuating slightly, with an estimated population of about 19,800 mature individuals wintering in northeastern South America.

- DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Recent estimates based on population modelling indicate that a total of about 10,400 Red Knot of all ages winter in coastal areas of the southeastern United States, with at least 5,000 additional knots likely wintering on islands in the Caribbean, for a total of about 15,400 birds. Adults likely make up about 60% of these totals, resulting in an overall southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) estimate of 9,300 mature individuals. The weight of evidence from migration and wintering surveys indicates that the population has experienced steep long-term declines, in the range of 33-84% over three generations, with no evidence of recovery.

Threats and Limiting Factors

Many of the key threats to Red Knot are associated with its long-distance migrations and physiological changes that maximize flying efficiency and breeding success. Its relatively inflexible life history strategy makes Red Knot particularly sensitive to the effects of human interventions and changing climate and habitat conditions. Threats affecting all five DUs to varying extents include ecosystem modifications/biological resource use which affect food resources needed at critical times of the year (e.g., Horseshoe Crab harvest in Delaware Bay, Grunion fishery in Mexico), habitat shifting and alteration (e.g., climate change effects on habitat conditions and predator relationships on the breeding grounds), and changes to coastal habitats resulting from sea-level changes. Significant disturbance from human activities occurs in many areas, and most DUs are affected by increased predation or disturbance from increasing falcon populations. Oil spills pose a threat to all DUs. Increased frequency and intensity of storms on the breeding grounds, and hurricanes in migration areas, may periodically cause significant mortality, especially for those DUs that undergo long trans-oceanic migratory flights.

- DU1 - *islandica* subspecies. *Overall threat impact: Low-Medium*. Shoreline stabilization and dredging for cockles (now much reduced) in coastal wintering areas of NE Europe has reduced the quality of foraging and roosting habitats. Changing climate may affect breeding habitats and cause increased predation on breeding grounds and lead to reduced habitat quality at migration and wintering sites owing to sea level rise and ocean acidification.

- DU2 - *roselaari* subspecies. *Overall threat impact: Medium-High*. Over-fishing of Grunion in Upper Gulf of California, Mexico reduces availability of their eggs which are a key food resource for Red Knot in the critical period before spring migration. Coastal development, aquaculture, and shoreline stabilization on the Pacific coast may degrade foraging and roosting habitats used on migration and in winter. Changing climate may affect habitats and lead to increased predation on breeding grounds, and reduced habitat quality at migration and wintering sites owing to sea level rise and ocean acidification.

- DU3 - Tierra del Fuego / Patagonia wintering population. *Overall threat impact: High-Very High*. The Tierra del Fuego / Patagonia wintering population (DU3) had the highest overall threat impact of all DUs, likely related to its having the longest migration. Major threats include ongoing issues with Horseshoe Crab abundance in Delaware Bay, increased predation and disturbance from increasing falcon populations throughout its range, disturbance from recreational activities, and possible effects from climate change, including increasing storm frequency, on breeding grounds (habitat alteration, predation) and on migration and wintering areas (e.g., sea-level rise).

- DU4 - northeastern South America wintering population. *Overall threat impact: Medium-High*. Major threats include ongoing issues with Horseshoe Crab abundance in Delaware Bay, increased predation and disturbance from increasing falcon populations, and possible effects from climate change, including increasing storm frequency on breeding grounds (habitat alteration, predation) and on migration and wintering areas (e.g., sea-level rise).

- DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. *Overall threat impact: Medium-High*. Disturbance by recreationists significantly affects quality of foraging and roosting areas on wintering and migration areas in eastern North America. Major threats include ongoing issues with Horseshoe Crab abundance in Delaware Bay, increased predation and disturbance from increasing falcon populations, and possible effects from climate change, including increasing storm frequency on breeding grounds (habitat alteration, predation) and on migration and wintering areas.

Number of Locations

As Red Knot from all DUs nest at many widely distributed sites, across the high Arctic in Canada, Alaska, or eastern Russia, the number of locations for each DU during the breeding season is much greater than 10, as geographically distinct nesting areas are likely exposed to differing risks from key threats, such as ecosystem modifications and climate change. However, fewer locations are often used on migration or in winter. Non-breeding season estimates for the number of locations are: DU1, *islandica* subspecies, likely >10 in winter; DU2, *roselaari* subspecies, likely >10 on migration; DU3, Tierra del Fuego / Patagonia wintering population, likely 5-10 in winter; DU4, northeastern South America wintering population, likely >10 on migration; DU5, southeastern USA / Gulf of Mexico / Caribbean wintering population, likely >10 on migration.

Protection, Status and Ranks

Red Knot is protected in Canada under the *Migratory Birds Convention Act* (1994). It was listed on Schedule 1 of the *Species at Risk Act* in 2012, as follows: *C. c. rufa* Endangered (the southern Tierra del Fuego / Patagonia wintering population, now DU3); *C. c. roselaari* Threatened (including present DU2, the northeastern South America wintering population in northern Brazil and the southeastern USA / Gulf of Mexico / Caribbean wintering population, DU4 and DU5, now believed to be *C. c. rufa*), and *C. c. islandica* (now DU1) Special Concern (the previous DUs reflect earlier taxonomic designations). Red Knot (*C. c. rufa*) is also listed under species-at-risk legislation in Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland and Labrador. *C. c. islandica* and *C. c. roselaari* are not listed under provincial or territorial species-at-risk legislation.

Red Knot (*C. c. rufa*) is listed federally in the United States as Threatened, and as Threatened in New Jersey and as of Special Concern in Georgia. *C. c. rufa* was added to Appendix 1 of the Convention on Migratory Species in 2005. Red Knot was listed as Critically Endangered on the Brazilian list in 2014 and categorized as Endangered in Argentina, Chile and Uruguay. France declared the species to be protected in Guadeloupe and Martinique in 2012 and in French Guiana in 2014. *C. c. roselaari* has been designated as Endangered in Mexico and as a species of management concern in the United States.

NatureServe lists *C. c. rufa* globally as G4T1, nationally in Canada as N1B and N1N, and nationally in the United States as N1N. It ranks *C. c. rufa* as S1 to S3 in Northwest Territories, Ontario, Quebec, Saskatchewan, Prince Edward Island, Nova Scotia, New Brunswick, and Newfoundland in Canada, and in Virginia in the United States. *C. c. islandica* is ranked N3B nationally and S2B in Northwest Territories.

TECHNICAL SUMMARY: *islandica* subspecies (Designatable Unit 1)

Calidris canutus islandica

Red Knot *islandica* subspecies

Bécasseau maubèche de la sous-espèce *islandica*

Range of occurrence in Canada (province/territory/ocean): Nunavut, Northwest Territories

[Populations breeding in Northeastern Canadian High Arctic and wintering in Europe]

Demographic Information

Generation time	7 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No. Numbers appear to be stable or fluctuating slightly, based on winter surveys
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	No decline, numbers apparently stable or fluctuating slightly, based on winter surveys
Observed percent reduction in total number of mature individuals over the last 3 generations (21 year) (2000-2018)	No decline, numbers apparently stable or fluctuating slightly over the past three generations, based on winter surveys
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
Observed percent reduction in total number of mature individuals over any 3 generations period, over a time period including both the past and the future.	No decline, numbers apparently stable or fluctuating slightly, based on winter surveys
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Not applicable - No longer declining
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1,084,949 km² within Canada
Index of area of occupancy (IAO) (Always report 2x2 km grid value).	327,212 km², as measured on the breeding grounds
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	>10 on wintering areas used in Europe
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown, but unlikely

* See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown, but unlikely
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Not applicable; single population
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed or projected declines in habitat quality in areas used for breeding, on migration and in winter
Are there extreme fluctuations in number of subpopulations?	Not applicable
Are there extreme fluctuations in number of “locations”?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Canadian breeding population	At least 128,000; at least 40% of global population estimate

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Analysis not conducted

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this Designatable Unit? Yes, on 11-12 February 2020, by Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)

islandica subspecies: The assigned overall threat impact is **Low-Medium.** The following contributing threats were identified, listed in decreasing order of impact:

11.1 Habitat shifting and alteration (Medium-Low)
7.3 Other ecosystem modifications (Low)
9. Industrial and military effluents (Low)
1.1 Housing and urban areas (Negligible)
1.2 Commercial and industrial areas (Negligible)
1.3 Tourism and recreation areas (Negligible)

2.4	Marine and freshwater aquaculture (Negligible)
3.1	Oil and gas drilling (Negligible)
3.3	Renewable energy (Negligible)
5.1	Hunting and collecting terrestrial animals (Negligible)
6.1	Recreational activities (Negligible)
6.3	Work and other activities (Negligible)
7.2	Dams and water management/use (Negligible)
8.2	Problematic native species/diseases (Unknown)
9.1	Domestic and urban waste water (Unknown)
9.3	Agricultural and forestry effluents (Unknown)
9.5	Air-borne pollutants (Unknown)
11.4	Storms and flooding (Unknown)

What additional limiting factors are relevant?
Key factors limiting the productivity and survival of Red Knot *islandica* subspecies relate to its long-distance, trans-oceanic migration between the Canadian High Arctic and Europe, and the associated physiological changes it undergoes to maximize flying efficiency during migration. This relatively inflexible life history strategy makes *islandica* subspecies Red Knots sensitive to the effects of human interventions and changing climates and habitat conditions.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Apparently stable or fluctuating in Greenland
Is immigration known or possible?	Unknown
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Unknown
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Unknown

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC Status History: Designated Special Concern in April 2007. Status re-examined and designated Not at Risk in November 2020.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Not at Risk	Not applicable

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Reasons for designation: This medium-sized shorebird breeds in the northeastern Canadian High Arctic and migrates across the North Atlantic Ocean to overwinter in coastal Europe. About 120,000 birds breed in Canada and make up 40% of the global population. Winter surveys in Europe indicate that populations have been stable or fluctuating slightly over the past three generations. Individuals congregate at many sites in winter, where they may be exposed to threats such as disturbance and effects of shoreline stabilization. Risks from exposure to storms and severe weather during trans-oceanic migratory flights may increase with climate change. However, as past population declines have been halted, and former threats from shellfish harvesting in Europe are much reduced, the status of this population has improved since the last assessment.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Number of mature individuals in the population is not declining.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO of 1,084,949 km² and IAO of 327,212 km² are both higher than threshold levels.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population estimate of 128,000 mature individuals is higher than threshold levels.
Criterion D (Very Small or Restricted Population): Not applicable. Population estimate of 128,000 mature individuals is higher than threshold levels.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

TECHNICAL SUMMARY: *roselaari* subspecies (Designatable Unit 2)

Calidris canutus roselaari

Red Knot *roselaari* subspecies

Bécasseau maubèche de la sous-espèce *roselaari*

Range of occurrence in Canada (province/territory/ocean): British Columbia, Yukon

[Populations wintering mainly on the Pacific coast of North and Central America]

Demographic Information

Generation time	7 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, observed continuing decline, based on International Shorebird Surveys and Christmas Bird Counts
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]	Estimated reduction of 39-64% over 3 generations (21 years), based on International Shorebird Surveys and Christmas Bird Counts.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Estimated reduction of 39-64% over past 3 generations, based on ISS and CBC counts, likely continuing into future, based on assessed medium to high overall threat impact
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. No c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO) in Canada	167,016 km², based on records in coastal British Columbia during the non-breeding season, 2009-2018
Index of area of occupancy (IAO) (Always report 2x2 grid value).	500-2000 km^2, based on records in coastal British Columbia and the Pacific coast of the United States during the non-breeding season
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No

Number of “locations”[*] (use plausible range to reflect uncertainty if appropriate)	Likely >10, based on areas used on migration
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Not applicable; single population
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed or projected declines in habitat quality in areas used for breeding, on migration and in winter
Are there extreme fluctuations in number of subpopulations?	Not applicable
Are there extreme fluctuations in number of “locations”∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	22,000 (16,200-30,300); although only a few hundred birds are recorded annually in Canada, most of the population likely migrates through Canadian airspace

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Analysis not conducted.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for *roselaari* subspecies? Yes, on 11-12 February 2020, by Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)

[*] See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

The assigned overall threat impact for Red Knot *roselaari* subspecies is **Medium-High**. The following contributing threats were identified, listed in decreasing order of impact: 7.3 Other ecosystem modifications (Medium-Low) 11.1 Habitat shifting and alteration (Medium-Low) 1.1 Housing and urban areas (Low) 1.2 Commercial and industrial areas (Low) 2.4 Marine and freshwater aquaculture (Low) 6.1 Recreational activities (Low) 8.2 Problematic native species/diseases (Low) 9.2 Industrial and military effluents (Low) 1.3 Tourism and recreation areas (Negligible) 3.1 Oil and gas drilling (Negligible) 5.1 Hunting and collecting terrestrial animals (Negligible) 6.3 Work and other activities (Negligible) 8.1 Invasive non-native species/diseases (Negligible) 3.3 Renewable energy (Unknown) 7.2 Dams and water management/use (Unknown) 9.1 Domestic and urban waste water (Unknown) 9.3 Agricultural and forestry effluents (Unknown) 9.5 Air-borne pollutants (Unknown) 11.4 Storms and flooding (Unknown) What additional limiting factors are relevant? Key factors limiting the productivity and survival of Red Knot *roselaari* subspecies relate to its trans-oceanic and coastal migration and the associated physiological changes it undergoes to maximize flying efficiency during migration. This relatively inflexible life history strategy makes *roselaari* subspecies Red Knots particularly sensitive to the effects of human interventions and changing climates and habitat conditions.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	
Is immigration known or possible?	Not applicable
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Does not breed in Canada, uncommon on migration and in winter on British Columbia coast
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown
Is the Canadian population considered to be a sink?[+]	Unknown
Is rescue from outside populations likely?	Not applicable

Data Sensitive Species

Is this a data sensitive species?	No

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status History

COSEWIC Status History: The species '*roselaari* type' was considered a single unit (which included three groups) and designated Threatened in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies (Northeastern South America wintering population, Southeastern USA / Gulf of Mexico / Caribbean wintering population). The remaining unit now includes only the *roselaari* subspecies. The *roselaari* subspecies was designated Threatened in November 2020.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** A2bc+4bc
Reasons for designation: This medium-sized shorebird breeds in northwestern Alaska and on Wrangel Island in the eastern Russian Arctic, overwintering on the Pacific coast of the Americas. The global population numbers about 22,000 mature individuals, most of which likely migrate through Canadian airspace, although only small numbers are recorded annually on coastal islands of British Columbia on spring migration and in winter. Migration and winter counts indicate a long-term population decline of 39-64% over three generations, although trend estimates have low precision. Habitat quality is declining in areas used throughout the year. Population and habitat declines are anticipated to continue. Individuals congregate at key sites on migration in Alaska, Washington, and California, making them vulnerable to localized threats. Threats include disturbance from recreational activities, coastal development, aquaculture, and shoreline stabilization, as well as over-fishing of grunion (small fish whose eggs are an important food source) in coastal Mexico. Exposure to storms and severe weather during long migratory flights may increase with climate change.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened, A2bc and A4bc. Estimated rate of reduction in number of mature individuals of 39-64% over the past three generations (21 years), based on migration and winter surveys, is higher than the threshold levels, and habitat quality is declining. Population and habitat declines are likely to continue into the future based on assessed medium-high overall threat impact, indicating a likely population decline >30% over a three-generation period spanning past and future.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO of 167,016 km² is higher than threshold levels, and IAO of 500-2000 km² is lower than the threshold level for Threatened, but the population is not severely fragmented, occurs at more than 10 locations, and does not experience extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population estimate of 22,000 mature individuals is higher than threshold levels.
Criterion D (Very Small or Restricted Population): Not applicable. Population estimate of 22,000 mature individuals is higher than threshold levels.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

TECHNICAL SUMMARY: *rufa* subspecies (Tierra del Fuego / Patagonia wintering population) (Designatable Unit 3)

Calidris canutus rufa

Red Knot *rufa* subspecies (Tierra del Fuego / Patagonia wintering population)

Bécasseau maubèche de la sous-espèce *rufa* (Population hivernant dans la Terre de Feu et en Patagonie)

Range of occurrence in Canada (province/territory/ocean): Nunavut, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador

Demographic Information

Generation time	7 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, observed continuing decline from 2000-2020, based on winter surveys
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Estimated continuing decline of 35% over 2 generations (14 years: 2006-2020), based on winter surveys
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Estimated 73% reduction over 3 generations (21 years: 1999-2020), based on winter surveys
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Estimated 73% reduction over 3-generation period of 21 years based on winter surveys, likely continuing into future based on assessed high to very high overall threat impact
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Uncertain b. Partly c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1,500,261 km² (Includes entire *rufa* breeding range; the proportion occupied by the Tierra del Fuego / Patagonia wintering population is unknown)
Index of area of occupancy (IAO)	1100-1300 km^2, estimated on the wintering grounds

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Likely 5-10, based on areas used in winter
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, observed decline in IAO (area occupied on wintering grounds)
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Not applicable; single population
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, projected decline in area, extent and quality of habitat used on migration and in winter
Are there extreme fluctuations in number of subpopulations?	Not applicable
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	7,500

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Analysis not conducted.

* See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for the Tierra del Fuego / Patagonia wintering population of Red Knot? Yes, on 11-12 February 2020, by Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS) The assigned overall threat impact for the Tierra del Fuego / Patagonia wintering population is **High-Very High**. The following contributing threats were identified, listed in decreasing order of impact: 7.3 Other ecosystem modifications (High-Low) 8.2 Problematic native species/diseases (Medium) 6.1 Recreational activities (Medium-Low) 11.1 Habitat shifting and alteration (Medium-Low) 11.4 Storms and flooding (Medium-Low) 1.1 Housing and urban areas (Low) 1.2 Commercial and industrial areas (Low) 1.3 Tourism and recreation areas (Low) 2.4 Marine and freshwater aquaculture (Low) 7.2 Dams and water management/use (Low) 9.2 Industrial and military effluents (Low) 3.1 Oil and gas drilling (Negligible) 3.2 Mining and quarrying (Negligible) 6.3 Work and other activities (Negligible) 2.3 Livestock farming and ranching (Unknown) 3.3 Renewable energy (Unknown) 5.1 Hunting and collecting terrestrial animals (Unknown) 9.1 Domestic and urban waste water (Unknown) 9.3 Agricultural and forestry effluents (Unknown) 9.5 Air-borne pollutants (Unknown) What additional limiting factors are relevant? Key factors limiting the productivity and survival of the Tierra del Fuego / Patagonia wintering population of Red Knot relate to its long-distance, trans-oceanic migration between the Canadian Arctic and Tierra del Fuego, and the extreme physiological changes it undergoes to maximize flying efficiency during migration. This relatively inflexible life history strategy makes knots in the Tierra del Fuego / Patagonia wintering population particularly sensitive to the effects of human interventions and changing climates and habitat conditions.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Not applicable – other Red Knot populations (Designatable Units) are considered distinct
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable

Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Possibly
Are conditions for the source (i.e., outside) population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Not applicable

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC Status History:

The *rufa* subspecies was considered a single unit (consisting solely of southern wintering birds from Tierra del Fuego / Patagonia) and designated Endangered in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies (Northeastern South America wintering population, Southeastern USA / Gulf of Mexico / Caribbean wintering population). The Tierra del Fuego / Patagonia wintering population of the *rufa* subspecies was designated Endangered in November 2020.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2bc+4bc

Reasons for designation:
This medium-sized shorebird breeds in the central Canadian Arctic and overwinters in Tierra del Fuego at the southern tip of South America, with migratory round-trips of over 30,000 km each year. Annual winter surveys indicate that the population of about 7,500 mature individuals has declined by 73% over the past three generations. Habitat quality is declining in areas used for breeding, migration stopovers and in winter. Population and habitat declines are anticipated to continue. The population congregates at a few key sites on migration on the east coasts of North and South America, and on the wintering grounds, making it highly vulnerable to threats. Threats include human harvesting of Horseshoe Crab (whose eggs are an essential food source for northbound migrants) in Delaware Bay, disturbance and predation from recovering falcon populations, oil development, and disturbance from recreational activities. Risks from exposure to storms and severe weather during very long trans-oceanic migratory flights may increase with climate change.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2bc and A4bc. Estimated rate of reduction in number of mature individuals of 73% over the past three generations (21 years), based on wintering population surveys, is higher than threshold levels, and habitat quality is declining. Population and habitat declines are likely to continue into the future based on assessed “high-very high” overall threat impact, indicating a likely decline >50% over a three-generation period spanning past and future.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened, B2ab(iii,v). IAO of 1100-1300 km^2 is lower than the threshold level of 2000 km^2, the population exists at <10 locations in winter, and there is a projected continuing decline in quality of migration and winter habitat, and an observed continuing decline in the number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened, C2a(ii). The population estimate of 7,500 mature individuals is lower than the threshold level of 10,000 mature individuals, and there is an observed continuing decline in the number of mature individuals, all of which occur in the same subpopulation.
Criterion D (Very Small or Restricted Population): Not applicable. Population estimate of 7,500 mature individuals is higher than threshold levels.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

TECHNICAL SUMMARY: *rufa* subspecies (Northeastern South America wintering population) (Designatable Unit 4)

Calidris canutus rufa

Red Knot *rufa* subspecies (Northeastern South America wintering population)

Bécasseau maubèche de la sous-espèce *rufa* (Population hivernant dans le nord-est de l'Amérique du Sud)

Range of occurrence in Canada (province/territory/ocean): Nunavut, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador

Demographic Information

Generation time	7 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No. Numbers likely stable, based on winter surveys. Higher counts in recent surveys reflect improved survey coverage.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	No decline, numbers apparently stable, based on winter surveys
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	No decline, numbers apparently stable, based on winter surveys
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	No decline, numbers apparently stable, based on winter surveys
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Not applicable. Numbers not declining
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1,500,261 km² (Includes entire *rufa* breeding range; proportion occupied by the northeastern South America wintering population is unknown)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	1000-1600 km^2; calculated on the wintering grounds
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No

Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	Likely >10, based on areas used on migration
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Not applicable; single population	Not applicable; single population
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Unlikely
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed or projected declines in habitat quality in areas used for breeding, on migration and in winter
Are there extreme fluctuations in number of subpopulations?	Not applicable
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	19,800

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Analysis not conducted.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for the northeastern South America wintering population of Red Knot? Yes, on 11-12 February 2020, by Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)

The assigned overall threat impact for the northeastern South America wintering population is **Medium-High**. The following contributing threats were identified, listed in decreasing order of impact:

7.3 Other ecosystem modifications (Medium-Low)

* See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

8.2	Problematic native species/diseases (Medium-Low)
11.1	Habitat shifting and alteration (Medium-Low)
11.4	Storms and flooding (Medium-Low)
1.1	Housing and urban areas (Low)
2.4	Marine and freshwater aquaculture (Low)
6.1	Recreational activities (Low)
7.2	Dams and water management/use (Low)
9.2	Industrial and military effluents (Low)
1.2	Commercial and industrial areas (Negligible)
1.3	Tourism and recreation areas (Negligible)
3.1	Oil and gas drilling (Negligible)
3.2	Mining and quarrying (Negligible)
6.3	Work and other activities (Negligible)
3.3	Renewable energy (Unknown)
5.1	Hunting and collecting terrestrial animals (Unknown)
9.1	Domestic and urban waste water (Unknown)
9.3	Agricultural and forestry effluents (Unknown)
9.5	Air-borne pollutants (Unknown)

What additional limiting factors are relevant?
Key factors limiting the productivity and survival of Red Knot in the northeastern South America wintering population relate to its long-distance, trans-oceanic migration between the Canadian Arctic and northeastern South America, and the physiological changes it undergoes to maximize flying efficiency during migration. This relatively inflexible life history strategy makes knots in the northeastern South America wintering population particularly sensitive to the effects of human interventions and changing climates and habitat conditions.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Not applicable – other Red Knot populations (DUs) are considered distinct
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?+	Possibly
Are conditions for the source (i.e., outside) population deteriorating?+	Not applicable
Is the Canadian population considered to be a sink?+	No
Is rescue from outside populations likely?	Not applicable

Data Sensitive Species

Is this a data sensitive species?	No

+ See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status History

COSEWIC Status History:
The species '*roselaari* type' was considered a single unit (which included three groups) and designated Threatened in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies. The Northeastern South America wintering population of the *rufa* subspecies was designated Special Concern in November 2020.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: This medium-sized shorebird breeds in the central Canadian Arctic and migrates long distances to overwinter on the northeastern coast of South America, centred in northern coastal Brazil. Overall numbers appear to be stable, with an estimated wintering population of about 19,800 mature individuals. During migration, the population congregates at key sites on the eastern seaboard of the United States, where it is vulnerable to threats from human harvesting of Horseshoe Crab (whose eggs are an essential food source for northbound migrants) in Delaware Bay, disturbance and predation from recovering falcon populations, and disturbance from recreational activities. Risks from exposure to storms and severe weather during long migratory flights may increase with climate change.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Number of mature individuals in the population is not declining.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Although IAO of 1000-1600 km^2 is lower than the threshold level for Threatened, the population is not severely fragmented, occurs at more than 10 locations, and does not experience extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population estimate of 19,800 mature individuals is higher than threshold levels.
Criterion D (Very Small or Restricted Population): Not applicable. Population estimate of about 19,800 mature individuals is higher than threshold levels.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

TECHNICAL SUMMARY: *rufa* subspecies (Southeastern USA / Gulf of Mexico / Caribbean wintering population) (Designatable Unit 5)

Calidris canutus rufa

Red Knot *rufa* subspecies (Southeastern USA / Gulf of Mexico / Caribbean wintering population)

Bécasseau maubèche de la sous-espèce *rufa* (Population hivernant dans le sud-est des États-Unis, le golfe du Mexique et les Caraïbes)

Range of occurrence in Canada (province/territory/ocean): Nunavut, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador

Demographic Information

Generation time	7 years.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred continuing decline, based on International Shorebird Surveys and Christmas Bird Counts.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Inferred reduction of 33-84% over three generations, based on International Shorebird Surveys and Christmas Bird Counts.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Inferred reduction of 33-84% over three generations, based on ISS and CBC counts, likely continuing into future, based on assessed medium to high overall threat impact
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Uncertain b. Partly c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	1,500,261 km² Includes entire *rufa* breeding range; proportion occupied by the southeastern USA / Gulf of Mexico / Caribbean wintering population is unknown
Index of area of occupancy (IAO) (Always report 2x2 grid value).	Minimum estimate of 2,548 km², based on key spring migration stopover areas in W. Hudson Bay, where entire population is thought to occur

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Likely > 10, based on areas used on migration
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Not applicable; single population
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed and projected decline in area, extent and quality of habitat used for breeding, on migration and in winter
Are there extreme fluctuations in number of subpopulations?	Not applicable
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Regional Totals (no identifiable subpopulations)	**N Mature Individuals**
Southeastern United States and Gulf states	6,240
Caribbean islands	3,060
Total	9,300

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Analysis not conducted

* See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for the southeastern USA / Gulf of Mexico / Caribbean wintering population of Red Knot? Yes, on 11-12 February 2020, by Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS) The assigned overall threat impact for the southeastern USA / Gulf of Mexico / Caribbean wintering population is **Medium-High**. The following contributing threats were identified, listed in decreasing order of impact: 6.1 Recreational activities (Medium-Low) 7.3 Other ecosystem modifications (Medium-Low) 8.2 Problematic native species/diseases (Medium-Low) 11.1 Habitat shifting and alteration (Medium-Low) 11.4 Storms and flooding (Medium-Low) 1.1 Housing and urban areas (Low) 1.3 Tourism and recreation areas (Low) 2.4 Marine and freshwater aquaculture (Low) 7.2 Dams and water management/use (Low) 9.2 Industrial and military effluents (Low) 1.2 Commercial and industrial areas (Negligible) 3.1 Oil and gas drilling (Negligible) 3.2 Mining and quarrying (Negligible) 5.1 Hunting and collecting terrestrial animals (Negligible) 6.3 Work and other activities (Negligible) 3.3 Renewable energy (Unknown) 9.1 Domestic and urban waste water (Unknown) 9.3 Agricultural and forestry effluents (Unknown) 9.5 Air-borne pollutants (Unknown) 11.2 Droughts (Unknown) What additional limiting factors are relevant? Key factors limiting the productivity and survival of Red Knot in the southeastern USA / Gulf of Mexico / Caribbean wintering population relate to its migration between the Canadian Arctic and the US Gulf States and Caribbean Sea, and the physiological changes it undergoes to maximize flying efficiency during migration. This relatively inflexible life history strategy makes knots in the southeastern USA / Gulf of Mexico / Caribbean wintering population particularly sensitive to the effects of human interventions, changing climates and habitat conditions, such as loss of stopover sites.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Not applicable – other Red Knot populations (DUs) are considered distinct
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable

Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?[+]	Possibly
Are conditions for the source (i.e., outside) population deteriorating?[+]	Not applicable
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	Not applicable

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC Status History: The species '*roselaari* type' was considered a single unit (which included three groups) and designated Threatened in April 2007. Based on the Designatable Unit report on Red Knot (COSEWIC 2019), a new population structure was proposed and accepted by COSEWIC; two groups previously assessed under the '*roselaari* type' were transferred to the *rufa* subspecies. The Southeastern USA / Gulf of Mexico / Caribbean wintering population of the *rufa* subspecies was designated Endangered in November 2020.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** A2bc+4bc
Reasons for designation: This medium-sized shorebird breeds in the central Canadian Arctic and overwinters along the coasts of southeastern United States, Gulf of Mexico and islands in the Caribbean Sea. Migration and wintering surveys indicate that the population has experienced steep declines, in the range of 33-84% over three generations, with no evidence of recovery. The current population is estimated to be about 9300 mature individuals. During migration it congregates at a few key sites on the eastern seaboard of the United States, making it vulnerable to threats from human harvesting of Horseshoe Crabs (whose eggs are an essential food source for northbound migrants) in Delaware Bay, disturbance and predation from recovering falcon populations, and disturbance from recreational activities. Risks from exposure to storms and severe weather during fall and winter may increase with climate change.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2bc and A4bc. Inferred rate of reduction in number of mature individuals of 33-84% over the past three generations (21 years), based on migration and winter surveys, is higher than threshold levels, and habitat quality is declining. Population and habitat declines are likely to continue into the future based on assessed medium-high overall threat impact.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO of 1,500,261 km^2 and minimum estimate of IAO of 2,548 km^2 are both higher than threshold levels.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened, C2a(ii). The population estimate of 9,300 mature individuals is lower than the threshold level of 10,000 mature individuals, and there is an observed continuing decline in number of mature individuals, all of which occur in the same subpopulation.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Criterion D (Very Small or Restricted Population): Not applicable. Population estimate of 9,300 mature individuals is higher than threshold levels.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

PREFACE

The status of Red Knot (*Calidris canutus*) was assessed in 2007 (COSEWIC 2007) and listed on Schedule 1 of the *Species at Risk Act* in 2012, on the basis of three designatable units (DUs) that aligned with three subspecies as then described: *C. c. rufa* Endangered; *C. c. roselaari* Threatened, and *C. c. islandica* Special Concern. Red Knot taxonomy has since been significantly revised, on the basis of genetic, moult, and movement studies (Baker *et al.* 2012a,b, 2013, 2020). The two populations that overwinter in the southeastern United States/Gulf of Mexico/Caribbean and on the northeastern coast of Brazil, which were formerly regarded as part of *C. c. roselaari*, are now considered to belong to *C. c. rufa* (Baker *et al.* 2013, 2020; Burger *et al.* 2020). Only those Red Knot wintering on the west coast of the Americas are now considered to be *C. c. roselaari* (Carmona *et al.* 2013), while those wintering in Europe are still considered to be *C. c. islandica*, as in COSEWIC (2007). *C. c. rufa* is further subdivided here into three populations, based on widely disjunct wintering areas, namely those wintering in extreme southern South America including Tierra del Fuego (formerly the only group included in *C. c. rufa*) and the two wintering groups noted above (Baker *et al.* 2013, 2020; Verkuil *et al.* 2017).

The COSEWIC Birds Specialist Subcommittee examined lines of evidence for discreteness and evolutionary significance of these Red Knot populations, to determine the appropriate number and delineation of DUs, and proposed five DUs based on the wintering areas described above (COSEWIC Birds Specialist Subcommittee 2019). In November 2019, COSEWIC approved the five proposed Red Knot DUs for use in the present status assessment (COSEWIC Birds Specialist Subcommittee 2019).

There is a considerable amount of new information available on many aspects of the biology of Red Knot (summarized in Baker *et al.* 2013, 2020; Niles *et al.* 2010a; USFWS 2014a). New population size estimates are available for most DUs, based on mark-resighting data from flagged birds and from ground and aerial surveys (e.g., Lyons *et al.* 2016, 2018; Morrison *et al.* 2020a,b,c). Population trends have been reassessed for most DUs, based on analysis of International Shorebird Survey data, extensive ground-based counts, and aerial surveys (e.g., USFWS 2014a; Morrison 2018; NJA 2020). Migratory connectivity and degree of mixing on wintering areas has been assessed through observations of knots marked with coloured flags, radio-tags, geolocators, and GPS units (e.g., USFWS 2014a; Baker *et al.* 2020; Burger *et al.* 2020). Important new migration stopover areas have been identified through geolocator records and aerial surveys (e.g., McKellar *et al.* 2015; Burger *et al.* 2020; Johnson pers. comm. 2020; MacDonald 2020).

A Species at Risk Recovery Strategy and Management Plan for Red Knot, which incorporated a preliminary threat assessment for each of the three subspecies, was produced in 2017 (Environment and Climate Change Canada 2017), based on the three DUs identified in COSEWIC (2007).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2020)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Red Knot
Calidris canutus

islandica subspecies (*Calidris canutus islandica*)
roselaari subspecies (*Calidris canutus roselaari*)
rufa subspecies (*Calidris canutus rufa*)
Tierra del Fuego / Patagonia wintering population
Northeastern South America wintering population
Southeastern USA / Gulf of Mexico / Caribbean wintering population

in Canada

2020

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE 7
Name and Classification 7
Subspecies 7
Morphological Description 8
Population Spatial Structure and Variability 9
Designatable Units 10
Special Significance 19
DISTRIBUTION 20
Global Range 20
Canadian Range 20
Extent of Occurrence (EOO) and Index of Area of Occupancy (IAO) 22
Search Effort 30
HABITAT 31
Habitat Requirements 31
Habitat Trends 32
BIOLOGY 35
Life Cycle and Reproduction 35
Longevity and survival 36
Physiology and Adaptability 37
Dispersal and Migration 38
Interspecific Interactions 45
POPULATION SIZES AND TRENDS 46
Sampling Effort and Methods 46
Abundance 50
Fluctuations and Trends 53
Summary of Trends 67
Rescue Effect 69
THREATS AND LIMITING FACTORS 69
Threats 69
Limiting Factors 97
Number of Locations 97
PROTECTION, STATUS AND RANKS 99
Legal Protection and Status 99
Non-Legal Status and Ranks 101
Habitat Protection and Ownership 103

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED 105
Authorities contacted 106
INFORMATION SOURCES.. 109
BIOGRAPHICAL SUMMARY OF REPORT WRITER.. 146
COLLECTIONS EXAMINED 147

List of Figures

Figure 1. Worldwide distribution of the six recognized subspecies of Red Knot. Arrows connect non-breeding (= wintering) areas identified by dots (scaled to relative population size) with breeding areas (purple shading). For this report, *islandica* populations represent DU1 and *roselaari* populations represent DU2. For *rufa* wintering populations, dots in Tierra del Fuego represent DU3 (the Tierra del Fuego / Patagonia wintering population), those on the north coast of South America represent DU4 (the northeastern South America wintering population), and those in the southeastern United States and central America represent DU5 (the USA / Gulf of Mexico / Caribbean wintering population). Map by Hugo Ahlenius, GRID-Arendal 2010. 8

Figure 2. Breeding range of Red Knot in the Canadian Arctic. *C. c. islandica* breeds in the High Arctic regions of northeastern Canada and Greenland. *C. c. roselaari* breeds in northern and northwestern Alaska, and on Wrangel Island, Russia (not shown). *C. c. rufa* breeds entirely within Canada in the central Canadian Arctic. (Map created by the COSEWIC secretariat, COSEWIC 2007). 12

Figure 3. Known breeding range, distribution of preferred nesting habitats, and distribution of surveys and sightings of Red Knot (REKN) in the Canadian Arctic (from Rausch and Smith 2013). 21

Figure 4. Extent of occurrence (EOO) and Index of Area of Occupancy (IAO) for Red Knot *C. c. islandica* (DU1) in Canada, based on the known breeding range within the northeastern Canadian Arctic (from Figure 2; map prepared by R. Nobre Soares and S. Allen). 23

Figure 5. Extent of occurrence (EOO) and that portion of the Index of Area of Occupancy (IAO) for Red Knot *C. c. roselaari* (DU2) that occurs within Canada, based on records of Red Knot on migration or in winter (2009-2018) from eBird (2019), shown by black dots, and records from GPS-tagged birds during spring migration in 2017 and 2018 (Johnson pers. comm. 2020), shown by blue dots (map prepared by S. Allen). 24

Figure 6. Extent of occurrence (EOO) for Red Knot *C. c. rufa* (DUs 3, 4, and 5) in Canada, based on the known breeding range of the subspecies within the central Canadian Arctic (from Figure 2; map prepared by R. Nobre Soares and S. Allen). 25

Figure 7. Primary areas included in the Index of Area of Occupancy (IAO) for Red Knot *C. c. rufa* Tierra del Fuego / Patagonia wintering population (DU3) on its wintering grounds in southern Argentina and Chile, based on the distribution of regularly occupied wintering sites (2009-2018) on the coasts of Tierra del Fuego and Patagonia (eBird 2019; Morrison *et al.* 2020b; Morrison unpubl. data; map prepared by R. Nobre Soares and S. Allen). 27

Figure 8. Primary areas included in the Index of Area of Occupancy (IAO) for Red Knot *C. c. rufa* northeastern South America wintering population (DU4) on its wintering grounds in northeastern Brazil, based on the distribution of regularly-occupied coastal wintering sites (2010-2019) in the states of Maranhão and Ceara (eBird 2019; Morrison, Ross, Mobley and Mizrahi unpubl. data; Morrison *et al.* 2020c; map prepared by R. Nobre Soares and S. Allen). 28

Figure 9. Primary areas included in the Index of Area of Occupancy (IAO) for Red Knot *C. c. rufa* USA / Gulf of Mexico / Caribbean wintering population (DU5) at migration stopover sites on the coast of Hudson Bay in Manitoba and Ontario, near the mouth of the Nelson River (2009-2018), where all USA / Gulf of Mexico / Caribbean wintering population (DU5) knots are thought to occur during spring migration (eBird 2019; McKellar *et al.* 2015; Burger *et al.* 2020; map prepared by R. Nobre Soares and S. Allen). 29

Figure 10. North American regions of the International Shorebird Survey (including the Atlantic Canada Shorebird Survey and Ontario Shorebird Survey) used in analysis of survey results on southward migration (July-August; Figure courtesy of P.A. Smith). 48

Figure 11. Annual indices of abundance and estimated trend of *C. c. islandica* Red Knot wintering in Europe, 1976-2016, based on International Waterbird Census counts, including DU1 birds from Canada (Wetlands International 2018; IWC 2020; van Roomen pers. comm. 2020). Analytical methods are described in van Roomen *et al.* (2018): trends were detected and estimated using the program TrendSpotter, which produces trend lines (dark line) and 95% confidence intervals (light blue lines) (Visser 2004; Soldaat *et al.* 2007; Figure from van Roomen *et al.* 2018, courtesy of M. van Roomen). 54

Figure 12. Linear fit of annual indices of abundance of Red Knot, mostly birds from *C. c. roselaari* (DU2), based on fall surveys from the International Shorebird Survey Pacific and Intermountain Region for the 21-year period 1992-2013. The linear rate of decline was significant (-4.73%/year, r=-0.594, p=0.004), although precision of this estimate is relatively low. 56

Figure 13. Total counts of *C. c. rufa* Red Knots from the Tierra del Fuego / Patagonia wintering population (DU3) during aerial surveys in Tierra del Fuego, 1982-2020 (from: Morrison *et al.* 2020a,b; Morrison unpubl. data). There was a significant exponential decline across the period 2000-2020 (-6.3%/year, r=0.794, p=0.000). 59

Figure 14. Annual index of abundance of *C. c. rufa* Red Knot, mostly birds from the SE USA / Gulf of Mexico / Caribbean wintering population (DU5), based on fall surveys from the International Shorebird Survey in the Southeast US Coast Region of the United States, 1974-2016. While the overall regression is significant (dashed line, r=0.804, p=0.000), the points (solid lines) suggest relative stability from about 1974 to 1985 (r=0.210, p=0.512), followed by a period of significant decline from about 1984 to 1995 (r=-0.721, p=0.019), with more stable counts since about 1995 (r=-0.270, p=0.236)........................... 62

Figure 15. Exponential fit of annual indices of abundance of *C.c. rufa* Red Knot, mostly birds from the USA / Gulf of Mexico / Caribbean wintering population (DU5), based on fall surveys from the International Shorebird Survey Midcontinental Region for the 21-year period 1995-2016. 63

Figure 16. Exponential fit of annual indices of abundance of *C.c. rufa* Red Knot, mostly birds from the USA / Gulf of Mexico / Caribbean wintering population (DU5), based on fall surveys from the International Shorebird Survey Texas Coastal Region for the 21-year period 1993-2013. 64

Figure 17. Total number *C. c. rufa* Red Knot counted on aerial surveys (likely including birds from DUs 3, 4, and 5) during spring migration in Delaware Bay, 1982-2017 (L.J. Niles unpubl. data), showing linear (dashed line) and exponential (solid line) estimates of decline. 67

List of Tables

Table 1. Summary of habitat trends for Red Knot Designatable Units (DUs). DU1 = *C. c. islandica*; DU2 = *C. c. roselaari*; DU3 = *C. c. rufa* Tierra del Fuego / Patagonia wintering population; DU4 = *C. c. rufa* northeastern South America wintering population; DU5 = *C. c. rufa* southeastern USA / Gulf of Mexico / Caribbean wintering population.. 32

Table 2. Annual rates of changes in Red Knot numbers and likely DUs involved, derived from International Shorebird Survey counts from various regions of North America, showing annual rate of change (with 95% confidence limits), and the percent decrease that would occur (a) over the entire period 1974-2016, and (b) over a 3-generation period (21 years, 1995-2016)*. Statistically significant rates of change (where confidence limits do not include zero) are shown in bold/italics. DU2 = *C. c. roselaari*; DU3 = *C. c. rufa* Tierra del Fuego / Patagonia wintering population; DU4 = *C. c. rufa* northeastern South America wintering population; DU5 = *C. c. rufa* southeastern USA / Gulf of Mexico / Caribbean wintering population. 55

Table 3. Trend analyses of Christmas Bird Count data for different Bird Conservation Regions (BCRs) used by wintering populations of Red Knot in DU 2 (Pacific coast wintering population of *C.c. roselaari*) and DU5 (southeastern USA/Caribbean/Gulf of Mexico wintering population of *C. c. rufa*). Trends are shown as % change/year over the period indicated: (a) long-term 1970-2019 (49 years), and (b) 1993-2019 (26 years) provided by National Audubon Society (T. Meehan pers. comm. 2020), with upper and lower 95% confidence limits. Significant declines, where the confidence limits do not include zero, are shown in bold. Estimated declines over indicated periods are calculated from the annual rate of change for the entire period (49 years) and most recent three-generation period (21 years, based on the 1993-2019, 26-year period estimate). 57

Table 4. Status of Red Knot in the United States (NatureServe 2017). See Table 5 for ranking symbols.. 100

Table 5. Conservation status ranks in Canada for subspecies of Red Knot; *C. c. rufa*, *C. c. roselaari*, and *C. c. islandica* (CESCC 2016; NatureServe 2017)................. 101

Table 6. Critical habitat identified for Red Knot in Canada, showing current protectionstatus (CEC 2017; ECCC 2017), including the Western Hemisphere Shorebird Reserve Network (WHSRN), the Ramsar Convention (Ramsar), the Important Bird Areas initiative of BirdLife International (IBA), and other designations. 103

Table 7. Key sites used by Red Knot in other countries that receive protection or conservation status by conservation organizations, including the Western Hemisphere Shorebird Reserve Network (WHSRN), the Ramsar Convention (Ramsar), the Important Bird Areas initiative of BirdLife International (IBA), and other designations. "x" indicates that the site has been officially recognized by the organization. 104

List of Appendices

Appendix 1. Proportions of juvenile, sub-adult and adult birds in populations of Red Knot. 148

Appendix 2. Threats calculator table for Red Knot, *islandica* subspecies (DU1) 150

Appendix 3. Threats calculator table for Red Knot, *roselaari* subspecies (DU2) 154

Appendix 4. Threats calculator table for Red Knot, *rufa* subspecies, Tierra del Fuego / Patagonia wintering population (DU3) 159

Appendix 5. Threats calculator table for Red Knot, *rufa* subspecies, northeastern South America wintering population (DU4) 164

Appendix 6. Threats calculator table for Red Knot, *rufa* subspecies, USA / Gulf of Mexico / Caribbean wintering population (DU5) 169

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Calidris canutus* (Linnaeus 1758) (*C. c. islandica, C. c. roselaari, C. c. rufa*)

English name: Red Knot

French name: Bécasseau maubèche

Other names: Qajorlak (Inuktitut), Sitjariaq (Inuktitut from Nunavik), Playero rojizo (Latin American Spanish), Correlimos Gordo (Spanish), Maçarico-de-papo-vermelho (Portuguese)

Classification: Class: Aves

Order: Charadriiformes

Family: Scolopacidae

Subspecies

Globally, Red Knot is classified into six subspecies, each with distinctive morphological traits, breeding areas, migration routes, wintering areas, and annual cycles (Piersma and Davidson 1992; Tomkovich 1992, 2001; Piersma and Baker 2000; Piersma and Spaans 2004; Buehler and Baker 2005; Baker *et al.* 2013; Figure 1). Three subspecies occur in Canada: *Calidris canutus islandica*, *C. c. roselaari*, and *C. c. rufa*.

C. c. islandica (DU1) breeds in the northeastern Canadian High Arctic, probably as far west as Prince Patrick Island and south to Prince of Wales Island (Godfrey 1992; Morrison and Harrington 1992; Baker *et al.* 2013), and in the High Arctic of Greenland from the northwest around the north coast to about Scoresby Sound on the east coast. It winters in the United Kingdom, the Netherlands and other coastal areas of the European seaboard, and migrates to and from the breeding grounds through Iceland and northern Norway.

C. c. roselaari (DU2) breeds in northwestern Alaska and on Wrangel Island in Russia, and winters along the Pacific coast of the Americas, particularly on the coasts of southern California and northern Mexico. It migrates northwards via the Pacific coast of the United States and Canada, and southwards more directly from staging areas in Alaska to wintering areas from southern California to northwest Mexico (Buchanan *et al.* 2010; Carmona *et al.* 2013; Bishop *et al.* 2016; J. Johnson pers. comm. 2020).

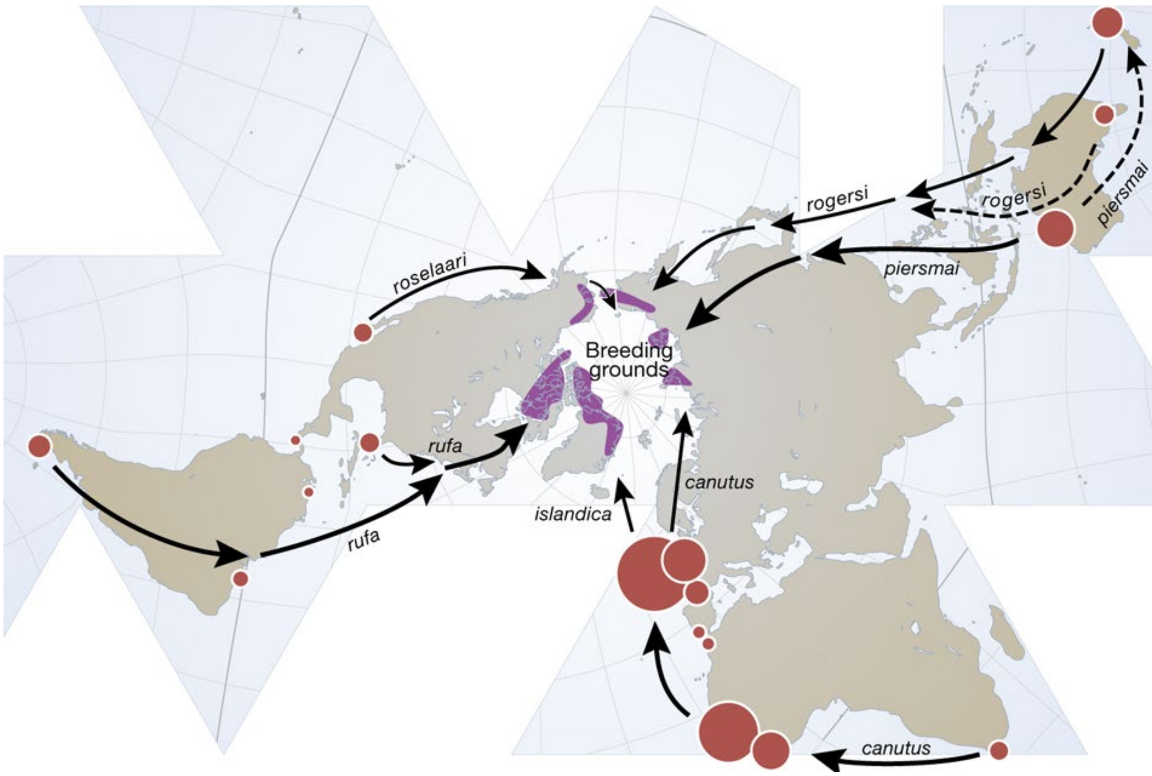

Figure 1. Worldwide distribution of the six recognized subspecies of Red Knot. Arrows connect non-breeding (= wintering) areas identified by dots (scaled to relative population size) with breeding areas (purple shading). For this report, *islandica* populations represent DU1 and *roselaari* populations represent DU2. For *rufa* wintering populations, dots in Tierra del Fuego represent DU3 (the Tierra del Fuego / Patagonia wintering population), those on the north coast of South America represent DU4 (the northeastern South America wintering population), and those in the southeastern United States and central America represent DU5 (the southeastern USA/Gulf of Mexico/Caribbean wintering population). Map by Hugo Ahlenius, GRID-Arendal 2010.

C. c. rufa breeds across the central Canadian low and middle Arctic, and has three distinct and widely separated wintering populations (Baker *et al.* 2013, 2020), in (a) southern South America, primarily in Tierra del Fuego (Chile and Argentina), with some birds in the coastal Patagonia region of Argentina (DU3 - Tierra del Fuego / Patagonia wintering population); (b) on the northeastern coast of South America, principally in the area of Maranhão, Brazil (DU4 - northeastern South America wintering population); and (c) in the southeastern United States and Gulf of Mexico, including areas in coastal Texas and adjacent areas of Mexico, as well as on islands in the Caribbean Sea (DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population).

Morphological Description

Red Knot is a medium-sized shorebird with a typical calidridine sandpiper profile (cover photograph), with a proportionately small head, and straightish bill tapering from thicker base to thinner tip and slightly longer than the head. It has a short neck, short tibia, stout tarsus, and long tapered wings giving an elongated streamlined profile to the body (length 23-25 cm, mass about 135 g although highly variable; Baker *et al.* 2013).

Red Knot is distinctive in breeding, or alternate, plumage, with face, neck, breast, and much of the underparts coloured rufous red. The lower belly and vent behind the legs tend to be lighter, especially in *rufa*, and some whitish or brownish feathers may be scattered through the breast (Baker *et al.* 1999). Feathers on the upperparts have dark brown-black centres edged with rufous and grey, giving the bird a spangled appearance that provides effective camouflage on the sparsely vegetated High Arctic breeding grounds. Flight feathers range inwards from dark brown or black in the primaries to grey in the secondaries and tail feathers, and there is a narrow whitish wing bar. Males tend to be more brightly coloured than females, with more extensive rufous on the underparts (Prater *et al.* 1977; Cramp and Simons 1983; Roselaar 1983; Hayman *et al.* 1986; Baker *et al.* 2013, 2020).

Red Knot is much plainer in winter, or basic, plumage, with white underparts and a pale, un-patterned grey back. The upper breast has greyish or brownish streaking, extending laterally along the flanks, and the head has dull greyish patterning with a whitish supercilium (Cramp and Simmons 1983).

Juveniles have similar plumage to winter adults but can be distinguished by dark subterminal bands on the feathers of the mantle, scapulars and coverts, giving the bird a characteristic scaly appearance (Prater *et al.* 1977). Juveniles may also have a pale dull buffish colour suffusing the breast (Baker *et al.* 2013).

Population Spatial Structure and Variability

The six subspecies of Red Knot that occur globally (Figure 1) are generally differentiated by the relative depth and extent of reddish colour on the ventrum, darkness of markings on the dorsum, bill length and body mass, as well as by differences in scheduling of migration and moult, and by geographic separation (Piersma and Davidson 1992; Tomkovich 1992, 2001; Piersma and Baker 2000; Piersma and Spaans 2004; Buehler and Baker 2005; Buehler and Piersma 2008, Baker *et al.* 2013, 2020). Recent genetic studies conducted by Verkuil *et al*. (2017) using 15,000 genome-wide single-nucleotide polymorphisms (SNPs), showed that all six subspecies can be differentiated genetically.

These subspecies likely diverged after the glacial maximum of the Wisconsin glaciation, 22,000-18,000 years BP, through eastwards expansion from a single Red Knot population that survived the glaciation by breeding in unglaciated regions of central and eastern Eurasia (Buehler and Baker 2005). The North American group is thought to have diverged from a Siberian ancestor about 12,000 BP, and split into the three North American subspecies within the past 5,500 years (Buehler and Baker 2005; USFWS 2014a), perhaps as recently as the last 1,000 years (Buehler *et al.* 2006).

Recent research on population genetics, migratory strategies and connectivity has resulted in the reassignment of some Red Knot populations to different subspecies than were considered in the previous COSEWIC Status Report (COSEWIC 2007). Those birds wintering on the Pacific coast of North and Central America, along southeastern USA / Gulf of Mexico / Caribbean coasts, and on the northeastern coast of South America, were formerly considered to be *C. c. roselaari* and were treated as such by COSEWIC (2007). However, *C. c. roselaari* is now considered only to comprise birds breeding in northwest Alaska, and Wrangel Island in Russia, and migrating to wintering areas on the Pacific coast of the Americas, centred in Mexico, with some birds in Panama and farther south (Buchanan *et al.* 2010; Baker *et al.* 2013; Carmona *et al.* 2013). All Red Knot wintering in the southeastern United States, Gulf of Mexico and Caribbean, as well as those in northeastern South America, are now considered part of subspecies *rufa* (Baker *et al.* 2012a,b; 2013; 2020; Verkuil *et al.* 2017; Burger *et al.* 2020).

The three Red Knot wintering populations now referable to *rufa* (Tierra del Fuego, northeastern South America, and southeastern USA / Gulf of Mexico / Caribbean) all migrate north to breeding areas in the low- and mid-Canadian Arctic islands (Niles *et al.* 2010a, 2012a; Burger *et al.* 2012a, 2020; Baker *et al.* 2013, 2020; Newstead *et al.* 2013). Movement studies using radio-telemetry, geolocators, and coloured leg bands indicate that most knots wintering in Texas, west Florida, the Gulf of Mexico, and the Caribbean migrate north in spring through central North America and likely nest in the westerly portions of the Canadian breeding range (Newstead *et al.* 2013). Birds from east Florida, northeastern Brazil, and Tierra del Fuego pass up the Atlantic coast of the United States in spring and likely nest in the more easterly part of the range (Niles *et al.* 2008; Newstead *et al.* 2013). However, details of where birds from each of these wintering populations breed within this area have yet to be determined.

Designatable Units

Revisions to the taxonomy of North American Red Knot populations since 2007, and the results of research on population genetics, morphometrics, migratory connectivity, and moult and migration scheduling, have necessitated a reconsideration of the delineation and number of Red Knot DUs. In November 2019, COSEWIC approved the use of five Red Knot DUs in this status assessment, based on information presented by the COSEWIC Birds Specialist Subcommittee (2019), and key points from that report are presented here.

DUs are considered by COSEWIC to be "discrete and evolutionarily significant units of the taxonomic species, where "significant" means that the unit is important to the evolutionary legacy of the species as a whole and, if lost, would likely not be replaced through natural dispersion" (COSEWIC 2017a). A population (or group of subpopulations) is recognized by COSEWIC as a DU if it has attributes that make it both discrete and evolutionarily significant, relative to other populations. COSEWIC recognizes three different lines of evidence for discreteness and four for evolutionary significance and uses a weight of evidence approach that builds on them (COSEWIC 2017a). At least one of the following lines of evidence from each should be met to justify a DU designation:

Discreteness:

- D1. Genetic distinctiveness, including inherited traits (e.g., morphology, life history, or behaviour) and/or neutral genetic markers (e.g., allozymes, DNA microsatellites, DNA RFLPs, or DNA sequences);

- D2. Natural disjunction between substantial portions of the species' geographic range, such that past and future movement of individuals between regions is severely limited, and where disjunction likely favours evolution of local adaptations;

- D3. Occupation of differing eco-geographic regions that reflect historical or genetic distinction. Although some dispersal may occur between regions, it is insufficient to prevent local adaptation.

Evolutionary Significance:

- E1. Evidence that the discrete population differs markedly from others in characteristics that reflect relatively deep phylogenetic divergence. Differences could be manifested by fixed differences in functional genes, or in stable cultural behaviour, or indicated by qualitative genetic differences at relatively slow-evolving markers;

- E2. Persistence of the discrete population in an unusual or unique ecological setting that is likely or known to have given rise to local adaptations;

- E3. Evidence that the discrete population represents the only surviving natural occurrence of a species that is more abundant elsewhere as an introduced population;

- E4. Evidence that loss of the discrete population would result in an extensive disjunction in the range of the species in Canada, where disjunction is defined as regions of species' occurrence widely separated geographically by regions of non-occupancy, such that natural dispersal among such regions is unlikely to occur.

The previous COSEWIC assessment of Red Knot recognized three DUs, corresponding to the subspecies occurring in Canada as then delineated (COSEWIC 2007). Although the populations assigned to two of these subspecies have been revised (see **Population Spatial Structure and Variability**), the three subspecies currently recognized in the Americas meet criteria for recognition as distinct DUs, based on the body of evidence from studies of population genetics (Verkuil *et al.* 2017), migratory connectivity (Morrison 1975; Niles *et al.* 2010b, 2012a; Wilson *et al.* 2011; Burger *et al.* 2012a, 2020; Carmona *et al.* 2013; Newstead *et al.* 2013; Baker *et al.* 2020), and morphometrics and moult patterns (Morrison and Harrington 1992; Engelmoer and Roselaar 1998; Harrington *et al.* 2007, 2010; Baker *et al.* 2013).

Red Knot of the subspecies *C. c. rufa* breed exclusively in Canada, nesting in the low to mid-Canadian Arctic (Figure 2). There are three distinct and widely separated *rufa* wintering populations: (a) in extreme southern South America, primarily in Tierra del Fuego, with some birds in the coastal Patagonia region of Argentina and small numbers on Chiloé Island, Chile; (b) on the northeastern coast of South America, principally in the area of Maranhão, Brazil; and (c) in coastal areas of the southeastern United States, Gulf of Mexico, including areas in coastal Texas and adjacent areas of Mexico, as well as on islands in the Caribbean Sea (Baker *et al.* 2013).

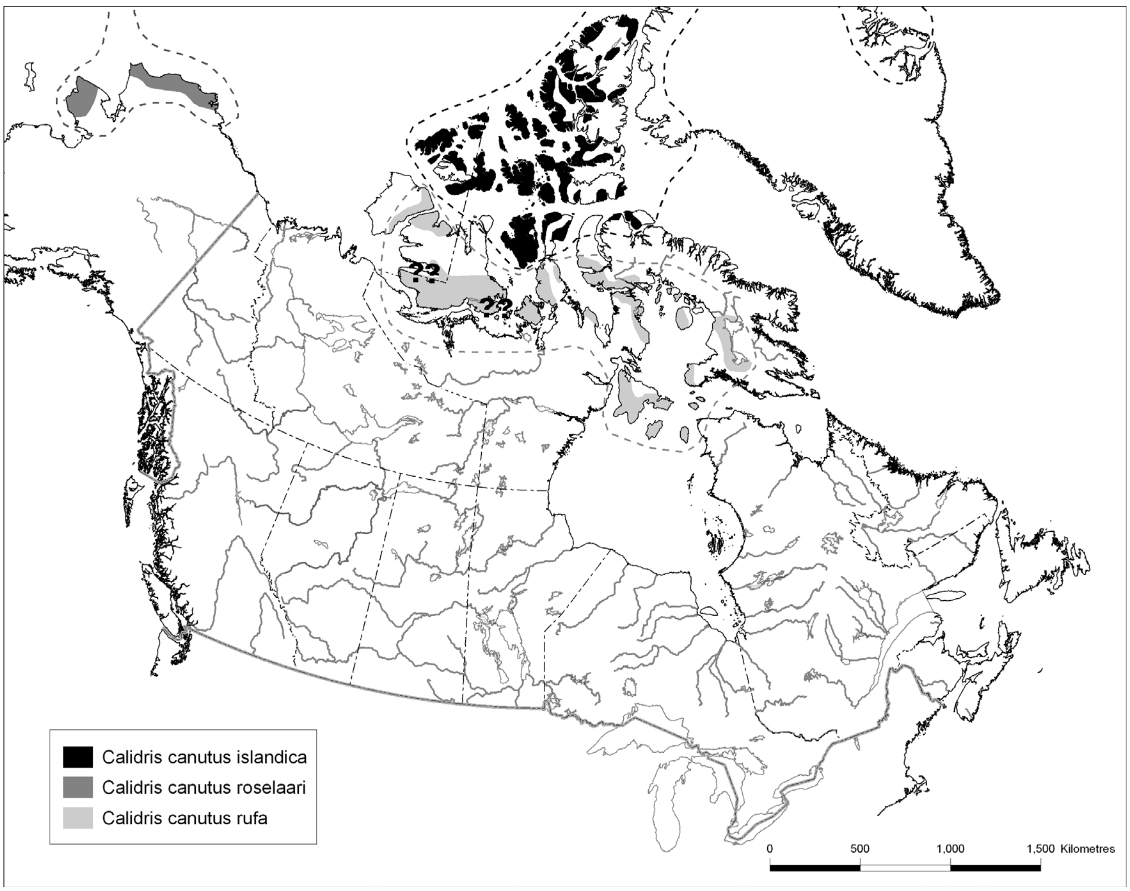

Figure 2. Breeding range of Red Knot in the Canadian Arctic. *C. c. islandica* breeds in the High Arctic regions of northeastern Canada and Greenland. *C. c. roselaari* breeds in northern and northwestern Alaska, and on Wrangel Island, Russia (not shown). *C. c. rufa* breeds entirely within Canada in the central Canadian Arctic. (Map created by the COSEWIC secretariat, COSEWIC 2007).

These three major wintering populations of *C. c. rufa* are also separable genetically (Baker *et al*. 2012a,b; Verkuil *et al.* 2017; Verkuil pers. comm. 2019), with an analysis of AFLP markers showing separation of individuals among the three populations (Baker *et al.* 2012a), with F_{ST} estimates of 0.16 - 0.20 (Verkuil pers. comm. 2019). While there are no strict thresholds for estimates of genetic differentiation in avian systems, F_{ST} >0.1 reflects strong genetic distinctiveness that is highly suggestive of evolutionary divergence (Toews pers. comm. 2019). As this genetic analysis does not show strong differences in slow-evolving neutral genetic markers, nor evidence of multiple fixed nuclear markers, these genetic data only indirectly support the use of criterion E1 to differentiate among DUs 3, 4 and 5, and suggest a more recent evolution of differences reflected in the genome-wide AFLPs.

Baker e*t al.* (2012a,b) concluded that the three genetically distinguishable wintering populations of *rufa* (DUs 3, 4, and 5) must show high fidelity to their wintering sites for the observed level of population structure to have evolved. They also indicated that these populations would likely be isolated on their Arctic breeding grounds, as gene flow and dispersal would otherwise swamp these genetic differences (Baker e*t al.* 2012a). There does appear to be overlap of breeding areas used by these populations within the low- and mid-Canadian Arctic, e.g., Southampton Island (Smith pers. comm. 2019) and elsewhere (Burger *et al*. 2020; Porter pers. comm. 2020). However, details of where each of these discrete wintering populations breeds, and the mechanism(s) by which these DUs maintain their genetic separation on the breeding grounds, remain unclear.

The five Red Knot DUs are described below with reference to relevant lines of evidence for discreteness and evolutionarily significance.

DU1 - *islandica* subspecies

This DU includes *islandica* Red Knot, which breed in the northeastern Canadian High Arctic, probably as far west as Prince Patrick Island and south to Prince of Wales Island (Godfrey 1992; Morrison and Harrington 1992; Baker *et al.* 2013, 2020; Figure 2). They winter in the United Kingdom, the Netherlands and other coastal areas of the western European seaboard and follow northward migration routes through Iceland and northern Norway (Godfrey 1992; Wilson 1981; Wilson *et al*. 2011, 2014). The delineation of this DU is unchanged from that previously assessed by COSEWIC (2007). Significant interchange of individuals between *islandica* and *rufa* breeding populations is unlikely, given their different migration systems, genetic separation (Verkuil *et al.* 2017), and largely non-overlapping breeding ranges (Godfrey 1992).

DU1 - *islandica* subspecies meets the following lines of evidence: D1, D2, D3, E2, E4.

- D1: Studies have shown varying degrees of genetic variation that support genetic distinctiveness of *islandica* and other Red Knot subspecies, with small differences in the frequency of different mitochondrial DNA sequences (Buehler and Baker 2005) but significant differentiation in single-nucleotide polymorphisms (Verkuil *et al.* 2017).

- D2: The breeding range of *islandica* in the northeastern Canadian High Arctic is thought to be largely disjunct from the breeding areas of rufa in the low- and mid-Canadian Arctic (Godfrey 1992), although the breeding range may overlap at mid-Arctic latitudes, for example around Somerset, North Baffin, Prince Patrick, and Melville Islands (USFWS 2014a; 2019). Its migratory pathways between nesting areas and wintering areas in western Europe are unique and disjunct, and these natural disjunctions likely favour the evolution of local adaptations related to migration and foraging strategies.
- D3: Birds of the *islandica* subspecies winter in coastal areas of northern boreal eco-geographic regions of Europe, over 5000 km from the nearest coastal wintering areas of *rufa*, and in very different ecoregions from those used by Red Knot wintering in southern North America and South America (Niles *et al.* 2006; Verkuil *et al.* 2017). They are thus exposed to different ecological conditions both on migration and in winter, which likely favour the evolution of local adaptations.
- E2: Red Knot of the *islandica* subspecies are unique in migrating from the Canadian High Arctic across the North Atlantic Ocean to western Europe. The disjunct nature of this discrete wintering population and its long-term persistence, likely since the end of the last Pleistocene glaciation (Buehler and Baker 2005), have led to adaptations involving considerable physiological transformation of internal organs and muscles during and after migration related to flight and breeding requirements (Piersma *et al.* 1999; Morrison *et al.* 2007).
- E4: Despite some areas of possible overlap of nesting *rufa* and *islandica*, current evidence suggests that all Red Knot breeding north of approximately 76°N are of the *islandica* subspecies (USFWS 2014a). Loss of this subspecies would eliminate this large and distinct portion of the Canadian breeding range.

DU2 - *roselaari* subspecies (*C. c. roselaari*; 2007 status report – *C. c. roselaari* and present DUs 4 and 5).

This DU includes *roselaari* Red Knot, which breed in northern and northwestern Alaska and on Wrangel Island in Russia (Figure 2), and migrate down or over the Pacific coast of Canada and the northwestern United States to coastal wintering grounds in California and the Pacific northwestern region of Mexico and parts of Central and South America (Buchanan *et al*. 2010; Carmona *et al*. 2013; Bishop *et al.* 2016). This delineation of *roselaari* differs significantly from that considered by COSEWIC (2007), which also included those populations now considered part of subspecies *rufa*, that overwinter in northeastern South America (DU 4) and southeastern USA / Gulf of Mexico / Caribbean (DU5; below).

C. c. roselaari is genetically distinguishable in genome-wide SNP variation from the other five Red Knot subspecies, including *rufa* (Verkuil *et al.* 2017). It is effectively isolated, with no indication of recent interchange with other groups of Red Knot and is most closely related genetically to *C. c. rogersi*, the subspecies that breeds farther west in eastern Russia (Verkuil *et al*. 2017). *C. c. roselaari* uses very different migration routes from other subspecies, moving between breeding areas in Alaska and Wrangel Island and wintering areas on the Pacific coast of North America (Carmona *et al.* 2013), although some birds of both *roselaari* and *rufa* may occur in Panama and Chiloé Island in winter (Navedo and Gutierrez 2018; Newstead and LeBlanc 2018), and Texas in spring (USFWS 2014a). Birds from the *roselaari* subspecies normally occur in Canada only in small numbers (hundreds or fewer) on the Pacific coast of British Columbia during spring and fall migration (e.g., Campbell *et al*. 1992; eBird 2019). Recent GPS tracking studies indicate that some *roselaari* Red Knot may stop regularly on isolated offshore islands off the coast of British Columbia during northward migration (Johnson pers. comm. 2020), and a few individuals may over-winter in some years (eBird 2019).

Verkuil *et al.* (2017) also identified genetic differentiation between *roselaari* breeding in Alaska and Wrangel Island. Emerging genetic evidence suggests that these differences might be as significant as other divisions in the Red Knot population structure (Conklin pers. comm. 2020). Observations of northward knot migration along the northwest Pacific coast of the United States suggest passage of two populations with slightly different timing and habitat use (Buchanan *et al*. 2017). However, with no ability to discern which individuals stopover in Canada during migration, there is currently insufficient information to warrant further subdivision of *roselaari* into two DUs.

The *roselaari* subspecies (DU2) meets the following lines of evidence: D1, D2, D3, E2.

- D1: *C. c. roselaari* is genetically distinguishable from the other five Red Knot subspecies, based on thousands of genome-wide SNPs (Verkuil *et al.* 2017).
- D2: The breeding range of *roselaari* in Alaska and Wrangel Island is disjunct from those of the *rufa* and *islandica* subspecies in the Canadian High Arctic (Portenko 1981; Godfrey 1992; Buehler and Piersma 2008). Its Pacific migratory pathways are unique and largely disjunct, although a few *roselaari* may overlap with *rufa* in Panama and Texas (USFWS 2014a). These natural disjunctions likely favour the evolution of local adaptations related to migratory flight and foraging strategies.
- D3: Birds of the *roselaari* subspecies winter in coastal areas of Pacific eco-geographic regions of western North America, in quite different ecoregions from those used by *rufa* Red Knot wintering in southeastern North America and northeastern and extreme southern South America. The major wintering areas of the two subspecies are at least 2000 km apart, although a few birds of these two subspecies may overlap in Panama and Texas (USFWS 2014a). Most are thus exposed to quite different ecological conditions both on migration and in winter, which likely favour the evolution of local adaptations.
- E2: Red Knot of the *roselaari* subspecies are unique in migrating from nesting areas in Alaska and Wrangel Island in Siberia down the Pacific coast of North America. The disjunct nature of this discrete breeding and wintering population, and its apparent long-term persistence, probably since the end of the last Pleistocene glaciation (Buehler and Baker 2005), has likely led to local adaptations to this ecological situation.

DU3 - Tierra del Fuego / Patagonia wintering population

This DU includes those *rufa* Red Knot that winter principally in Tierra del Fuego, with a few birds wintering along the Patagonian coast of Argentina and at Chiloé Island, Chile (USFWS 2014a), and it aligns with the full subspecies *rufa* as previously assessed by COSEWIC (2007). Birds from this population are unique in migrating much farther south than other populations, to distinct wintering areas that are disjunct by over 5000 km from the next nearest areas in coastal Brazil (USFWS 2014a). The wing moult schedule of this population differs from those wintering in more northerly areas, as it occurs entirely on the wintering grounds (Harrington *et al.* 2007, 2010a,b; Baker *et al.* 1998, 2013, 2020). Red Knot in the Tierra del Fuego / Patagonia wintering population (DU3) differ from those in DUs 4 and 5 in being smaller (e.g., in bill length and mass; Niles *et al.* 2008, Baker *et al.* 2013, 2020), and apparently in the degree of physiological changes on migration, as these longer-distance migrants likely undergo more reduction in their digestive apparatus and augmentation of flight muscles prior to migration (Baker *et al.* 2004; Atkinson *et al.* 2006, 2007).

The Tierra del Fuego / Patagonia wintering population (DU3) meets the following lines of evidence: D1, D3, E2.

- D1: This population has been differentiated from other wintering *rufa* populations based on an analysis of genome-wide AFLP markers (Baker *et al.* 2012a; Verkuil pers. comm. 2019). The degree and significance of this genetic differentiation is the subject of ongoing study (Conklin pers. comm. 2020).
- D3: Tierra del Fuego / Patagonia wintering population (DU3) individuals winter in coastal portions of the Southern Andes Ecozone in extreme southern South America, over 5000 km from birds from the northeastern South America wintering population (DU4) that winter in coastal areas of the equatorial Amazonian Orinocan Lowland Ecozone (Griffith *et al*. 2019), likely reflecting both historical and genetic distinctions. They thus over-winter in quite different coastal ecosystems. Although some birds from the Tierra del Fuego / Patagonia wintering population (DU3) pass through areas of coastal Brazil used by the northeastern South America wintering birds (DU4), any interchange has been insufficient to prevent local adaptation (see E2 below), and there are no records of individually marked birds changing wintering regions between years.

- E2: Birds in the Tierra del Fuego / Patagonia wintering population (DU3) are unique in migrating long distances (some 15,000 km in each direction) from the Canadian Arctic to extreme southern South America, with most overwintering in relatively harsh coastal climates of Tierra del Fuego. The disjunct nature of this discrete wintering population has led to local adaptations arising from their different ecological situations as compared to other *rufa* knot (northeastern South America wintering population - DU4, and southeastern USA / Gulf of Mexico / Caribbean wintering population - DU5), including moulting on the wintering grounds rather than at migration stopover areas in eastern North America (Baker *et al*. 1998, 2013; Harrington *et al*. 2007, 2010a,b), and being smaller and lighter (Baker *et al*. 2013; USFWS 2014a). These birds are also thought to undergo more pronounced physiological changes that facilitate their long migration, including accumulating large fat stores, undergoing substantial changes in metabolic rates, reducing the size of leg muscle, gizzard, stomach, intestines and liver, while increasing the size of pectoral muscles and heart (Baker *et al.* 2004; Atkinson *et al.* 2006; Niles *et al.* 2008).

<u>DU4 - northeastern South America wintering population</u>

This DU includes those *rufa* Red Knot that winter along the northeastern coast of South America, especially in the states of Maranhão and Ceara in northeastern Brazil, and occasional birds may winter in adjacent French Guiana and Suriname. This population was considered part of the *roselaari* DU in the previous status assessment (COSEWIC 2007). These Red Knot appear to be genetically distinguishable from the other wintering populations (Baker *et al.* 2012a; Verkuil pers. comm. 2019) and differ in using a disjunct geographical wintering area, morphometrics (measurements and weights; heavier than Tierra del Fuego / Patagonia wintering population (DU3) birds), and flight feather moult schedules (some of the northeastern South America wintering population (DU4) birds start but do not complete moult on migration in the eastern United States, while others undertake the entire wing moult on their South American wintering areas; Baker *et al*. 2013).

While birds from this population may co-occur with other *rufa* populations in Delaware Bay during northward migration, and at other east coast US sites during southward migration, their migration and moult schedules appear to be different (Baker *et al.* 2013; Lyons *et al.* 2017; Burger *et al.* 2020), and genetic studies indicate that the populations can be distinguished through high-resolution genetic techniques (Baker *et al.* 2012a; Verkuil pers. comm. 2019). Although some Tierra del Fuego / Patagonia wintering population (DU3) birds may occur on migration in northern Brazil, there are no observations of colour-marked birds from either of the Tierra del Fuego / Patagonia wintering population (DU3) or the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) there during the winter (Fedrizzi *et al.* 2016).

The northeastern South America wintering population (DU4) meets the following lines of evidence: D1, D3, E2.

- D1: This population has been differentiated from other wintering *rufa* populations based on an analysis of genome-wide AFLP markers (Baker *et al.* 2012a; Verkuil pers. comm. 2019). The degree and significance of this genetic differentiation is the subject of ongoing study (Conklin pers. comm. 2020).
- D3: Birds in the northeastern South America wintering population (DU4) winter in coastal areas of the equatorial Amazonian Orinocan Lowland Ecozone (Griffith *et al.* 2019), over 5000 km from birds in Tierra del Fuego / Patagonia wintering population (DU3) that winter in coastal portions of the boreal Southern Andes Ecozone, and over 2000 km from those that winter in coastal areas of the Eastern Temperate Forest and Tropical Wet Forest Ecoregions of southeastern US and Caribbean, likely reflecting historical distinctions supported by genetic differentiation (Baker *et al.* 2012a). They thus over-winter in different coastal ecosystems. Although some Tierra del Fuego / Patagonia wintering population (DU3) birds migrate through areas of coastal Brazil used by wintering birds from the northeastern South America (DU4), interchange appears to have been insufficient to prevent local adaptation within the northeastern South America wintering population (DU4; see E2 below), and there are no records of birds changing wintering areas.
- E2: Birds in the northeastern South America wintering population (DU4) have a variable moult schedule that differs from other *rufa* populations (Baker *et al.* 1998, 2013; Harrington *et al*. 2007, 2010a,b). Birds in this DU have slightly different morphometrics (Baker *et al*. 2013), and likely undergoing less pronounced physiological changes linked to migration strategies, especially compared to Tierra del Fuego / Patagonia wintering birds (DU3; Atkinson *et al*. 2006; Niles *et al*. 2008).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population

This DU includes those *rufa* Red Knot that winter in the southeastern United States, including coasts of Florida, the Gulf of Mexico coasts of Louisiana and the Texas/Mexico coastal border region, and islands in the Caribbean Sea. This population was considered part of the *roselaari* DU in the previous status assessment (COSEWIC 2007). These birds are genetically distinct from wintering populations in northern Brazil (the northeastern South America wintering population - DU4) and Tierra del Fuego / Patagonia wintering birds - DU3; Baker *et al.* 2012a,b; Verkuil pers. comm. 2019). While Red Knot that winter in the southeastern United States (eastern Florida and Georgia) appear to migrate northwards along the Atlantic coast through Delaware Bay, the birds wintering along the Gulf Coast (western Florida, Louisiana, Texas) migrate north in spring through central areas of the United States and Canada and likely nest in the more westerly parts of the Arctic breeding range (Newstead *et al.* 2013). The genetic separation that has been observed suggests that mixing does not occur with other *rufa* populations on the breeding grounds (Baker *et al.* 2012a).

The southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) meets the following lines of evidence: D1, D3, E2.

- D1: This population has been differentiated from other wintering *rufa* populations based on an analysis of genome-wide AFLP markers (samples involved Florida birds; Baker *et al.* 2012a; Verkuil pers. comm. 2019). The degree and significance of this genetic differentiation is the subject of ongoing study (Conklin pers. comm. 2020).
- D3: Birds in the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) winter in coastal areas of the Eastern Temperate Forest and Tropical Wet Forest Ecoregions of southeastern US and Caribbean, over 2000 km from those that winter in the equatorial Amazonian Orinocan Lowland Ecozone (Griffith *et al*. 2019), likely reflecting historical distinctions supported by genetic differentiation (Baker *et al*. 2012a). They thus over-winter in different coastal ecosystems.
- E2: Birds in the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) are relatively short-distance migrants, migrating only from the Canadian High Arctic to overwinter in coastal climates of the Gulf of Mexico and Caribbean Sea. The disjunct nature of this discrete wintering population appears to have led to local adaptations to this ecological situation, including a moult schedule that differs from other *rufa* populations that migrate longer distances, as they likely undertake their complete wing and body moult at migration stopover areas in eastern North America (Baker *et al*. 1998, 2013; Harrington *et al*. 2007, 2010a, 2010b); they also undergo less pronounced physiological changes linked to migration strategies (Baker *et al.* 2004; Atkinson *et al*. 2006; Niles *et al*. 2008).

Special Significance

Red Knot has long been considered a flagship species for shorebird conservation, owing to its long trans-hemispheric migrations, dependence on a relatively small number of key wintering and stopover areas, and its vulnerability to a range of environmental and climate-related factors (Morrison *et al.* 2004; Morrison 2018). Conservation of the habitats for Red Knot brings benefits to many other species of shorebirds and waterbirds. At some sites, knots and other shorebirds are economically important in attracting eco-tourists and birdwatchers (Karnicki 2016). Red Knot is one of the most studied shorebird species, and has served as a focal research species for development of conservation strategies for long-distance migrants (Myers et al. 1987; Harrington and Flowers 1996; Piersma and Baker 2000). It has been a focus of conservation efforts in Delaware Bay, and one individual knot (known as B95 from the inscription on his flag) was the subject of a popular book, *Moonbird* (Hoose 2012). This individual survived for more than 20 years through the major population crash of the Tierra del Fuego population and would have flown the distance to the Moon and back over the course of its lifetime (Hoose 2012). Conservation concerns surrounding knots and Horseshoe Crabs (*Limulus polyphemus)*, in Delaware Bay have been featured in newspaper articles, documentary films, and the award-winning book *The Narrow Edge* (Cramer 2015).

Aboriginal Traditional Knowledge was not identified for the Red Knot. However, this species is part of ecosystems that are important to Indigenous people who recognize the interconnectedness of all species within the ecosystem.

DISTRIBUTION

Global Range

The global distribution of the six currently recognized subspecies of Red Knots is shown in Figure 1 and described in the **Subspecies** section.

Canadian Range

The breeding range of Red Knot in the Canadian Arctic and likely breeding ranges of the three subspecies are shown in Figure 2.

Most *C. c. islandica* (DU1) breed in High Arctic areas of Greenland (Salomonsen 1950, 1967), with about 40% of the global breeding population nesting on the islands of the northeastern Canadian High Arctic (based on numbers in Whitfield *et al.* 1996; Morrison *et al.* 2006; COSEWIC 2007; Andres *et al.* 2012). The precise division between the ranges of *C. c. islandica* and *C. c. rufa* is uncertain, and birds nesting on either side of marine waters separating the mid-Arctic islands from the Queen Elizabeth Islands may be either subspecies (Godfrey 1992; Morrison and Harrington 1992).

Breeding grounds of *C. c. roselaari* (DU2) are found in north and northwestern Alaska and on Wrangel Island off northeastern Siberia in eastern Russia. This subspecies migrates through Canadian airspace in spring, and is usually observed in Canada only in small numbers on migration in coastal British Columbia (eBird 2019) and sometimes as far inland as Whitehorse, Yukon (Sinclair pers. comm. 2019). A few birds occasionally overwinter on the coast of southern British Columbia (eBird 2019). It is not known whether the birds occurring in Canada breed in Alaska or Russia, but is likely that both populations migrate through Canadian airspace.

The breeding range of *C. c. rufa* (Tierra del Fuego / Patagonia wintering birds (DU3), northeastern South America wintering population (DU4), and southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5)) falls entirely within the central and southern parts of the Canadian Arctic archipelago. Suitable habitat is not continuous in this region, resulting in discontinuities in occupancy (Figure 3). *Rufa* breeds on Coats and Mansel islands in northern Hudson Bay, Southampton Island, the east coast of Foxe Basin (Godfrey 1986; Gaston 2019), some islands in Foxe Basin (e.g., Prince Charles Island, Rowley Island, but not on Air Force Island; Johnston pers. comm. 2015), the west coast of Baffin Island (Morrison unpublished data; Niles *et al.* 2005, 2008, 2010a), probably across the Boothia Peninsula, King William Island, and southern Victoria Island (Parmelee *et al.* 1967). There seems to be no suitable habitat between northern Hudson Bay and the Rasmussen Basin (Niles *et al.* 2005), and Red Knot was not recorded there (Godfrey 1986,

1992) or in the Rasmussen Lowlands (Johnston *et al.* 2000). Although *rufa* appears to breed on the west side of the Boothia Peninsula and on King William Island (Niles *et al.* 2005), it is believed to be replaced by *islandica* on Prince of Wales Island to the north (Manning and Macpherson 1961; Godfrey 1992). Although there appears to be suitable habitat on Banks Island in the western Arctic archipelago, Red Knot has not been recorded breeding there (Manning *et al.* 1956; Johnston pers. comm. 2015) (see Figure 3; **Habitat**).

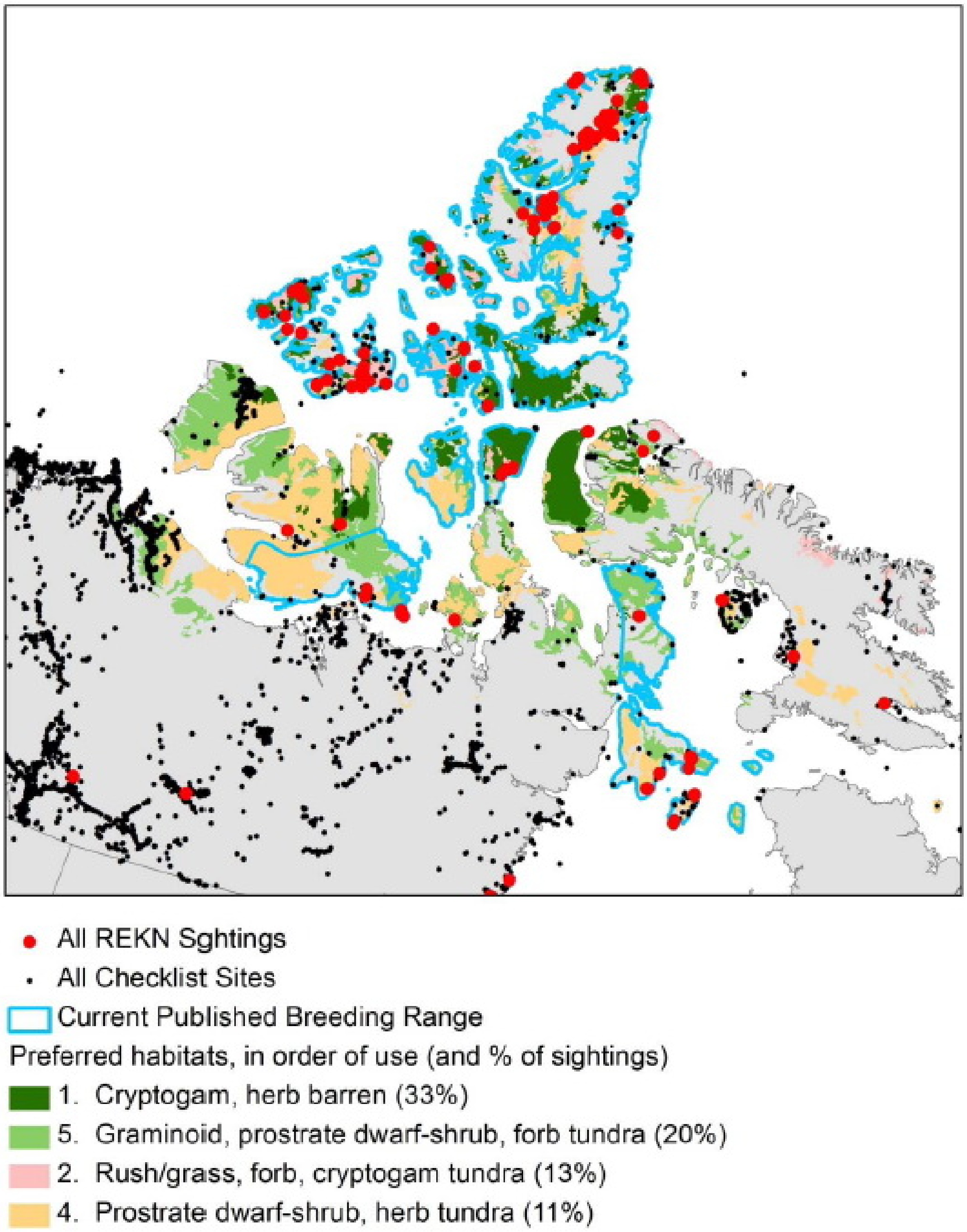

Figure 3. Known breeding range, distribution of preferred nesting habitats, and distribution of surveys and sightings of Red Knot (REKN) in the Canadian Arctic (from Rausch and Smith 2013).

Figure 3 was compiled by Rausch and Smith (2013) using the Circumpolar Arctic Vegetation Map (CAVM) and sightings of Red Knot in the Canadian Arctic, to determine the nesting habitats most used by the species (see **Habitat**). Overlaying the preferred habitats on a recent range map (Ridgely *et al.* 2007; CWS 2009) suggests that the current range likely includes large areas of unsuitable habitats, and that further surveys may reveal Red Knot breeding in areas with suitable habitat not included in the current range, such as the Brodeur Peninsula (Lathrop *et al.* 2018).

Extent of Occurrence (EOO) and Index of Area of Occupancy (IAO)

Little specific information is available on where Red Knot from each DU breed across the high Arctic, and the smallest area essential at any stage to the survival of knots from the Tierra del Fuego / Patagonia wintering population (DU3), northeastern South America wintering population (DU4), and southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) occurs outside Canada. Knots from the *roselaari* subspecies (DU2) only occur in Canada during the non-breeding period. As a consequence, different approaches and data sources were used to calculate the extent of occurrence (EOO) and index of area of occupancy (IAO) for each DU, as described below.

DU1 - *islandica* subspecies

The EOO for *C. c. islandica* in Canada was estimated as 1,084,949 km^2, calculated as a minimum convex polygon that encompasses its known breeding range within the northeastern Canadian Arctic, with an assumption of Prince of Wales Island as the southernmost limit (Figure 4).

The IAO for *islandica* was estimated as 327,212 km^2 (Figure 4), determined using a 2 x 2 km grid drawn over the Canadian breeding range (Figure 2), based in part on the distribution of preferred nesting habitats (Figure 3).

As different methods and data sources were used in the previous status report (COSEWIC 2007) to determine the EOO and IAO for DU1 - *islandica* subspecies, it is not possible to assess trends in these parameters.

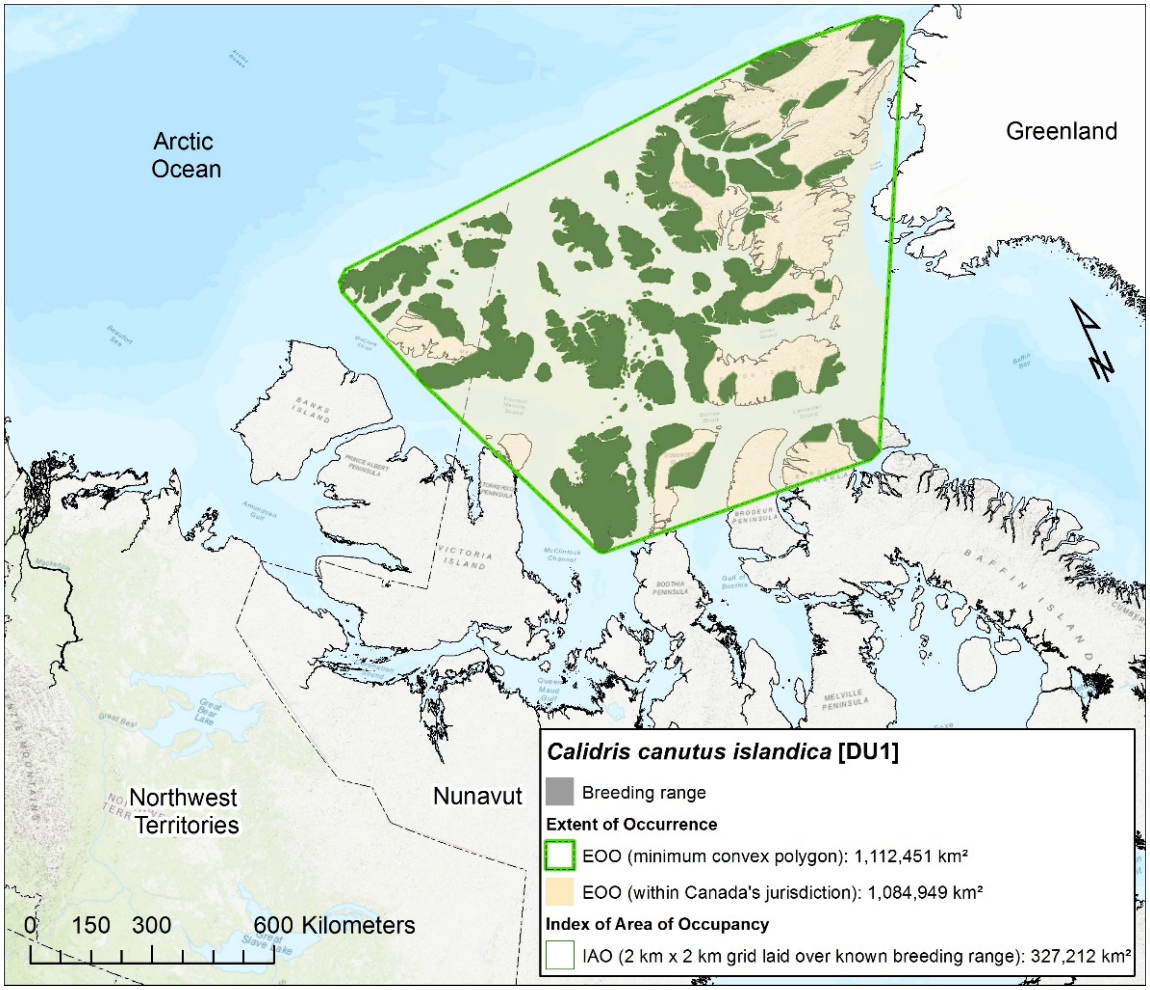

Figure 4. Extent of occurrence (EOO) and index of area of occupancy (IAO) for Red Knot *C. c. islandica* (DU1) in Canada, based on the known breeding range within the northeastern Canadian Arctic (from Figure 2; map prepared by R. Nobre Soares and S. Allen).

DU2 - *roselaari* subspecies

The EOO for *C. c. roselaari* in Canada was estimated as 167,016 km^2, which encompasses areas along the Pacific coast of British Columbia where Red Knot have been recorded on migration or during winter during the 10-year period 2009-2018 (eBird 2019), together with records of GPS-tagged birds made during spring migration in 2017 and 2018 (Johnson pers. comm. 2020) (Figure 5).

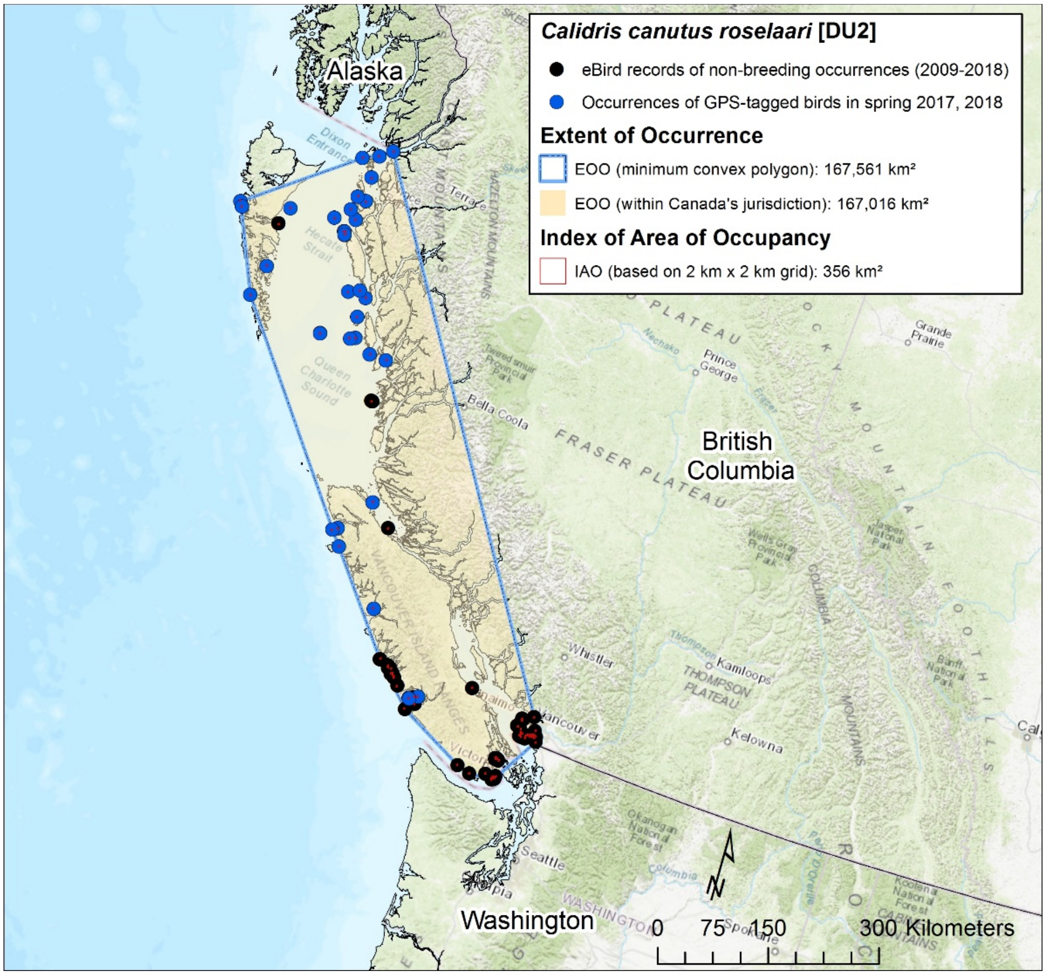

Figure 5. Extent of occurrence (EOO) and that portion of the index of area of occupancy (IAO) for Red Knot *C. c. roselaari* (DU2) that occurs within Canada, based on records of Red Knot on migration or in winter (2009-2018) from eBird (2019), shown by black dots, and records from GPS-tagged birds during spring migration in 2017 and 2018 (Johnson pers. comm. 2020), shown by blue dots (map prepared by S. Allen).

In some cases (e.g., crucial feeding sites for migratory taxa), the relevant area of occupancy is the smallest area essential at any stage to the survival of the taxon (IUCN Standards and Petitions Subcommittee 2017; COSEWIC 2019), and in such cases, this area need not occur within Canada. As stopover sites used on spring migration likely represent the smallest essential areas used during the annual cycle by *roselaari* Red Knots (Johnson pers. comm 2020), IAO was calculated for this DU during spring migration. A minimum estimate of the Canadian portion of the IAO during the spring migration period is 356 km^2, based on the same migration records in coastal British Columbia used to estimate EOO (Figure 5). However, IAO calculated for this life stage should account for other undocumented sites in British Columbia, as well as coastal sites in Alaska and the Pacific Coast of the contiguous United States, in order to reflect the smallest area essential during spring migration for this DU. As these sites are together estimated to total an additional 200-800 km of coastline, it is probable that overall IAO is between 500 and 2000 km^2 during spring migration.

As EOO and IAO for this DU were not delineated the same way in the previous status report (COSEWIC 2007), it is not possible to assess trends in EOO and IAO.

Tierra del Fuego / Patagonia wintering population (DU3), northeastern South America wintering population (DU4), and southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5)

The size of the EOO for *C. c. rufa,* which comprises these three DUs, was estimated as 1,500,261 km^2, calculated as a minimum convex polygon that encompasses the breeding range of these three DUs within the central Canadian Arctic (Figure 6).

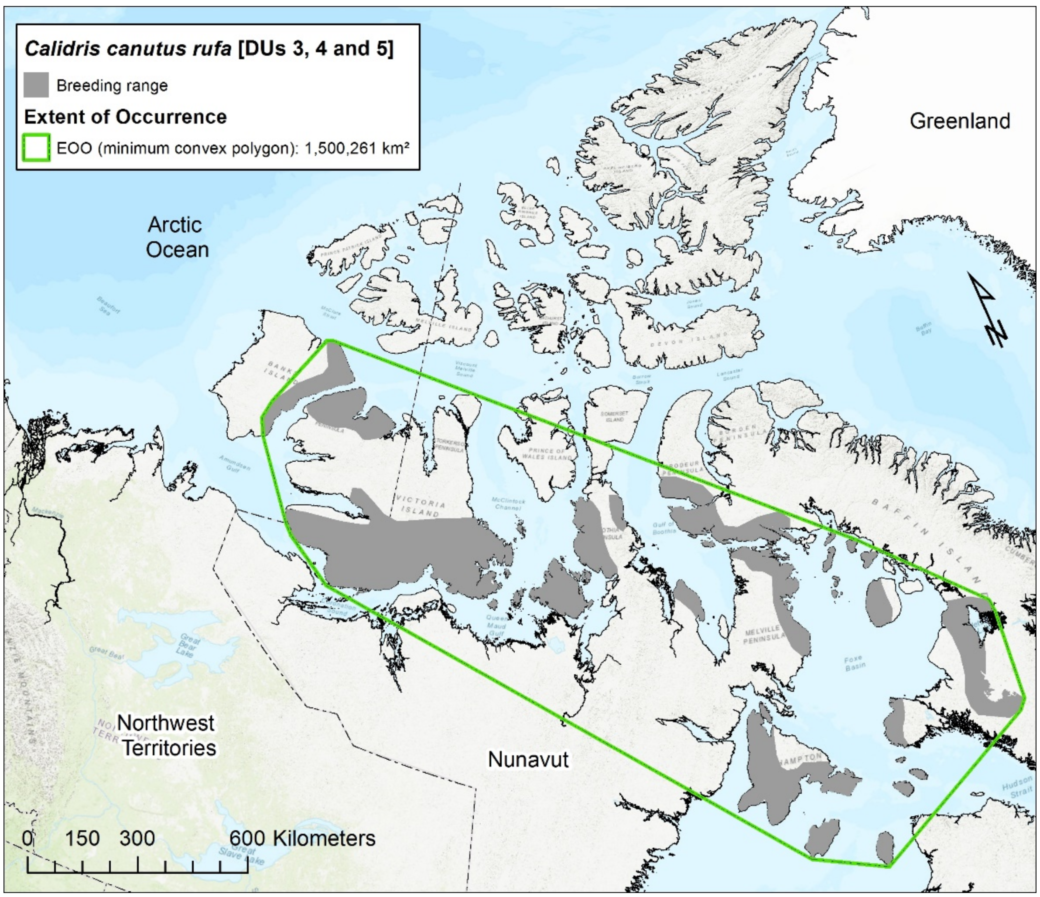

Figure 6. Extent of occurrence (EOO) for Red Knot *C. c. rufa* (DUs 3, 4, and 5) in Canada, based on the known breeding range of the subspecies within the central Canadian Arctic (from Figure 2; map prepared by R. Nobre Soares and S. Allen).

Although there is some recent information available on breeding sites of individuals from these DUs, no consistent patterns have emerged (Burger *et al.* 2020; Porter pers. comm. 2020). Although there appears to be significant overlap of the EOO of all three DUs within the central Canadian Arctic, the finding that genetic markers can differentiate among the wintering populations (DUs) suggests some degree of genetic isolation on the breeding grounds (Baker *et al.* 2012a,b). As the portion of the total EOO of *C. c. rufa* assignable to each of the Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4), and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) is thus unknown, each is assigned the same value of 1,500,261 km^2, equal to the EOO for all *C. c. rufa*, based on the breeding distribution shown in Figure 6. This is clearly a maximum value, although considering the abundance estimates of each DU and the scattered breeding dispersion of Red Knot across much of the Canadian Arctic, it is very likely that the actual EOO for each far exceeds 20,000 km^2 and other EOO thresholds used in applying assessment criteria.

As Red Knots from the Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4) and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) breed in a dispersed fashion over relatively large areas of the Canadian Arctic, but are concentrated in smaller areas at migration stopovers or on the wintering grounds outside Canada, IAO was calculated for these DUs at these latter sites.

A minimum estimate of IAO for the Tierra del Fuego / Patagonia wintering population (DU3) of 1072 km^2 was calculated by overlaying a grid with a cell size of 2x2 km on regularly occupied sites within the concentrated wintering range on the coasts of Tierra del Fuego and southern Patagonia, where Red Knot has been recorded during the 10-year period 2009-2018 (eBird 2019; Morrison *et al.* 2020a; Morrison unpubl. data) (Figure 7). Up to 5% of the total population (maximum of 375 mature individuals) may occur in winter at sites outside this area (Morrison pers comm. 2019). If each individual occurred in a separate 2x2 km grid square, they could account for an additional portion of the IAO of up to 1500 km^2. However, given the tendency of wintering Red Knots to cluster in flocks, the additional portion of the IAO occupied by the peripheral birds is likely 100-200 km^2 at most, suggesting that the actual IAO used by Red Knot from DU3 in winter is probably 1100-1300 km^2.

Red Knot from the northeastern South America wintering population (DU4) also concentrate in coastal South America during winter, where IAO was calculated. The area of the core IAO of 684 km^2 was calculated by overlaying a grid with a cell size of 2 x 2 km over regularly occupied sites within the wintering range on the coasts of northeastern Brazil, where Red Knot has been recorded during the 10-year period 2010-2019 (Morrison, Ross, Mobley, and Mizrahi unpubl. data; eBird 2019; NJA 2020; Morrison *et al.* 2020c) (Figure 8). However, some birds from this DU overwinter in small groups at other scattered coastal sites in adjacent French Guiana and Suriname. If these birds represent about 5% of the population, or about 1000 individuals (Morrison pers. obs.), they likely occupy an additional portion of the IAO roughly equal to about 300-600 km^2, suggesting that the total IAO used by Red Knot from DU4 in winter is probably about 1000-1600 km^2.

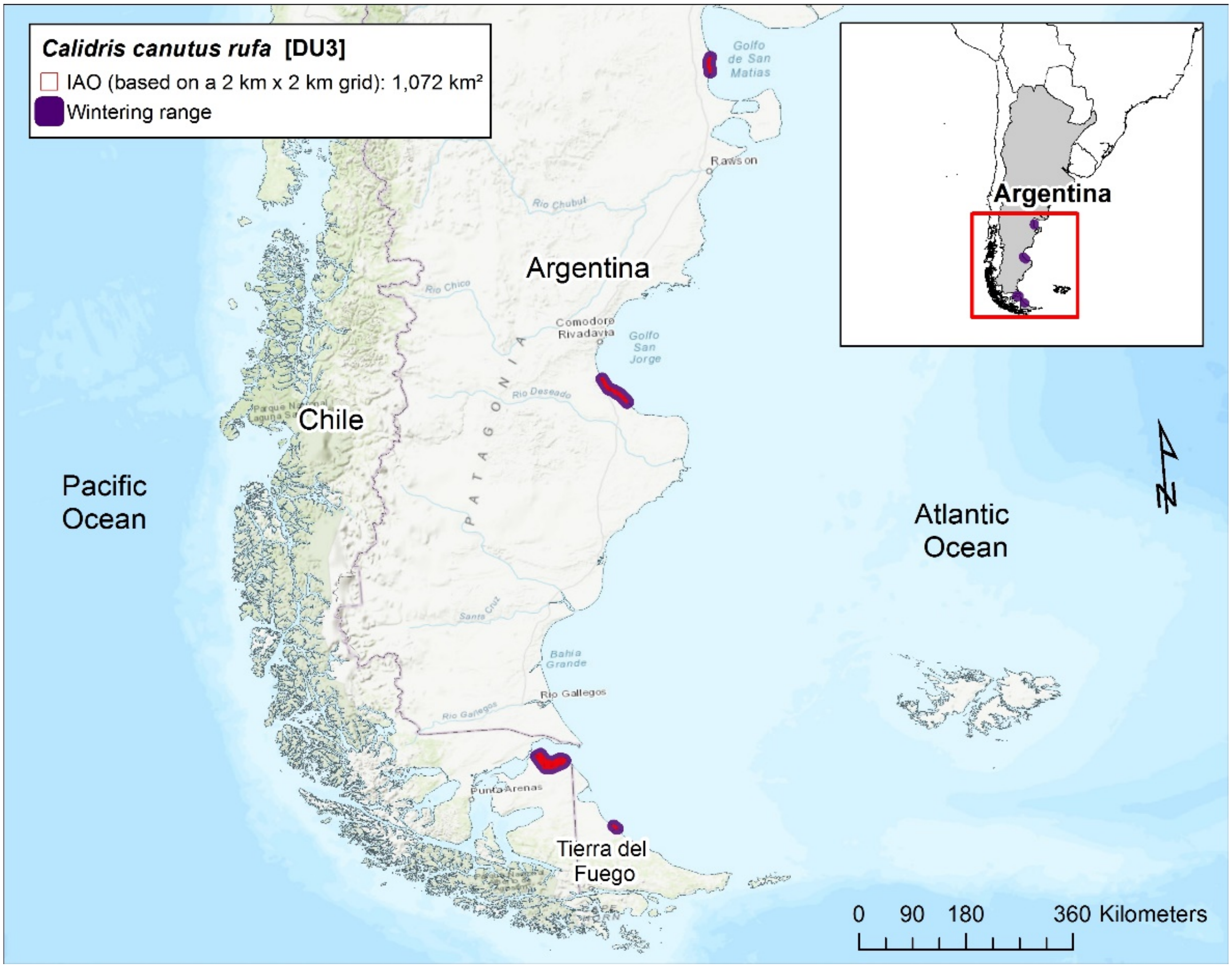

Figure 7. Primary areas included in the index of area of occupancy (IAO) for Red Knot *C. c. rufa* Tierra del Fuego / Patagonia wintering population (DU3) on its wintering grounds in southern Argentina and Chile, based on the distribution of regularly occupied wintering sites (2009-2018) on the coasts of Tierra del Fuego and Patagonia (eBird 2019; Morrison *et al.* 2020b; Morrison unpubl. data; map prepared by R. Nobre Soares and S. Allen).

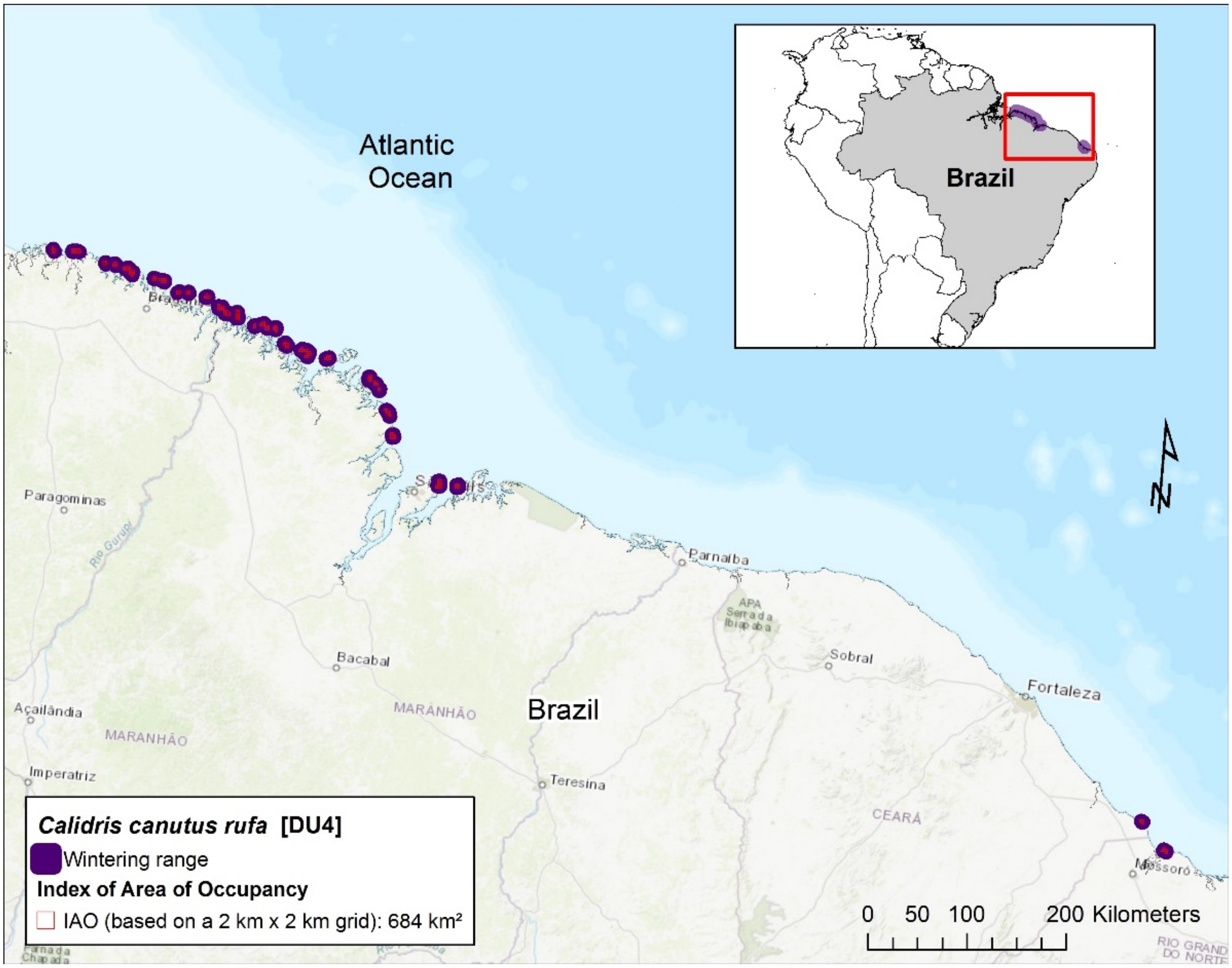

Figure 8. Primary areas included in the index of area of occupancy (IAO) for Red Knot *C. c. rufa* northeastern South America wintering population (DU4) on its wintering grounds in northeastern Brazil, based on the distribution of regularly occupied coastal wintering sites (2010-2019) in the states of Maranhão and Ceara (eBird 2019; Morrison, Ross, Mobley and Mizrahi unpubl. data; Morrison *et al.* 2020c; map prepared by R. Nobre Soares and S. Allen).

The IAO for the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) of 2,548 km^2 was calculated by overlaying a grid with a cell size of 2 x 2 km over migration stopover sites along the coast of Hudson Bay in Manitoba and extreme northwestern Ontario, near the mouth of the Nelson River, where all or most of the birds in the DU are thought to occur during spring migration, during the 10-year period 2009-2018 (McKellar *et al.* 2015; Burger *et al.* 2020; eBird 2019) (Figure 9). This value is considered to be a minimum estimate, as it is likely that small numbers may occur in coastal Hudson Bay outside the survey area in spring.

As different data sources, areas, and DU delineation methods were used to determine the EOO and IAO of the Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4), and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), compared to the 2007 Status Report (COSEWIC 2007), it is not possible to assess trends in these parameters for these DUs.

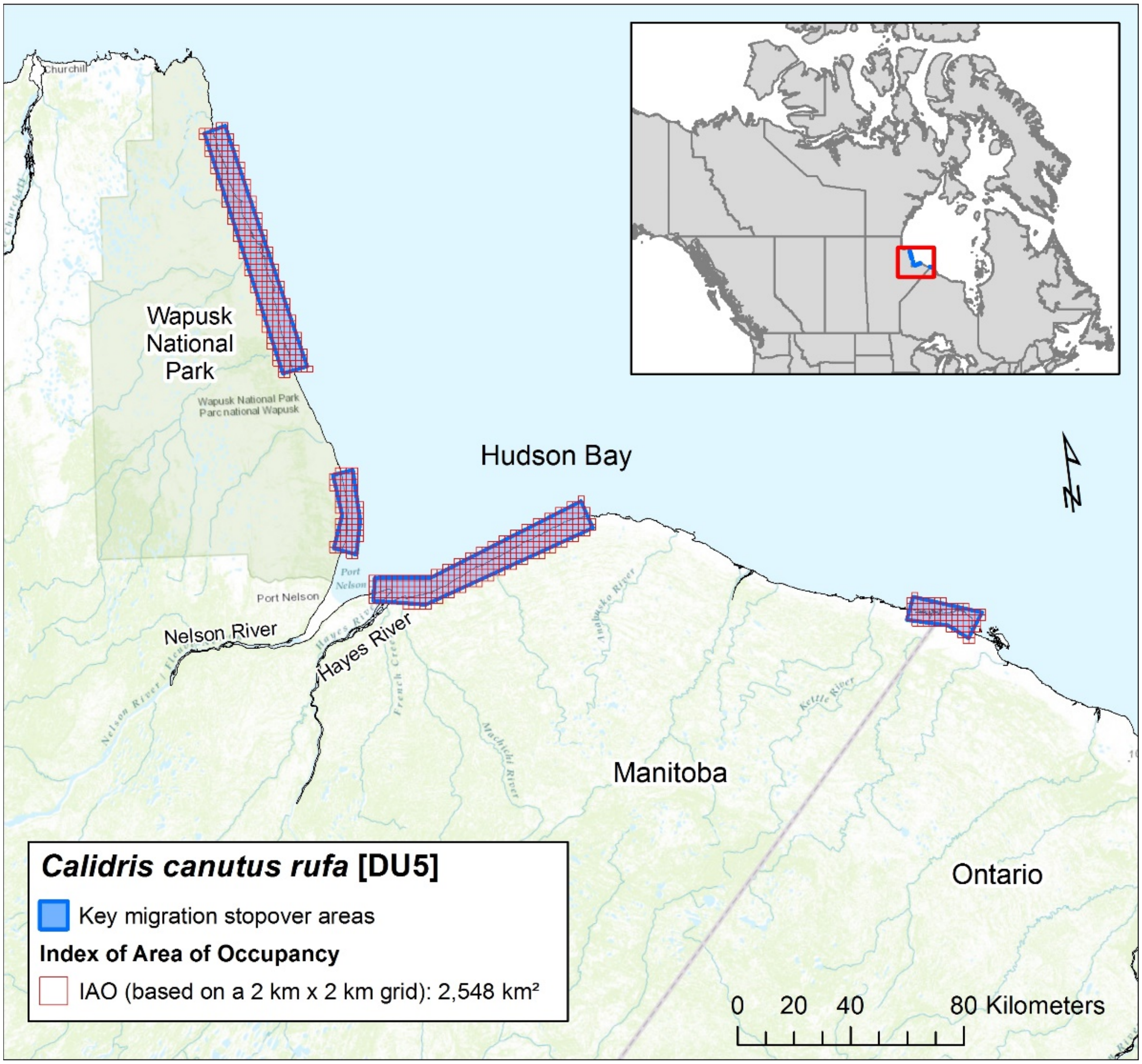

Figure 9. Primary areas included in the index of area of occupancy (IAO) for Red Knot *C. c. rufa* southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) at migration stopover sites on the coast of Hudson Bay in Manitoba and Ontario, near the mouth of the Nelson River (2009-2018), where all southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) knots are thought to occur during spring migration (eBird 2019; McKellar *et al.* 2015; Burger *et al.* 2020; map prepared by R. Nobre Soares and S. Allen).

Search Effort

For the *islandica* subspecies (DU1), the Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4), and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), information from Arctic nesting grounds has come from targeted regional and local surveys, such as the Arctic Program for Regional and International Shorebird Monitoring (Arctic PRISM) (Bart and Johnston 2012; Government of Canada 2018), and the Northwest Territories - Nunavut Bird Checklist Survey (CWS 2009), as well as from historical avifaunal surveys (e.g., MacDonald 1953; Parmelee and MacDonald 1960; Parmelee *et al.* 1967; Godfrey 1986). In Europe, counts of *islandica* subspecies (DU1) Red Knot on the wintering grounds are coordinated by Wetlands International (Wetlands International 2018).

For the Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4), and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), information on numbers and distribution of Red Knot in Canada south of the breeding grounds comes from ground counts and aerial surveys. Ground counts include surveys conducted by biologists (e.g., in Quebec) and volunteer survey schemes such as the Atlantic Canada Shorebird Survey scheme (ACSS, formerly Maritimes Shorebird Survey scheme, MSS) and the Ontario Shorebird Survey (OSS). These volunteer programs are coordinated through PRISM (Bart *et al.* 2002; U.S. Shorebird Conservation Plan Partnership 2018). Aerial surveys conducted by the Canadian Wildlife Service of Environment and Climate Change Canada (CWS) have provided important information from James Bay (Morrison and Harrington 1979; Friis 2017; Friis and Morrison 2018) and Hudson Bay (McKellar *et al.* 2015), and the Mingan Islands, Quebec (Buidin *et al.* 2010; Lyons *et al.* 2017; Aubry pers. comm. 2019). For the *roselaari* subspecies (DU2), historical records from the west coast of Canada (Campbell *et al.* 1998) have been supplemented with records from eBird (2019), which also provides information on records from all DUs from all parts of the Americas.

Internationally, coastal aerial surveys have provided much information on shorebird distribution at migration stopover areas and wintering sites, involving *roselaari* subspecies (DU2), Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4), and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5). ECCC-CWS conducted “Atlas” surveys covering the coasts of South America in the 1980s (Morrison and Ross 1989) and further “Atlas” projects were conducted in Panama (Morrison *et al.* 1998) and Mexico (Morrison *et al.* 2009). For the Tierra del Fuego / Patagonia wintering population (DU3), the key areas in Tierra del Fuego have been surveyed annually since 2000 (Morrison 2018; Morrison *et al.* 2020a), with additional coverage of the coastline of Patagonia in 2002, 2003, 2004 and 2012 (Morrison *et al.* 2004, 2020b; Morrison 2018). For the northeastern South America wintering population (DU4), aerial surveys of the northeastern coast of South America (covering the Guianas and north and northeastern Brazil) have been conducted in various years between 2008 and 2019. These ongoing surveys provide regular monitoring of the most important wintering areas (Morrison *et al.* 2012, 2020a,b,c; NJA 2020). For the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), ground and aerial surveys have provided information from the southeastern United States (Niles *et al.* 2006). Further information on search effort is given in **Sampling Effort and Methods** and **Population Sizes and Trends**.

HABITAT

Habitat Requirements

Red Knot uses different habitats for breeding, migration, and wintering. In the Arctic, knots nest in exposed barren habitats, such as windswept ridges, slopes, or plateaus (Pleske 1928; Parmelee and MacDonald 1960; Nettleship 1974; Baker *et al.* 2013). Nest sites are usually on dry, south-facing sites, often near wetlands or lake edges which may be used for feeding and where the young are led after hatching (Whitfield and Brade 1991; Tomkovitch and Soloviev 1996). Using the Circumpolar Arctic Vegetation Map (CAVM), Rausch and Smith (2013) found that preferred nesting habitats for Red Knot were "cryptogam, herb barren", "graminoid prostrate dwarf-shrub, forb tundra", "rush/grass, forb, cryptogam tundra", and "prostrate dwarf-shrub, herb tundra" habitats which are widely distributed across the Arctic (Figure 3). Nesting densities are usually low, with nests often 0.75-1 km or more apart (Nettleship 1974; Niles *et al.* 2010a). An analysis of breeding habitat characteristics of *C. c. rufa,* based on 21 nests on Southampton Island and relocations of radio-tagged birds over a wider section of the central Canadian Arctic, indicated that birds generally nested within 150 m of sea level, within 50 km of the coast, and in areas with less than 5% vegetation cover (Niles *et al.* 2005, 2008; Lathrop *et al.* 2018). Foraging habitats may be considerable distances from nests (up to 10 km) and are usually in damp or wetland habitats, or barren areas (Whitfield and Brade 1991; Niles *et al.* 2010a; Baker *et al.* 2013; Morrison unpubl. data).

On migration and in winter, Red Knot favours coastal areas with extensive intertidal flats, usually sand although sometimes mud, where the birds feed on bivalves and other benthic invertebrates (Schneider and Harrington 1981; Piersma *et al.* 1993; Baker *et al.* 2013). The most important wintering habitats of birds from the Tierra del Fuego / Patagonia wintering population (DU3) are the massive intertidal sand and mudflats at Bahia Lomas, Chile, and Bahia San Sebastian, Argentina, in Tierra del Fuego. Knots also forage on *restinga* habitats, rocky intertidal platforms that support a variety of invertebrates, at Rio Grande on the Atlantic coast of Tierra del Fuego, Argentina, and on migration stopover areas on the coast of Patagonia (Morrison and Ross 1989; González *et al.* 1996). Similar rocky intertidal habitat is used in the Mingan Archipelago, Quebec, during southward migration (Baker *et al.* 2013). During spring migration in Delaware Bay, knots forage on sandy beaches used by nesting Horseshoe Crab, feeding on crab eggs (Botton *et al.* 1994; Tsipoura and Burger 1999). Red Knot also use eroding peat banks along the shoreline of the eastern United States on northward and southward migration, where they feed on mussel spat (Niles *et al.* 2010a; Baker *et al.* 2013). They sometimes forage within the tide wrack on beaches, salt marshes, brackish lagoons, mangrove areas, and mudflats on migration and in winter, in the southeastern United States and northeastern Brazil (Niles *et al.* 2005, 2010a; Cohen *et al.* 2009, 2010). Knots moving through the interior of North

America may use inland saline lakes and agricultural fields (Gratto-Trevor *et al.* 2001; Beyersbergen and Duncan 2007; Baker *et al.* 2013).

An important aspect of habitat quality for Red Knot on migration and wintering areas is the proximity of suitable roosting areas that provide an undisturbed area safe from ground or aerial predators and human disturbance (Ferrari *et al.* 2002; Peters and Otis 2006; Rogers *et al.* 2006).

Habitat Trends

Habitat trends for the DUs are summarized in Table 1, based on the following assessments.

Table 1. Summary of habitat trends for Red Knot Designatable Units (DUs). DU1 = *C. c. islandica*; DU2 = *C. c. roselaari*; DU3 = *C. c. rufa* Tierra del Fuego / Patagonia wintering population; DU4 = *C. c. rufa* northeastern South America wintering population; DU5 = *C. c. rufa* southeastern USA / Gulf of Mexico / Caribbean wintering population.

	Stage of Annual Cycle	Habitat trend summary	Risk[1]	Reference[2]
DU1	Breeding	Possible short-term increase in southern areas; large long-term losses may result in longer migration distances to reach suitable nesting habitat.	Medium to High	1,2,3
	Migration	Likely losses due to sea level rise	Medium to High	4
	Wintering	Likely losses due to sea level rise; habitat degradation through commercial shell-fish fisheries	Medium	5
DU2	Breeding	Long-term negative effects likely from reduced habitat quality	Medium	1
	Migration	Likely severe loss of habitat through sea level rise; estimates include 44% loss by 2100 and 14-39% by 2050-2100.	Medium to High	4,6,7
	Winter	Likely losses from sea level rise.	Medium	
DU3	Breeding	Likely losses in southern part of breeding range, possibly severe in the long term, with longer migration distances to reach suitable habitat. 1-36% of currently suitable habitat remaining by 2070-2100.	Medium to High	2,3
	Migration	Habitat losses through sea level rise, 20-57% habitat loss by 2050-2100.	Medium to High	4,6
	Winter	Disturbance and disease affecting some wintering habitats; oil developments and pollution affecting feeding habitats	Medium to High	8,9

	Stage of Annual Cycle	Habitat trend summary	Risk[1]	Reference[2]
DU4	Breeding	Loss of habitat in southern part of breeding range, possibly severe in the long term, with longer migration distances needed to reach suitable habitat. 1-36% of currently suitable habitat remaining by 2070-2100.	Medium to High	2,3
	Migration	Habitat losses through sea level rise, 20-57% habitat loss by 2050-2100.	Medium to High	4,6
	Winter	Largely not assessed. Proposed wind farm developments may threaten some wintering habitats.	Medium	10
DU5	Breeding	Loss of habitat in southern part of breeding range, possibly severe in the long term, with longer migration distances needed to reach suitable habitat. 1-36% currently suitable habitat remaining by 2070-2100.	Medium to High	2,3
	Migration	Habitat losses through sea level rise, 20-57% habitat loss by 2050-2100.	Medium to High	4,6
	Winter	Ongoing coastal development, storm degradation of habitats	Medium to High	11

[1]General assessment based on description of trends

[2]References: 1. Meltofte *et al.* 2007; 2. Lathrop *et al.* 2018; 3. Wauchope *et al.* 2016; 4. Galbraith *et al.* 2014; 5. Blew *et al.* 2017; 6. Galbraith *et al.* 2005; 7. Glick *et al.* 2007; 8. Escudero *et al.* 2012; 9. Morrison 2018; 10. RIGM pers. obs.; 11. Niles *et al.* 2010a.

It is unlikely that major changes in the extent of breeding habitat have recently occurred in the Canadian Arctic, although long-term changes resulting from climate change will likely affect Red Knot (all DUs), probably in a negative fashion (Meltofte *et al.* 2007). Lathrop *et al.* (2016) assessed likely future habitat changes in the Canadian Arctic under three climate change scenarios - full (*islandica* and *rufa* – DU1 and DUs 3,4,5), *islandica*-only (DU1), and *rufa*-only (DUs 3,4,5). Their modelling results: (1) predicted a widespread decrease in breeding habitat suitability in the southern portion of the *rufa* breeding range, while the *rufa*-only (DUs 3,4,5) model suggested increasing habitat suitability in selected areas in the central portion of the *rufa* range; (2) the *islandica*-only (DU1) model suggested an increase in suitable habitat area extending across the southern section of the High Arctic Islands; (3) in both cases, a significant portion of the new habitat areas predicted by the models occurred at the spatially distant end of the subpopulation breeding ranges, requiring each subspecies population to travel farther to utilize new habitat; and (4) results suggest that the *rufa* subpopulation would be more vulnerable to effects of future climate change than *islandica*. Scenarios presented by Wauchope *et al.* (2016) under different climate change models are less optimistic. Whereas the amount of “climatically-suitable breeding conditions” increased for about half of 24 shorebird species analyzed in the North American Arctic, for Red Knot few such areas would remain by 2070; 12% and 5% compared to present under “optimistic” and “pessimistic” emission scenarios, respectively. The percentage of suitable habitat remaining by 2070 was 6-36% and 1-18% under the two scenarios.

There have been significant (>50%) historical wetland habitat losses in North America (Dahl 1990a,b) and elsewhere globally (Davidson 2014), including coastal wetlands (Li *et al.* 2018), potentially affecting birds from all DUs on migration and wintering areas. These losses mean that shorebirds have fewer alternative sites should they encounter problems at current sites in migration or wintering areas, potentially limiting their options for successfully completing the annual cycle. In the United States, ongoing losses and changes in coastal habitats resulting from coastal protection measures are expected (USFWS 2015). Potentially, the most significant losses to coastal habitats are anticipated from sea level rise resulting from warming climates (Galbraith *et al.* 2002, 2005, 2014). In Europe, populations of *C. c. islandica* (DU1) are likely to be affected by reductions in habitat through projected sea level rise. In the Wadden Sea, degradation of feeding habitats through commercial shellfisheries has affected *islandica* subspecies (DU1) and may still be affecting this subspecies (Blew *et al.* 2017).

For *roselaari* subspecies (DU2), Glick *et al.* (2007) estimated that 44% of the tidal flats at 11 sites in the Pacific Northwest of the United States would be lost by 2100, based on a model forecasting a sea-level rise of 0.69 m. Galbraith *et al.* (2002, 2005) modelled sea level rise impacts at five major shorebird sites in the United States, which predicted losses of 20-70% of current intertidal areas. For *roselaari* subspecies (DU2), four sites on the Pacific coast of the United States were forecast to lose between 14.1% and 38.9% of their intertidal habitat by 2050 and 2100, respectively, under a 2°C warming scenario. Under the same scenario, the respective losses would be 19.8% and 57.4% for the Tierra del Fuego / Patagonia wintering population (DU3), the northeastern South America wintering population (DU4), and parts of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) passing through Delaware Bay (Galbraith *et al.* 2005). The Bolivar Flats in Texas, used by the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), were estimated to lose 19.8% and gain 1.8% of the area of intertidal flats by 2050 and 2100, respectively. Galbraith *et al.* (2005) concluded that if their 50% probability predictions occurred, San Francisco Bay and Delaware Bay sites “could not possibly support shorebird numbers that are even only fractions of their current sizes”.

However, such predictions of habitat changes are complicated, both technically and in interpretation. For instance, modelling by Glick *et al.* (2008) predicted increases in tidal flats in Delaware Bay (15-fold), though decreases in most other areas in the Chesapeake Bay area (47-96%). They mostly forecast increases in beach habitats in Delaware Bay and elsewhere the region, but it is unknown whether such beaches would support Red Knot and Horseshoe Crab populations as in their present relationship.

The likely effect on habitat was a fundamental element in the assessment by Galbraith *et al.* (2014) on the vulnerability of Red Knot to climate change. Vulnerability was increased from a Risk Level of 4 (High Concern) to 6, a new category reflecting an assessment of "Critical" under the risk categories described in the United States Shorebird Conservation Plan (Brown *et al.* 2001; Galbraith *et al.* 2014).

BIOLOGY

The information in this section is drawn mostly from the species account for Red Knot in *Birds of North America* (Baker *et al.* 2013) and *Birds of the World* (Baker *et al.* 2020), the United States Red Knot status assessment (Niles *et al.* 2008), and the *Red Knot Conservation Plan for the Western Hemisphere* (Niles *et al.* 2010a), as well as from the writer's personal experience (Morrison pers. obs.). Most information presented here applies to all five DUs, except as noted.

Life Cycle and Reproduction

Red Knot has a monogamous mating system (Parmelee and MacDonald 1960). Males often arrive first on the breeding grounds (Whitfield and Brade 1991), with pair bonds forming soon after arrival, although display songs may be heard during northward migration (Piersma *et al.* 1991; Morrison unpubl. data; Baker *et al.* 2013). Mating occurs on the breeding grounds and pair bonds remain intact until shortly after the eggs hatch (Whitfield and Brade 1991; Niles *et al.* 2008). Egg-laying occurs after a period of physiological reorganization within the bird's body following arrival on the breeding grounds, with eggs formed from local food resources rather than from body stores brought from migration areas (Morrison and Hobson 2004). Clutches are laid over a six-day period (Nettleship 1974). There is normally only one clutch per year, although a replacement clutch may be laid if the nest is lost early in the season (Whitfield *et al.* 1996). Clutches normally consist of four eggs (Parmelee and MacDonald 1960; Nettleship 1974; Niles *et al.* 2007; Baker *et al.* 2013), although three-egg clutches have been recorded on Ellesmere Island (Nettleship 1974). The latter may be a result of a re-nesting attempt after loss of the first clutch (in Alaska, Johnson pers. comm. *in* Baker *et al.* 2013).

Nests are usually simple scrapes placed in small patches of vegetation, which may be lined with pieces of lichen or other vegetation (Pleske 1928; Nettleship 1974). Incubation takes 21-22 days and is shared by males and females (Bird *in* Salomonsen 1950; Nettleship 1968). Territories are large and hence nest densities are low, with nests typically widely separated (0.75-1 km apart in Parmelee and MacDonald 1960; Nettleship 1974; Niles *et al.* 2010a; Baker *et al.* 2013). Estimated regional densities for *C. c. islandica* (DU1) in the Canadian Arctic and in Greenland varied between 0.13 and 2 pairs/km^2, with densities in local study areas on Ellesmere Island ranging between 0.4 and 12.7 pairs/km^2 (Whitfield *et al.* 1996). Although territories are defended from other conspecifics, off-duty birds tend to feed away from their territory in communal feeding areas (Parmelee and MacDonald 1960; Flint 1972; Nettleship 1974). Male Red Knots are highly faithful to the same breeding area from year to year (Baker *et al.* 2020). One *islandica* Red Knot bred at a site near Alert, on the north coast of Ellesmere Island, over a period of at least 11 years between 1992 and 2002 (Morrison unpubl. data).

Hatching generally occurs in the first half of July in the Canadian Arctic (Parmelee and MacDonald 1960; Nettleship 1974), and up to two weeks earlier for *C. c. roselaari* (DU2) in Alaska and northern Russia (Loktionov *et al.* 2015; Johnson 2018). The young leave the nest within 24 hours of hatching, and the brood begins to wander large distances across the tundra within 1-2 days, often travelling several kilometres (Morrison 1992; Morrison unpubl. data; Baker *et al.* 2020). The female departs a few days after hatch, leaving the male to care for the brood, and fledging takes place at approximately 18 days (Parmelee and MacDonald 1960; Nettleship and Maher 1973 Nettleship 1974). Males depart following fledging and are followed by the juveniles 1-3 weeks later (Morrison 1992). Nesting success may vary considerably from year to year, depending on weather conditions and predator cycles, affecting population numbers in the following wintering season (Boyd and Piersma 2001).

Longevity and Survival

Red Knots can live for more than 20 years, and most start breeding at age two (Baker *et al.* 2013). The oldest known *islandica* was about 25 years old (COSEWIC 2007) and the iconic *rufa* Red Knot known as B95 was about 21 years old when last observed in Tierra del Fuego in January 2014 (Morrison 2018, unpubl. data).

Mendez *et al.* (2018) reviewed annual survival estimates of shorebirds and reported values for Red Knot from eight studies ranging from 0.62 to 0.92, with a modelled overall adult survival rate (corrected for methodological biases) of 0.801 ± 0.011. Annual survival rates of knots on southward migration in James Bay averaged about 0.70 over the period 2009-2018 (MacDonald 2020) and were not time-dependent, while annual survival at Mingan during 2006-2016 also averaged about 0.70 (0.46-0.86), but was time-dependent and apparently lower in more recent years (Aubry pers. comm. 2020). Given that the most current apparent survival estimates from Delaware Bay are about 0.90 (Smith pers. comm. 2020), an overall value for adult survival of 0.80 seems appropriate.

Generation time calculated using the online IUCN Generation Length Workbook spreadsheet (IUCN Standards and Petitions Subcommittee 2017) is 7 years, based on adult (>2 years) survival of 0.80 and fecundity of 1.5, juvenile survival of 0.25 and fecundity of 0, and sub-adult survival of 0.65 and fecundity of 1.5 (Appendix 1). Method 2 in the IUCN guidelines (Generation Time = 1/adult mortality + age at first reproduction) also produces an estimate of 7 years. Note that assuming the age of first reproduction as 2 years is defensible, as IUCN guidelines indicate that a lower value would encompass age of first breeding as less than 2 years (between 12 and 24 months), and some knots may not breed until older than 2 years (Azpiroz and Rodríguez-Ferraro 2006; Martínez-Curci *et al.* 2020; see Baker *et al.* 2013, 2020), and Watts *et al.* (2015) used age of first reproduction as 2-3 years.

The calculated generation time of 7 years is similar to that of 6.9 years recently estimated by Bird *et al.* (2020) and is used here for all five DUs. This value is considerably higher than the generation time of 4-5 years given in the 2007 status report, which suggested that very few knots live for more than about 7-8 years (COSEWIC 2007), and it is now known that some live at least 20 years (Baker *et al*. 2013).

For the *rufa* Tierra del Fuego / Patagonia wintering population (DU3), Baker *et al.* (2004) estimated knot survival as 0.85 when conditions were good in Delaware Bay, and 0.56 in years with little food there, producing generation times of 8.7 and 4.3 years, respectively. The McGowan *et al.* (2011) estimate of survival for Red Knot in Delaware Bay of 0.92, implying a generation time of 14.5 years, seems unrealistically high, but may be possible when conditions are particularly favourable. Rakhamberdiev *et al.* (2015) noted that winter and summer survival of *C. c. islandica* (DU1) can vary considerably, sometimes in a compensatory manner. Population matrix analysis suggests that substantial population increases may be possible when conditions are particularly favourable (Wilson pers. comm. 2018; Appendix 1).

Much less is known about survival of juvenile birds during their first two years of life. Annual survival of juveniles at Mingan, Quebec, during 2006-2016 was estimated as 0.12-0.42, but was time-dependent and apparently lower in more recent years (Aubry pers. comm. 2020). Juvenile survival has been estimated as 0.25 (Mendez *et al.* 2018 and see Appendix 1; Boyd and Piersma (2001) for *C. c. islandica*), or as half adult survival (Baker *et al.* 2004), but field estimates are lacking for most DUs. Little information is available on where young birds spend their first summer before breeding at age two, and how their movements and habitats used affect their survival and recruitment into the breeding population (Martínez-Curci *et al.* 2020).

Physiology and Adaptability

Red Knot undergoes many significant physiological changes during migration, especially during the final stopover on northward migration (Piersma *et al.* 1999; Baker *et al.* 2004). These changes increase flight efficiency to enable birds to reach the breeding grounds and involve accumulating sufficient additional body stores to breed successfully. Fat deposition continues towards the end of the migration stopover, while the "flight machinery" that will power the flight – e.g., heart, flight muscles, fat deposits – increases in size (Piersma *et al.* 1999). In contrast, the digestive organs and muscles that will be used less or not at all during the flight – e.g., leg muscles, gizzard, gut, liver – decrease in size (Piersma *et al.*1999). Thus, by the time the bird departs, it is well-prepared for the long flight to the Arctic. The stores of fat and protein that remain when knots arrive on the breeding grounds are then used to enable gut, gizzard, heart (which decreases in size during flight), liver, gonads, etc. to be regrown in preparation for the breeding attempt (Morrison *et al.* 2005; Morrison 2006). Failure to accumulate the needed stores and undergo the complex physiological transformations before migration and breeding would have severe survival consequences (Baker *et al.* 2004; Morrison *et al.* 2007; see **Threats** section).

The ability to undergo physiological changes that reduce the mass of the digestive apparatus before long flights is likely most critical for long-distance migrants, such as *islandica* Red Knot (DU1) *en route* from European wintering grounds via Iceland to the Canadian Arctic, and the long-distance *rufa* (DU3) migrating from Tierra del Fuego via Delaware Bay to the Arctic (Atkinson *et al.* 2007). The availability of easily digestible and energetically rich Horseshoe Crab eggs in Delaware Bay is thought to be of greater importance during northward migration for long-distance *rufa* migrants from the Tierra del Fuego / Patagonia wintering population (DU3) than for populations from closer wintering areas (northeastern South America wintering population DU4, southeastern USA / Gulf of Mexico / Caribbean wintering population DU5), and the latter may undergo less extensive physiological changes during migration. Restoration of Horseshoe Crab populations in Delaware Bay is therefore thought to be critical for future recovery of the Tierra del Fuego / Patagonia wintering population (DU3; Niles *et al.* 2009).

Dispersal and Migration

Recent studies of Red Knot tagged with coded flags, geolocators, or radio nanotags have provided much new information on migration routes used by birds in all five DUs (Burger *et al.* 2020). Light-level geolocators provide relatively continuous information on the birds' position, based on day-length and date, but require the recapture of the bird to download data from the geolocator (Porter and Smith 2013). The 24-hour daylight in Arctic breeding areas often precludes an accurate position fix, but recorded periods of light and dark do provide information on incubation schedules (Burger *et al.* 2012b). The development of an automated MOTUS radio telemetry tower network, to detect the presence and movements of birds carrying VHF 'nanotags', is increasingly enabling the tracking of migrating Red Knot in both North and South America (Taylor *et al.* 2017; Motus 2018).

DU1 - *islandica* subspecies

It is well-established that the Red Knot populations breeding in the northeastern Canadian High Arctic (DU1) migrate to European wintering grounds (e.g., Morrison 1975; Davidson and Wilson 1992; Baker *et al.* 2013, 2020). Two major routes are used on northwestward migration from Europe, via Iceland and via northern Norway, and birds have occasionally been detected switching between stopover sites on different routes in subsequent years (Wilson *et al.* 2011). On fall migration, knots from the northern parts of the Canadian breeding range are likely able to fly directly to Europe, as judged by departure weights and stable isotope patterns (Morrison unpubl. data; Dietz *et al.* 2010; Baker *et al.* 2013, 2020).

Conditions at final spring stopover sites play a key role in influencing survival and reproductive success. Only those knots departing in good condition from Iceland stopover sites were later detected alive after a series of difficult summers on the breeding grounds, and departure condition from Iceland appears to be directly related to length of survival, even during normal summers (Piersma 1998; Piersma *et al.* 1999; Morrison 2006; Morrison *et al.* 2007).

There are three records of individual Red Knot using different flyways in different years: (1) a bird captured at the Mingan Archipelago in August 2008 during southward migration seen in northeast Iceland in May 2010 on northward migration, (2) a bird captured in northern Norway on northward migration in May 2009 and seen at the Mingan Archipelago in July 2009 on southward migration; and (3) a bird banded in eastern England in March 1971 and found on Barbados in August 1972 (Wilson *et al.* 2010). It is interesting to note that *islandica* and *rufa* have the lowest degree of genetic differentiation amongst Red Knot subspecies (Verkuil *et al.* 2017), perhaps reflecting their evolutionary history (Buehler and Baker 2005; Buehler *et al.* 2006). However, such records appear to be very uncommon.

DU2 - *roselaari* subspecies

Movements from the breeding areas in Alaska and Wrangel Island to the main wintering areas on the Pacific coast of California and Mexico, through the four major stopover areas on the Pacific coast (Grays Harbor and Willapa Bay, Washington, and Copper River and Yukon-Kuskokwim Deltas, Alaska) have been documented through observations of flagged and radio-tagged birds (Buchanan *et al.* 2010; Carmona *et al.* 2013; Bishop *et al.* 2016). High site-fidelity has been found at Pacific stopover sites (Buchanan *et al.* 2012). Knots are thought to make long-distance flights between the main areas during northward migration (Carmona *et al.* 2013; Bishop *et al.* 2016), and very few Red Knot (generally <100) are seen on the coast annually in British Columbia (Campbell *et al.* 1998; eBird 2019).

Although many *roselaari* Red Knot fly directly from stopover sites at estuaries in Washington to those in Alaska during northward migration, results from recent GPS tracking studies have shown that many (27 of 47; 54%) stopped for 1-5 days on small islands or rocky islets on the coast of British Columbia, perhaps to rest or avoid headwinds or predators rather than to refuel (Johnson pers. comm. 2020; Figure 5). In the autumn, GPS tracking indicates that knots fly from staging areas in Alaska directly to wintering areas from southern California to northwest Mexico (Buchanan pers. comm. 2020; Johnson pers. comm. 2020). Red Knots seen in British Columbia (generally <100 annually; Campbell *et al.* 1998; eBird 2019; although note GPS tracking results) can be referred to these populations of *roselaari*.

Most *roselaari* Red Knot appear to fly directly from spring migratory stopover sites on estuaries in Washington to Alaskan stopover sites during northward migration (Buchanan pers. comm. 2020; Johnson pers. comm. 2020), presumably flying between them in a relatively direct line, unless deflected by weather conditions. The most direct “Great Circle” route from Gray’s Harbor and adjacent Willapa Bay in Washington to the Copper River Delta in southeast Alaska passes directly over Haida Gwaii in British Columbia (Google Earth 2019), well within Canada’s 200 mile EEZ (Exclusive Economic Zone). Flying in a straight line from these Washington stopover sites to the Yukon-Kuskokwim Delta in southwest Alaska would take a route slightly farther west, likely missing Haida Gwaii but well within Canada’s 200 mile limit (Google Earth 2019). Virtually all *roselaari* Red Knots

(DU2) thus likely travel through Canadian airspace when migrating northwards between Washington and Alaskan stopover sites. Indeed, many of these birds likely stop briefly in Canada, as evidenced by the sample noted above, in which 54% of 47 GPS-tagged northbound *roselaari* knots stopped on remote islets in British Columbia (Johnson pers. comm. 2020; Figure 5).

June records indicate that the northeast coast of the Gulf of California, Mexico is important for one-year-old knots summering south of the breeding grounds, the only such area known for the DU (Soto-Montoya *et al.* 2009).

There is some indication that birds breeding on Wrangel Island are genetically distinct from those in northwest Alaska (Verkuil *et al.* 2017) and may migrate northwards on different schedules (Buchanan *et al.* 2018), at least in some years (Buchanan pers. comm. 2020). Much less is known about southward migration, and few large concentrations of knots have been detected between breeding and wintering areas (Carmona 2013).

DU3 - Tierra del Fuego / Patagonia wintering population

Southern-wintering *rufa* knots (Tierra del Fuego / Patagonia wintering population DU3) make their way north from their main wintering grounds in Tierra del Fuego, up the coast of Patagonia, stopping at several key sites (Morrison and Harrington 1992) including San Antonio Oeste (González *et al.* 1996, 2001), Bahia Blanca (Petracci pers. comm. 2019), Punta Rasa (Martínez-Curci *et al.* 2015, 2020), and Lagoa do Peixe in southern Brazil (Baker *et al.* 1998). Studies of weight gain and geolocator tracking suggest that some knots leave on a long flight from the more northerly of these stopover sites, crossing Amazonia directly to the east coast of the United States (Niles *et al.* 2010b; Burger *et al.* 2020). However, many birds stop on the north coast of Brazil (Morrison and Harrington 1992; Rodrigues 2000; Rodrigues and Lopes 2000; Fedrizzi *et al.* 2016; Mobley pers. comm. 2019) – some 83% of geolocator birds from southern South America stopped here during northward migration (Burger *et al.* 2020). It is likely that most Red Knot from the Tierra del Fuego / Patagonia wintering population (DU3) then pass through the Delaware Bay system in spring (88% of geolocator birds) (Niles *et al.* 2010b; Burger *et al.* 2020).

Rates of weight gain of Red Knot in Delaware Bay are amongst the highest recorded for the species globally (Atkinson *et al.* 2007). The birds feed principally on the eggs of the Horseshoe Crab, which provide an easily digestible and energy-rich food source. Several studies have shown that failing to reach adequate body condition before leaving the last spring stopover area may have severe survival consequences for Red Knot (Baker *et al.* 2004; Morrison *et al.* 2006). When knots were unable to reach optimal departure weights in Delaware Bay in the early 2000s, owing to reduced availability of Horseshoe Crab eggs, their survival rates fell from about 85% to 56% (Baker *et al.* 2004). The modelled declining population trajectory closely matched that observed during aerial surveys in Tierra del Fuego over the same period (Baker *et al.* 2004; Morrison *et al.* 2004, Morrison 2018). Recent tracking of radio-tagged knots departing from Delaware Bay has shown that birds in better condition departed later, arrived on the breeding grounds earlier, and migrated south later than individuals in poor condition, indicating they were more likely to have bred successfully (Duijns *et al.* 2017). In addition, these studies indicated that birds in poor condition were less likely to be subsequently observed in autumn, suggesting higher mortality.

Geolocator studies have shown that knots departing from Delaware Bay and other east coast US sites fly directly to more northerly areas in Canada (Niles *et al.* 2010b). Many pass through southern James Bay in late May (Morrison and Harrington 1992; Morrison pers. obs.). Many (92% of geolocator records) of the Tierra del Fuego / Patagonia wintering population (DU3) knots use the recently (re)discovered stopover site near the mouth of the Nelson River on Hudson Bay, where over 4,000 birds have been counted in late May and early June (McKellar *et al.* 2015; Burger *et al.* 2020). It is unknown how long knots may have been using this site, though 3,500 were reported from the area in spring 1974 (Morrison *et al.* 1995; IBA 2013).

Although the easterly migration route taken by birds from the Tierra del Fuego / Patagonia wintering population (DU3) suggests that they might occupy the more easterly parts of the breeding range, geolocator results show that birds thought to be from DU3 are found in many parts of the Arctic (Porter pers. comm. 2020). Banded Argentinian *rufa* knots have been found nesting at both eastern and western extremes of the Canadian Arctic breeding range, and 100 randomly selected *rufa* knots from Delaware Bay were tagged with radio transmitters and later relocated, scattered across the whole breeding range (Lathrop *et al.* 2018). These and other results suggest that there is some degree of overlap in breeding range of the three *rufa* DUs (USFWS 2014a). However, despite this, the genetic separation among the DUs indicates that they somehow remain largely or entirely reproductively isolated (Baker *et al.* 2012a,b). More information is needed on this aspect of knot breeding and migration.

Following breeding, large numbers of *rufa* knots pass southwards through the southwest coast of Hudson Bay (Manitoba and Ontario) and western and southern coasts of James Bay (Ontario), during July and August (Hope and Shortt 1944; Manning 1952; Ross *et al.* 2003), including birds from the Tierra del Fuego / Patagonia wintering population (DU3) banded in Argentina (Friis 2017). The most important areas appear to be in southwestern James Bay between Big Piskwamish Point and North Point, where up to 10,000 Red Knot have been observed during aerial surveys in August (Morrison, Ross, and Friis unpubl. data; Friis and Morrison 2018). Mark-recapture analyses indicated a total population passing through western James Bay of 9,200 in 2017 and 13,200 in 2018, accounting for turnover (MacDonald 2020).

In eastern Canada, the most important area for *rufa* Red Knot on southward migration is the Mingan Islands Archipelago on the north shore of the St. Lawrence estuary (Buidin *et al.* 2010; Allard *et al.* 2014), where over 9,000 knots have been estimated to stop (Lyons *et al.* 2017). Ouellet (1969) identified four Red Knot collected from a flock of 200 on Anticosti Island as belonging to the *rufa* subspecies. Large numbers of re-sightings of colour-marked individuals between Mingan and Argentina confirm that many of these birds belong to the Tierra del Fuego / Patagonia wintering population (DU3), although birds from the northeastern South America wintering population (DU4) and southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) also occur (Aubry pers. comm. 2019).

Red Knots from the Tierra del Fuego / Patagonia wintering population (DU3) also pass through the east coast of the United States in fall. Although some mixing with the other *rufa* DUs occurs there, the three groups differ in migration chronologies, length of stopover, weight gain, and moult patterns, as well as foods and feeding habitats (Harrington *et al.* 2007, 2010a,b; Niles *et al.* 2008, 2012a; Burger *et al.* 2012a, 2020; Lyons *et al.* 2018). Knots from the Tierra del Fuego / Patagonia wintering population (DU3) typically arrive and depart earlier and have a shorter stopover duration; in addition, they put on weight for the forthcoming long migration flight and do not undergo wing moult. These differences in phenology, moult patterns, and requirements for weight gain distinguish the DUs, despite their using some of the same stopover sites during migration.

Southbound Red Knot from the Tierra del Fuego / Patagonia wintering population (DU3) leave from the east coast of North America to fly south-southeast across the Atlantic Ocean to the northeastern coast of South America. Although Tierra del Fuego / Patagonia wintering knots (DU3) may pass through the northeastern coast of Brazil (used by the northeastern South America wintering population DU4 in winter) on migration, there are no records of such birds present during winter in Maranhão or Ceara (Baker *et al.* 2005a; Mobley pers. comm. 2019). Similarly, Tierra del Fuego / Patagonia wintering knots (DU3) are thought to migrate through French Guiana, although the few birds that winter there are probably from the northeastern South America wintering population DU4 (Niles *et al.* 2013a; de Pracontal 2017). Given that many thousands of birds have been marked in different wintering areas, these observations indicate that the wintering populations remain functionally separate, as supported by genetic studies. Tierra del Fuego / Patagonia wintering knots (DU3) continue southwards, arriving in Uruguay, southern Patagonia, and Tierra del Fuego in October and November (Baker *et al.* 2005b; Aldabe *et al.* 2015; Figure 7).

The small number of Red Knots wintering in Chiloé Island, Chile are thought to be mostly *rufa* birds from DU3 (Navedo and Gutiérrez 2019), although geolocator records indicate that a few *roselaari* (DU2) birds may also occur there (Newstead and LeBlanc 2018; Handmaker 2020).

Less is known about the distribution of over-summering one-year old knots south of the breeding grounds. Regular numbers are observed during the northern summer at Punta Rasa, Buenos Aires Province, Argentina (Martínez-Curci *et al.* 2015, 2020) (although not all birds were one-year-olds) and southern Brazil (Belton 1984; Scherer and Petry 2012).

DU4 - northeastern South America wintering population

The main wintering grounds of Red Knot from the northeastern South America wintering population (DU4) are thought to centre along the northeastern coast of Brazil, especially in the states of Maranhão (Morrison and Ross 1989; Wilson *et al.* 1998; Rodrigues 2000a; Rodrigues and Lopes 2000; Baker *et al.* 2005a) and Ceara (Carlos *et al.* 2010; Fedrizzi *et al.* 2016; Mobley pers. comm. 2019; Figure 8), with a few birds wintering in nearby French Guiana and Suriname. Birds from the northeastern South America wintering population (DU4) depart northwards by about March (Rodrigues 2000; Rodrigues and Lopes 2000; Fedrizzi 2016) and geolocator records indicate that most fly up the east coast of the United States (90% of geolocator birds stopped in Delaware Bay; Burger *et al.* 2020). Flagged birds from the northeastern South America wintering population (DU4) pass northwards through Virginia during northward migration, before moving to other areas, including Delaware Bay (Duerr *et al.* 2011; Watts and Truitt 2015). Marked birds from Brazil have not been recorded in Georgia (Smith *et al.* 2017). From the east coast of the United States, northeastern South America wintering population (DU4) birds move on to James Bay and Hudson Bay (95% of geolocator birds) *en route* to the breeding grounds (Burger *et al.* 2020; Porter pers. comm. 2020).

As with the Tierra del Fuego / Patagonia wintering population (DU3), there is uncertainty regarding which parts of the *rufa* breeding range are occupied by birds from the northeastern South America wintering population (DU4). Geolocator birds wintering in northeast Brazil have been tracked to Southampton Island and near Pelly Bay in the Canadian Arctic (Niles *et al.* 2010b).

On southward migration, knots from northeastern South America wintering population (DU4) pass through James Bay (sightings of flagged birds; Friis 2017; MacDonald 2020) and the Mingan Islands (Aubry pers. comm. 2019). One geolocator bird stopped at Mingan on both its northward (2009) and southward journeys (2009, 2010) after which it flew directly to northern Brazil (Burger *et al.* 2020). The northeastern South America wintering population (DU4) knots also pass through various other sites on the east coast of the United States, such as Georgia (Lyons *et al.* 2018) and Monomoy, Massachusetts (17% of geolocator birds from the northeastern South America wintering population (DU4); note no geolocator birds from the Tierra del Fuego / Patagonia wintering population (DU3) have been detected at Monomoy; Burger *et al.* 2020). Long-distance migrants from the Tierra del Fuego / Patagonia wintering population and the northeastern South America wintering population (DU3, DU4) generally have different migration strategies than the shorter distance migrants from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), including migration chronologies (earlier), length of stopover (shorter), weight gain (greater), and moult patterns (no moult), as well as different foods and feeding habitats (Harrington *et al.* 2007, 2010a,b; Niles *et al.* 2008, 2012a; Burger *et al.* 2012a, 2020; Lyons *et al.* 2018).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population

Red Knot from wintering areas on the Atlantic coast of Florida and Georgia, as well as parts of the Caribbean (part of the southeastern USA / Gulf of Mexico / Caribbean wintering population, DU5), migrate up the Atlantic coast of the United States in spring. Their flights are shorter than those of the long-distance migrants from the Tierra del Fuego / Patagonia wintering population and the northeastern South America wintering population (DU3, DU4) and may involve leap-frog movements: only about half are thought to stop in Delaware Bay (compared to approximately 90% of the Tierra del Fuego / Patagonia wintering population (DU3) and the northeastern South America wintering population (DU4; Burger *et al.* 2020)). In Delaware Bay, it is likely that the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) birds make greater use of coastal habitats and are less dependent on Horseshoe Crab eggs within Delaware Bay, because shorter-distance migrants are able to use hard-shelled bivalves in these habitats as they have not undergone as extensive a reduction in digestive organs as long-distance migrants (Niles *et al.* 2009, 2012a). Geolocator studies show that some birds fly directly from Florida or other southeastern states to Hudson Bay (Burger *et al.* 2020).

Knots in the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) wintering on the west coast of Florida, as well as Louisiana, Texas, and Caribbean islands, migrate up through central North America, some stopping in the Canadian Prairies (Saskatchewan), with others flying directly to the Nelson River area on the west coast of Hudson Bay (Newstead *et al.* 2013; Newstead pers. comm. 2018; Bianchini *et al.* 2020). Recent geolocator and nanotag results suggest that birds wintering in Louisiana and Texas may take different routes. Birds from Louisiana appear to move up the Mississippi Flyway directly to James Bay and Hudson Bay, while those from Texas move up the Central Flyway to use stopover sites in Saskatchewan en route to James Bay and Hudson Bay. Birds wintering on the Gulf coast of Florida likely fly directly to James Bay (Newstead pers. comm. 2018). Some of these birds may return south in fall via the east coast of the United States, as suggested by recent geolocator records (Niles *et al.* 2012a; Lyons *et al.* 2018; Bianchini *et al.* 2020).

The portions of the breeding range of *rufa* occupied by birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) are unclear. The central migration route of the Texas/Louisiana birds might suggest a destination in the west-central Arctic. One knot that wintered in coastal Maryland migrated northwards through Delaware Bay, then to Hudson Bay and on to a breeding site thought to be near Foxe Basin in the eastern part of the range; it returned south to the same wintering area via James Bay (Burger *et al.* 2020).

Interspecific Interactions

Nest and adult predation

Long-tailed Jaeger (*Stercorarius longicaudus*) and Arctic Fox (*Alopex lagopus)* are common egg and chick predators of Red Knot on the Arctic breeding grounds, especially in years with low lemming populations (e.g., Birula *in* Pleske 1928; Nettleship 1974). High nest predation by Arctic Fox may also occur in years with late snowmelt, when predators have a smaller area of patchy open tundra to search (Tomkovich and Soloviev 1996). Other breeding ground predators include Parasitic (*S. parasiticus)* and Pomarine Jaeger (*S. pomarinus*), Gyrfalcon (*F. rusticolus*), and sometimes Herring (*Larus argentatus*) and Glaucous Gull (*L. hyperboreus*; Niles *et al.* 2008). Other potential undocumented predators include Common Raven (*Corvus corax*), Sandhill Crane (*Antigone canadensis*), and Ermine (*Mustela erminea*), especially in the lower latitudes of the breeding range (Smith pers. comm. 2020).

Away from the breeding grounds, most common predators are large falcons such as Peregrine Falcon (*Falco peregrinus*; Piersma *et al.* 1993), but others include harriers (*Circus* spp.), accipiters (*Accipiter* spp.), Merlin (*F. columbarius*), Short-eared Owl (*Asio flammeus*), and Great Black-backed Gull (*L. marinus*; Piersma *et al.* 1993; Niles *et al.* 2008). Large avian predators generally migrate southwards later than most shorebirds, so that early migrating shorebirds (e.g., female knots) are less prone to predation compared to later migrants (e.g., juvenile and some male knots) (Lank *et al.* 2003).

Other interspecific interactions

Red Knots usually form and fly in monospecific flocks, but will readily join with other species of shorebirds in flight on feeding areas, including Ruddy Turnstone (*Arenaria interpres*), dowitchers *Limnodromus* spp., Black-bellied Plover (*Pluvialis squatarola*), and larger shorebirds such as godwits (*Limosa* spp.).

On the breeding grounds, knots and turnstones may combine to defend their chicks against predators such as Long-tailed Jaeger, perhaps more effectively than if breeding separately (Parmelee and MacDonald 1960).

The Tierra del Fuego / Patagonia wintering population (DU3) is heavily dependent on the eggs of Horseshoe Crab as their main prey in Delaware Bay and other coastal areas of the Atlantic United States during spring migration (Tsipoura and Burger 1999; Haramis *et al.* 2007). Birds from the northeastern South America wintering population (DU4) and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) passing through Delaware Bay also depend on this food resource, although likely to a lesser extent (Atkinson *et al.* 2007). Elsewhere in its wintering and migration ranges, Red Knot feeds mostly on bivalves (Alerstam *et al.* 1992; Piersma *et al.* 1993; González *et al*. 1996; Cohen *et al.* 2009), although a variety of invertebrates are eaten on migration in eastern Canada (Sahlin 2010, 2011). On its breeding grounds, Red Knot feeds on tundra invertebrates as well as vegetation (Parmelee and MacDonald 1960; Nettleship 1974; Baker *et al*. 2013).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Aerial surveys

Counting Red Knot on the wintering grounds is generally considered the best method of assessing population size, as birds are often concentrated in relatively restricted stretches of suitable habitat, and little movement of birds is likely to occur among sites (Brown *et al.* 2001). Aerial surveys usually provide the most effective method of covering extensive areas of habitat, especially in remote areas that are difficult to access from the ground. If the entire wintering range can be surveyed within one season, the overall survey effectively becomes a census in which all the birds are counted. Any uncertainties in the total number of birds result from counting, identification, and detection errors, as there is no sampling or extrapolation involved. Detection issues may arise when coastal surveys need to be carried out at a specific tide height (usually high tide) and coverage of large areas may preclude ideal conditions throughout the survey (Morrison 2018; Morrison *et al.* 2020c; NJA 2020).

For *C. c. islandica* (DU1), aerial surveys have been used to determine numbers on migration in Iceland (Gudmundsson and Gardarsson 1993) but are not generally used on the wintering grounds in Europe where most information comes from ground counts.

For *C. c. roselaari* (DU2), aerial surveys provided early information on Red Knot distribution (Morrison and Ross 2009) on the wintering grounds of *C. c. roselaari* in Mexico. Aerial surveys have also been used extensively on Alaskan migration areas (Gill and Handel 1990; Alaska Shorebird Group 2018).

The Tierra del Fuego / Patagonia wintering population (DU3) has been extensively censused by aerial surveys. The entire Patagonian coast and suitable coastline of Tierra del Fuego were originally surveyed in the 1980s, when the main wintering sites were discovered (Morrison and Ross 1989). Surveys were resumed in 2000 and continued annually until 2019. In recent years, accuracy of counts has been assessed by comparing aerial counts with those from photographs, and for these and other air/ground comparisons, mean overall errors were within 5-10% of the photographic counts (Morrison 2018), with mean absolute errors averaging 8-10%. A notable feature of the Tierra del Fuego surveys is that all have been carried out by the same observers (R.I.G. Morrison, often with R.K. Ross), maximizing the consistency of counting. In addition, counts from Tierra del Fuego and estimates of the population size made through re-sighting studies during migration have been in close agreement (González *et al.* 2004).

Aerial surveys of wintering areas used by *rufa* birds in the northeastern South America wintering population (DU4) were originally carried out in the 1980s, and have been repeated in recent years (2008-2019; Morrison and Ross 1989; Baker *et al.* 2005a; Morrison *et al.* 2012, 2020c).

Aerial surveys have been used to count *rufa* Red Knot the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) in coastal Texas and Louisiana (Newstead pers. comm. 2018) and Florida (Niles *et al.* 2010c), albeit on a sporadic basis, and these do not cover all known wintering areas used by birds from this DU.

Aerial surveys have also been used to count Red Knot on migration in other areas where DU identification is uncertain or where birds from more than one DU may occur. For instance, aerial surveys have been conducted in Delaware Bay since 1982 and are ongoing, until recently using standard protocols and the same observers (Clark *et al.* 1993, 2001; Niles *et al.* 2010c). Red Knot from the Tierra del Fuego / Patagonia wintering population (DU3) mix with those from the northeastern South America wintering population (DU4) and the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) during migration through the bay, although most knots from the latter two DUs pass through this site earlier than those from the Tierra del Fuego / Patagonia wintering population (DU3; Atkinson *et al.* 2005). Aerial surveys have also been conducted during northward migration in coastal Virginia and Georgia (Watts and Truitt 2015; Smith *et al.* 2017). Aerial surveys of the James Bay coastline have confirmed that a significant number of *rufa* knots (>10,000 individuals) use this area during southward migration (Friis 2017; R.I.G. Morrison, R.K. Ross, and C. Friis unpubl. data), although it is unclear which DU(s) these birds are from.

<u>Ground counts</u>

Although numbers at migration areas may be affected by turnover rates (e.g., birds may move through a site at different times, or at different rates in different years) and by uncertainties regarding the proportion of the population using the site (Bart *et al.* 2007), they nevertheless provide valuable additional data on trends in a migratory population (Morrison *et al.* 1994; Morrison 2001). Maximum or mean counts have been used as indices of annual abundance, sometimes during a specific time window, e.g., to estimate adult numbers when their passage time differs from juveniles (Morrison 2004).

In Europe, information on wintering numbers of *C. c. islandica* (DU1) comes from an internationally coordinated program of ground counts (Wetlands International 2018).

In North America, various volunteer survey operations are coordinated through PRISM (Bart *et al.* 2002). Major components include the Atlantic Canada Shorebird Survey (ACSS, originally the Maritimes Shorebird Survey - MSS), the Ontario Shorebird Survey (OSS), and the International Shorebird Survey (ISS) covering areas in the United States and farther south. The MSS/ACSS and ISS were started in 1974, and typically involve volunteers who count shorebirds in a consistent manner at their study site at two-week or 10-day intervals throughout the period of southward migration (Morrison *et al.* 1994; Morrison 2001; Morrison and Hicklin 2001; Howe *et al.* 1989). Analyses of these data are conducted by Environment and Climate Change Canada scientists at the National Wildlife Research Centre.

Combined results from different regions (referred to as ISS results in the analyses below) are useful and relevant for examining trends in different DUs of Red Knot. These counts are conducted during southward migration (July to November) and the sampling regions are shown in Figure 10. ISS trends were estimated with a hierarchical Bayesian model using Markov Chain Monte Carlo sampling, assuming that counts follow an over-dispersed, Poisson distribution, for the periods indicated (ECCC 2019), except for Pacific and Intermountain Region, Texas Coastal Region, and Delaware Bay, for which linear regression of annual indices was used.

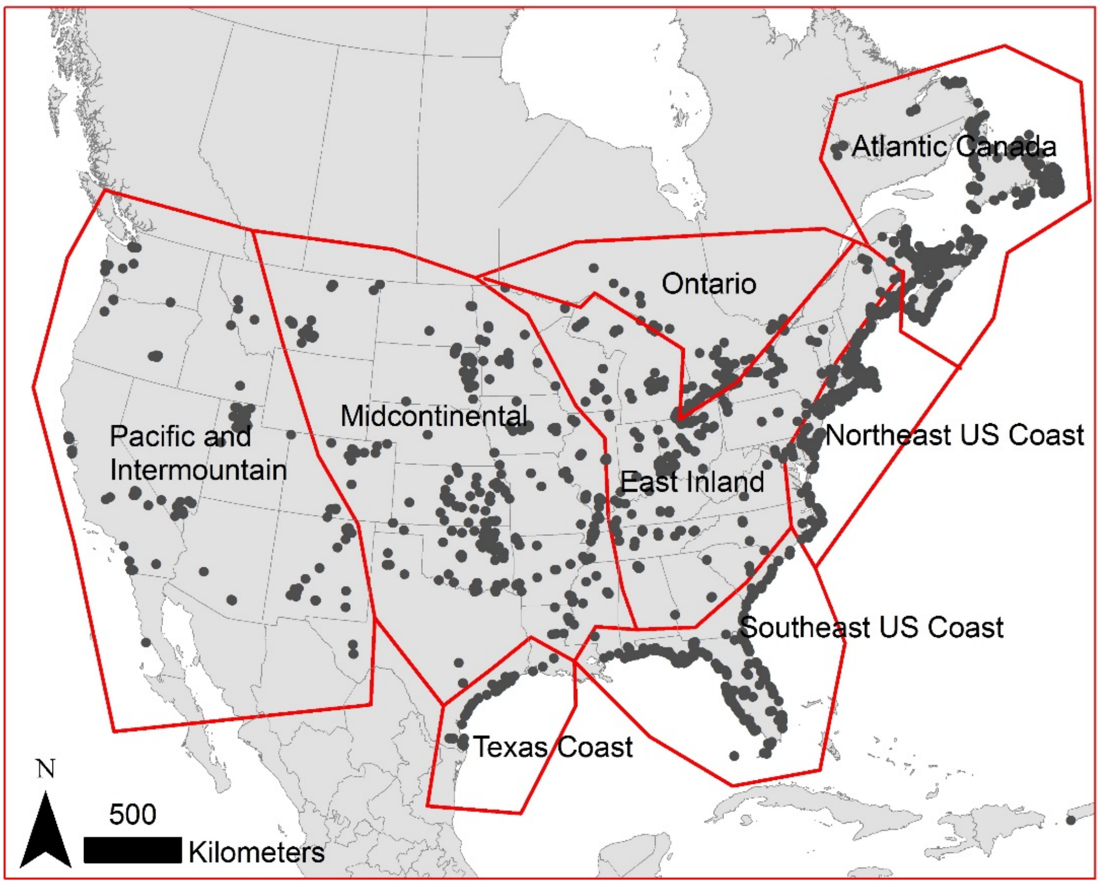

Figure 10. North American regions of the International Shorebird Survey (including the Atlantic Canada Shorebird Survey and Ontario Shorebird Survey) used in analysis of survey results on southward migration (July-August; Figure courtesy of P.A. Smith).

Counts from coastal sites in the Pacific and Intermountain region most likely refer to the *roselaari* population (DU2) migrating along the Pacific coast, although there is a possibility that some southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) *rufa* may also occur there. Counts from Atlantic Canada and the Northeast US Coast are likely to involve all three *rufa* DUs, but may nevertheless provide relevant perspective on declines of different DUs. It is likely that birds in Atlantic Canada may contain a higher proportion of birds from the Tierra del Fuego / Patagonia wintering population (DU3), whereas areas farther south on the east coast of the United States may contain a higher proportion of birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) (Harrington *et al.* 2010b; Lyons *et al.* 2018).

In Quebec, trends in numbers of Red Knot have been obtained from analysis of checklist data submitted to the Étude des populations d'oiseaux du Québec (ÉPOQ) for areas along the St. Lawrence River system from 1976-1998 (Aubry and Cotter 2001, 2007) and likely contain a high proportion of birds from the Tierra del Fuego / Patagonia wintering population (DU3). Counts reported via eBird will have a similar relevance to the different DUs on the geographical basis indicated for the ISS counts.

Migration counts from the southeast US Coast region may be relevant to the more easterly wintering portion of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) (with some from the Tierra del Fuego / Patagonia wintering population (DU3) and the northeastern South America wintering population (DU4)); counts from the Texas coast region may be relevant to the portion of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) that winters on the coast of Texas; and counts from the Midcontinental Region may be useful in assessing portions of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) that winter in west Florida, the Louisiana Gulf coast, and Texas.

Christmas Bird Counts, organized by the National Audubon Society since 1900, provide information on numbers of birds wintering in the United States and Canada (National Audubon Society 2020). Counts are carried out within a 24.1 km diameter circle over a one-day period (24-hours) between 14 December and 5 January (Audubon Science-CBC 2014). Number of count-hours and observers are recorded in order to assess sampling effort. CBC trends are estimated using a log-linear hierarchical model with an effort function, as described by Link and Sauer (2007). Counts from the Pacific coast will refer to DU2 *roselaari* subspecies, in the more northerly parts of its wintering range, while counts from the Gulf of Mexico and southeastern United States will refer to wintering populations of DU5 *rufa* subspecies.

Trends in the Tierra del Fuego / Patagonia wintering population (DU3) have been estimated from counts at various sites in southern South America. At San Antonio Oeste, Rio Negro Province, on the coast of Patagonia in Argentina, a complete "local census" has provided approximately weekly counts during March and April. Counts have been conducted at Fracasso Beach, on the Valdes Peninsula, Chubut Province, Argentina. Finally, a series of counts spanning 1995-2003 is available from the National Park at Lagoa do Peixe, Rio Grande do Sul state, in southern Brazil, another major stopover area for Tierra del Fuego / Patagonia wintering population knots (DU3). These all showed declines in Red Knot numbers that are consistent with those observed at the core sites in Tierra del Fuego (COSEWIC 2007). Updated information is not available from these areas.

Arctic PRISM surveys provide the most comprehensive description of abundance and distribution on the breeding grounds (Bart and Johnston 2012, Rausch and Smith 2013, Lathrop *et al.* 2018). These surveys involve ground-based counts in 12-16 ha plots distributed in a stratified random fashion across the whole of the Canadian Arctic. More than 2700 plots were surveyed between 1994 and 2018. Additional plots were surveyed intensively over a 5-week period at 14 sites throughout the Arctic, to establish detection rates and allow for corrections in the larger sample. Although Arctic PRISM surveys will eventually provide population trends from the breeding grounds, full coverage of the Canadian Arctic was just recently achieved and trends are therefore not yet available. The only information on recent trends in *rufa* Red Knot numbers on the breeding grounds in the central Canadian Arctic comes from surveys conducted annually in a 9.2 km^2 study area on Southampton Island, between 2000 and 2005 (Niles *et al.* 2005). Changes in numbers of Red Knots of the *roselaari* subspecies (DU2) breeding on Wrangel Island, Russia, were reported by Tomkovitch and Dondua (2008).

Abundance

Arctic PRISM surveys provide regional estimates of abundance, but because Red Knot from DUs 3, 4 and 5 appear to mix on the breeding grounds, and the southern boundary separating DU 1 from DUs 3, 4 and 5 is not well-known, it is difficult to partition Arctic PRISM results into DU-specific population estimates. Across all of Arctic Canada, PRISM surveys yielded an preliminary Red Knot population estimate (±SE) of 667,633 ± 188,608 breeding (mature) individuals (Smith pers. comm. 2020). Density was higher in wetland habitats than in mesic and sparsely vegetated, dry habitats (0.80 birds/km^2, 0.26 birds/km^2, and 0.30 birds/km^2, respectively). However, owing to the much larger spatial extent of the latter habitat category, most Red Knot were estimated to occur in these dry, barren habitats (proportion: 0.17 in wetlands, 0.16 in mesic habitats, and 0.67 in dry habitats; Smith pers. comm. 2020).

Summing regional PRISM results from within the range of DUs 3, 4, and 5 yields a preliminary estimate for *rufa* of 81,530 ± 45,404 breeding indivuals. The imprecision reflects the rarity of sightings within the surveyed plots. This estimate is consistent with population estimates given below for these DUs from non-breeding grounds, especially when considering the confidence limits of the estimate, and that the surveys occurred over periods stretching back to 1994 (Smith pers. comm. 2020).

If it is assumed that all Red Knot nesting on Devon, Prince Patrick and Melville Islands, and areas further north, are *islandica*, PRISM surveys suggest a preliminary population estimate for *islandica* of 552,567 ± 165,164 mature individuals. In contrast to results for *rufa*, this estimate is substantially larger the previous population estimates. As described below for DU1, previous estimates rely on unverified assumptions about the proportion of the population occurring in Canada, and PRISM survey results suggest that the proportion is likely larger than previously believed (Smith pers. comm. 2020).

Age structure and number of mature individuals

COSEWIC considers species abundance in terms of the number of mature individuals, defined as "the number of individuals known, estimated or inferred to be capable of reproduction" (IUCN Standards and Petitions Subcommittee 2017). Most Red Knot counts, either aerial or ground, record the total number observed, with little information on the age categories present. Red Knot is generally considered to start breeding when two (or more) years old. A bird up to 1 year old is considered a juvenile, a bird 1-2 years old approaching its first breeding season is a sub-adult, and a bird older than 2 years is an adult. The proportion of each age class in the population depends on the annual survival of each age class and the fecundity of the birds and can be modelled in a population matrix. This modelling exercise, undertaken by S. Wilson and R.I.G. Morrison using parameter values considered to be the most realistic, is presented in Appendix 1.

Overall results suggest that a relatively stable population would contain about 25% juveniles, 15% subadults, and 60% adults (Appendix 1). For surveys on the wintering grounds, the proportion of mature individuals would be 60% of the counted population, because sub-adults are not yet considered mature individuals. This value has been used to convert wintering survey numbers to numbers of mature individuals. Uncertainties may arise where the three age classes have different geographical distributions, and in declining populations which may have age-specific differences in mortality. These proportions may not apply during migration, e.g., all birds counted during northward migration at North American stopover areas are presumably adults, and adults precede juveniles during southward migration.

DU1 - *islandica* subspecies

The global *islandica* population was previously considered to number about 270,000 individuals (then considered equivalent to 202,500 mature individuals using 75% adults plus sub-adults, currently 162,000 using 60% adults) (COSEWIC 2007). More recent estimates indicate population levels of 450,000 birds (equivalent to 270,000 mature individuals; Delaney *et al.* 2009), and 500,000-565,000 birds (up to 2016) (equivalent to 300,000-339,000 mature individuals; mean of about 320,000) based on counts and expert opinion (Wetlands International 2018). International Waterbird Census count totals in Europe fluctuated between 273,000 and 423,000 during the period of 2011–2015 (Wetlands International 2018) and increases may represent wider survey coverage, in part.

The Canadian breeding population of *islandica* Red Knot (DU1) is thought to hold at least 40% of the subspecies population, based on previous population estimates (Whitfield *et al.* 1996; Meltofte 1985; Morrison *et al.* 2006; COSEWIC 2007; Smith pers. comm. 2020). However, this proportion should be regarded as approximate, and recent Arctic PRISM survey estimates suggest it may be an underestimate (Smith pers. comm. 2020). Applying this proportion to a global estimate of about 320,000 mature individuals gives a Canadian breeding population estimate of *islandica* Red Knot of at least 128,000 mature individuals (Morrison *et al.* 2006; Andres *et al.* 2012).

DU2 - *roselaari* subspecies

Carmona *et al.* (2013) reviewed records of Red Knot on the Pacific coast of the Americas, showing that there were few sites there which held large numbers of birds, and concluding that the concentrations observed were compatible with the then current estimate of 17,000 individuals. More recent work using superpopulation modelling approaches by Lyons *et al.* (2016) has estimated the population of adult *roselaari* (DU2) using the Pacific coast at 21,770 (16,200-30,320), which is considered to be equivalent to the number of mature individuals in the Canadian population estimate in this report.

DU3 - Tierra del Fuego / Patagonia wintering population

Initial estimates of the size of the *rufa* population in the 1980s, derived from band re-sighting data and counts, suggested the population numbered between 100,000 and 150,000 individuals (B.A. Harrington unpubl. results, *in* Morrison and Harrington 1992), although this estimate included all three *rufa* DUs (Harrington *et al.* 1988; Morrison and Harrington 1992; Morrison *et al.* 2001). While these counts are considerably higher than current combined estimates (Morrison *et al.* 2020b) of the three *rufa* DUs, the general trajectory of abundance indices from the International Shorebird Surveys and Delaware Bay in particular (see **Trends**), suggests they may well be relatively accurate.

The first direct count for the Tierra del Fuego / Patagonia wintering population (DU3) was by Morrison and Ross (1989) who found some 67,500 knots during aerial surveys of the coastlines of Patagonia (14,314) and Tierra del Fuego (53,232), including approximately 40,500 mature individuals, in the 1980s. This population has since suffered a major decline (see **Trends**) and the latest survey in January 2020 resulted in total of 11,795 individuals on Tierra del Fuego (Morrison *et al.* 2020c). As estimates for the total number on the coast of Patagonia in 2003, 2004, and 2012 averaged approximately 670 birds, it is likely that the current total population of birds in the Tierra del Fuego / Patagonia wintering population (DU3) is 12,500 knots or less, representing approximately 7,500 mature individuals. It is thought likely that not all juvenile birds migrate to the southern parts of the wintering range (Baker *et al.* 2004, 2013, 2020), so that this estimate of the number of mature individuals may be a slight underestimate.

DU4 - northeastern South America wintering population

Counts of Red Knot on the northeastern coast of Brazil have increased in recent years, although this is thought to be almost entirely a result of better survey coverage. The original surveys in the 1980s produced a total of 8,150 knots in the Maranhão region (Morrison and Ross 1989). Subsequent aerial surveys in 2005 found a similar number of 7,575 birds (Baker *et al.* 2005a) but were conducted at variable tide heights. Smaller numbers of knots were found using ground or boat surveys during the winter, although as many as 7,000 have been recorded there during the migration period (Wilson *et al.* 1998; Rodrigues 2000; Rodrigues and Lopes 2000). Aerial surveys in 2011 (total knots 3,660) and 2013 (total knots 15,485) provided improved coverage of the Maranhão and northeastern Brazil coastline. However, experience gained during these surveys showed that detection of knots was extremely dependent on tide height during the survey, necessitating coverage of the main roosting areas on headlands, offshore islands and sandbars at or very close to high tide. The most recent survey in 2019, following this protocol, resulted in a count of 32,515 (estimated 19,500 mature individuals), centred mostly in Maranhão.. Numbers recorded in 2019 in areas covered in previous years at similar tide conditions were similar, so the additional coverage of offshore areas likely accounted for the higher total in 2019 (see further comments below in **Trends**; Morrison *et al.* 2020c).

The 2019 survey may be regarded as the most accurate estimate of the population to date (Morrison *et al.* 2020c; NJA 2020). The most recent survey confirms that the Cajuais Bank, farther east in Brazil in the State of Ceara, supports approximately 1000 knots in winter (>500, Fedrizzi *et al.* 2016; 900-1200, Mobley pers. comm. 2019).

Although Red Knot is not reported as wintering in Suriname (Spaans 1978), small numbers have been recorded on eBird (eBird 2019). In French Guiana, small (irregular) numbers have been recorded in winter (up to 480; de Practontal 2017; up to 105, eBird 2019). These records are likely referable to the northeastern South America wintering population (DU4).

The total wintering population size for Brazil and the Guianas is thus estimated as approximately 33,000 birds, including 19,800 mature individuals.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population

Estimates of the number of Red Knot in Florida and southeastern Atlantic states (part of the southeastern USA / Gulf of Mexico / Caribbean wintering population DU5) over the past 30 years have ranged from 10,000 (Morrison and Harrington 1992) to 7,500 (Harrington pers. comm. 2005) to 4,500 total individuals (Sprandel *et al.* 1997; Niles *et al.* 2005). The latter estimate was based on aerial and ground surveys during the winter of 2005-2006 (Niles *et al.* 2006). However, more recent results from mark-recapture-resight studies of Red Knot in Georgia (Lyons *et al.* 2018) resulted in estimates of approximately 10,400 knots wintering in the southeastern United States, with another 5,100 wintering elsewhere in the northern wintering range, with most probably on islands in the Caribbean (a further 5,400 in Brazil are referable to the northeastern South America wintering population DU4). This gives an overall wintering estimate for DU5 of 15,500 individuals, and assuming that 60% of these birds are adults, the total number of mature individuals is approximately 9,300.

Fluctuations and Trends

DU1 - *islandica* subspecies

Trend analyses of *islandica* Red Knot wintering in Europe are mixed, but indicate that whereas over the long term (1975-2015) there has been a statistically significant strong increase (annual rate 1.0138, SE 0.0043), in more recent years (2006-2015) the trend has been uncertain or fluctuating (annual rate 0.9923, SE 0.0314) (Figure 11; IWC 2020).

Moderate decreases up to 2012 were followed by more recent increases (statistically significant long-term 1975-2015) or fluctuating estimates (Nagy *et al*. 2014; BirdLife International 2015; Wetlands International 2018); the population trend in recent years (2006-2016) is less certain and appears to be either stable or fluctuating slightly (IWC 2020; van Roomen pers. comm. 2020) (Figure 11). The trend is based on counts of wintering knot in ten countries, dominated by counts from the United Kingdom and Netherlands, where wintering numbers have decreased in Great Britain and Ireland, but increased in the Wadden Sea (Netherlands) and in northwest France. Analytical methods are described by Wetlands International (2017). Van Roomen *et al.* (2012) estimated the population trend of wintering Red Knot in the Wadden Sea at between +1 and +2% per year for the period 1991-2009. It is assumed that the population trends observed for Red Knot *islandica* birds wintering in western Europe are representative of the Canadian population.

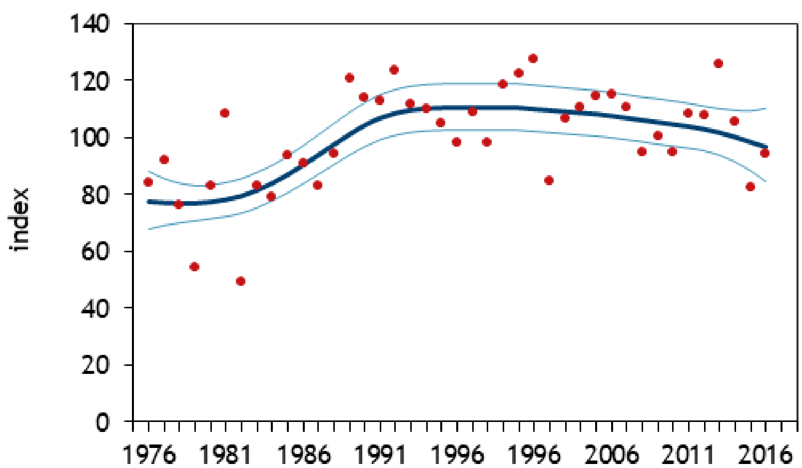

Figure 11. Annual indices of abundance and estimated trend of *C. c. islandica* Red Knot wintering in Europe, 1976-2016, based on International Waterbird Census counts, including DU1 birds from Canada (Wetlands International 2018; IWC 2020; van Roomen pers. comm. 2020). Analytical methods are described in van Roomen *et al.* (2018): trends were detected and estimated using the program TrendSpotter, which produces trend lines (dark line) and 95% confidence intervals (light blue lines) (Visser 2004; Soldaat *et al.* 2007; Figure from van Roomen *et al.* 2018, courtesy of M. van Roomen).

DU2 - *roselaari* subspecies

There was a strong decline in numbers of Red Knot *roselaari* subspecies breeding on Wrangel Island, Russia, between 1974-1977 and 2007, with densities falling from an estimated 6.7 pairs/km^2 to a maximum of 2.5 pairs/km^2, a decrease of at least 63% over the 30-year period (Tomkovich and Dondua 2008).

The limited amount of information available to assess trends in the *roselaari* population (DU2) migrating along the Pacific coast also suggests large long-term decreases. Trends calculated from the International Shorebird Survey for the

Pacific/Intermountain Region (Table 2; Figure 12) indicate dramatic decreases over the first 20 years of records (1974-1994), with ongoing but lower declines during the next 20-year period, when fewer counts were made in this region (Smith pers. comm. 2020; Figure 12). A logarithmic plot shows a significant relationship for the entire period (1974-2013) with an overall rate of decline of -8.45% per year, equivalent to a decrease of 96.8% over the entire period (not illustrated; Table 2). Over the 3-generation period (1992-2013; the latest for which data are available), there was a significant rate of decline of -4.73% per year, equivalent to a decrease of 63.9% over three generations (Figure 12; Table 2). It should be noted, however, that precision of this estimate is low owing to small sample sizes (5 out of 23 sites; Smith pers. comm. 2020).

Table 2. Annual rates of changes in Red Knot numbers and likely DUs involved, derived from International Shorebird Survey counts from various regions of North America, showing annual rate of change (with 95% confidence limits), and the percent decrease that would occur (a) over the entire period 1974-2016, and (b) over a 3-generation period (21 years, 1995-2016)*. Statistically significant rates of change (where confidence limits do not include zero) are shown in bold/italics. DU2 = *C. c. roselaari*; DU3 = *C. c. rufa* Tierra del Fuego / Patagonia wintering population; DU4 = *C. c. rufa* northeastern South America wintering population; DU5 = *C. c. rufa* southeastern USA / Gulf of Mexico / Caribbean wintering population.

International Shorebird Survey Region	Likely DUs	Annual % rate of change	-95% confid. limit	+95% confid. limit	% change over period
a. 1974-2016					
Atlantic Canada	3,4,5	***-8.37***	***-9.07***	***-7.66***	-97.0
East Inland	3,4,5	0.055	-2.74	2.99	2.32
Midcontinental	5	***-11.3***	***-15.3***	***-7.25***	-99.1
Northeast US Coast	3,4,5	***-4.48***	***-5.39***	***-3.52***	-84.8
Ontario	3,4,5	***-7.21***	***-9.68***	***-4.88***	-95.2
Pacific and Intermountain 1974-2013	2	***-8.45***	***-9.63***	***-7.28***	-96.8
SE US Coast	(3,4),5	***-4.61***	***-7.04***	***-1.98***	-85.6
Texas Coastal 1974-2013	5	***-6.37***	***-7.54***	***-5.20***	-92.3
Continental	2,3,4,5	***-5.67***	***-10.2***	***-0.561***	-90.8
Delaware Bay 1982-2017	3,4,5	***-3.68***	***-5.31***	***-2.04***	-66.3
b. 1995-2016					
Atlantic Canada	3,4,5	***-5.79***	***-7.11***	***-4.42***	-70.4
East Inland	3,4,5	2.88	-0.391	6.16	83.1
Midcontinental	5	***-8.84***	***-13.2***	***-4.34***	-84.4
Northeast US Coast	3,4,5	***-1.78***	***-3.4***	***-0.041***	-31.2
Ontario	3,4,5	***-4.59***	***-7.31***	***-1.89***	-61.9
Pacific and Intermountain 1992-2013	2	***-4.73***	***-8.4***	***-0.011***	-63.9
SE US Coast	(3,4),5	-1.91	-4.7	0.874	-33.1

International Shorebird Survey Region	Likely DUs	Annual % rate of change	-95% confid. limit	+95% confid. limit	% change over period
Texas Coastal 1992-2013	5	-2.73	-6.4	0.010	-44.1
Continental	2,3,4,5	-3.00	-7.84	2.35	-46.8
Delaware Bay 1996-2017	3,4,5	***-3.60***	***-6.69***	***-0.51***	-53.7

*ISS analyses trends were estimated with a hierarchical Bayesian model using Markov Chain Monte Carlo sampling, assuming that counts follow an over-dispersed Poisson distribution, for the periods indicated (ECCC 2019), except for Pacific and Intermountain Region, Texas Coastal Region, and Delaware Bay, for which linear regression of annual indices was used

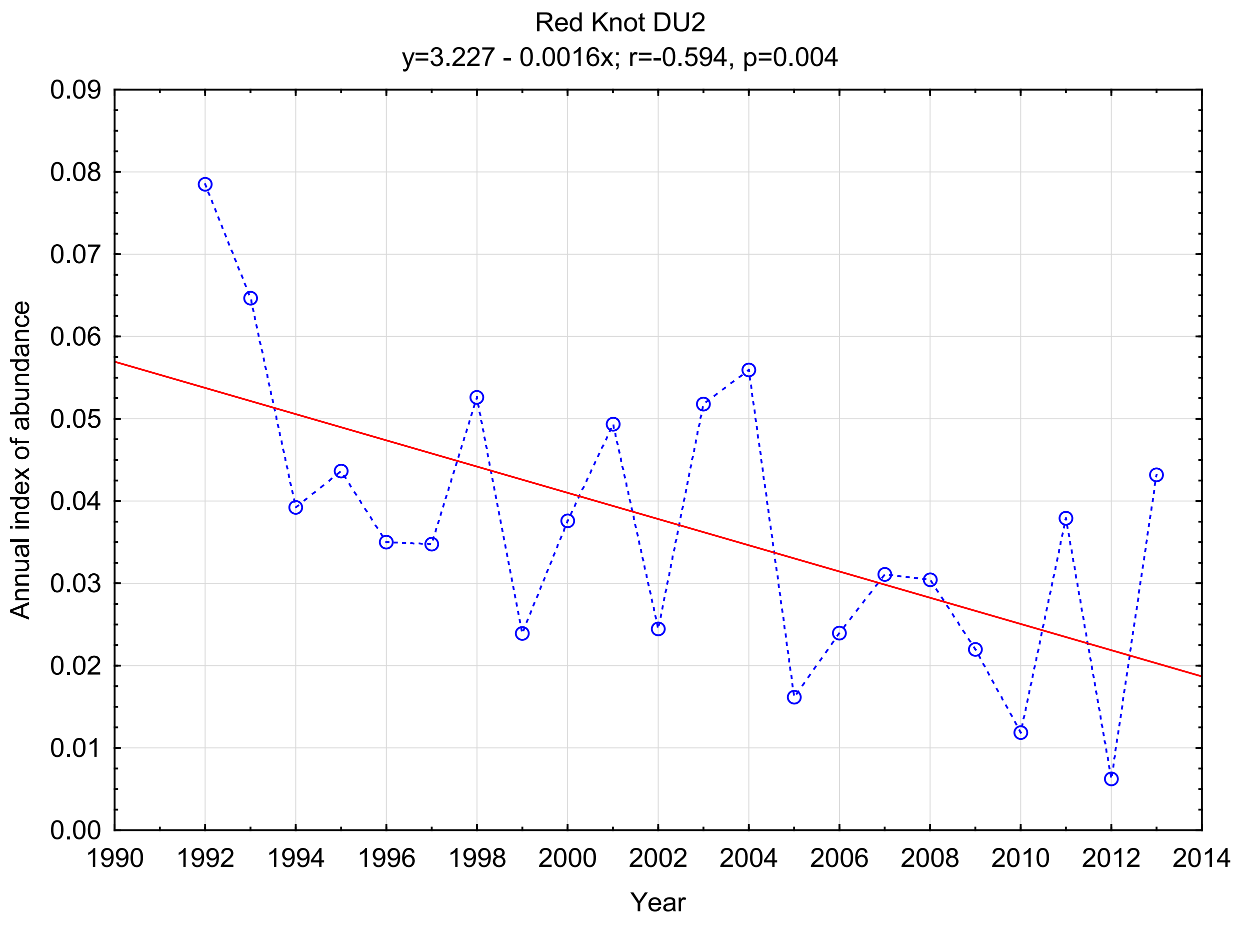

Figure 12. Linear fit of annual indices of abundance of Red Knot, mostly birds from *C. c. roselaari* (DU2), based on fall surveys from the International Shorebird Survey Pacific and Intermountain Region for the 21-year period 1992-2013. The linear rate of decline was significant (-4.73%/year, r=-0.594, p=0.004), although precision of this estimate is relatively low.

Christmas Bird Counts conducted in California (BCR-32) and Washington (BCR-5), which would sample DU2 *roselaari* knots in the northern part of their wintering range

(Carmona *et al.* 2013, Baker *et al.* 2020), also suggest substantial declines. Over the most recent 21 year period (1998-2019), trends were estimated as -2.33% per year (significant) and -3.47% per year, respectively, which would imply decreases of -38.7% in California and -51.7% in Washington over that period (Table 3). The longer-term (1970-2019) decrease was significant in both BCRs, at -2.32% and -3.93% per year implying decreases of -67.1% in California and -85.4% in Washington, respectively (Table 3).

Table 3. Trend analyses of Christmas Bird Count data for different Bird Conservation Regions (BCRs) used by wintering populations of Red Knot in DU 2 (Pacific coast wintering population of *C.c. roselaari*) and DU5 (southeastern USA/Caribbean/Gulf of Mexico wintering population of *C. c. rufa*). Trends are shown as % change/year over the period indicated: (a) long-term 1970-2019 (49 years), and (b) 1993-2019 (26 years) provided by National Audubon Society (T. Meehan pers. comm. 2020), with upper and lower 95% confidence limits. Significant declines, where the confidence limits do not include zero, are shown in bold. Estimated declines over indicated periods are calculated from the annual rate of change for the entire period (49 years) and most recent three-generation period (21 years, based on the 1993-2019, 26-year period estimate).

(a) 1970-2019 (49 years)

Region*	BCR*	Designatable Unit	Annual % rate of change	-95% confid. limit	+95% confid. limit	% change over period
NE Gulf/SE US	27	DU5	-0.73	-3.48	+1.61	*-30.1*
NW Gulf/Texas	37	DU5	**-9.09**	**-13.8**	**-6.04**	*-98.8*
Florida	31	DU5	**-3.63**	**-4.74**	**-2.51**	*-83.1*
California	32	DU2	**-2.32**	**-3.81**	**-0.80**	*-67.9*
Washington	5	DU2	**-3.93**	**-7.80**	**-0.14**	*-85.4*

(b) 1993-2019 (26 year period, 21 year % decline)

Region*	BCR*	Designatable Unit	Annual % rate of change	-95% confid. limit	+95% confid. limit	% change over period (21 years)
NE Gulf/SE US	27	DU5	-0.87	-3.64	+1.68	*-16.7*
NW Gulf/Texas	37	DU5	**-8.08**	**-12.68**	**-5.17**	*-81.7*
Florida	31	DU5	**-4.22**	**-6.29**	**-2.63**	*-58.8*
California	32	DU2	**-2.33**	**-3.92**	**-0.76**	*-38.7*
Washington	5	DU2	-3.47	-7.33	+0.59	*-51.7*

* BCR Regions are as follows: BCR-27 = Northeast Gulf of Mexico and southeastern United States, excluding Florida; BCR-37 = northwest Gulf of Mexico and coast of Texas; BCR-31 = Florida; BCR-32 = California (and parts of northwest Pacific coast of Mexico); BCR-5 Pacific coast north of California. Christmas Bird Count trends were estimated using a log-linear hierarchical model with an effort function, as described by Link and Sauer (2007).

Counts from the large Alaskan estuaries (Copper River and Yukon-Kuskokwim deltas) used as stopover sites on northward migration are more complicated to interpret, but also suggest that substantial decreases have occurred. Analysis of a 31-year (1978-2008) series of spring counts from the Tutakoke River area on the Yukon-Kuskokwim delta showed no statistical evidence for a decrease in peak spring counts (McCaffery *et al.* 2009). However, several much larger counts were recorded in the 1970s, suggesting that larger numbers of knot occurred there then than in recent years. For instance, Kessel and Gibson (1978) reported a one-day count of 40,000 knots on the Copper River Delta on 11 May 1975, where estimates of up to 100,000 knots have been made (Islieb 1979; Islieb in Kessel 1989). However, Islieb's (1979) observations appear to be based on extrapolation, which would not be appropriate for knots which occur in clumped distributions. A count of a possible 110,000 knots on the central Yukon-Kuskokwim Delta on 21 May 1980 (Gill and Handel 1990) may be anomalous, perhaps a result of late spring conditions (Kessel and Gibson 1978; Gill and Handel 1990). Given the unusual nature of this count, the data and original field observations were thoroughly reviewed for this report by Gill and Handel (Gill pers. comm. 2020), who concluded that a revised total of 90,000 was appropriate for that observation. Interestingly, and perhaps coincidentally, back-calculating from the recent estimate of 22,000 *roselaari* in 2009 (Lyons *et al.* 2017), using the 3-generation rate of decline of -4.73%, gives an estimated population of 86,725 birds in 1980. No clear reason has been established for the high count in 1980 (McCaffery *et al.* 2009), but such numbers may have been possible if unusual conditions brought together all knots that normally staged across the un-vegetated flats and coastal meadows of the large Yukon-Kuskokwim and Copper River deltas (Gill pers. comm. 2020). Reports of Red Knot passing through both deltas have generally involved several tens of thousands of birds (Kessel and Gibson 1978; Islieb 1979; Gill and Handel 1981, 1990), compared with current estimates of about 10,000 knots using these areas (Bishop *et al.* 2016). If most *roselaari* knots move through southern Alaska on spring migration, the total would be closer to 22,000 (Buchanan pers. comm 2020). Overall, it appears there have been substantial decreases in numbers of Red Knots using Alaskan estuaries during northward migration, despite some uncertainties surrounding earlier counts.

DU3 - Tierra del Fuego / Patagonia wintering population

The overall wintering population of Tierra del Fuego / Patagonia wintering population *rufa* Red Knot (DU3) was approximately 67,500 birds in 1982, of which 78.8% were reported in Tierra del Fuego and 21.2% on the coast of Patagonia (Morrison and Ross 1989). At core wintering areas in Tierra del Fuego, the population count fell from 51,255 birds when surveys were resumed in 2000 to a low of 9,840 in 2018, representing a decrease of 80.8% over 18 years, less than three generations (Morrison 2018) (Figure 13). The most recent count in January 2020 of 11,795 (Morrison *et al.* 2020a) indicates a three-generation decline of 77.0%. Although the steepest declines occurred in steps between 2000 and 2011, a logarithmic plot of counts from 2000-2020 shows a significant relationship, with an annual decrease of -6.3%, equivalent to a decline of 73.4% over 3 generations (21 years: 1999-2020; Figure 13). The reasons for this very substantial decline are discussed under DU3 in **Dispersal and Migration** above, showing that the declines in Tierra del Fuego are reflected in the decrease in annual survival recorded in Delaware Bay during this period (Baker *et al*. 2004).

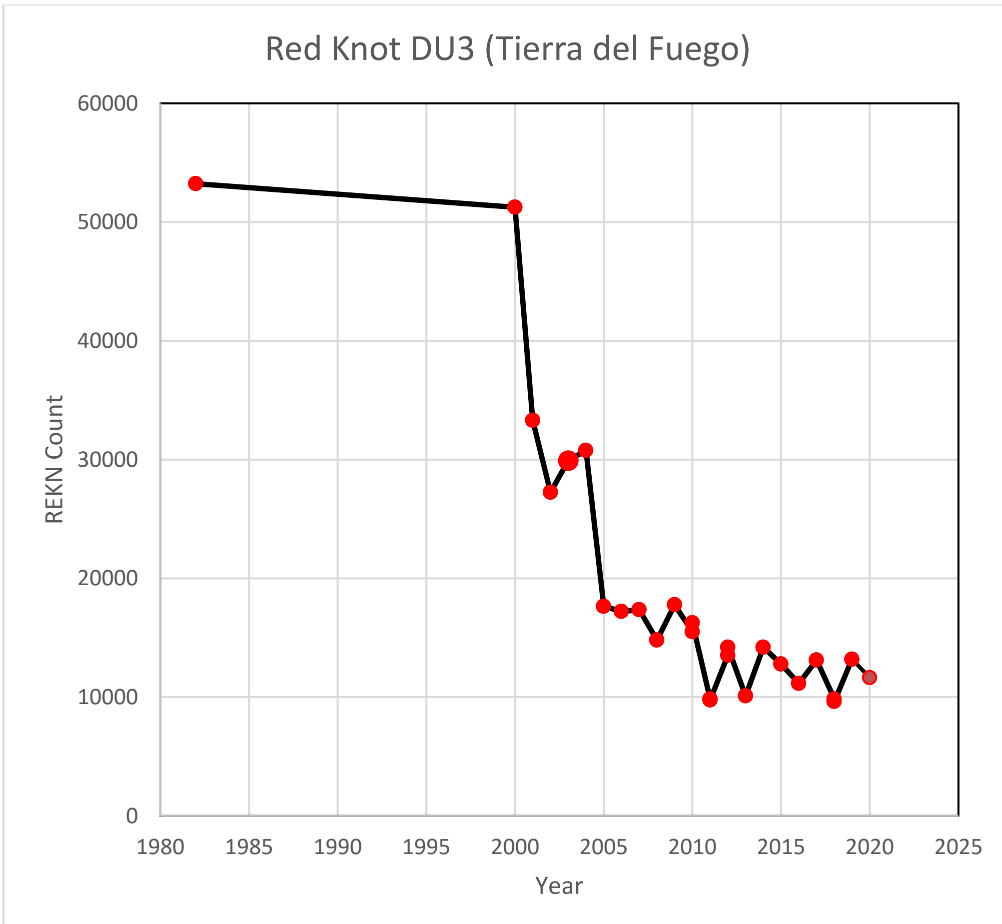

Figure 13. Total counts of *C. c. rufa* Red Knots from the Tierra del Fuego / Patagonia wintering population (DU3) during aerial surveys in Tierra del Fuego, 1982-2020 (from: Morrison *et al.* 2020a,b; Morrison unpubl. data). There was a significant exponential decline across the period 2000-2020 (-6.3%/year, r=0.794, p=0.000).

Four surveys have been flown along the Patagonia coast since 2000 (in 2002, 2003, 2004, 2012) to determine whether declines in Tierra del Fuego may have resulted from redistribution to more northerly areas. They showed instead that declines had been steeper and more extensive in Patagonia (Morrison *et al.* 2004; Morrison unpubl. data). Whereas in 1982 about 21.2% of the southern population wintered at Patagonian sites, this proportion fell to 6.9%, 1.8%, 2.8%, and 4.0% in the four survey years, respectively, so that by 2012, >95% of the Tierra del Fuego / Patagonia wintering population (DU3) wintered in Tierra del Fuego.

Declines have been particularly severe at Rio Grande, Argentina on the Atlantic coast of Tierra del Fuego (Morrison 2018). Whereas some 3,500-5,000 wintered in this area up to 2008 (and in 1982), numbers fell rapidly to less than 200 by 2012. Logarithmic plots of counts show the annual overall decrease between 2000 and 2018 was -27.0% and between 2008 and 2018 was -33.0%. Note that the rapid declines at Rio Grande began after the major declines in Bahia Lomas, suggesting that different factors may have influenced numbers at this site (Escudero *et al.* 2012).

DU4 - northeastern South America wintering population

There is relatively little information available with which to assess trends for birds from the northeastern South America wintering population (DU4), centred in northeastern Brazil. Early surveys suggested that approximately 8,000 Red Knot wintered in the Maranhão region (Morrison and Ross 1989; Baker *et al.* 2005a), with a survey in 2013 increasing this total to 15,485, and the most recent aerial survey of this region in 2019 producing a total of 32,515 knots (Morrison *et al.* 2020c; NJA 2020). Experience gained during the surveys showed that numbers of knots encountered were very sensitive to tide height during the surveys, as roosting flocks are found almost entirely on sandy outer headlands and offshore sandy islands and sandbars, with the birds dispersing rapidly on the falling tide to feeding areas, where they are not detected. Differences in survey timing and coverage appear to account for the large difference between the 2013 and 2019 surveys. In 2019, all survey sectors were covered at or very close to high tide, including onshore outer headlands/beaches and offshore islands/sandbars. In 2013, only 72% of sectors were covered at high tide, and only one sandbar or island was covered. If the 2013 total (15,485) is adjusted by the difference in totals between the areas not covered at high tide in the two years (5,595) and the additional offshore sandbars/islands covered in 2019 (8,320), the adjusted total would be 29,400, a difference of about 5.3% lower than the 2019 total. The difference in totals between survey years thus appears to be a result of the more complete coverage in 2019 rather than an appreciable population increase. Conditions during aerial surveys prior to 2013 were also highly subject to variable timing at key roosting areas, as they were designed to assess numbers of all shorebird species and to cover long stretches of coastline under constraints of time and fuel availability. Thus, it is difficult to ascertain trends from the survey results over the years. Ground observations, however, suggest that the overall size of this population has been relatively stable (Mobley pers. comm. 2019).

It is important to note that there appears to be negligible interchange of Red Knot between DU3 and DU4, as discussed in **Dispersal and Migration** (above), so that changes in numbers in the two wintering areas cannot be accounted for by redistribution of the birds.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population

Red Knot wintering on the Atlantic coast of the southeastern United States are likely to be surveyed at ISS sites there during migration. While some birds from the Tierra del Fuego / Patagonia wintering population (DU3) and the northeastern South America wintering population (DU4) may pass through the southeastern United States area, the bulk of these birds appear to be from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5; Lyons *et al.* 2018). Birds from wintering areas on the west coast of Florida, Gulf of Mexico and Texas are thought to take an interior route to and from the breeding grounds, so counts from the Texas and Midcontinent Regions of the ISS may also reflect population trends for these birds (southeastern USA / Gulf of Mexico / Caribbean wintering population DU5).

Trends of numbers of Red Knot in the ISS Southeast US Coast region, primarily from this DU, are shown in Figure 14. The population appears to have been relatively stable from 1974 to about 1985, then declined rapidly until about 1995, and has been relatively stable at a lower level or declining slightly since then. The rate of decline over the past 21 years (three generations) was -1.91% per year (-33.1% total), although the trend parameter was not significantly different from zero. Over the longer term 1974-2016, the annual rate of change was -4.61%, implying an 85.6% population decrease, which was statistically significant (Table 2).

Counts of Red Knot from the ISS Midcontinental Region, likely mostly from the southeastern USA / Gulf of Mexico / Caribbean wintering population, have shown dramatic decreases (Table 2), and the long-term rate of decline from 1974-2014 was -11.3%/year, which would be equivalent to an apparent (and somewhat unrealistic) decrease of -99.1% over 40 years. The rate of decline over a recent three-generation period (1995-2016) was -8.84 %/year, also significant, equivalent to a decrease of -84.4% over 3 generations (Figure 15). While this rate of decline is substantial, ISS survey coverage is modest in the Midcontinental Region, so these results must be interpreted with caution.

Fall ISS counts in the Texas Coastal Region include Red Knot wintering in Texas and in areas farther south, mostly from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5). A significant long-term decline occurred over the period 1974-2013 (Table 2), at a rate of -6.37% per year, equivalent to a decrease of 92.3% over 40 years. The rate of decline over a recent three-generation period (1993-2013) was -2.73%/year (44.1% decrease), but was not significant (Table 2, Figure 16).

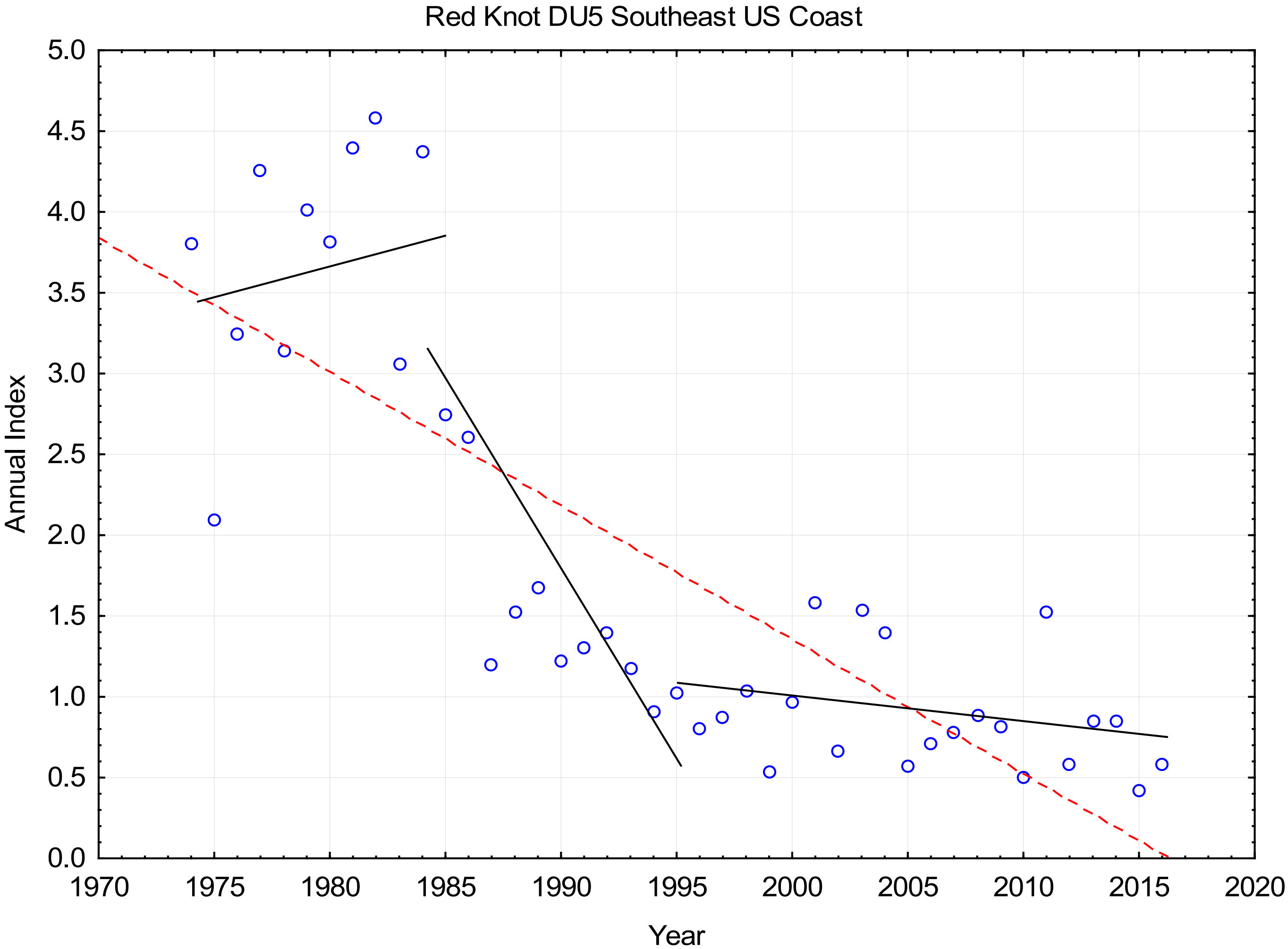

Figure 14. Annual index of abundance of *C. c. rufa* Red Knot, mostly birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), based on fall surveys from the International Shorebird Survey in the Southeast US Coast Region of the United States, 1974-2016. While the overall regression is significant (dashed line, r=0.804, p=0.000), the points (solid lines) suggest relative stability from about 1974 to 1985 (r=0.210, p=0.512), followed by a period of significant decline from about 1984 to 1995 (r=-0.721, p=0.019), with more stable counts since about 1995 (r=-0.270, p=0.236).

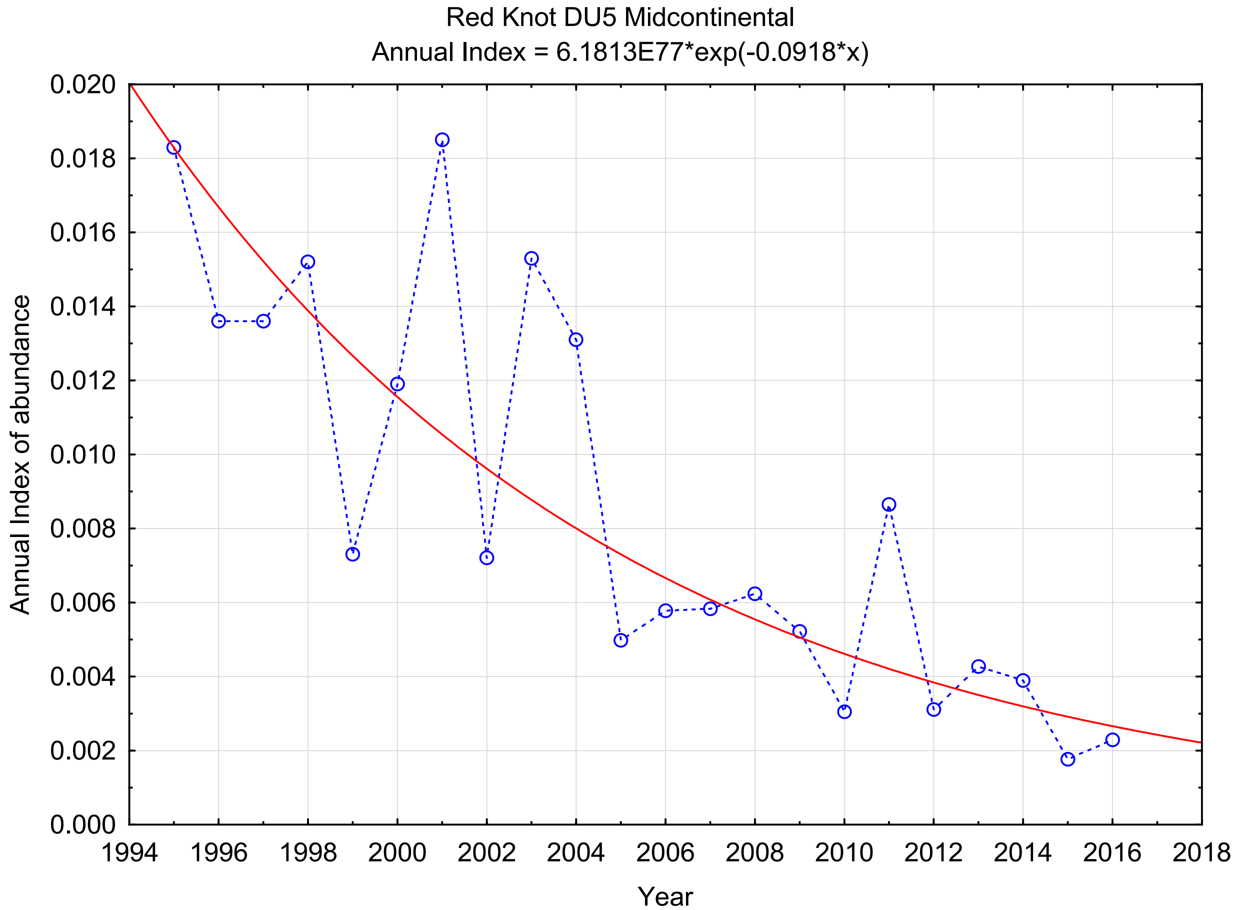

Figure 15. Exponential fit of annual indices of abundance of *C.c. rufa* Red Knot, mostly birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), based on fall surveys from the International Shorebird Survey Midcontinental Region for the 21-year period 1995-2016.

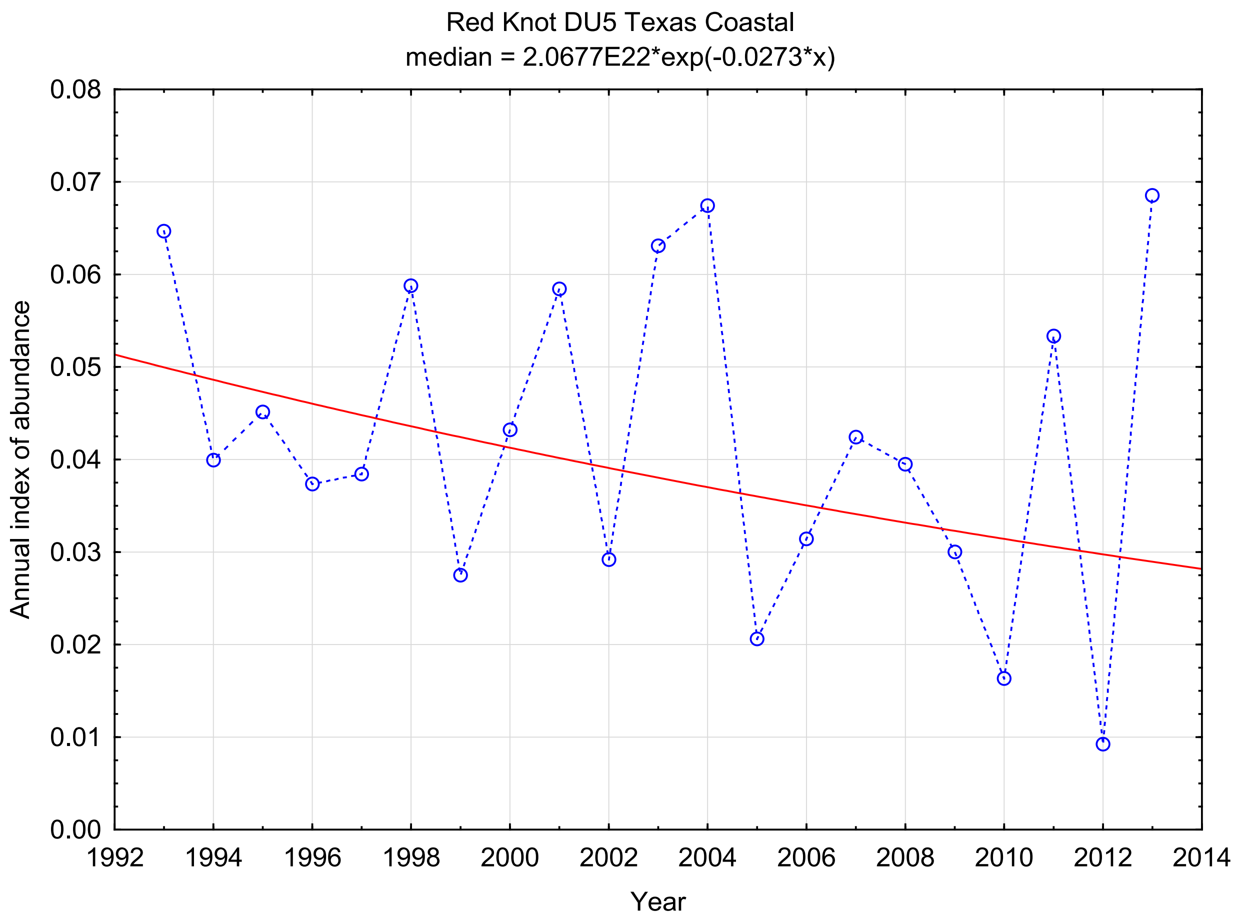

Figure 16. Exponential fit of annual indices of abundance of *C.c. rufa* Red Knot, mostly birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), based on fall surveys from the International Shorebird Survey Texas Coastal Region for the 21-year period 1993-2013.

Trends derived from Christmas Bird Count data directly measure changes in some DU5 wintering populations, and CBC results are broadly similar to those from the ISS. In Florida (BCR-31, equivalent to the ISS Southeast Region), the decrease over three generations (1998-2019) was calculated as -58.8%, based on the statistically significant decline rate of -4.22%/year recorded for 1993-2019 (Table 3). The long-term (1970-2019) rate of decline was also significant at -3.63%/year (-83.1% decrease). For the Texas and northwest Gulf of Mexico region (BCR-37, equivalent to the Midcontinental and Texas Regions of the ISS), the decrease over three generations was also significant and calculated as -81.7%, using a 21-year rate of decline of -8.08%/year. The long-term (1970-2019) rate of decline was also significant at -9.09%/year (-98.8% decrease).

The ISS and CBC results are thus consistent in indicating that appreciable decreases in numbers of Red Knots wintering in the Gulf of Mexico/Texas region appear to be considerably greater than for those birds wintering in Florida.

In summary, these results suggest that Red Knot numbers in the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) have declined substantially over three generations, with decreases in the western part of the wintering range (northern Gulf Coast and Texas) (Figures 15, 16; Table 2) being higher than those in Florida (Figure 14, Table 2). Efforts to derive an overall rate of population decline for Red Knot in this DU are complicated by birds in different areas having different migration routes, and possibly belonging to different subgroups; e.g., the USFWS considers DU5 to consist of two different wintering populations (USFWS 2014a). Estimated decreases over three generations for the more westerly wintering regions were -84.4% (ISS Midcontinental), -44.1% (ISS Texas Coastal) and -81.7% (CBC; BCR-37), while decreases for Florida were estimated as -33.1% (ISS Southeast US Coast) and -58.8% (CBC; BCR-31) (Tables 2, 3).

Trend estimates for populations of *rufa* on spring and fall migration in eastern North America (Tierra del Fuego / Patagonia wintering population DU3, northeastern South America wintering population DU4, and southeastern USA / Gulf of Mexico / Caribbean wintering population DU5)

Fall migration (ISS)

Although *rufa* Red Knot from all three DUs occur at most major migration sites in eastern North America on fall migration, the relative proportion of the different populations using those sites differs. Harrington *et al.* (2007) found that most knots passing southward through Massachusetts migrate to Patagonia and Tierra del Fuego (DU3), whereas most knots found in Georgia winter in the southeastern United States and are therefore from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5). Subsequent work in Georgia has supported this conclusion, based on re-sighting analysis of flagged birds supported by stable isotope analysis of birds from different populations (Lyons *et al.* 2018). Although it appears that increasing numbers of *rufa* Red Knot from the “northern” wintering groups (northeastern South America wintering population DU4, and southeastern USA / Gulf of Mexico / Caribbean wintering population DU5) have been using Massachusetts stopovers since about 2009, they use the area for different purposes (moult versus ongoing migration, with moulting birds staying longer and birds on migration gaining weight and leaving) and generally feed on different resources in different habitats (Harrington *et al.* 2010a,b). It appears likely that knots migrating south through Atlantic Canada and the northeast coast of the United States include a high proportion of birds from the Tierra del Fuego / Patagonia wintering population (DU3), and that declines in different ISS survey regions may reflect differences in rates of decline of the various DUs. As the most severe declines have been recorded for the Tierra del Fuego / Patagonia wintering population (DU3), higher rates of decline might be expected at more northerly migration areas on the east coast of North America. This appears to be the case (Table 2). Counts during the period 1974-2016 showed an annual rate of decline of -8.37%/ year in the Atlantic Canada region of the ISS, -4.48%/year in the Northeast US Coast region, and -4.61%/year in the Southeast US Coast region: all were statistically significant. The same pattern was observed for the decline rates during the past three generations (21 years, 1995-2016): Atlantic Canada -5.79% (significant), Northeast US Coast -1.78% (significant) and Southeast US Coast -1.91% (not significant). The consistency of these patterns suggests that the declines are the result of reductions in numbers rather than changes in distribution, and that the large declines recorded on the wintering grounds of the Tierra del Fuego / Patagonia population (DU3) are reflected in the decline rates observed during southward migration at sites on the east coast of North America, especially in eastern Canada.

Spring migration (Delaware Bay)

Delaware Bay is the key refuelling stop for *C. c. rufa* from the Tierra del Fuego / Patagonia wintering population (DU3) during spring migration, before the final leg of their journey to the Arctic breeding grounds. Although knots from Florida and the southeastern United States (part of the southeastern USA / Gulf of Mexico / Caribbean wintering population DU5) and northeastern South America (DU4) wintering populations also pass through this site, they do so slightly earlier and may use different habitats (Atkinson *et al.* 2005). Up to 90% of the Tierra del Fuego / Patagonia wintering population (DU3) and the northeastern South America wintering population (DU4) may use Delaware Bay, compared to perhaps 50% of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5; Bittel 2017; Burger *et al.* 2020), so that declines at this site are also likely to reflect the extensive decrease in numbers wintering in the far south. Comparison of modelled and aerial survey estimates of numbers in Delaware Bay suggests that Horseshoe Crab abundance influences length-of-stay of the Tierra del Fuego / Patagonia wintering population (DU3) and thus the peak numbers observed during the aerial surveys (Lyons 2017; Niles and Morrison unpubl. data).

Aerial survey totals in Delaware Bay before 1990 showed peaks of >90,000 knots, which have fallen to about 20,000 over the past 15 years (2003-2017; Figure 17). A logarithmic plot of the counts from 1982-2017 shows a significant decline of -4.84% per year equivalent to an overall decrease of -85.5% over 35 years, and over the most recent 21-year period a significant decline of -3.60% per year, equivalent to a decline of -53.7% over three generations (Table 2).

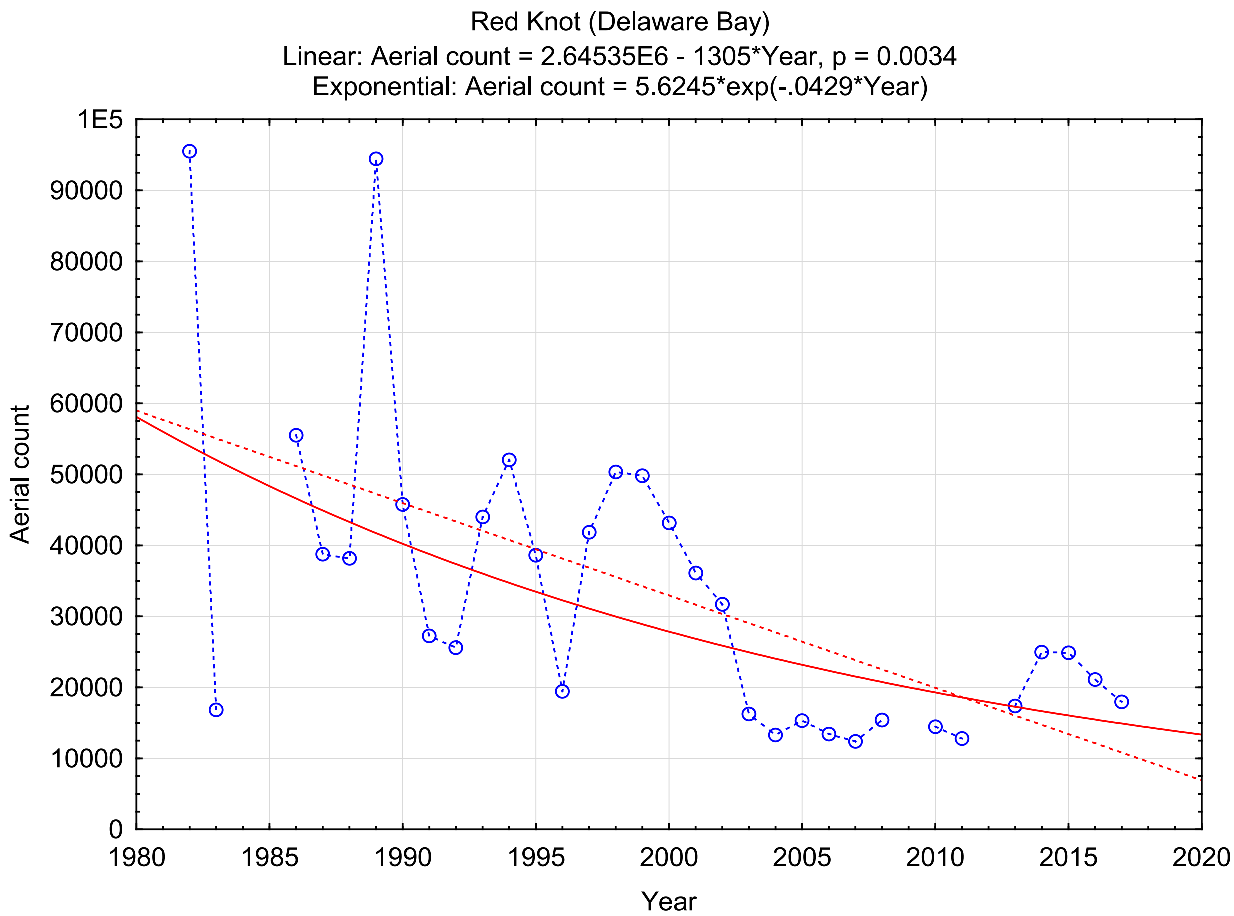

Figure 17. Total number of *C. c. rufa* Red Knot counted on aerial surveys (likely including birds from DUs 3, 4, and 5) during spring migration in Delaware Bay, 1982-2017 (L.J. Niles unpubl. data), showing linear (dashed line) and exponential (solid line) estimates of decline.

Trends on the breeding grounds

Surveys on Southampton Island showed that *rufa* Red Knot breeding densities fell from 1.16 nests/km^2 in 2000 to 0.33-0.55 nests/km^2 in 2003-2004 (Niles *et al.* 2005). The difference in mean density in 2000 compared to the last two years was significant (ANOVA, $F_{1,3}$ = 10.09, p = 0.0502) (Niles *et al.* 2007, 2010a). This work occurred at a time when the Tierra del Fuego / Patagonia wintering population (DU3) underwent particularly steep numerical declines, although the wintering area used by knots breeding in this area is currently not known.

Summary of Trends

DU1 - *islandica* subspecies

Survey data from European wintering grounds suggest the population is stable or fluctuating over the past three generations.

DU2 - *roselaari* subspecies

Trend analyses of data from International Shorebird Survey (migration counts) and Christmas Bird Count (wintering counts) suggest major continuing declines. Estimates of decreases over the most recent three generations were -63.9% in the Pacific and Intermountain Region (ISS migration counts; 1992-2013), and -38.7% in California (BCR-32) and -51.7% in Washington (BCR-5) (CBC wintering counts; 1998-2019). This is consistent with counts of about 100,000 birds in Alaska in the 1970s compared to current estimates of 22,000 individuals. Data from the breeding grounds on Wrangel Island, Russia, also suggest decreases of about 63% between 1974-1977 and 2007.

DU3 - Tierra del Fuego / Patagonia wintering population

Winter counts in Tierra del Fuego show that the population has declined substantially since 2000, with an observed reduction of 77.0% over 20 years. There was an annual decrease of -6.3% in Tierra del Fuego, equivalent to a decline of 73.4% over a 21-year period (3 generations). As almost all birds now occur in Tierra del Fuego, it is presumed that the rate of decline was higher at other wintering sites in southern Patagonia.

DU4 - northeastern South America wintering population

Differences in estimates from aerial survey counts in 2013 and 2019 suggested an appreciable population increase, but this is believed to primarily reflect more complete survey coverage in 2019 rather than population change. Calculations to assess the effect of expanded coverage in 2019 suggest that actual population change was within about 5%, and overall numbers are thought to be relatively stable.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population

Both International Shorebird Surveys (migration) and Christmas Bird Counts (wintering) indicate that substantial declines have taken place. Counts in major wintering areas show significant large decreases over three generations (1998-2019) in Florida (BCR-31) and the Northwest Gulf/Texas Region (BCR-37), of -58.8% and -81.7%, respectively. Smaller non-sigificant decreases were recorded in other areas of the Northeast Gulf/Southeastern US Region(-16.7%). ISS migration period trends also showed large and significant three-generation decreases in the Southeastern US Region (mainly Florida, comparable to BCR-31) of -33.1%, while decreases in Texas Coastal and Midcontinental Regions (comparable to BCR-37) were estimated at -44.1% and -84.4%, respectively. Although these results only present population trends for unknown but likely substantial portions of this population, the weight of evidence drawn from results of the ISS and CBC together indicates that the numbers have declined appreciably over the past three generations, with a high probability that the overall decline is in the range of 33-84%.

Rescue Effect

DU1 - *islandica* subspecies

Studies show that adult male Red Knot tend to be very site-faithful on the breeding grounds (Tomkovich and Soloviev 1994; Morrison *et al.* 2005; Baker *et al.* 2013, 2020), but little is known about dispersal from natal areas of birds breeding for the first time. Whereas it is theoretically possible that *C. c. islandica* DU1 Red Knot from Greenland might potentially rescue populations in northern Canada, it is unknown whether this is likely to occur in practice.

DU2 - *roselaari* subspecies

C. c. roselaari breeds on Wrangel Island, Russia, and in Alaska, and occurs in Canada only as a relatively scarce migrant in British Columbia, so rescue considerations do not apply.

Tierra del Fuego / Patagonia wintering population (DU3), northeastern South America wintering population (DU4), southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5)

The three DUs within the *C. c. rufa* subspecies, all of which breed entirely within Canada, are by definition separate populations and are thus not candidates for rescuing one another.

THREATS AND LIMITING FACTORS

Threats

The threats to the five designatable units of Red Knot reviewed below are categorized following the IUCN-CMP (International Union for Conservation of Nature – Conservation Measures Partnership) unified threats classification system, based on the standard lexicon for biodiversity conservation of Salafsky *et al.* (2008). This assessment addresses threats to the five Red Knot DUs in Canada, as well as those on migration and on the wintering grounds, based on perspectives provided by species experts captured in Appendices 2, 3, 4, 5, and 6.

The highest impact threats affecting all Red Knot DUs to varying degrees were human disturbance, ecosystem modifications and changes, and other problem species, while climate change was important for all DUs (Appendices 2, 3, 4, 5, and 6). The assigned overall threat impacts are: *islandica* subspecies (DU1): **Low-Medium** (Appendix 2), *roselaari* subspecies (DU2): **Medium-High** (Appendix 3), Tierra del Fuego / Patagonia wintering population (DU3): **High-Very High** (Appendix 4), northeastern South America wintering population (DU4): **Medium-High** (Appendix 5), southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5): **Medium High** (Appendix 6). The lowest overall threat impact score was for DU1, which winters in Europe, and the highest threat impact score was for the Tierra del Fuego / Patagonia wintering population (DU3), which undergoes the longest migration.

In order to facilitate useful comparison of commonalities and differences among threats across the five Red Knot DUs, and for easy cross-referencing to the threats calculator tables (Appendices 2, 3, 4, 5, and 6), the applicable threats are discussed below in numerical order by sub-category, rather than in decreasing order of severity of impact.

1. Residential and commercial development

1.1 Housing and urban areas;1.2 Commercial and industrial areas; 1.3 Tourism and recreation areas

Continuing human population growth, resulting in increasing industrial activity and expanding recreation and tourism, leads to pressure to develop coastal environments, creating conflicts with many waterbird species, including Red Knot. While threat impacts in this category for most DUs were generally considered Low, such threats are widespread both in Europe and many parts of the Americas.

DU1 - *islandica* subspecies. Negligible threat impact (1.1, 1.2, 1.3).

Increased pressure from housing demands and from commercial and industrial developments in coastal NE Europe are presumed to result in loss of winter habitat used by the *islandica* subspecies (DU1) of Red Knot. Increased development of tourist and recreation facilities at beaches in NE Europe is also likely affecting knots, for instance in the Wadden Sea in the Netherlands (Blew *et al.* 2017). An estimated 9% of the *islandica* population winters along the Atlantic coast of France (Bocher *et al.* 2012), where suitable roosting habitat may be limited by pressure from urban, commercial, and industrial development (Leyrer *et al.* 2014).

DU2 - *roselaari* subspecies. Low threat impact (1.1, 1.2), negligible threat impact (1.3).

For many years, increasing pressure from housing demands and from commercial and industrial developments has affected or limited areas and habitats used by *roselaari* subspecies (DU2) Red Knot in many areas of the Pacific coast of United States (e.g. Washington, San Francisco area) and Mexico (e.g., Baja California, Guerrero Negro) (USFWS 2014; Buchanan pers. comm. 2020). Development of coastal tourist facilities and beach access points also cause limited habitat loss in areas used on migration in the western United States (USFWS 2014a; Buchanan pers. comm. 2020), and in winter in Mexico (Carmona *et al.* 2019).

DU3 - Tierra del Fuego / Patagonia wintering population. Low threat impact (1.1, 1.2, 1.3).

In Río Gallegos, Argentina, reclamation of tidal flats and salt marshes for urban, commercial, and industrial development presents a threat to the Tierra del Fuego / Patagonia wintering population (DU3) of Red Knot, and development in Rio Grande, Tierra del Fuego, appears to have reduced knot numbers. Housing, tourism, and industrial developments are all thought to affect Red Knot at the important stopover area at San Antonio Oeste, Argentina. The development of coastal tourist facilities and beach access points, leading to disturbance and habitat loss, are affecting areas used by Red Knot on migration in the eastern United States, and on migration and in winter in Argentina and Tierra del Fuego (Ferrari *et al.* 2002; Escudero *et al.* 2012; USFWS 2014a; Morrison 2018; WHSRN 2020; Morrison unpubl. obs.). Human disturbance threatens Red Knot at southbound stopovers in Massachusetts and New Jersey, especially during public holidays, when long distance migrants are putting on weight prior to the arrival of raptors in early September (Niles unpubl. obs.).

DU4 - northeastern South America wintering population. Low threat impact (1.1), negligible threat impact (1.2, 1.3).

Many migration stopover areas in E and SE North America used by Red Knot from the northeastern South America wintering population (DU4) are being significantly affected by increased housing pressure, as well as by increased impacts from tourist facilities and beach access, and commercial and industrial development (USFWS 2014a). Urban, commercial, and industrial development may pose a risk to birds from this DU (Andreade *et al.* 2016).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Low threat impact (1.1, 1.3), negligible threat impact (1.2).

Habitats used by Red Knot in E and SE United States (USFWS 2014a) and the Caribbean are affected and/or limited by increasing demands for housing and urban development, and by commercial and industrial development. Impacts of development of coastal tourist facilities and beach access points in areas used on migration and winter in the United States are also locally important.

2. Agriculture and aquaculture

2.1 Annual and perennial non-timber crops; 2.2 Wood and pulp plantations; 2.3 Livestock farming and ranching; 2.4 Marine and freshwater aquaculture

Threats in sub-categories 2.1 and 2.2 were not considered to be measureable for any of the five Red Knot DUs. Sub-category 2.3 was considered to have a potential effect on the Tierra del Fuego / Patagonia wintering population (DU3) in South America, whereas sub-category 2.4 was thought to have a considerable potential impact on the *roselaari* subspecies (DU2) and the three *rufa* populations (DUs 3, 4, and 5).

DU2 - *roselaari* subspecies. Low threat impact (2.4).

Threats to Red Knot *roselaari* subspecies (DU2) from aquaculture relate to shellfish aquaculture in Grays Harbor, Washington, and to extensive shrimp aquaculture in Upper Gulf of California and Marismas Nacionales, Mexico, which was considered to reduce quality of foraging habitats (Berlanga-Robles *et al.* 2011; Arreola-Lizárraga *et al.* 2014; FAO 2019), and thus potentially affect the population (Carmona *et al.* 2019, WHSRN 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. Unknown threat impact (2.3), low threat impact (2.4).

Threats to Red Knot in the Tierra del Fuego / Patagonia wintering population (DU3) from agriculture and aquaculture are fairly widespread, although the impact is uncertain. In South America, cattle ranching occurs on lands adjacent to reserves at Río Gallegos, Argentina (Niles *et al.* 2008), and extensive cattle grazing impacts coastal habitats near Lagoa do Peixe on the southeast coast of Brazil (WHSRN 2020). Neighbouring upland coastal habitats near Lagoa do Peixe in Brazil and Río Gallegos in Argentina show signs of degradation from food farming (e.g., of onions, rice, corn) (USFWS 2014a; WHSRN 2020). Stopover sites in Brazil may be negatively impacted by adjacent farming practices, including shrimp farming (Carlos *et al*. 2010), that alter hydrology and increase siltation of important lagoon habitats (Niles *et al.* 2008; USFWS 2014a). In Canada, clam farming in Quebec impacts the quality of habitat for foraging *rufa*, involving birds from all three DUs (Sahlin 2010, 2011; Aubry pers. comm. 2020). New aquaculture initiatives (especially for oysters) in Delaware Bay may threaten essential habitats used by shorebirds, including Red Knot, during migration (Burger *et al.* 2015; Burger and Niles 2017), but a recent study indicates that intertidal oyster aquaculture and migrating shorebirds can effectively co-utilize the resource-rich intertidal areas in which they both occur (Maslo *et al.* 2020). Seaweed farming and salmon aquaculture are potentially degrading the quality of Red Knot habitat in Argentina and on Chiloé Island, Chile (USFWS 2014a).

DU4 - northeastern South America wintering population. Low threat impact (2.4).

Red Knot from this DU pass through Quebec on migration, where foraging habitats may be affected by clam farming in the Gulf of St. Lawrence (Aubry pers. comm. 2020; Sahlin 2010, 2011). In Delaware Bay, new aquaculture initiatives may affect shorebird use of important habitats during migration (Burger and Niles 2017; Maslo *et al.* 2020). Shrimp farming and resultant habitat loss and degradation have likely greatly reduced available stopover and wintering coastal habitats for Red Knots and other migratory shorebirds in NE Brazil over the past 20–25 years (Carlos *et al.* 2010).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Low threat impact (2.4).

Red Knot in the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) may be somewhat less affected by threats from agriculture and aquaculture than other *rufa* DUs, owing to their smaller migration range. Foraging habitats may be affected by clam farming in the Gulf of St. Lawrence (Sahlin 2010, 2011; Aubry pers. comm. 2020) and new aquaculture initiatives in Delaware Bay may affect shorebird use of important habitats during migration (Burger and Niles 2017; Maslo *et al.* 2020).

3. Energy production and mining

3.1 Oil and gas drilling; 3.2 Mining and quarrying; 3.3 Renewable energy

Threats in this category relate mostly to direct impact from exploration and infrastructure, rather than with resulting pollution or spills, which are considered under sub-category 9.2. Although the likely overall impact of threats in these sub-categories is considered low, the potential for local impacts is high, whether on Arctic breeding grounds, migration areas, or wintering grounds. Mining and associated infrastructure in the Canadian and Alaskan Arctic may have had past effects in reducing the quality of breeding habitat. Increased mining activities in the Canadian Arctic (e.g., for diamonds, iron ore, aggregate extraction) and associated infrastructure may pose a localized threat to breeding *rufa* Red Knot. Quarrying and mining also occur along watercourses that flow through stopover sites along the east (Quebec) and west (Ontario) coasts of James Bay, and exploration in this area is ongoing (ECCC 2017). Developments of new mines and quarries near coastal habitats in South America may affect habitat quality. Sand mining from eastern US beaches may reduce quality of migration habitat for *rufa* birds from three DUs (van Dusen *et al.* 2012), as may gravel mining in Tierra del Fuego for birds wintering there (DU3). Infrastructure, such as wind turbines, may have both direct (i.e., mortality owing to collisions) and indirect (e.g., habitat loss, avoidance behaviour) effects on birds (e.g., Stewart *et al.* 2007; Sansom *et al.* 2016).

DU1 - *islandica* subspecies. Negligible threat impact (3.1, 3.3).

Coastal oil and gas industry production and infrastructure may have local effects on European wintering habitats. Mining and associated infrastructure in the Canadian Arctic may have had past localized effects in reducing the quality of breeding habitat. A controversial proposal for coal extraction on Ellesmere Island put forward in 2012 is currently on hold (Latimer 2012; Braden 2014). Further assessment is needed of potential impacts on Red Knot and other waterbirds of existing and proposed infrastructure wind power installations near the Wadden Sea in the Netherlands (Blew *et al.* 2017). Wind turbines have had a significant disturbance effect on Golden Plover (*Pluvialis apricaria*) on breeding grounds in the United Kingdom (Sansom *et al.* 2016).

DU2 - *roselaari* subspecies. Negligible threat impact (3.1), unknown threat impact (3.3).

Development and infrastructure associated with the oil and gas industry may have significant impacts on coastal or breeding habitat in northern Alaska (Alaska Shorebird Group 2019). Mining and associated infrastructure in the Alaskan Arctic may have had past localized effects in reducing the quality of breeding habitat. New petroleum discoveries and a projected increase in oil production are expected onshore in the Arctic in Alaska

(Resource Development Council 2015). The impacts of coastal wind turbines in the small area between Willapa Bay and Grays Harbor which Red Knot use in spring are unknown (Buchanan pers. comm. 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. Negligible threat impact (3.1, 3.2), unknown threat impact (3.3).

The major wintering site for the Tierra del Fuego / Patagonia wintering population (DU3) Red Knot at Bahia Lomas, Chile, is the focus of extensive oil drilling and exploration: infrastructure *per se* may not directly affect wintering knot populations, although some of the drilling rigs are within the intertidal zone (RIGM pers. obs.). Quarrying of sand and gravel near Rio Grande, Tierra del Fuego, Argentina, is thought to have affected habitats and food resources of wintering knots (González pers. comm. 2019). Breeding grounds in the Arctic may be affected by increased mining (e.g., for diamonds, iron ore, aggregate extraction) and associated infrastructure may pose a local threat to Red Knot. Quarrying and mining along watercourses that flow into James Bay could affect important migration stopover sites along both coasts, where exploration is ongoing (Brownell *et al*. pers. comm. 2015 *in* ECCC 2017). Gold mining (largely uncontrolled) in northern South America may directly damage riverbeds and banks, causing siltation downstream, and releasing mercury into the environment that could reach the coast and affect migration habitats (Alvarez-Berríos and Aide 2015). Within the Canadian Arctic, the use of wind to power industry and communities is expected to increase (Lamont pers. comm. 2015, *in* ECCC 2017). Since 2009, wind power has rapidly increased as a source of power in Brazil, extensive wind farm development has already occurred near the coast in northern Brazil (Lucena and Lucena 2019; Morrison unpubl. obs.), and there is growing interest in developing offshore sites (Lucena and Lucena 2019). Environmental impacts of a coastal wind farm in the northeastern state of Ceará include removal of large quantities of sand that was replaced by quarry sand and clay, effects on sediment transport, burial of inter-dunal lakes, and compaction of soil and sand (Meireles *et al.* 2013). Such developments would affect migration areas used by the Tierra del Fuego / Patagonia wintering population (DU3), and it is presently unclear how these and future wind developments would affect Red Knot.

DU4 - northeastern South America wintering population. Negligible threat impact (3.1, 3.2), unknown threat impact (3.3).

New oil drilling and exploration is taking place in Para and Maranhão on the northeastern coast of Brazil (Pellegrini and Ribeiro 2019), potentially affecting birds from this DU. A massive oil spill occurred in this area in 2019 (Handmaker 2019). Sand mining from eastern US beaches may reduce quality of migration habitat (van Dusen *et al.* 2012). Increased use of wind power in the Canadian Arctic could potentially affect breeding DU4 Red Knot (Lamont pers. comm. 2015, *in* ECCC 2017). Extensive development of coastal wind farms has occurred in northern Brazil since 2009, with effects on habitats described for the Tierra del Fuego / Patagonia wintering population (DU3), where there is growing interest in developing offshore sites (Lucena and Lucena 2019; Morrison unpubl. obs.). However, the overall impact of these and future wind developments on the northeastern South America wintering population (DU4) Red Knot is unclear.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Negligible threat impact (3.1, 3.2), unknown threat impact (3.3).

Breeding Red Knot from this DU are likely affected by threats from oil and gas drilling, and from mining and quarrying, as described above for the Tierra del Fuego / Patagonia wintering population (DU3) and for the northeastern South America wintering population (DU4), as well as for portions of the population migrating through James Bay. Sand mining from eastern US beaches may reduce quality of migration and wintering habitats (van Dusen *et al.* 2012). Wind development is also increasing within the Canadian (e.g., southwestern Ontario and Lake Ontario shoreline) and United States migration range of Red Knot, and onshore wind farms are already established (Burger *et al.* 2011), which may affect migrating and wintering birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5). A proposal for wind farm development near migration stopover areas at Chaplin Lake, Saskatchewan, was denied a permit (Lusney 2016), but has since re-located to a site 5 km southwest of Reed Lake IBA, also an important stopover site for Red Knot (McKellar pers comm. 2020). Wind energy development is projected to increase (Zimmerling *et al.* 2013) in an effort to reduce carbon pollution (Executive Office of the President 2013).

4. Transportation and service corridors

4.1 Roads and railroads; 4.2 Utility and service lines; 4.3 Shipping lanes; 4.4 Flight paths

Factors occurring in this category were not considered overall to be measurable threats for any Red Knot DUs. Impacts of oil spills from shipping are considered in **9.2. Industrial and military effluents**.

5. Biological resource use

5.1 Hunting and collecting terrestrial animals; 5.2 Gathering terrestrial plants; 5.3 Logging and wood harvesting; 5.4 Fishing and harvesting aquatic resources

Threats in sub-categories 5.2, 5.3, and 5.4 were not considered to be measurable for any Red Knot DUs. Impacts of Horseshoe Crab harvest in Delaware Bay and of the Grunion (Pejerrey; *Leuresthes sardina*) fishery in northwest Mexico on migrating Red Knot are considered in **7.3 Other ecosystem modifications.**

5.1 Hunting and collecting terrestrial animals

Although shorebirds are widely protected in North America and much of Europe, both subsistence and recreational hunting of Red Knot may still occur in some areas, including the Caribbean islands, the Guianas, and other parts of the northeast coast of South America (Bourget and Laporte 1983; Baker *et al.* 2013, 2020; Wege *et al*. 2014; Watts and Turrin 2016), as well as France (Bocher *et al.* 2012). Increasing awareness of the potential effects on Red Knot and other shorebird populations in the Caribbean has led to the Red Knot recently being added to the no-hunting list for French Guiana (2014), Guadeloupe (2012), and Martinique (2013) (Sorenson and Douglas 2013; Andres 2017). Hunting in these areas would affect birds from all three *rufa* DUs that occur in these areas during migration or after weather events. Red Knot is still a game species in France (Bocher *et al.* 2012; Duncan pers. comm. 2015), although it may soon be removed from the list of hunted species (Sorensen and Douglas 2013; Duncan pers. comm. 2015).

DU1 - *islandica* subspecies. Negligible threat impact.

Hunting of shorebirds still occurs in some countries in Europe, including France (Bocher *et al.* 2012). The specific threat to *islandica* Red Knot is uncertain, although likely small, as the population occurring in France comprises an estimated 9% of the European wintering population of *islandica* subspecies (DU1) (Bocher *et al.* 2012). Most key wintering sites for knots in that country (5 of 6) are all or partly in reserves where hunting is not allowed (Bocher *et al.* 2012).

DU2 - *roselaari* subspecies. Negligible threat impact.

Shorebirds are legally protected throughout their range in North America, and it would appear that threats from hunting are limited for *roselaari* subspecies (DU2). Red Knot is not on the list of species available for subsistence hunting in northwest Alaska (Alaska Department of Fish and Game 2019; Buchanan pers. comm. 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. Unknown threat impact.

Red Knot from the Tierra del Fuego / Patagonia wintering population (DU3) may be affected by shorebird hunting while on migration through northern South America, which is legal in several countries (see Introduction to 5.1 above and DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population).

DU4 - northeastern South America wintering population. Unknown threat impact.

Red Knot from the northeastern South America wintering population (DU4) may be affected by hunting for food which occurs in parts of the Guianas and northeastern Brazil, although harvest levels are not well understood (Andres 2017) (see Introduction to 5.1 above).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Negligible threat impact.

Red Knot from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) are most likely to be affected by shorebird hunting that occurs in the Caribbean, where these birds spend the winter. Although subsistence and recreational hunting, both legal and illegal, is still common in parts of the region, Red Knot is now protected in Guadeloupe (2012) and Martinique (2013), as well as French Guiana

(Sorenson and Douglas 2013; Andres 2017). Harvest levels are not well documented but are likely low.

6. Human intrusions and disturbance

6.1 Recreational activities; 6.2 War, civil unrest and military exercises; 6.3 Work and other activities

Threats in sub-category 6.2 were not considered to be measurable for any Red Knot DUs.

Numerous studies have shown that repeated human-related disturbance (e.g., walkers, fishers/collectors, dogs, off-highway vehicles (OHVs), boats, kite surfers) can negatively affect shorebirds, disrupting behaviour patterns and affecting energy balance (e.g., Davidson and Rothwell 1993a,b; West *et al.* 2002). All Red Knot DUs experience disturbance at some point in their annual cycle, and the effects may be significant in some areas.

Surveys, banding, and research activities are designed to minimize impacts, but may disturb Red Knot at migration or wintering sites, although population-level effects are likely insignificant, and in the context of providing information needed for conservation, acceptable. The Mexican Grunion fishery can result in disturbance and disruption to knots feeding on Grunion eggs (Carmona *et al.* 2017).

DU1 - *islandica* subspecies. Negligible threat impact (6.1, 6.3).

The effects of disturbance on European estuaries on shorebirds, including *islandica* subspecies (DU1) Red Knot, have been documented for many years (Cayford 1993; Davidson and Rothwell 1993a,b), and pressure from disturbance has increased as human populations have grown. In open estuarine areas, disturbance is likely to be much more significant for roosting congregations than to dispersed feeding flocks (Collop *et al.* 2016). Increasing disturbance by recreationists may affect the quality of roosting areas in NE Europe, and Blew *et al.* (2017) noted that recreation in the Wadden Sea already impacting many high tide roost sites may expand, as more people visit the area, expanding their stay into spring and autumn. Ongoing banding activities on some UK and European estuaries may cause periodic disturbance.

DU2 - *roselaari* subspecies. Low threat impact (6.1), negligible threat impact (6.3).

Increasing disturbance by recreationists likely has a significant effect on quality of foraging and roosting areas used by Red Knot *roselaari* subspecies (DU2) along Pacific coasts of the United States (especially near urban areas such as San Francisco Bay and San Diego), Mexico (e.g., Santa Clara, upper Gulf of California; Carmona *et al.* 2017*,* 2019) and Central America. Less disturbance may occur in stopover areas such as Willapa Bay, Washington, and in Alaska (Donaldson pers. comm. 2015; Buchanan pers. comm. 2020). Disturbance from humans and dogs occurs on sandy beaches (McCrary and Pierson

2002), and many shorebird areas on the coast of British Columbia are thought to be disturbed by human activities (Drever *et al.* 2016). Banding studies and aerial surveys may cause occasional disturbance. Recreationists and those involved in the shoreline Grunion fishery in the Upper Gulf of California, Mexico may periodically disturb foraging or roosting birds in late winter and spring (Carmona *et al.* 2017).

DU3 - Tierra del Fuego / Patagonia wintering population. Medium-low threat impact (6.1), negligible threat impact (6.3).

Human disturbance from recreationists is common in migration and wintering areas for the Tierra del Fuego / Patagonia wintering population (DU3) of Red Knot. Disturbance on southward migration in the Magdalen Islands, from recreational clam-digging, kite buggying, wildlife viewing, and off-road vehicle use in intertidal areas, is a concern for *rufa* birds, many of which are from the Tierra del Fuego / Patagonia wintering population (DU3; ECCC-CWS Quebec region unpubl. data). Although disturbance was once a significant problem for shorebirds in Delaware Bay in spring (Burger *et al.* 1995), since 2003, closure of major sections of the New Jersey shore to human use during peak migration has successfully reduced disturbance (Burger *et al.* 2004; Niles *et al.* 2005), although there are no restrictions on use on the Delaware side of the bay. Disturbance is still a significant factor elsewhere on the east coast of the United States, causing shorebirds to abandon prime foraging or roosting habitats (USFWS 2014a; Mengak and Dayer 2020). Disturbance of roosting and foraging flocks by humans and dogs has been reported in Florida, Georgia, North Carolina, South Carolina, Virginia, Massachusetts, and Panama (Buehler 2002; Niles *et al.* 2005) and represents an important threat. Disturbance also affects beaches in southern Brazil used on migration (Soniak 2015). On the wintering grounds in Tierra del Fuego, roosting flocks at Rio Grande are frequently disturbed by walkers, runners, fishers, dogs, OHVs, and motor cycles (Niles *et al.* 2005; Morrison pers. obs.) and this disturbance is considered to be one cause of the extensive decline of *rufa* knots using Rio Grande (Escudero *et al.* 2012). In Argentina, similar disturbance to knots during migration, including kite-surfers, has been reported in Río Gallegos, Peninsula Valdes, San Antonio Oeste, Estuario de Bahía Blanca, and Bahía Samborombon (Niles *et al.* 2005; Martínez-Curci *et al.* 2015; ICFC 2018; Rare 2018; González pers. comm. 2019). Aerial surveys for determining population status occur in most years in Delaware Bay and on the wintering areas in Tierra del Fuego, although population-level effects are likely negligible.

DU4 - northeastern South America wintering population. Low threat impact (6.1), negligible threat impact (6.3).

Many of the issues related to disturbance from recreationists in eastern North America noted for Red Knot from the Tierra del Fuego / Patagonia wintering population (DU3) also apply to birds from the northeastern South America wintering population (DU4), which pass through the same areas on migration. Shorebird disturbance caused by tourism has been reported in wintering areas of northeast Brazil (Cardoso and Nascimento 2007; Andrade *et al*. 2016). Aerial surveys for determining population status occur in Delaware Bay and on the wintering areas on the north coast of South America, although population-level effects are likely insignificant.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Medium-low threat impact (6.1), negligible threat impact (6.3).

Many of the issues related to disturbance from recreationists in eastern North America noted for Red Knot from the Tierra del Fuego / Patagonia wintering population (DU3) also apply to birds from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), which pass through the same areas on migration to its wintering areas in the southeastern United States, Gulf of Mexico, and the Caribbean Sea (Mengak and Dayer 2020). However, the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) knots are exposed to disturbance threats for a longer period than other DUs each year because they winter in an area of high recreational activity. Aerial surveys for determining population status occur in Delaware Bay and occasionally in Florida, although population-level effects are likely negligible.

7. Natural system modifications

7.1 Fire and fire suppression, 7.2 Dams and water management/use, 7.3 Other ecosystem modifications

Threats in sub-category 7.1 were not considered to be measurable for any Red Knot DUs.

7.2 Dams and water management/use

Altered river flows into estuaries, lagoons and deltas, including management of water levels of inland wetlands, can have a great impact on physical and biological properties of coastal estuaries (Gillanders and Kingsford 2002). Altered flow patterns can reduce food and habitat availability and quality of coastal areas, including stopover and wintering areas used by shorebirds. Such phenomena are widespread (Roseberg *et al.* 1995, 1997) and likely affect all Red Knot DUs, although effects of much of this management may have taken place in the past.

DU1 - *islandica* subspecies. Negligible.

Altered flow into estuaries and deltas has reduced habitat quality of coastal wintering areas in Europe in the past, but altered river flow is likely having little effect currently on wintering *islandica* subspecies (DU1) Red Knots.

DU2 - *roselaari* subspecies. Unknown threat impact.

Many rivers in Mexico have been dammed, mainly for hydroelectric power generation (Rhoda and Burton 2010), resulting in altered river flows in coastal habitats, including the important area at the mouth of the Colorado estuary, upper Gulf of California, used by *roselaari* subspecies (DU2) Red Knots, where fresh water input has almost ceased (Gillanders and Kingsford 2002; All 2006; Carmona *et al.* 2017). These effects may reduce habitat quality of stopover and wintering areas; while some effects may have taken place in the past, many may be ongoing.

DU3 - Tierra del Fuego / Patagonia wintering population. Low threat impact.

Some Red Knot in this DU may be affected by the conditions described below for interior migration routes of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) birds. The important staging area identified near the mouth of the Nelson River on the coast of Hudson Bay (McKellar *et al.* 2015) has likely been affected by dams on the Nelson River (Rosenberg *et al.* 1995, 1997). Although many of the changes have already taken place, there are ongoing plans for new proposals (Lunn 2013). Hydroelectric dams in Quebec are thought to have affected coastal habitats in southern James Bay (Drinkwater and Frank 1994; Rosenberg *et al.* 1995, 1997; Environment Canada 2013), altering the coastal ecology and likely affecting shorebirds including Red Knot.

DU4 - northeastern South America wintering population. Low threat impact.

Red Knot from the northeastern South America wintering population (DU4) are likely subject to the same effects of dams and water management and use as those for the Tierra del Fuego / Patagonia wintering population (DU3) described above.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Low threat impact.

An estimated 50% of Red Knot in the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5), primarily those that winter in the Gulf of Mexico, migrate northwards through the interior of North America (Burger *et al.* 2020). Many important wetlands used by migrating shorebirds are intensively managed in the Canadian prairies (Gratto-Trevor pers. comm. 2015, *in* ECCC 2017), which may have a negative effect on food supplies and suitable roosting habitat of migrating shorebirds. Water management (i.e., drawdown or re-flooding within a wetland complex) may benefit shorebirds in some areas if the timing and duration of management is appropriate (Skagen and Thompson 2013). Unregulated and unlicensed drainage of wetlands has been identified as a threat to shorebird habitat at Quill Lakes, Saskatchewan (WHSRN 2020), and infilling is documented as a threat to ephemeral and temporary inland wetlands important for shorebirds (Skagen and Thompson 2013). In the Gulf of Mexico, altered freshwater inflow may be one of the most common stressors on estuaries, lagoons, and deltas (Sklar and Browder 1998), potentially affecting nutrient levels, salinity, sedimentation, topography, dissolved oxygen levels, and other ecosystem components. The ecosystem response to altered freshwater flow is complex and often unpredictable (Sklar and Browder 1998). Knot from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) concentrate at the important staging area near the mouth of the Nelson River on the coast of Hudson Bay (McKellar *et al.* 2015) during spring migration, which has likely been affected by dams on the Nelson River (Rosenberg *et al*. 1995, 1997). Although many of the changes have already taken place, there are ongoing plans for new proposals (Lunn 2013). Habitats in southern James Bay have also likely been affected by hydroelectric developments (Drinkwater and Frank 1994; Environment Canada 2013).

7.3 Other ecosystem modifications

Harvesting of marine and intertidal resources used by Red Knots for food has a major impact on their populations, particularly the three *rufa* DUs which migrate through Delaware Bay in spring. Harvesting of Grunion in northwest Mexico is likely affecting populations of *roselaari* subspecies (DU2) on the Pacific coast of North America during spring migration (Carmona *et al.* 2017, 2019); harvesting of intertidal resources in Europe has also affected knot *islandica* subspecies populations (DU1) (Piersma *et al.* 2001; Blew *et al.* 2017).

Efforts to stabilize shorelines, using hard structures such as seawalls and soft ones such as sandbags and beach nourishment of eroding coastlines may reduce quality of some migration stopover and wintering sites (USFWS 2014a). Beach management activities in the Delaware Bay area to maintain habitat for Red Knot and Horseshoe Crabs are important for the three *rufa* DUs and may have a net benefit.

DU1 - *islandica* subspecies. Low threat impact.

Until recently, there was an extensive harvest of Common Cockles (*Cerastoderma edule*) and other invertebrates in the Dutch Wadden Sea (Piersma *et al.* 2001), which was thought to have caused declines in numbers of *islandica* subspecies (DU1) Red Knot and other shorebirds using the area, although this harvest has now been restricted (Nehls *et al.* 2009; Blew *et al.* 2017). The carrying capacity of the Wadden Sea decreased for Red Knot as the result of this overexploitation of benthic resources (Kraan *et al.* 2009). In France, some *islandica* Red Knot may be impacted by professional clam or cockle harvesters at estuarine bays during winter (Bocher *et al.* 2012).

DU2 - *roselaari* subspecies. Medium-low threat impact.

It is likely that the harvest of Grunion in northern Baja California in northwest Mexico is affecting Red Knot on northward migration (Carmona *et al*. 2019). Grunion eggs are a major food resource taken by Red Knot roselaari subspecies (DU2) before departure on northward migration. Grunions come to the edge of the shore to lay their eggs, in a manner comparable to Horseshoe Crabs in Delaware Bay (Hernández-Alvares *et al*. 2013), and extensive human intervention in harvesting the fish has resulted in the resource being compromised for *roselaari* Red Knots (Carmona *et al*. 2019).

Shoreline stabilization may be a threat to subspecies *roselaari* (DU2) throughout its range in the continental United States (USFWS 2011), especially in the San Francisco Bay and San Diego areas (Buchanan pers. comm. 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. High-low threat impact.

In eastern Canada, seaweed harvesting occurs at fall stopover sites in Cacouna, Quebec, with uncertain implications for *rufa* stopover habitat (Aubry pers. comm. 2015, in ECCC 2017). Harvest of Horseshoe Crabs, and the concomitant reduction in availability of their eggs, which are a major food resource for knots migrating through Delaware Bay in the spring (Morrison and Harrington 1992; Castro and Myers 1993; Clark *et al.* 1993; Botton *et al.* 1994; Tsipoura and Burger 1999; Karpanty *et al.* 2006; Baker *et al.* 2013; Haramis *et al.* 2007), has been a major factor in the decline of the three Red Knot *rufa*populations since about 2000 (Baker *et al.* 2004; González *et al.* 2006; Morrison 2018; Morrison *et al.* 2020b). This once-superabundant food supply was greatly reduced by over-harvesting of adult Horseshoe Crabs (USFWS 2014a). Reduced egg densities were too low to enable knots to meet their energetic requirements (Baker *et al.* 2004; Hernández 2005), leading to inadequate departure masses and subsequent reduced survival, reflected in the observed decline in the wintering population in Tierra del Fuego (Baker *et al.* 2004; González *et al.* 2006; Morrison 2018; Morrison *et al.* 2020a,b). The southern Tierra del Fuego / Patagonia wintering population (DU3) is thought to have been particularly impacted, because of the additional physical demands and constraints related to their long-distance migration (Niles *et al.* 2010a). Horseshoe Crab harvest is now adaptively managed in Delaware Bay in accordance with a collaborative management plan approved in 1998, with addenda added up to 2006 (Kreamer and Michels 2009; Niles *et al.* 2010a). The restricted harvest has resulted in apparent stability of the crab population, although not recovery (Atlantic States Marine Fisheries Commission 2015; Dey *et al.* 2020), so it is not known to what extent knot populations will be able to recover.

Much of the developed coastline of the United States within the migration range of all three *rufa* DUs, and wintering grounds of some knots from the southeastern USA / Gulf of Mexico / Caribbean wintering populations (DU5), has undergone some form of shoreline stabilization, e.g., hard structures such as groins, seawalls, and breakwaters; soft structures such as geotubes, coir matting, sand bags, and beach nourishment through the addition of sand to eroding shorelines (USFWS 2014a). Shoreline stabilization measures impact some coastal sites in Canada as well (Lemmen *et al.* 2016). Loss of beach and intertidal habitats required by Red Knot is accelerated when shoreline stabilization projects are implemented that block natural shoreline landward migration and alter beach morphology, sediment quality, and water dynamics (e.g., Najjar *et al.* 2000).

Severe storms (Lathrop *et al.* 2013) and shoreline stabilization with hard structures (Myers 1986; Jackson *et al.* 2010) may degrade habitat required for spawning Horseshoe Crabs. After Hurricane Sandy destroyed many beaches used by nesting Horseshoe Crabs in Delaware Bay in 2012 (Niles *et al.* 2012b), massive efforts to replenish the beaches restored these habitats in time for Horseshoe Crabs to breed and for the Red Knot migration (Niles *et al.* 2013b; Wetlands Institute 2018). However, beach nourishment may have negative impacts on shorebirds, as it must be repeated to maintain beaches and may disturb shorebirds if work is undertaken while birds are present. Nourishment can cause temporary or permanent alteration of shorebirds' invertebrate prey base (Schlacher *et al.* 2012; Peterson *et al.* 2014; USFWS 2014a), but can also enhance, restore, or create suitable habitat for invertebrates at degraded sites. Such restoration efforts are underway in Delaware Bay to maintain habitat for both Horseshoe Crabs and shorebirds that depend on their eggs to fuel northward migration (Siok and Wilson 2011; Niles *et al.* 2013b; USFWS 2014a).

DU4 - northeastern South America wintering population. Medium-low threat impact.

Red Knot from the northeastern South America wintering population (DU4) pass through Delaware Bay on northward migration and have been substantially affected by the reduction in their main food source, Horseshoe Crab eggs, as described for the Tierra del Fuego / Patagonia wintering population (DU3). Northeastern South America wintering population (DU4) knots may also be affected on southward migration by seaweed harvesting at fall stopover sites in Cacouna, Quebec, with uncertain implications for *rufa* stopover habitat (Aubry pers. comm. 2015).

Shoreline stabilization threats described for the Tierra del Fuego / Patagonia wintering population (DU3) also apply to the northeastern South America wintering population (DU4) of Red Knot while migrating through eastern North America.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Medium-low threat impact.

Some 50% of Red Knots from this DU pass northwards through Delaware Bay on northward migration (Burger *et al.* 2020), compared to approximately 90% of Red Knots from the Tierra del Fuego / Patagonia (DU3) and the northeastern South America wintering populations (DU4; Burger *et al.* 2020), and were also likely substantially affected by the reduction in Horseshoe Crab eggs described above. However, these shorter-distance migrants may more readily use alternate hard-shelled prey, as they are not thought to undergo the physiological changes shown by longer-distance migrants (Niles *et al.* 2010a).

Shoreline stabilization threats described for the Tierra del Fuego / Patagonia wintering population (DU3) also apply to populations of southeastern USA / Gulf of Mexico / Caribbean (DU5) Red Knot, both on migration through the United States and during the wintering period in southeastern North America.

8. Invasive and other problematic species and genes

8.1 Invasive non-native species/diseases, 8.2 Problematic native species/diseases, 8.3 Introduced genetic material, 8.4 Problematic species/diseases of unknown origin, 8.5 Viral/prion-induced diseases, 8.6 Diseases of unknown cause

Threats in sub-categories 8.3, 8.4, 8.5, and 8.6 were not considered to be measurable for any Red Knot DUs. Potential alterations to habitat through changing vegetation structure are considered under sub-category *11.1 Habitat shifting and alteration*.

8.1 Invasive non-native species/diseases

DU2 - *roselaari* subspecies. Negligible threat impact.

Important intertidal mudflat habitats used by Red Knot *roselaari* subspecies (DU2) in Willapa Bay and Grays Harbor, Washington, were largely over-run by the invasion of non-native Smooth Cordgrass *Spartina alterniflora*, native to the Atlantic coast, and converted to higher-level saltmarsh habitat (WDA 2017). Cordgrass has been largely removed but is likely to return if management is not continued (WDA 2017; WHSRN 2020; Buchanan pers. comm. 2020).

Migration areas used by birds of this DU in Willapa Bay and Grays Harbor, Washington, may be affected by the European Green Crab (*Carcinus maenas*) and other invasive species, which have the potential to significantly alter benthic prey communities (Buchanan pers. comm. 2020).

8.2 Problematic native species/diseases

Threats under this sub-category come under two main sources, firstly, an increase in risk from native predator populations, either from increases in predator numbers or from increased predation pressure resulting from habitat alteration caused by hyperabundant geese, and secondly, die-offs from diseases caused by toxic algal blooms.

Shorebirds enjoyed what Butler *et al.* (2003) termed a “predator vacuum” for several decades in the late twentieth century, as a result of greatly reduced populations of birds of prey (especially falcons) caused by human persecution and pesticide poisoning. Peregrine Falcon populations have increased in much of their range and are no longer considered at risk: the *anatum/tundrius* subspecies was delisted in Canada under the *Species at Risk Act* (SARA) in 2017 (COSEWIC 2017b). Impacts of falcons on knots and other shorebirds include disturbance, reducing foraging bouts, restricting access to prime foraging sites, modified migration behaviour, and even changes in physiology and mortality (e.g., Ydenberg *et al.* 2004, 2007; Stillman *et al.* 2005; Pomeroy *et al.* 2006; Niles *et al.* 2008, Niles 2010; van den Hout 2010). Although Peregrine Falcon populations may have simply returned to historically “normal” levels, many Red Knot populations are now considerably reduced, reflecting the “conservation conflict” situation that may appear under such circumstances (Watts 2009a; Watts and Truitt 2021). In some cases, Peregrine Falcon were introduced to areas in which the species did not breed historically, and nesting towers in some areas have been removed and birds relocated to historical areas to reduce the “conflict” (Watts 2009a,b; Watts *et al.* 2015, 2018; Wurst 2018).

On the Arctic breeding grounds, the combined effects of hyperabundant goose-induced changes in habitat and predator-prey interactions with shorebirds may be contributing to local or regional declines in Arctic-nesting shorebird populations (Flemming *et al.* 2016, 2019a,b,c). Overgrazing by Snow Geese (*Chen caerulescens*) has altered many coastal habitats used by *rufa* Red Knots on migration in Hudson Bay and James Bay, although how this may affect shorebirds on migration is not well known (Abraham and Jefferies 1997).

Harmful algal blooms caused by a variety of organisms are widespread throughout the range of Red Knot (USFWS 2014a; USNOHAB 2020). These include Amnesic Shellfish Poisoning (ASP; occurring in Atlantic Canada, caused by *Pseudo-nitzchia* spp.); Neurotoxic Shellfish Poisoning (NSP, also called “red tide”; occurring on the US coast from Texas to North Carolina, caused by *Karenia brevis* and other species); and Paralytic Shellfish Poisoning (PSP; occurring in Atlantic Canada, the US coast in New England, Argentina, and Tierra del Fuego, caused by *Alexandrium* spp. and others; FAO 2004; USNOHAB 2020). The highest levels of PSP toxins have been recorded in shellfish from Tierra del Fuego (IAEA 2004, *in* USFWS 2014a), and high levels can persist in molluscs for months following a PSP bloom (FAO 2004).

DU1 - *islandica* subspecies. Unknown threat impact.

Peregrine Falcon has increased greatly on wintering grounds of the *islandica* subspecies (DU1) in the Dutch Wadden Sea (van den Hout 2009) and, in addition to causing direct mortality (which may be low), has a significant effect on the distribution and physiology of the knots (van den Hout 2009, 2010; Blew *et al.* 2017).

Harmful algal blooms have occurred in many parts of the European seaboard used by knots from this DU, increasing in number and distribution between 1970 and 2015 (USNOHAB 2020).

DU2 - *roselaari* subspecies. Low threat impact.

Peregrine Falcon populations appear to have increased along the Pacific coast of North America. This species is a known predator of Red Knot on wintering grounds in Mexico (Enderson *et al*. 1991; White *et al.* 2002; COSEWIC 2017c), which are likely to be affected by this threat in a manner similar to other DUs.

Harmful algal blooms occur on the Pacific coast and have increased in number and distribution between 1970 and 2015 (USNOHAB 2020). Agricultural runoff has led to the development of blooms on the northwest coast of Mexico (Berman *et al*. 2005).

DU3 - Tierra del Fuego / Patagonia wintering population. Medium threat impact.

Recovering peregrine populations are believed to have altered stopover behaviour of shorebirds in the Bay of Fundy (Dekker *et al*. 2011) during the fall migration period. In this and other parts of the east coast, predation threat is considered important, with southbound migrants attempting to depart before the arrival of migrating raptors (Lank *et al*. 2003; Niles pers. comm. 2018). Watts and co-workers (Watts 2009a; Watts and Truitt 2021; Watts *et al*. 2015) showed that falcon presence reduced the shorebird carrying capacity of coastal Virginia by 30% during spring migration. Other impacts of falcons on knots may include disturbance, reducing foraging bouts, restricting access to prime foraging sites, modified migration behaviour, and changes in physiology (e.g., Stillman *et al*. 2005; Pomeroy *et al*. 2006; Ydenberg *et al*. 2007; Niles *et al*. 2008, Niles 2010; van den Hout 2010).

Increasing Peregrine Falcon numbers have been noted in South America, including Suriname (Ottema *et al*. 2009), French Guiana (USFWS 2014a) and by implication northern Brazil, where Tierra del Fuego / Patagonia wintering birds (DU3) occur on migration. Many Red Knot freshly killed by Peregrine Falcons were reported by Baker *et al*. (1998) on northward migration at Lagoa do Peixe in southern Brazil in early April 1997. At the important northward stopover area at San Antonio Oeste, Argentina, higher numbers of falcons, including Peregrines, have caused knots to move to lower quality habitats and changed timing of migration (González pers. comm. 2020). Shorebirds are known to be amongst prey taken by Peregrine Falcons in Patagonia and Tierra del Fuego (Ellis *et al*. 2002). Peregrine and Aplomado Falcons (*Falco femoralis*) are known to hunt shorebirds on the main wintering area in Bahia Lomas, Chile (Matus pers. comm. 2020).

Some breeding areas in the central Canadian Arctic used by the Tierra del Fuego / Patagonia wintering population (DU3) have likely been negatively affected by overabundant geese (Flemming *et al.* 2016, 2019a,b,c). Overgrazing by geese has also altered many coastal habitats at migration stopover areas in Hudson and James Bays, although how this may affect shorebirds on migration is not known (Abraham and Jefferies 1997).

Harmful algal blooms are widespread in the migration and wintering range of knots from this DU (USFWS 2014a; USNOHAB 2020). Various types of shellfish poisoning occur in Atlantic Canada (caused by *Pseudo-nitzchia* spp.), on the east coast of the United States (red tides caused by *K. brevis* and other species), and in New England, Argentina, and Tierra del Fuego (caused by *Alexandrium* spp. and others; FAO 2004; USNOHAB 2020). The highest levels of PSP toxins have been recorded in shellfish from Tierra del Fuego (IAEA 2004, *in* USFWS 2014a), and high levels can persist in molluscs for months following a PSP bloom (FAO 2004). Mortality events have been documented for *rufa* knots from the Tierra del Fuego / Patagonia wintering population (DU3) in Uruguay in 2007 (over 300 knots found dead, Aldabe 2007; Aldabe *et al.* 2015; Aspiroz *et al.* 2018), and in southern Brazil in 1997 and 2000 (Baker *et al.* 1998; Buehler *et al.* 2010; Aspiroz *et al.* 2018). In Tierra del Fuego, mortality of clams eaten by Red Knot, possibly from accumulation of algal toxins or parasites, was recorded by Escudero *et al.* (2012; USFWS 2014a). "Red tides" regularly occur in Tierra del Fuego (Almandoz *et al.* 2011). The wider geographical spread of threat from harmful algal blooms suggests that the Tierra del Fuego / Patagonia wintering population (DU3) may be more at risk from this threat than other DUs.

DU4 - northeastern South America wintering population. Medium-low threat impact.

The northeastern South America wintering population (DU4) Red Knots are subject to the threats from falcons described for the Tierra del Fuego / Patagonia wintering population (DU3) during migration through eastern North America, and on their wintering grounds in northern South America.

Some breeding areas in the central Canadian Arctic, and migration areas in Hudson and James Bays used by the northeastern South America wintering population (DU4) of Red Knots have likely been negatively affected by overabundant geese, although effects are not clearly known (Abraham and Jefferies 1997; Flemming *et al.* 2016, 2019a,b,c).

Red Knot from the northeastern South America wintering population (DU4) are subject to the same risks from harmful algal blooms as other *rufa* DUs while on migration in North America, as they pass through broadly the same areas. Risk on the wintering areas in northeastern Brazil would appear to be lower than that on wintering areas used by the other *rufa* DUs (USNOHAB 2020), although little information is available from that region.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Medium-low threat impact.

Populations of southeastern USA / Gulf of Mexico / Caribbean (DU5) Red Knot are subject to the threats from falcons described for the Tierra del Fuego / Patagonia wintering population (DU3) on southbound migration through eastern North America, on northbound migration through central North America, and on wintering areas in the Gulf of Mexico and Caribbean (COSEWIC 2017c). Peregrine Falcons frequently occur along beaches in Texas where Red Knots forage along the narrow beachfront (Niles *et al*. 2009), and peregrine predation on Red Knots has been observed in Florida (A. Schwarzer *in* USFWS 2014a). Some migrating knots from this DU are affected by Peregrine Falcons known to hunt shorebirds at migration stopover sites in Virginia and Delaware Bay (Niles *et al.* 2008; Niles 2010).

Some breeding areas in the central Canadian Arctic, and migration areas in Hudson and James bays used by Red Knots from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) have likely been negatively affected by overabundant geese, although effects are not clearly known (Abraham and Jefferies 1997; Flemming *et al.* 2016, 2019a,b,c).

Harmful algal blooms are thought to affect birds from this DU, especially on wintering areas in Florida and the Gulf of Mexico coast (Woodward *et al.* 1977; Corcoran *et al.* 2013; USFWS 2014a). Harmful algal blooms can be caused by a variety of organisms, with red tides produced by the dinoflagellate *K. brevis* being particularly common in the Gulf of Mexico, including areas in Florida and Texas used by Red Knot (Niles *et al.* 2008; Corcoran *et al.* 2013; Florida Fish and Wildlife Conservation Commission 2020). The dinoflagellate produces highly potent neurotoxins (brevetoxins), which accumulate in benthic invertebrates including those consumed by knots (Bricelj *et al.* 2012) and can be highly toxic to birds and other organisms. There is some evidence of Red Knots being directly affected by red tides in Florida (USFWS 2014a).

9. Pollution

9.1 Domestic and urban waste water, 9.2 Industrial and military effluents, 9.3 Agricultural and forestry effluents, 9.4 Garbage and solid waste, 9.5 Air-borne pollutants, 9.6 Excess energy

Threats in sub-categories 9.4 and 9.6 were not considered to be measurable for any Red Knot DUs.

All Red Knot DUs are likely to be affected by pollution during their annual cycles. Untreated sewage in NW Mexico, Brazil, Argentina and other coastal migration stopover and wintering sites may have undetermined toxic effects on Red Knot. Risk of oil spills from shipping and petroleum exploration and extraction in coastal areas used by Red Knot on migration or in winter have potential for serious impacts on birds and their habitats. Human-related sources of such pollution include spills from shipping vessels; leaks or spills from offshore oil rigs or undersea pipelines; leaks, spills, or effluent from onshore facilities such as petroleum refineries and petrochemical plants; beach-stranded barrels and containers that fall from cargo ships or offshore rigs; discharges of ballast water from oil tankers; oil/water separators on production platforms; and terrestrial sources such as effluent from sewage treatment plants and runoff from roads and parking lots (Blackburn *et al.* 2014; USFWS 2014a). Several key Red Knot wintering or stopover areas contain large-scale operations for petroleum extraction, transportation, or both (USFWS 2014a). Red Knot and its prey may be exposed to toxic agricultural effluents in many parts of its range (Mateo-Sagasta *et al.* 2017; FAO 2018), including northwest Mexico, northern South America and other regions, on migration or in winter. Most Red Knot are likely exposed to airborne pollutants at some point in their life cycle, but it is unclear whether these may affect the species.

9.1 Domestic and urban waste water

DU1 - *islandica* subspecies. Unknown threat impact.

Proximity of some wintering sites to urban areas may expose birds to impacts of sewage and wastewater. In the Dutch Wadden Sea, eutrophication has resulted from elevated levels of phosphorus, nitrogen and phosphates entering from rivers (van Beusekom *et al.* 2017).

DU2 - *roselaari* subspecies. *Unknown threat impact.*

Proximity of some stopover and wintering sites to urban areas, such as Willapa Bay and Grays Harbor, Washington, and northwest Mexico, may expose knots to impacts of sewage and wastewater (Donaldson pers. comm. 2015). Contaminant issues at the Salton Sea spring stopover may affect *roselaari* Red Knots on northward migration (Buchanan pers. comm. 2020). Important wetlands in northwest Mexico are affected by eutrophication resulting from sewage and agrochemicals (WHSRN 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. Unknown threat impact.

Red Knots from the Tierra del Fuego / Patagonia wintering population (DU3) may be affected by sewage discharges into coastal waters in eastern North America during migration. On wintering areas, untreated sewage was discharged in Red Knot habitat in Río Gallegos, Argentina, until 2012 (USFWS 2014a; WHSRN 2020), and the short- and long-term impacts of previously dumped sewage are unknown. Untreated sewage has also been discharged into coastal habitats at Rio Grande (Atkinson *et al.* 2005; WHSRN 2020), although a sewage treatment plant was scheduled to be constructed by 2019 (BNamericas 2017).

DU4 - northeastern South America wintering population. Unknown threat impact.

Red Knot from the northeastern South America wintering population (DU4) may be affected by sewage discharges into coastal waters in eastern North America during migration. Sewage discharge is likely to be relatively low in the more remote parts of the wintering areas in northeastern Brazil.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Unknown threat impact.

Red Knot from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) may be affected by sewage discharges into coastal waters in eastern North America during migration, and in wintering areas in the southeastern United States and Gulf of Mexico regions.

9.2 Industrial and military effluents

DU1 - *islandica* subspecies. Low threat impact.

Risk of oil spills in coastal areas of NE Europe used by *islandica* Red Knot on migration or in winter have potential for periodic serious impacts on birds and their habitats, although the incidence of oil spills in the North Sea area has decreased over the past several decades (Schultz *et al.* 2017). A 1978 spill off the coast of France caused mass mortality of clams (Blackburn *et al.* 2014), and ingestion of contaminated prey may be a source of toxicity for shorebirds (Peterson *et al.* 2003).

DU2 - *roselaari* subspecies. Low threat impact.

Risk of oil spills in areas of the Pacific coast of the United States and Mexico used by *roselaari* Red Knot on migration or in winter have potential for periodic serious impacts on birds and their habitats. Threats from oil spills and toxic contaminants are present on the Copper River Delta, Alaska (WHSRN 2020). Knot are at risk from both catastrophic spills, such as the Exxon Valdez in Alaska in 1989, and chronic low levels of pollution (Peterson *et al.* 2003). Spills in Willapa Bay or Grays Harbor, Washington, or in Alaska, could have population-level impacts on Red Knot *roselaari* subspecies (DU2) during migration periods (Buchanan pers. comm. 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. Low threat impact.

Shipping to re-supply communities during the ice-free season occurs along the coasts of James and Hudson bays (Andrews 2017) and throughout the Canadian Arctic, and activity is projected to grow as the northern ice-free period increases (Smith and Stephenson 2013; Pizzolato *et al.* 2014). Response times to major spills in these remote areas may be inadequate (DFO 2012). Important estuarine areas for Red Knot such as Delaware Bay, the coasts of James Bay, and the Gulf of St. Lawrence are at risk from effluents and shipping accidents. Both birds (e.g., Leighton 1991; Peterson *et al.* 2003; Henkel *et al.* 2012) and their marine invertebrate prey (Blackburn *et al.* 2014) could be exposed to petroleum in contaminated intertidal habitats. Foraging areas near the Mingan Islands, in the Gulf of St. Lawrence, are at risk of contaminant exposure from large ships carrying titanium and iron that transit the archipelago throughout the year (Aubry pers. comm. 2015). A ship-sourced oil spill in March 1999 resulted in oil reaching the shore in the Mingan area (Roberge and Chapdelaine 2000; Niles *et al.* 2008).

Oil and natural gas exploration have intensified along the northeastern and northern coasts of Brazil (Paschoa 2013) and is ongoing in Suriname and Guyana (Morrison *et al.* 2012). In northern and northeast Brazil, an enormous oil spill covering 4,000 km of coast came ashore in August 2019, including areas used extensively by shorebirds, including Red Knots (Handmaker 2019; Schulte and Stirling 2019; BirdLife International 2020). Extensive onshore and offshore oil developments near major wintering areas of the Tierra del Fuego / Patagonia population (DU3) in both Chilean and Argentinian sectors of Tierra del Fuego represent a considerable threat (WHSRN 2020; Morrison and Ross unpubl. data). Two oil spills from shipping have been recorded near the Strait of Magellan First Narrows (Niles *et al.* 2005), and small amounts of oil have been noted on Red Knot captured during banding operations in Bahía Lomas (Dey and Niles unpubl. data). Harrington and Morrison (1980) noted 15% of knots seen near Commodoro Rivadavia on the coast of Argentina in December 1979 were visibly oiled. The important migration stopover area at San Antonio Oeste, Argentina, also faces potential pollution by calcium chloride from a soda ash factory and from port activities (González pers. comm. 2019).

DU4 - northeastern South America wintering population. Low threat impact.

Red Knot from this DU face risks from oil spills very similar to those described for the Tierra del Fuego / Patagonia wintering population (DU3) in the Arctic, in James and Hudson bays, and in eastern North America on migration. Petroleum exploration and iron ore and gold mining can result in oil and mercury pollution and habitat loss. These activities are important threats on the northcentral coast of Brazil for Red Knots in the northeastern South America wintering population (Niles *et al.* 2005). An enormous oil spill covering 4,000 km of coast came ashore in northeastern Brazil in August 2019, affecting areas used extensively by the northeastern South America wintering population (DU4) of Red Knots (Handmaker 2019; Schulte and Stirling 2019; BirdLife International 2020).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Low threat impact.

Red Knot from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) face risks from oil spills similar to those described for the Tierra del Fuego / Patagonia wintering population (DU3) in the Arctic, in James and Hudson Bays, and in eastern North America on migration, as well as on the southeast coast of the United States on the wintering grounds. Large amounts of oil have been released into the Gulf of Mexico from shipping and drilling operations, including the catastrophic Deepwater Horizon spill in 2010 (Blackburn *et al.* 2014; USFWS 2014a). While direct observations of oiled Red Knots were sparse, their habitats were compromised, and it is highly likely the birds themselves were negatively affected (USFWS 2014a).

9.3 Agricultural and forestry effluents

Red Knot and their prey may be exposed to toxic agricultural effluents in many parts of their range (Mateo-Sagasta *et al.* 2017; FAO 2018), including northwest Mexico, northern South America and other regions, on migration or in winter.

DU1 - *islandica* subspecies. Unknown threat impact.

Agricultural runoff likely contributes to eutrophication in the Dutch Wadden Sea, an important wintering area for *islandica* subspecies (DU1) Red Knot (van Beusekom *et al.* 2017), and herbicides have been reported to affect estuaries in western France (Niquil *et al.* 2006).

DU2 - *roselaari* subspecies. Unknown threat impact.

Red Knot *roselaari* subspecies (DU2) overwintering at the mouth of the Colorado River may be particularly negatively affected by agricultural effluent in the United States and Mexico (Donaldson pers. comm. 2015; WHSRN 2020). Farther south in Sonora Province, Mexico, agricultural runoff has led to large blooms of phytoplankton in coastal waters (Berman *et al.* 2005).

DU3 - Tierra del Fuego / Patagonia wintering population. Unknown threat impact.

In Canada, small numbers of the Tierra del Fuego / Patagonia wintering population (DU3) Red Knot may be exposed to herbicides and pesticides originating from farming activities upstream of the Bay of Fundy (WHSRN 2020). Red Knot and their prey may be exposed to toxic agricultural effluent associated with the management of rice fields in Trinidad, Uruguay, Argentina, and French Guiana (Blanco *et al.* 2006; Niles 2012; USFWS 2014a). Although few Red Knot were recorded in rice field surveys in Brazil, Uruguay and Argentina, larger numbers (e.g., 1,700 birds) have been observed in rice fields in French Guiana (Niles 2012b), and Red Knots have been reported from rice fields in Trinidad (eBird 2019).

DU4 - northeastern South America wintering population. Unknown threat impact.

In Canada, small numbers of the northeastern South America wintering population (DU4) Red Knot may be exposed to herbicides and pesticides in the Bay of Fundy (WHSRN 2020). Red Knot and their prey may be exposed to toxic agricultural effluent associated with the management of rice fields in Trinidad, Uruguay, Argentina, and French Guiana (Blanco *et al*. 2006; Niles 2012; USFWS 2014a). In Suriname, shorebirds are known to use rice fields, which are regularly sprayed with pesticides, adjacent to coastal areas, although knots were not amongst the species recorded (Vermeer *et al.* 1974; Hicklin and Spaans 1993). While the chemicals previously used were toxic to wildlife, most currently used are not harmful to birds (WHSRN 2020). There have been unverified concerns, however, of disposal of residual chemicals on the mudflats, which would degrade the quality of the mudflats as foraging habitat (WHSRN 2020).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Unknown threat impact.

In Canada, small numbers of the southeastern USA / Gulf of Mexico / Caribbean wintering population of Red Knot (DU5) may be exposed to herbicides and pesticides in the Bay of Fundy (WHSRN 2020), and to agricultural effluents during northbound migration in midcontinent agricultural fields (McKellar pers comm. 2020). Red Knot, and their prey, may be exposed to toxic agricultural effluent associated with the management of rice fields in Trinidad (Blanco *et al*. 2006; Niles 2012; USFWS 2014a). Agricultural effluents are not listed as a threat for WHSRN sites bordering the Gulf of Mexico (WHSRN 2020).

9.5 Air-borne pollutants

All DUs

Unknown threat impact.

Most Red Knot are likely exposed to air-borne pollutants at some point in their life cycle, but there is no information as to whether these pollutants may affect the species, or how such effects might differ among the five Red Knot DUs.

10. Geological events

10.1 Volcanoes, 10.2 Earthquakes/tsunamis, 10.3 Avalanches/landslides

Threats in sub-categories 10.1, 10.2, and 10.3 were not considered to be measureable for any of the five Red Knot DUs.

11. Climate change and severe weather

11.1 Habitat shifting and alteration, 11.2 Droughts, 11.3 Temperature extremes, 11.4 Storms and flooding, 11.5 Other impacts

Threats in sub-category 11.3 and 11.5 were not considered to be measureable for any Red Knot DUs. Ecosystem-level changes related to rising temperatures are considered in sub-category 11.1 *Habitat Shifting and Alteration*.

Climate change and severe weather are anticipated to affect many aspects of the Red Knot life cycle. Climatic changes in Arctic breeding areas present cumulative risks to Red Knot through reductions in breeding habitat quality (Meltofte *et al*. 2007), such as the invasion of shrubby vegetation into tundra habitat (Myers-Smith *et al.* 2011), and increased predation due to disruption of predator-rodent cycles. Drying of habitats and uncoupling of food availability from breeding requirements may be regionally important (Kwon *et al.* 2020). Rising sea levels will reduce coastal habitat availability in areas used in migration and winter, and ocean acidification may reduce availability of bivalve prey. More frequent severe weather, such as storms and hurricanes, may affect migration performance or survival. Many climate-related effects may primarily occur beyond the 3-generation time period, and some may be positive. Rapid irreversible ecosystem change may occur if climatic changes exceed a threshold, with negative effects in many regions (USCCSP 2009a,b; USFWS 2014a).

11.1 Habitat shifting and alteration

Responses of Red Knot and their prey to climate change are difficult to predict, as changes may have positive, neutral, or negative effects which may change over time or with the degree of environmental change. Galbraith *et al.* (2014) indicated that climate change increased risk and vulnerability scores for most shorebird species, including Red Knot. The Arctic has warmed more than any other region over the past 30 years (NSID 2015) and is most likely to be affected by climate change (ACIA 2004). Lathrop *et al.* (2016) and Wauchope *et al.* (2016) indicated negative effects from habitat shifts resulting from climate change. Meltofte *et al.* (2007) reviewed potential effects of climate change in the Arctic on shorebirds, among which long-term reductions in High Arctic habitat quality and uncoupling of phenology of food resources and breeding events (e.g., chicks no longer hatching during period of peak food availability) were potentially important. Such effects have already been noted for Red Knot breeding in the Russian Arctic, where reduced chick growth rates led to increased mortality on wintering grounds (van Gils *et al.* 2016), and for

Hudsonian Godwit (*Limosa haemastica*) breeding in the North American Arctic (Senner 2012). Effects may differ across the Arctic (Kwon *et al.* 2020) and may affect different populations to varying extents (Senner *et al.* 2017; Smith *et al*. 2020). Disruption of predator-rodent cycles linked to climate change is already occurring, and may lead to increased predation of breeding adult Red Knots, their eggs and chicks (Meltofte *et al.* 2007; Kausrud *et al.* 2008; Niles *et al.* 2008; Fraser *et al.* 2013; Bulla *et al.* 2019, Kubelka *et al.* 2018, 2019).

On migration and wintering areas, ocean acidification may lead to a decline in calcium-dependent prey such as bivalves (Byrne and Przeslawski 2013; Parker *et al.* 2013), and may also result in increased disease in the marine environment, with negative impacts on Red Knot and its prey (Burge *et al.* 2014). Potential loss of intertidal habitats owing to sea level rise were projected to range between 20 and 70% during the next century, at five major stopover sites in the United States, including Delaware Bay (60% loss of habitat; Galbraith *et al.* 2002). Habitat loss due to sea level rise is projected in Tierra del Fuego (USFWS 2014a) and at other key sites. While detailed effects are difficult to predict (IPCC 2001; CCSP 2009; USFWS 2014a), substantial changes to shorelines are expected over the next 100 years, which may reduce the capacity of sites to support shorebirds, with increased future stress on Red Knot populations (Iwamura *et al.* 2013). Iwamura *et al.* (2013) found that predicted reductions in population in migratory networks far exceeded the proportion of habitat lost from sea level rise.

Red Knot in the three *rufa* DUs may benefit from projected short-term warmer temperatures, if climate warming results in fewer cold-induced spawning delays of Horseshoe Crabs in Delaware Bay (Smith and Michels 2006), although warmer waters may lead to earlier crab spawning and possible mismatch of timing with Red Knot migration. On the Arctic breeding grounds, climate change may result in earlier snowmelt but also heavier snow cover (Meltofte *et al.* 2007). Rakhimberdiev *et al.* (2015) found that Bar-tailed Godwit (*Limosa lapponica taymyrensis*) could partly compensate for changing insect phenology in the Arctic by decreasing refuelling times at the last northward stopover. This enabled birds to reach the breeding grounds earlier, but at a cost of decreased survival.

DU1- *islandica* subspecies. Medium-low threat impact.

Anticipated impacts on the Arctic breeding grounds of *islandica* subspecies (DU1) Red Knot are similar to those described above. Climate change induced sea-level rises are expected to affect wintering habitats in the Dutch Wadden Sea, although with uncertain results (Oost *et al.* 2017), and most will likely take effect in the future beyond the 10 year or 3-generation (21 years) time frame.

DU2 - *roselaari* subspecies. Medium-low threat impact.

Impacts on the Arctic breeding grounds of Red Knot *roselaari* subspecies (DU2) in Alaska and Russia are likely similar to those described above. Galbraith *et al.* (2005) found that predicted sea level rise would have a major effect on estuaries on the Pacific coast of North America, including Willapa Bay and San Francisco Bay, reducing the size and carrying capacity of these key shorebird stopover sites to only fractions of their current importance. The need to seek alternate food resources could reduce fitness of Red Knots (Buchanan pers. comm. 2020).

DU3 - Tierra del Fuego / Patagonia wintering population. Medium-low threat impact.

Anticipated impacts on the Arctic breeding grounds of the Tierra del Fuego / Patagonia wintering population (DU3) *rufa* Red Knot are as described above. Sea-level rise is expected to have a negative impact on quality and extent of migration habitats on the east coast of North America, including the critically important spring migration stopover in Delaware Bay (Galbraith *et al.* 2005), as well as important migration and wintering areas in South America (USFWS 2014a).

DU4 - northeastern South America wintering population. Medium-low threat impact.

Anticipated impacts on the Arctic breeding grounds of the northeastern South America wintering population (DU4) Red Knot are as described above. Sea-level rise is expected to have a negative impact on quality and extent of migration habitats on the east coast of North America, including the critically important spring migration stopover in Delaware Bay (Galbraith *et al.* 2005).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Medium-low threat impact.

Anticipated impacts on the Arctic breeding grounds of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) Red Knot are as described above. Sea-level rise is expected to have a negative impact on quality and extent of migration habitats on the east coast of North America, including the critically important spring migration stopover in Delaware Bay (Galbraith *et al.* 2005), used by about 50% of the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) population (Burger *et al.* 2020).

11.2 Droughts

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Unknown threat impact.

Few direct threats are anticipated from droughts, except in the Prairie provinces and states, where drying out of potholes and seasonal sloughs may affect habitat and food availability for the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) of Red Knot at spring migration stopover sites in interior North America. Ecosystem-level changes related to drying conditions are considered in sub-category 11.1 *Habitat Shifting and Alteration*.

11.4 Storms and flooding

There has been a significant increase in the number and strength of hurricanes globally (1970–2004), including those in areas of the North Atlantic used by Red Knot (Webster *et al.* 2005; Bender *et al.* 2010; R.I.G. Morrison unpubl. results). Geolocator tracking data have shown that Red Knot can modify its flight patterns to avoid weather systems, which increases energy expenditure and may influence survivorship (Niles *et al.* 2010b). Hurricanes may also destroy or disrupt habitats used by Red Knots (Niles *et al.* 2012b). The extent to which Red Knot is actually affected, either directly through increased mortality or indirectly through effects of storms reducing prey at foraging sites, is unknown. However, the increasing severity of weather events, including precipitation events (Fischer and Knutti 2015), represents a risk which is likely to increase with changing climates and rising ocean temperatures.

DU1 - *islandica* subspecies. Unknown threat impact.

Increased frequency and intensity of storms may periodically cause significant mortality of *islandica* subspecies (DU1) Red Knot on migration and wintering areas, and in the Arctic could result in loss of nests and chicks (Meltofte *et al.* 2007).

DU2 - *roselaari* subspecies. Unknown threat impact.

Hurricanes rarely strike the Pacific coast of the Americas (Thompson 2009) and are thus less likely to affect Red Knot *roselaari* subspecies (DU2) than birds of other DUs, although increased frequency and intensity of storms in the Arctic could result in loss of nests and chicks (Meltofte *et al*. 2007).

DU3 - Tierra del Fuego / Patagonia wintering population. Medium-low threat impact.

Red Knots from the Tierra del Fuego / Patagonia wintering population (DU3) will likely be impacted by changing weather and storms on the Arctic breeding grounds, as well as increasing hurricanes and severe weather on migration and in wintering areas, particularly early fall hurricanes that may strike southeastern North America during their trans-oceanic migration (Webster *et al.* 2005; Meltofte *et al.* 2007; Bender *et al.* 2010). An extremely rare hurricane in the South Atlantic Ocean came ashore in southern Brazil, impacting areas used by Red Knot north of Lagoa do Peixe (NASA Earth Observatory 2004).

DU4 - northeastern South America wintering population. Medium-low threat impact.

Red Knots in the northeastern South America wintering population (DU4) will likely be impacted by changing weather and storms on the Arctic breeding grounds, and increasing hurricanes and severe weather on migration and wintering areas, particularly early fall hurricanes that may strike southeastern North America during their trans-oceanic migration (Webster *et al.* 2005; Meltofte *et al.* 2007).

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population. Medium-low threat impact.

Red Knots from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) will likely be impacted by changing weather and storms on the Arctic breeding grounds, and the increasing incidence of severe hurricanes that may strike the southeastern United States, Gulf of Mexico, and Caribbean Sea during fall migration or early winter (Webster *et al.* 2005; Meltofte *et al.* 2007).

Limiting Factors

Factors limiting the productivity and survival of Red Knot are the same for all five DUs, and most are related to its long-distance migration strategy, and the associated physiological changes it undergoes to maximize its flying efficiency during migration (Morrison *et al.* 2007). This relatively inflexible adaptation to long distance migration makes Red Knot particularly sensitive to the effects of human interventions and changing climates and habitat conditions. For instance, reduction of food resources at key migration or wintering areas may prevent knots from attaining or maintaining optimal condition, with a consequent lowering of annual survival (Baker *et al.* 2004). The short season available for nesting and raising young on Arctic breeding grounds, together with a maximum clutch size of four eggs, limits potential reproductive output and restricts the knots' ability to respond to adverse weather and changing climate (Meltofte *et al.* 2007). Many of the above threats may negatively affect the knots' ability to undertake long-distance migratory flights between widely separated stopover sites, and subsequently breed successfully. Adult annual survival is generally high (Mendez *et al.* 2018), so factors that affect survival, such as reduced foraging effectiveness on migration, or disturbance at roosting and foraging sites, may contribute to population declines or prevent population recovery.

Number of Locations

For all DUs that nest at many widely dispersed sites across the Arctic in Canada (*islandica* subspecies - DU1, Tierra del Fuego / Patagonia wintering population - DU3, northeastern South America wintering population - DU4, southeastern USA / Gulf of Mexico / Caribbean wintering population - DU5) or in Alaska and Russia (*roselaari* subspecies - DU2), the number of locations calculated during the breeding season is likely much greater than 10, as these geographically distinct nesting areas are likely exposed to differing risks from key threats, such as ecosystem modifications and climate change-related habitat shifting and alteration. However, for most DUs, fewer locations are used during migration or when overwintering, as described below.

DU1 - *islandica* subspecies

Threats with the highest impact for this DU likely occur on the wintering grounds. Red Knot from the *islandica* subspecies (DU1) concentrate in coastal areas on the wintering grounds in Europe, occurring there at more than 10 discrete locations, as wintering areas across many European coastal states are exposed to differing risks from key threats such as human disturbance, coastal habitat modification and coastline stabilization, industrial development, and industrial effluents. The number of locations used on migration is difficult to determine, but likely well exceeds 10.

DU2 - *roselaari* subspecies

The number of breeding locations in Canada is not applicable for *roselaari* subspecies (DU2), as the numbers recorded in Canada are very small and variable (likely <1% of the estimated global population of *roselaari*) on spring migration and occasionally in winter on the Pacific coast of British Columbia (Campbell *et al.* 1998; eBird 2019; Johnson pers. comm. 2020), although most birds in this DU likely travel through Canadian airpace on migration without landing in Canada. Widely scattered records of small numbers of Red Knots have been recorded along the central and northern coasts of British Columbia during northward migration (Buchanan pers. comm. 2020; Johnson pers. comm. 2020). *C. c. roselaari* is thought to concentrate at a relatively small number of key sites on migration between the wintering areas and breeding grounds (Carmona *et al.* 2013; USFWS 2014a). For instance, a substantial proportion of the *C. c. roselaari* population stops at Grays Harbor and adjacent Willapa Bay, Washington each spring (Buchanan *et al.* 2012; Lyons *et al.* 2016), and telemetry studies by Bishop *et al.* (2016) confirm that sizable numbers using those sites also stop at both the Copper River and Yukon-Kuskokwim River Deltas in Alaska. However, telemetry studies also show that many other sites in the coastal United States are also used by smaller numbers of birds on migration (Buchanan pers. comm. 2020; Johnson pers. comm. 2020). The relevant threats to birds of the *roselaari* subspecies (DU2) that could rapidly impact portions of the population on migration include coastal development, aquaculture, shoreline stabilization, and over-fishing of Grunion in north-coastal Mexico. As these likely occur with different impacts and intensities at the many coastal sites used by Red Knot on migration, the number of locations used is likely well above 10.

DU3 - Tierra del Fuego / Patagonia wintering population.

The number of occurrences for the southern *rufa* Tierra del Fuego / Patagonia wintering population of Red Knot (DU3) is given by NatureServe (2017) as 1-5 on the basis of the number of sites used on migration, as most of the population migrates through Delaware Bay (Niles *et al.* 2007). Over 90% of birds from this DU are thought to stop on the coast of Hudson Bay near the mouth of the Nelson River during northward migration (Burger *et al.* 2020). The key threats in Delaware Bay are impacts of the Horseshoe Crab fishery on food for migrating knots. Over 95% of the Tierra del Fuego / Patagonia wintering population (DU3) spends the boreal winter at a single site, Bahia Lomas in Tierra del Fuego (Morrison *et al.* 2004, 2020a,b), with smaller numbers at a small number of nearby sites and in southern Patagonia (Figure 7) where the main threats likely relate to severe weather conditions and oil developments and spills. These threats are likely to affect most birds of the population at once. The total number of locations for the Tierra del Fuego / Patagonia wintering population (DU3) in winter is therefore likely to be between 5 and 10.

DU4 - northeastern South America wintering population

Most of the northeastern South America wintering population of Red Knot (DU4) over-winter in the northeastern Brazilian state of Maranhão, with fewer birds in the state of Ceara, and a few birds in nearby French Guiana and Suriname. They are distributed at many sites along the coast, each with different degrees of risk from human disturbance, effluents, etc., which suggests that the number of wintering locations is likely greater than 10. Some 90% of northbound migrants are thought to stop over in the Nelson River area of the coast of Hudson Bay (Burger *et al.* 2020). However, in the absence of a plausible threat that could rapidly affect all individuals present there, the concept of locations likely does not apply in Hudson Bay. Many knots from this DU (recently estimated as 90%; Burger *et al.* 2020) pass through Delaware Bay on northward migration, although they also use many other Atlantic coast sites, which are exposed to different combinations of threats, including effects of Horseshoe Crab harvesting. About 21% of birds from the northeastern South America wintering population (DU4) used stopovers in Georgia, North Carolina and South Carolina (Burger *et al.* 2020), and it is likely that the number of locations used during spring migration well exceeds 10.

DU5 - southeastern USA / Gulf of Mexico / Caribbean wintering population

Red Knot from the southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5) over-winter at various locations on both coasts of Florida, in Louisiana and Texas, and on islands in the Caribbean, and as these areas are subject to different risks from threatening events, such as human intrusion and disturbance, recreation and ecological modification, the number of locations in winter is likely appreciably greater than 10. Populations from west Florida, the Gulf coasts and Caribbean likely migrate northwards through the interior of the United States and Canada and are found at a relatively small number of locations in Saskatchewan and northern US interior states, as well as on the Hudson Bay coast near the Nelson River, where an estimated 100% of geolocator-marked birds from this DU occurred (Burger *et al.* 2020). The apparent high dependence on the Hudson Bay stopover identified by McKellar *et al.* (2015) suggests the number of sites used there may be <10. However, in the absence of a plausible threat that could rapidly affect all individuals present there, the concept of locations likely does not apply in Hudson Bay. Populations from the southeastern United States likely pass northwards through Delaware Bay (about 50%; Burger *et al.* 2020) and other Atlantic coast sites which are exposed to different combinations of threats, including effects of Horseshoe Crab harvesting, so in total, it is likely that the number of locations on migration likely well exceeds10.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In Canada, Red Knot is protected under the *Migratory Birds Convention Act 1994* (Government of Canada 2017). *C. c. rufa* is listed as Endangered, *C. c. roselaari* as Threatened, and *C. c. islandica* as a species of Special Concern on Schedule 1 of the federal *Species at Risk Act* (Government of Canada 2019), following assessment by COSEWIC in 2007 (ECCC 2017). Ontario, New Brunswick, Nova Scotia, and Newfoundland and Labrador have listed *C. c. rufa* under their endangered species acts (ECCC 2017). In Quebec, *C. c. rufa* is listed on the Liste des espèces susceptibles d'être désignées menacées ou vulnérables (list of wildlife species likely to be designated threatened or vulnerable). This list is produced according to the Loi sur les espèces menacées ou vulnérables (RLRQ, c E-12.01), (Act respecting threatened or vulnerable species) (CQLR, c E-12.01). *C. c. islandica* and *C. c. roselaari* are not listed under provincial or territorial endangered species legislation.

In the United States (Table 4), Red Knot is protected under the *Migratory Bird Treaty Act* (USFWS 2017), and *C. c. rufa* was listed as Threatened under the U.S. *Endangered Species Act* in 2014 (USFWS 2014b). At the state level, *C. c. rufa* is listed as Threatened in New Jersey and as a species of Special Concern in Georgia (Niles *et al.* 2005); other state ranks are shown in Table 4.

Table 4. Status of Red Knot in the United States (NatureServe 2017). See Table 5 for ranking symbols.

United States: National	United States: by Individual States
(N-Rank)	(S-Rank)
N1N	Alabama (SNRN), Arkansas (SNRN), Colorado (SNRN), Delaware (SNRN), Florida (SNR), Georgia (SNRN), Illinois (SNRN), Indiana (SNRN), Iowa (SNRN), Kansas (SNRN), Kentucky (SNRN), Louisiana (SNRN), Maine (SNRN), Maryland (SNRN), Michigan (SNRN), Minnesota (SNRN), Mississippi (SNRN), Missouri (SNRN), Montana (SNRN), Nebraska (SNRN), New Jersey (SNRN), New York (SNRN), North Carolina (SNRN), North Dakota (SNRN), Ohio (SNRN), Oklahoma (SNRN), Pennsylvania (SNRN), South Carolina (SNRN), South Dakota (SNRN), Tennessee (SNRN), Texas (SNRN), Virginia (S2M), West Virginia (SNRN), Wisconsin (SNRN)

Internationally, *C. c. rufa* was added to Appendix 1 of the Convention on Migratory Species in 2005 (Leyrer *et al.* 2014) concerning migratory species threatened with extinction. Red Knot was listed as Critically Endangered on the Brazilian Ministry of the Environment Red List in 2014 (Portaria Ministerio do Meio Ambiente (MMA) no. 444 on 17 Dec 2014). It was categorized as Endangered in Argentina (López-Lanús *et al.* 2008, Resolución 348 / 2010 Secretaría de Ambiente y Desarrollo Sustentable) and in Chile by the Ministerio de la Secretaría General de la Presidencia de Chile in 2008. In Uruguay, Red Knot is also categorized as Endangered (Azpiroz *et al.* 2012) and as a priority species for conservation by the Dirección Nacional de Medio Ambiente (Aldabe *et al.* 2015). France declared the species to be protected in French Guiana in 2014 (Journal Officiel n. 0235, p 16464, Arrete 1 Oct 2014), and other French territories including Guadeloupe and Martinique (30 juin 2012. Interdiction de la chasse au Bécasseau maubèche. Arrêté n°2012-746 PREF/DEAL-RN relatif à la saison de chasse dans le département de la Guadeloupe; 31 juillet 2013. Arrêté NOR : *DEVL1312811A* relatif à la protection du bécasseau maubèche dans le département de la Guadeloupe et de la Martinique. Ministère de l'écologie, du développement durable et de l'énergie).

C. c. roselaari has been designated as Endangered in Mexico (Diario Oficial de la Federacion 2010). In addition to being listed as Threatened in Canada, *C. c. roselaari* is considered a species of management concern in the United States (Alaska Department of Fish and Game 2015), and continentally as a Species of Greatest Concern (Shorebird Conservation Plan Partnership 2017; WDFW 2015).

Non-Legal Status and Ranks

Table 5 provides conservation status ranks for Red Knot in Canada, as designated by NatureServe (2017) and CESCC (2016). The global status of *C. c. rufa* is listed as G4T2, or imperilled at the subspecies level, and nationally as N1B, indicating the breeding population is critically imperilled. *C. c. roselaari* (G4TNR) is unranked, and *C. c. islandica* is now considered G4T4 or apparently secure. Red Knot conservation status ranks for the United States are shown in Table 4.

Table 5. Conservation status ranks in Canada for subspecies of Red Knot; *C. c. rufa*, *C. c. roselaari*, and *C. c. islandica* (CESCC 2016; NatureServe 2017).

Subspecies	Global Rank	National Rank	Sub-national Rank	NatureServe 2017	CESCC 2016
	G-Rank[c]	N-Rank[d]	S-Rank[e]		
C. c. rufa	G4T2; rounded T2	N1B, N3N4N, N3M	Northwest Territories*	S1B	S1S2B, S1S2M
			Nunavut	SNRB	S2B, S2M
			British Columbia**	SNR	S1S2M
			Alberta	SU	SUM
			Saskatchewan	S2M	S2M
			Manitoba	SNA	S2S3M
			Ontario	S1N	S3M

Subspecies	Global Rank	National Rank	Sub-national Rank	NatureServe 2017	CESCC 2016
	G-Rank[c]	N-Rank[d]	S-Rank[e]		
			Quebec	S1M	S1M
			New Brunswick	S3M	S2M
			Prince Edward Island	S2N	S2M
			Nova Scotia	S2S3M	S2M
			Newfoundland (Island)	S3N	S2M
			Labrador	S3N	S2M
C. c. roselaari	G4TNR; rounded TNR	Canada: NNR	Yukon	SNA	SNA
			Northwest Territories	SNR	-
			British Columbia	SNR	S1S2M
C. c. islandica	G4T4; rounded T4	Canada: N3B	Northwest Territories	S2B	-
			Nunavut	SNRB	-

[c] G-Rank -- Global Conservation Status Rank: G4 = species is Apparently Secure; T4 apparently secure; T2 = subspecies is Imperilled; and TNR = subspecies is unranked.

[d] N-Rank -- National Conservation Status Rank: N1 = population within Canada is Critically Imperilled; N3 = population within Canada is Vulnerable; N4 = population within Canada is Apparently Secure; and NNR = Unranked. B = Breeding; N = Non-breeding; and M = Migrant.

[e] S-Rank -- sub-national (provincial or territorial) ranks: S1 = Critically Imperilled; S2 = Imperilled; S3 = Vulnerable; S4 = Apparently Secure; S5 = Secure; U = Unrankable; NR = Unranked; and NA = Not Applicable. B = Breeding; N = Non-breeding; and M = Migrant.

*Status in NWT given as “At Risk”, indicating a species for which a detailed assessment has recently been completed and determined that the species is at high risk of extinction or extirpation by the Working Group on General Status of NWT Species (2016).

**No longer applicable after taxonomic revision

The International Union for the Conservation of Nature (IUCN) up-listed Red Knot globally from Least Concern in 2012 to Near Threatened in 2015 (BirdLife International 2017).

The Canadian Shorebird Conservation Plan (Donaldson *et al.* 2000) lists Red Knot as a Species of High Concern, and the US Shorebird Conservation Plan (Brown *et al.* 2001) lists *C. c. rufa* as a (sub-)Species of High Concern, and *C. c. islandica* and *C. c. roselaari* as (sub-)Species of Moderate Concern. In 2004, *C. c. rufa* was listed as Highly Imperilled in an update to the list of shorebirds considered of High Priority in the U.S. Shorebird Conservation Plan (US Shorebird Conservation Plan 2004; US Shorebird Conservation Plan Partnership 2017). Red Knot is categorized as Highly Imperilled in Canada by Hope *et al.* (2020).

In Alaska, the Alaska Center for Conservation Science (2019) ranked the Red Knot (*C. c. roselaari*) in its highest category (Red) of conservation concern and in Alaska and Washington it is a Species of Greatest Conservation Need (Alaska Department of Fish and Game 2015; Alaska Shorebird Group 2019; WDFW 2020).

In Canada, a *Species at Risk Act* recovery strategy and management plan for Red Knot has been published by Environment and Climate Change Canada (ECCC 2017). The Western Hemisphere Shorebird Reserve Network has published a Red Knot Conservation Plan for the Western Hemisphere (Niles *et al.* 2010a), and Red Knot was included in a proposal for concerted action by CMS (Convention on Migratory Species) in 2014 (Leyrer *et al.* 2014).

Habitat Protection and Ownership

Most of the important Red Knot habitats used on migration and in winter have been recognized by various conservation and habitat protection programs and initiatives, providing a variable degree of formal and informal protection. The Western Hemisphere Shorebird Reserve Network (WHSRN) is a non-government organization that identifies and seeks protection for important shorebird sites. The WHSRN system currently covers 107 sites in 17 countries, from Alaska to Tierra del Fuego (WHSRN 2020). Although designation as a WHSRN site itself carries no formal legal protection, it increases the conservation status of the site significantly. The Ramsar Convention is a worldwide intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands identified under the Convention. Several shorebird areas of importance to Red Knot are designated as both Ramsar and WHSRN sites (e.g., Quill Lakes, Saskatchewan). The Important Bird Areas (IBA) program of BirdLife International identifies and promotes conservation of important areas for birds. Nearly all sites designated by WHSRN are also identified as IBAs for shorebirds.

Protection for shorebird sites is also provided by various other designations, often at a national, state, or regional level, such as Wildlife Management Areas, Wildlife Refuges, Provincial Parks, and National Parks (e.g., Table 6). These initiatives raise the profile of important areas and may provide some level of legal protection for key habitats. Critical habitats for Red Knots in Canada (ECCC 2017) are listed in Table 6 (and see McKellar *et al.* 2020 for the most recent listing of potential WHSRN sites in Canada), and key international sites are listed in Table 7.

Table 6. Critical habitat identified for Red Knot in Canada, showing current protection status (CEC 2017; ECCC 2017), including the Western Hemisphere Shorebird Reserve Network (WHSRN), the Ramsar Convention (Ramsar), the Important Bird Areas initiative of BirdLife International (IBA), and other designations.

Province	Place	Status	Subspecies
Alberta	Beaverhill Lake	Beaverhill Lake Heritage Rangeland Natural Area	*rufa*
Saskatchewan	Reed Lake	WHSRN, IBA	*rufa*

Province	Place	Status	Subspecies
Saskatchewan	Chaplin Lake	WHSRN, IBA	*rufa*
Saskatchewan	Quill Lakes	Ramsar, Saskatchewan Heritage Marsh, WHSRN, IBA	*rufa*
Manitoba	Churchill, Hudson Bay coast	IBA, Wapusk National Park	*rufa*
Manitoba	Wapusk National Park, Hudson Bay coast	IBA, Wapusk National Park	*rufa*
Manitoba	Nelson River area, Hudson Bay coast	IBA, Wapusk National Park	*rufa*
Ontario	Pen Islands, Hudson Bay coast	IBA	*rufa*
Ontario	Polar Bear Provincial Park, Hudson Bay coast	IBAs	*rufa*
Ontario, Quebec, Nunavut	West coast James Bay, southeast James Bay, Akimiski Island	IBAs; proposed WHSRN and Ramsar sites in southern James Bay; Polar Bear Provincial Park; Moose River, Hannah Bay, Boatswain Bay, and Akimiski Island Migratory Bird Sanctuaries	*rufa*
Quebec	St. Lawrence River/Saguenay River	Parc marin du Saguenay-Saint-Laurent, IBA, World Biosphere Reserve	*rufa*
Quebec	Mingan Archipelago, St. Lawrence Estuary	Mingan Archipelago National Park Reserve, IBAs	*rufa*
Quebec	Magdalen Islands	IBAs	*rufa*

Table 7. Key sites used by Red Knot in other countries that receive protection or conservation status by conservation organizations, including the Western Hemisphere Shorebird Reserve Network (WHSRN), the Ramsar Convention (Ramsar), the Important Bird Areas initiative of BirdLife International (IBA), and other designations. "x" indicates that the site has been officially recognized by the organization.

Site	WHSRN	Ramsar	IBA	Other[1]	Subspecies
Bahia Lomas, Chile	x	x	x		*rufa*
Rio Grande/Bahia San Sebastian, Argentina	x	x	x	x	*rufa*
Peninsula Valdes, Argentina	x	x	x	x	*rufa*
San Antonio Oeste, Argentina	x		x	x	*rufa*
Lagoa do Peixe, Brazil	x	x	x	x	*rufa*
Maranhão, Brazil	x	x		x	*rufa*
Delaware Bay, New Jersey	x	x	x	x	*rufa*
San Francisco Bay, California	x	x	x		*roselaari*

Site	WHSRN	Ramsar	IBA	Other[1]	Subspecies
Grays Harbor estuary, Washington	x		x		*roselaari*
Willapa Bay, Washington	x			x	*roselaari*
Copper River Delta, Alaska	x		x	x	*roselaari*
Yukon-Kuskokwim River Delta, Alaska	x		x	x	*roselaari*
Salton Sea, California	x		x	x	*roselaari*
Bahia de Santa Maria, Mexico	x	x	x		*roselaari*
Gulf of California - Rio Colorado, Mexico	x	x	x		*roselaari*
Laguna Ojo de Liebre - Guerrero Negro, Mexico	x	x	x	x	*roselaari*
The Wash, United Kingdom	n/a	x	x	x	*islandica*
The Wadden Sea, Netherlands	n/a	x	x	x	*islandica*

[1]e.g., State or Provincial reserves, wildlife reserves

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Authorities Contacted

Artuso, Christian. Former Manitoba Program Manager, Bird Studies Canada, Winnipeg, Manitoba.

Aubry, Yves. Biologist-Migratory Birds, Canadian Wildlife Service Quebec Region, Environment and Climate Change Canada, Quebec, Quebec.

Basterfield, Mark. Director of Wildlife Management, Nunavik Marine Region Wildlife Board, Inukjuak, Quebec.

Bennet, Bruce. Coordinator, Yukon Conservation Data Centre, Whitehorse, Yukon Territory.

Bennett, Ron. Manager, Conservation Planning and Stewardship, Canadian Wildlife Service Prairie Region, Environment and Climate Change Canada, Edmonton, Alberta.

Benville, Andrea. Data Manager, Saskatchewan Conservation Data Centre, Regina, Saskatchewan.

Bijleveld, Allert. Coastal Systems Scientist, NIOZ (Royal Netherlands Insttitute for Sea Research), 't Horntje, Texel, The Netherlands.

Blaney, Sean. Executive Director/Senior Scientist, Atlantic Canada Conservation Data Centre, Sackville, New Brunswick.

Boyne, Andrew. Head, Conservation Planning, Canadian Wildlife Service Atlantic Region. Environment and Climate Change Canada. Dartmouth, Nova Scotia.

Brunelle, Josée. Analyst, Hunting, Fishing and Trapping Coordinating Committee, James Bay and Northern Quebec Agreement and the Northeastern Quebec Agreement, Montréal, Quebec.

Buchanan, Joe. Wildlife Biologist/Natural Resource Scientist, Wildlife Diversity Division, Washington Department of Fish and Wildlife, Olympia, Washington.

Cannings, Syd. Species at Risk Biologist, Canadian Wildlife Service Northern Region, Environment and Climate Change Canada, Whitehorse, Yukon.

Carmona, Roberto. Biologist, Bird Laboratory, Academic Department of Marine and Coastal Sciences, Universidad Autónoma de Baja California Sur, La Paz, Baja California Sur, Mexico.

Carriere, Suzanne. Biologist, Wildlife Division, Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories.

Conklin, Jesse. Researcher, Royal Netherlands Institute for Sea Research (NIOZ), Den Burg, Texel, Netherlands.

De Smet, Ken. Species at Risk Specialist, Manitoba Department of Conservation and Water Stewardship, Winnipeg, Manitoba.

Dey, Amanda. Principal Zoologist, Endangered and Nongame Species Program, Division of Fish and Wildlife, New Jersey Department of Environmental Protection, Millville, New Jersey.

Drever, Mark. Research Biologist, Canadian Wildlife Service Pacific Region, Environment and Climate Change Canada, Delta, British Columbia.

Durocher, Adam. Data Manager, Atlantic Canada Conservation Data Centre, Newfoundland and Labrador Wildlife Division, Endangered Species and Biodiversity Section, Corner Brook, Newfoundland and Labrador.

Friesen, Chris. Coordinator, Manitoba Conservation Data Centre, Winnipeg, Manitoba.

Friis, Christian. Wildlife Biologist, Canadian Wildlife Service Ontario Region, Environment and Climate Change Canada, Toronto, Ontario.

Gauthier, Isabelle. Biologiste, Coordonnatrice provinciale des espèces fauniques menacées ou vulnerables, Direction générale de la gestion de la faune et des hábitats, Ministère des Forêts, de la Faune et des Parcs, Québec, Québec.

Gill, R.E. Research Wildlife Biologist (Emeritus), United States Geological Survey, Alaska Science Center, Anchorage, Alaska.

González, Patricia M. Researcher, Fundación Inalafquen, San Antonio Oeste, Rio Negro Province, Argentina.

Harrington, Brian A. Independent Shorebird Researcher, Plymouth, Massachusetts.

Humber, Jessica. Ecosystem Management Ecologist, Endangered Species and Biodiversity Section, Department of Environment and Conservation, Government of Newfoundland and Labrador, Corner Brook, Newfoundland and Labrador.

Jean-Gagnon, Frankie. Wildlife Biologist, Nunavik Marine Region Wildlife Board, Inukjuak, Quebec.

Johnson, Jim. Shorebird Biologist, US Fish and Wildlife Service, Anchorage, Alaska.

Johnston, Vicky. Manager, Northern Region, Canadian Wildlife Service Northern Region, Environment and Climate Change Canada, Yellowknife, Northwest Territories.

Jung, Thomas. Senior Wildlife Biologist, Fish and Wildlife Branch, Environment Yukon, Government of Yukon, Whitehorse, Yukon.

Klymko, John. Zoologist, Atlantic Canada Conservation Data Centre, Sackville, New Brunswick.

MacDonald, Amie. Ph.D. student, Department of Biology, Trent University, Peterborough, Ontario.

McDonald, Rachel. Senior Environmental Advisor, National Defence (ADM(IE)/ DGESM/ DESM), Ottawa, Ontario.

McKellar, Ann. Wildlife Biologist, Canadian Wildlife Service Prairie Region, Environment and Climate Change Canada, Saskatoon, Saskatchewan.

McKnight. Julie. Conservation Biologist, Canadian Wildlife Service Atlantic Region. Environment and Climate Change Canada, Dartmouth, Nova Scotia.

Meijer, Marge. Staff, Alberta Conservation Information Management System, Parks Division, Environment and Parks, Edmonton, Alberta.

Milliken, Rhonda. Manager, Canadian Wildlife Service Pacific Region, Environment and Climate Change Canada, Delta, British Columbia.

Niles, Larry. Independent Shorebird Researcher, Wildlife Restoration Partnerships, Greenwich, New Jersey.

Paquet, Julie. Shorebird Biologist. Canadian Wildlife Service Atlantic Region. Environment and Climate Change Canada, Sackville, New Brunswick.

Picard, Karine. Chief Conservation Planning, Canadian Wildlife Service Quebec Region, Environment and Climate Change Canada, Quebec, Quebec.

Porter, Ron. Independent Researcher, Ambler, Pennsylvania, United States.

Powell, Todd. Manager, Biodiversity Programs, Fish and Wildlife Branch, Environment Yukon, Whitehorse, Yukon.

Rausch, Jennie. Shorebird Biologist, Canadian Wildlife Service Northern Region, Environment and Climate Change Canada, Yellowknife, Northwest Territories.

Ritchie, Kyle. Wildlife Management Biologist, Habitat and Species at Risk, Nunavut Wildlife Management Board, Iqaluit, Nunavut.

Robertson, Myra. Head, Wildlife and Habitat Assessment, Canadian Wildlife Service Northern Region, Environment and Climate Change Canada, Yellowknife, Northwest Territories.

Sabine, Mary. Biologist, Species at Risk Program, Department of Natural Resources, Hugh John Flemming Forestry Centre, Fredericton, New Brunswick.

Shepherd, Pippa. Ecosystem Scientist, Parks Canada, Vancouver, British Columbia.

Sinclair, Pam. Bird Conservation Biologist, Canadian Wildlife Service - Northern Region, Environment and Climate Change Canada, Whitehorse, Yukon.

Smith, Paul. Research Scientist, National Wildlife Research Centre, Environment and Climate Change Canada, Ottawa, Ontario.

Song, Samantha. Manager, Canadian Wildlife Service - Prairie Region, Environment and Climate Change Canada, Edmonton, Alberta.

Stipec, Katrina. B.C. Staff, Conservation Data Centre, Ecosystems Branch, British Columbia Ministry of Environment, Victoria, British Columbia.

Sutherland, Donald A. Zoologist, Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario.

van Roomen, Marc. Senior Project Manager-Monitoring, Sovon (Dutch Centre for Field Ornithology), Nijmegen, The Netherlands.

Verkuil, Yvonne. Researcher, NIOZ (Royal Netherlands Institute for Sea Research), Den Burg, Texel, Netherlands.

Walsh, Wendy. Senior Fish and Wildlife Biologist, New Jersey Field Office, United States Fish and Wildlife Service, Galloway, New Jersey.

Watkins, William. Zoologist, Water Stewardship and Biodiversity Division, Wildlife and Fisheries Branch, Manitoba Department of Conservation, Winnipeg, Manitoba.

Wilson, Greg. A/Head, Conservation Planning Unit, Canadian Wildlife Service Prairie Region, Environment and Climate Change Canada, Edmonton, Alberta.

Wilson, Scott. Research Scientist, National Wildlife Research Centre, Environment and Climate Change Canada, Ottawa, Ontario.

Zakharov, Yuri. Ecologist Team Leader, Parks Canada, Ucluelet, British Columbia.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Dr. R.I. Guy Morrison retired in 2012 from his position as *Research Scientist, Shorebirds*, after a 38-year career with the Canadian Wildlife Service and Wildlife and Landscape Science Directorate of Environment Canada. He remains active as a *Scientist Emeritus* with Environment and Climate Change Canada and maintains active involvement in research and survey work throughout North and South America. Dr. Morrison completed his undergraduate studies at the University of St. Andrews, Scotland, and his PhD at Cambridge University, England. While at Cambridge, Dr. Morrison organized a series of expeditions to Iceland to study Red Knot migration, and after completing his PhD, took up a position as a Research Scientist with the Canadian Wildlife Service. From 1973 to 2012, his work on the distribution and ecology of shorebirds took him from the Canadian High Arctic to southern South America. This work led to the concept and development of the Western Hemisphere Shorebird Reserve Network, the most important non-government shorebird conservation organization in the Western Hemisphere, with over 100 reserves protecting shorebird habitat from Alaska to Tierra del Fuego. His work at Alert, Ellesmere Island, was instrumental in understanding the role of body stores in Red Knot during migration and breeding. With Ken Ross, his South American Shorebird Atlas surveys led to the discovery of wintering areas of *rufa* Red Knot in Tierra del Fuego and Patagonia in the 1980s, and Morrison and Ross have since conducted repeated surveys documenting the rapid decline in knots on their wintering grounds since 2000. Dr. Morrison was appointed to the Order of Canada in 2016 for his services in the conservation of Arctic shorebirds.

COLLECTIONS EXAMINED

No collections were examined during the preparation of this report.

Appendix 1. Proportions of juvenile, sub-adult and adult birds in populations of Red Knot.

S. Wilson and R.I.G. Morrison. October 2018

Many counts of Red Knot are undertaken in non-breeding seasons, often in winter, and usually include birds of all age groups. However, as COSEWIC assessments require that abundance be given as the number of mature individuals, the proportion of these counts that represent mature individuals must be determined. Knots are generally considered to start breeding when two years old (Baker *et al.* 2013, 2020). Birds up to 1 year old are considered juveniles, those between 1 and 2 years old (approaching the first breeding season) as sub-adults, and birds 2 years and older as adults. The number of mature individuals in the population may thus be taken as the number of adults. The proportion of each age class in the population depends on the annual survival of each class and can be modelled in a population matrix.

A series of 11 scenarios is presented in which the annual survival of the three age groups is varied within likely limits (Appendix Table 1). In the most likely scenario (row 1), adult survival (S3) is taken as 0.80 (Mendez *et al.* 2018), juvenile survival (S1) from hatch to the wintering grounds as 0.2 (one quarter of adult survival, Boyd and Piersma 2011), and sub-adult survival (S2), from age 6 months to 18 months, as 0.65, intermediate between juvenile and adult. Annual population growth in this scenario of 0.979 is slightly negative, and the approximate proportions of juveniles, sub-adults and adults in the population are 22%, 14%, and 64%, respectively. The number of chicks produced per breeding pair was varied in the model between 1.5 and 2.0. Note that if productivity were 2.0 chicks/pair and juvenile survival half that of adults (and sub-adults) the population would increase rapidly (scenario 11). Considering the most likely scenario (row 1) and the mean of the scenarios presented, we suggest that the approximate proportions of each age group may be taken as juvenile 25%, sub-adult 15% and adult 60%, resulting in an estimate of the number of mature individuals for COSEWIC purposes as 60% of the total population.

Appendix Table 1. Proportions of juveniles, sub-adults and adults (equivalent to mature individuals) in a population of Red Knot under different scenarios, using different estimates of annual survival for each age group and fecundity (Wilson pers. comm. 2018). The most likely values are presented in Scenario 1.

Scenario	Chicks/pair	S1	S2	S3	Lambda	N1	N2	N3
1	**1.50**	**0.20**	**0.65**	**0.80**	**0.979**	**0.216**	**0.143**	**0.640**
2	1.50	0.20	0.60	0.80	0.967	0.218	0.135	0.646
3	1.75	0.15	0.65	0.80	0.960	0.197	0.134	0.669
4	1.75	0.20	0.55	0.80	0.977	0.244	0.137	0.619
5	1.75	0.20	0.70	0.70	0.936	0.252	0.188	0.560
6	2.00	0.20	0.60	0.75	0.962	0.272	0.198	0.530
7	2.00	0.30	0.50	0.80	1.060	0.338	0.160	0.501
8	1.50	0.30	0.50	0.80	1.002	0.288	0.144	0.569
9	1.50	0.30	0.60	0.70	0.955	0.298	0.187	0.515
10	1.50	0.35	0.65	0.70	1.005	0.320	0.207	0.474
11	2.00	0.40	0.80	0.80	1.258	0.364	0.232	0.404
Average	1.70	0.25	0.62	0.77	1.01	0.27	0.17	0.56

Chicks/pair	*Mean number of chicks hatched per pair*
S1	*6 month survival probability from hatch to wintering grounds*
S2	*Annual survival probability from 6 to 18 months*
S3	*Annual survival probability beyond 18 months*
Lambda	*Annual population growth*
N1	*Proportion 6 month old juveniles in January*
N2	*Proportion 18 month old subadults in January*
N3	*Proportion adults 30 months or older in January*

Appendix 2. Threats calculator table for Red Knot, *islandica* subspecies (DU1).

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	Red Knot, *islandica* subspecies (DU1)			
Element ID			**Elcode**	
Date:	2020-02-12			
Assessor(s):	Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)			
References:	Draft Red Knot update status report (27 January 2020), Draft Red Knot threats calculator (21 January 2020), Recovery strategy and management plan for the Red Knot (*Calidris canutus*) in Canada (ECCC 2017)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	1	0
	D	Low	2	3
Calculated Overall Threat Impact:			Medium	Low
Assigned Overall Threat Impact:				
Impact Adjustment Reasons:				
Overall Threat Comments	This is one of five designatable units of Red Knot assessed together on 11-12 February 2020. Generation time was assumed to be approximately 7 years.			

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Presumed loss of winter roosting habitat due to increased housing pressure in coastal NE Europe.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Roosting habitat in wintering areas in France limited by pressure from commercial and industrial developments.
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Presumed loss of wintering habitat due to increased development of tourist facilities at beaches in NE Europe.
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
2.1	Annual & perennial non-timber crops						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.2	Wood & pulp plantations						Not a measurable threat for any Red Knot DUs.
2.3	Livestock farming & ranching						Not a measurable threat for this DU.
2.4	Marine & freshwater aquaculture		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Shellfish aquaculture in Dutch Wadden Zee unlikely to affect wintering Red Knot.
3	Energy production & mining		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Oil and gas industry production and infrastructure may have local effects on European wintering habitats
3.2	Mining & quarrying						Mining and associated infrastructure in the Canadian Arctic may have had past effects in reducing the quality of breeding habitat.
3.3	Renewable energy		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Existing and proposed wind power developments may have some local effects on wintering areas in Europe.
4	Transportation & service corridors						
4.1	Roads & railroads						Not a measurable threat for any Red Knot DUs.
4.2	Utility & service lines						Not a measurable threat for any Red Knot DUs.
4.3	Shipping lanes						Not a measurable threat for Red Knot DUs; effects of oil spills from shipping are considered in **9.2. Industrial & military effluents**
4.4	Flight paths						Not a measurable threat for any Red Knot DUs.
5	Biological resource use		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Some hunting occurs in France, but is not well quantified. 5 of 6 key wintering sites are all or partly in reserves where hunting is not allowed (Bocher *et al.* 2012).
5.2	Gathering terrestrial plants						Not a measurable threat for any Red Knot DUs.
5.3	Logging & wood harvesting						Not a measurable threat for any Red Knot DUs.
5.4	Fishing & harvesting aquatic resources						Not a measurable threat for any Red Knot DUs.
6	Human intrusions & disturbance		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	Increasing disturbance by recreationists may have an effect on quality of foraging and roosting areas in NE Europe.
6.2	War, civil unrest & military exercises						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Ongoing banding activities on some UK and European estuaries may cause periodic disturbance.
7	Natural system modifications	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression						Not a measurable threat for any Red Knot DUs.
7.2	Dams & water management/use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Altered flow into estuaries and deltas may have reduced habitat quality of wintering areas, especially in the past.
7.3	Other ecosystem modifications	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Shoreline stabilization and dredging for cockles (now reduced) in many coastal areas of NE Europe is thought to be reducing the quality of foraging and roosting quality in parts of the wintering habitat.
8	Invasive & other problematic species & genes		Unknown	Pervasive - Restricted (11-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Not a measurable threat for this DU.
8.2	Problematic native species/diseases		Unknown	Pervasive - Restricted (11-100%)	Unknown	High (Continuing)	Increased predation from recovering Peregrine Falcon populations is likely at Dutch Wadden Sea wintering areas. Toxic algal blooms may present a risk in W European wintering areas.
8.3	Introduced genetic material						Not a measurable threat for any Red Knot DUs.
8.4	Problematic species/diseases of unknown origin						Not a measurable threat for any Red Knot DUs.
8.5	Viral/prion-induced diseases						Not a measurable threat for any Red Knot DUs.
8.6	Diseases of unknown cause						Not a measurable threat for any Red Knot DUs.
9	Pollution	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Unknown	Unknown	High (Continuing)	Proximity of some wintering sites to urban areas may expose birds to impacts of sewage and wastewater.
9.2	Industrial & military effluents	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Risk of oil spills in coastal areas of NE Europe used by Red Knot on migration or in winter has potential for periodic serious impacts on birds and their habitats.
9.3	Agricultural & forestry effluents		Unknown	Unknown	Unknown	High (Continuing)	Possible runoff from agricultural land into coastal estuaries in Europe.
9.4	Garbage & solid waste						Not a measurable threat for any Red Knot DUs.
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Most Red Knot are likely exposed to airborne pollutants at some point in their life cycle, but it is unclear whether any of them may affect this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.6	Excess energy						Not a measurable threat for any Red Knot DUs.
10	Geological events						
10.1	Volcanoes						Not a measurable threat for any Red Knot DUs.
10.2	Earthquakes/tsunamis						Not a measurable threat for any Red Knot DUs.
10.3	Avalanches/landslides						Not a measurable threat for any Red Knot DUs.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Changing climates may cause breeding habitat changes, increased predation on breeding grounds, and reduced habitat quality at migration and wintering sites due to sea level rise and ocean acidification, although many effects may occur primarily beyond 3 generations and some may be beneficial.
11.2	Droughts						Few direct threats anticipated from droughts; ecosystem-level changes related to drying conditions are considered in **11.1 Habitat Shifting and Alteration.**
11.3	Temperature extremes						Not a measurable threat for any Red Knot DUs; ecosystem-level changes related to rising temperatures are considered in **11.1 Habitat Shifting and Alteration.**
11.4	Storms & flooding		Unknown	Unknown	Unknown	High (Continuing)	Increased frequency and intensity of storms may periodically cause significant mortality and nest loss.
11.5	Other impacts						Other effects of climate change are likely captured by the above sub-categories for all DUs.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							

Appendix 3. Threats calculator table for Red Knot, *roselaari* subspecies (DU2).

THREATS ASSESSMENT WORKSHEET			
Species or Ecosystem Scientific Name	Red Knot, *roselaari* subspecies (DU2)		
Element ID		**Elcode**	
Date:	2020-02-12		
Assessor(s):	Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)		
References:	Draft Red Knot update status report (27 January 2020), Draft Red Knot threats calculator (21 January 2020), Recovery strategy and management plan for the Red Knot (*Calidris canutus*) in Canada (ECCC 2017)		

Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	2	0
	D	Low	5	7
Calculated Overall Threat Impact:			High	Medium
Assigned Overall Threat Impact:				
Impact Adjustment Reasons:				
Overall Threat Comments			This is one of five designatable units of Red Knot assessed together on 11-12 February 2020. Generation time was assumed to be approximately 7 years.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Increased housing pressure in many areas of the Pacific coast of USA (e.g., Washington, San Francisco area) and Mexico (e.g., Baja California, Guerrero Negro).
1.2	Commercial & industrial areas	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Roosting habitat on wintering areas in USA and Mexico (e.g., Baja California, Guerrero Negro) increasingly limited by pressure from commercial and industrial developments.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Development of coastal tourist facilities and beach access points cause slight habitat loss in areas used on migration in W USA, and in winter in upper Gulf of California, Mexico.
2	Agriculture & aquaculture	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops						Not a measurable threat for any Red Knot DUs.
2.2	Wood & pulp plantations						Not a measurable threat for any Red Knot DUs.
2.3	Livestock farming & ranching						Not a measurable threat for this DU.
2.4	Marine & freshwater aquaculture	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	Shellfish aquaculture in Grays Harbor and Willapa Bay, WA, and shrimp aquaculture in Upper Gulf California and Marismas Nacionales, Mexico may reduce quality of foraging habitats.
3	Energy production & mining		Unknown	Small (1-10%)	Unknown	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Existing oil and gas industry production and infrastructure may have locally important effects on Alaskan breeding habitats
3.2	Mining & quarrying						Mining and associated infrastructure in the Alaskan Arctic may have had past effects in reducing the quality of breeding habitat.
3.3	Renewable energy		Unknown	Small (1-10%)	Unknown	High (Continuing)	Effects of coastal wind turbines situated in the small area used by shorebirds in spring between Willapa Bay and Grays Harbor, WA, are largely unknown.
4	Transportation & service corridors						
4.1	Roads & railroads						Not a measurable threat for any Red Knot DUs.
4.2	Utility & service lines						Not a measurable threat for any Red Knot DUs.
4.3	Shipping lanes						Not a measurable threat for Red Knot DUs; effects of oil spills from shipping are considered in **9.2. Industrial & military effluents**
4.4	Flight paths						Not a measurable threat for any Red Knot DUs.
5	Biological resource use		Negligible	Negligible (<1%)	Unknown	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Very limited hunting for food, as harvest is illegal throughout most of its range.
5.2	Gathering terrestrial plants						Not a measurable threat for any Red Knot DUs.
5.3	Logging & wood harvesting						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources						Not a measurable threat for any Red Knot DUs; effects of Grunion fishery in NW Mexico are considered in **7.3 Other ecosystem modifications.**
6	Human intrusions & disturbance	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Increasing disturbance by recreationists likely has a significant effect on quality of foraging and roosting areas on parts of the Pacific coasts of USA, Mexico (e.g., Santa Clara, upper Gulf of California) and Central America; most Washington stopover areas are protected.
6.2	War, civil unrest & military exercises						Not a measurable threat for any Red Knot DUs.
6.3	Work & other activities		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Banding and aerial survey work may cause occasional disturbance. Shoreline Grunion fishery in Upper Gulf of California, Mexico may periodically disturb birds in winter and spring.
7	Natural system modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression						Not a measurable threat for any Red Knot DUs.
7.2	Dams & water management/use		Unknown	Unknown	Slight (1-10%)	High (Continuing)	Altered flow into estuaries, lagoons and deltas in W Mexico and Central America may reduce habitat quality of stop-over and wintering areas.
7.3	Other ecosystem modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Over-fishing of Grunion in Upper Gulf of California, Mexico reduces availability of their energy-rich eggs to foraging Red Knot in winter and spring. Shoreline stabilization on the Pacific coast is thought to be reducing the quality of foraging and roosting quality in parts of the wintering habitat.
8	Invasive & other problematic species & genes	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Previous impact of Smooth Cordgrass on high-use Red Knot habitats in Willapa Bay and Grays Harbor, WA now carefully managed; Green Crab may affect species composition of benthic communities in foraging areas.
8.2	Problematic native species/diseases	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Slightly increased predation and disturbance from recovering Peregrine Falcon populations at Pacific migration and wintering areas. Toxic algal blooms are known to occur along the Pacific coast in migration and wintering areas.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.3	Introduced genetic material						Not a measurable threat for any Red Knot DUs.
8.4	Problematic species/diseases of unknown origin						Not a measurable threat for any Red Knot DUs.
8.5	Viral/prion-induced diseases						Not a measurable threat for any Red Knot DUs.
8.6	Diseases of unknown cause						Not a measurable threat for any Red Knot DUs.
9	Pollution	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Unknown	Unknown	High (Continuing)	Proximity of some stopover and wintering sites to urban areas, such as Willapa Bay and Gray's Harbor, WA, Salton Sea, and NW Mexico, may expose birds to impacts of sewage and wastewater.
9.2	Industrial & military effluents	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Risk of oil spills in areas of the Pacific coast of USA (including Alaska) and Mexico used by Red Knot on migration or in winter have potential for periodic serious impacts on birds and their habitats.
9.3	Agricultural & forestry effluents		Unknown	Unknown	Unknown	High (Continuing)	Red Knot and their prey are likely exposed to toxic effluents in runoff from agricultural land into coastal estuaries, especially in Gulf of California, Mexico, wintering areas, including the polluted Salton Sea in S CA.
9.4	Garbage & solid waste						Not a measurable threat for any Red Knot DUs.
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Most Red Knot are likely exposed to airborne pollutants at some point in their life cycle, but it is unclear whether any of them may affect thid DU.
9.6	Excess energy						Not a measurable threat for any Red Knot DUs.
10	Geological events						
10.1	Volcanoes						Not a measurable threat for any Red Knot DUs.
10.2	Earthquakes/tsunamis						Not a measurable threat for any Red Knot DUs.
10.3	Avalanches/landslides						Not a measurable threat for any Red Knot DUs.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Changing climates may cause breeding habitat changes, increased predation on breeding grounds, and reduced habitat quality at migration and wintering sites due to sea level rise and ocean acidification, although many effects may occur primarily beyond 3 generations and some may be beneficial.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts						Few direct threats anticipated from droughts; ecosystem-level changes related to drying conditions are considered in **11.1 Habitat Shifting and Alteration.**
11.3	Temperature extremes						Not a measurable threat for any Red Knot DUs; ecosystem-level changes related to rising temperatures are considered in **11.1 Habitat Shifting and Alteration.**
11.4	Storms & flooding		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Increased frequency and especially intensity of storms may cause significant mortality and nest loss, with some threats posed to fall migrating and wintering birds by tropical storms.
11.5	Other impacts						Other effects of climate change are likely captured by the above sub-categories for all DUs.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							

Appendix 4. Threats calculator table for Red Knot, *rufa* subspecies, Tierra del Fuego / Patagonia wintering population (DU3)

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	Red Knot, *rufa* subspecies, Tierra del Fuego / Patagonia wintering population (DU3)			
Element ID			**Elcode**	
Date:	2020-02-12			
Assessor(s):	Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)			
References:	Draft Red Knot update status report (27 January 2020), Draft Red Knot threats calculator (21 January 2020), Recovery strategy and management plan for the Red Knot (*Calidris canutus*) in Canada (ECCC 2017)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	1	0
	C	Medium	3	1
	D	Low	3	6
Calculated Overall Threat Impact:			Very High	High
Assigned Overall Threat Impact:				
Impact Adjustment Reasons:				
Overall Threat Comments			This is one of five designatable units of Red Knot assessed together on 11-12 February 2020. Generation time was assumed to be approximately 7 years.	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Increased housing pressure in many coastal areas of USA, and Argentina, e.g., San Antonio Oeste.
1.2	Commercial & industrial areas	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Industrial developments, including coastal development in Tierra del Fuego, and near San Antonio Oeste, Argentina.
1.3	Tourism & recreation areas	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Coastal tourist facilities and beach access points in areas used on migration in E USA, and in winter in S Argentina, and Tierra del Fuego, cause disturbance and habitat loss.
2	Agriculture & aquaculture	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops						Not a measurable threat for any Red Knot DUs.
2.2	Wood & pulp plantations						Not a measurable threat for any Red Knot DUs.
2.3	Livestock farming & ranching		Unknown	Small (1-10%)	Unknown	High (Continuing)	Extensive cattle grazing impacts some coastal migration and wintering wetland habitats in S Brazil and Argentina, at lower end of scope range of 1-10%.
2.4	Marine & freshwater aquaculture	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	Quality of foraging habitats reduced by clam farming in Quebec, seaweed aquaculture in S. Brazil, Argentina and Chile, and new developments in Delaware Bay, USA.
3	Energy production & mining		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Oil and gas industry production and infrastructure at Bahia Lomas, Chile likely has a locally important effect on wintering habitat.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Mining and associated infrastructure in the Canadian Arctic may have had past effects in reducing the quality of breeding habitat. Sand mining from E USA beaches may reduce migration habitat quality, and gravel mining on the shore at Rio Grande may affect habitat and food resources in Tierra del Fuego.
3.3	Renewable energy		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Effects of proposed and developing wind power developments near areas used on migration in E USA, N Brazil, and Patagonia are generally unknown.
4	Transportation & service corridors						
4.1	Roads & railroads						Not a measurable threat for any Red Knot DUs.
4.2	Utility & service lines						Not a measurable threat for any Red Knot DUs.
4.3	Shipping lanes						Not a measurable threat for Red Knot DUs; effects of oil spills from shipping considered in **9.2. Industrial & military effluents.**
4.4	Flight paths						Not a measurable threat for any Red Knot DUs.
5	Biological resource use		Unknown	Small (1-10%)	Unknown	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Unknown	Small (1-10%)	Unknown	High (Continuing)	Hunting for food occurs in parts of the Caribbean, the Guianas, and NE Brazil, although harvest levels are not well known.
5.2	Gathering terrestrial plants						Not a measurable threat for any Red Knot DUs.
5.3	Logging & wood harvesting						Not a measurable threat for any Red Knot DUs.
5.4	Fishing & harvesting aquatic resources						Not a measurable threat for any Red Knot DUs; effects of Horseshoe Crab harvest in Delaware Bay are considered in **7.3 Other ecosystem modifications.**

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
6.1	Recreational activities	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Increasing disturbance by recreationists has a significant effect on quality of foraging and roosting areas in Magdalen Is., coastal USA, Brazil (e.g. Lagoa do Peixe), and Argentina.
6.2	War, civil unrest & military exercises						Not a measurable threat for any Red Knot DUs.
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Aerial and ground surveys and research may affect birds at migration stop-over sites (Delaware Bay) and wintering sites (Tierra del Fuego).
7	Natural system modifications	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	
7.1	Fire & fire suppression						Not a measurable threat for any Red Knot DUs.
7.2	Dams & water management/use	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Management of water levels of inland wetlands in Canadian and US prairies used on spring migration may reduce food availability and roost habitat quality. Infilling of inland sites and altered flow into estuaries, lagoons and deltas may reduce habitat quality of stopover and wintering areas in South America.
7.3	Other ecosystem modifications	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	Although harvest of Horseshoe Crab in Delaware Bay has been reduced by management actions, it likely continues to limit availability of its eggs as energy-rich food for spring migrating Red Knot in many years. Beach restoration and management activities in the Delaware Bay area are important in maintaining suitable habitat for Red Knot and Horseshoe Crab.
8	Invasive & other problematic species & genes	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Not a measurable threat for this DU.
8.2	Problematic native species/diseases	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Increased predation and disturbance from recovering populations of Peregrine Falcon and other raptors at migration and wintering areas. Overabundant goose populations may reduce habitat quality at breeding and migration stopover sites. Regular mortality from toxic algal blooms or shellfish in SE USA, S. Brazil, Uruguay, and Tierra del Fuego.
8.3	Introduced genetic material						Not a measurable threat for any Red Knot DUs.
8.4	Problematic species/diseases of unknown origin						Not a measurable threat for any Red Knot DUs.
8.5	Viral/prion-induced diseases						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.6	Diseases of unknown cause						Not a measurable threat for any Red Knot DUs.
9	Pollution	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Small (1-10%)	Unknown	High (Continuing)	Untreated sewage in the Rio Gallegos, Argentina, and other coastal migration stop-over and wintering sites may have unknown toxic effects.
9.2	Industrial & military effluents	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	Risk of oil spills in coastal areas used on migration or in winter, including the Gulf of St. Lawrence, E USA, NE Brazil, Chile, Argentina, and Tierra del Fuego, have potential for periodic serious impacts on birds and their habitats.
9.3	Agricultural & forestry effluents		Unknown	Unknown	Slight (1-10%)	High (Continuing)	Red Knot and their prey may be exposed to toxic agricultural rice field effluents in Lagoa do Peixe, Brazil, as well as in Uruguay and Argentina, on migration or in winter.
9.4	Garbage & solid waste						Not a measurable threat for any Red Knot DUs.
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Most Red Knot are likely exposed to airborne pollutants at some point in their life cycle, but it is unclear whether any of them may affect this DU.
9.6	Excess energy						Not a measurable threat for any Red Knot DUs.
10	Geological events						
10.1	Volcanoes						Not a measurable threat for any Red Knot DUs.
10.2	Earthquakes/tsunamis						Not a measurable threat for any Red Knot DUs.
10.3	Avalanches/landslides						Not a measurable threat for any Red Knot DUs.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Changing climates may cause breeding habitat changes, increased predation on breeding grounds, and reduced habitat quality at migration and wintering sites due to sea level rise and ocean acidification, although many effects may occur primarily beyond 3 generations, and some may be beneficial.
11.2	Droughts						Few direct threats anticipated from droughts; ecosystem-level changes related to drying conditions are considered in **11.1 Habitat Shifting and Alteration.**
11.3	Temperature extremes						Not a measurable threat for any Red Knot DUs; ecosystem-level changes related to rising temperatures are considered in **11.1 Habitat Shifting and Alteration.**

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	Increased frequency and especially intensity of storms may cause significant mortality and nest loss, with highest threats posed to fall migrating birds by hurricanes and tropical storms, especially near and while crossing the Gulf of Mexico/Caribbean.
11.5	Other impacts						Other effects of climate change are likely captured by the above sub-categories for all DUs.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							

Appendix 5. Threats calculator table for Red Knot, *rufa* subspecies, northeastern South America wintering population (DU4)

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	Red Knot, *rufa* subspecies, northeastern South America wintering population (DU4)			
Element ID			**Elcode**	
Date:	2020-02-12			
Assessor(s):	Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)			
References:	Draft Red Knot update status report (27 January 2020), Draft Red Knot threats calculator (21 January 2020), Recovery strategy and management plan for the Red Knot (*Calidris canutus*) in Canada (ECCC 2017)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	3	0
	D	Low	4	7
Calculated Overall Threat Impact:			High	Medium
Assigned Overall Threat Impact:				
Impact Adjustment Reasons:				
Overall Threat Comments			This is one of five designatable units of Red Knot assessed together on 11-12 February 2020. Generation time was assumed to be approximately 7 years.	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Increased housing pressure in coastal areas of E and SE USA used as migration stop-overs, less so at wintering areas.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Roosting habitat on migration areas in E and SE USA limited by pressure from commercial and industrial developments.
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Development of coastal tourist facilities and beach access points may cause habitat loss in areas used on migration in E and SE USA.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops						Not a measurable threat for any Red Knot DUs.
2.2	Wood & pulp plantations						Not a measurable threat for any Red Knot DUs.
2.3	Livestock farming & ranching						Not a measurable threat for this DU.
2.4	Marine & freshwater aquaculture	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	Quality of foraging habitats reduced by clam farming in Quebec, destruction of mangrove swamps for shrimp farms in NE Brazil, and new aquaculture developments in Delaware Bay.
3	Energy production & mining		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Oil and gas industry exploration and production at Para and Maranhão, Brazil, may have a locally important effect on wintering habitat.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Mining in the Canadian Arctic may have had past effects in reducing the quality of breeding habitat. Sand mining from E USA beaches may reduce migration habitat quality. Effluents from new iron ore and gold mines near Maranhão, Brazil, may reduce quality of adjacent winter habitat.
3.3	Renewable energy		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Effects of proposed and developing wind power developments near areas used on migration, and in winter in northern Brazil, are generally unknown.
4	Transportation & service corridors						
4.1	Roads & railroads						Not a measurable threat for any Red Knot DUs.
4.2	Utility & service lines						Not a measurable threat for any Red Knot DUs.
4.3	Shipping lanes						Not a measurable threat for any Red Knot DUs.
4.4	Flight paths						Not a measurable threat for any Red Knot DUs.
5	Biological resource use		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Hunting for food occurs in parts of the Guianas and NE Brazil, although harvest levels are not well known.
5.2	Gathering terrestrial plants						Not a measurable threat for any Red Knot DUs.
5.3	Logging & wood harvesting						Not a measurable threat for any Red Knot DUs.
5.4	Fishing & harvesting aquatic resources						Not a measurable threat for any Red Knot DUs; effects of Horseshoe Crab harvest in Delaware Bay are considered in **7.3 Other ecosystem modifications.**

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Increasing disturbance by recreationists has a significant effect on quality of foraging and roosting areas at migration stop-over sites in Magdalen Is., coastal USA, and the Caribbean.
6.2	War, civil unrest & military exercises						Not a measurable threat for any Red Knot DUs.
6.3	Work & other activities		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Aerial and ground surveys and research may affect birds at migration stop-over sites (Delaware Bay) and wintering sites (coastal NE Brazil).
7	Natural system modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression						Not a measurable threat for any Red Knot DUs.
7.2	Dams & water management/use	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Management of water levels of inland wetlands in Canadian and US prairies used on spring migration may reduce food availability and roost habitat quality. Infilling of inland sites and altered flow into estuaries, lagoons and deltas may reduce habitat quality of stopover and wintering areas in South America.
7.3	Other ecosystem modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Although harvest of Horseshoe Crab in Delaware Bay has been reduced by management actions, it likely continues to limit availability of its eggs as energy-rich food for spring migrating Red Knot in many years. Beach restoration and management activities in the Delaware Bay area are important in maintaining suitable habitat for Red Knot and Horseshoe Crab.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Not a measurable threat for this DU.
8.2	Problematic native species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Increased predation and disturbance from recovering Peregrine Falcon populations at migration and wintering areas. Overabundant goose populations may reduce habitat quality at breeding and migration stopover sites. Periodic mortality from toxic algal blooms or shellfish at SE US and Caribbean migration stop-over sites.
8.3	Introduced genetic material						Not a measurable threat for any Red Knot DUs.
8.4	Problematic species/diseases of unknown origin						Not a measurable threat for any Red Knot DUs.
8.5	Viral/prion-induced diseases						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.6	Diseases of unknown cause						Not a measurable threat for any Red Knot DUs.
9	Pollution	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Small (1-10%)	Unknown	High (Continuing)	Untreated sewage in N Brazil and other coastal migration stop-over and wintering sites may have undetermined toxic effects on Red Knot.
9.2	Industrial & military effluents	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	Risk of oil spills in coastal areas used on migration or in winter, including the Gulf of St. Lawrence, E USA, and NE South America, have potential for periodic serious impacts on birds and their habitats.
9.3	Agricultural & forestry effluents		Unknown	Unknown	Slight (1-10%)	High (Continuing)	Red Knot and their prey may be exposed to toxic agricultural rice field effluents in Surinam and French Guiana on migration or in winter.
9.4	Garbage & solid waste						Not a measurable threat for any Red Knot DUs.
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Most Red Knot are likely exposed to airborne pollutants at some point in their life cycle, but it is unclear whether any of them may affect this DU.
9.6	Excess energy						Not a measurable threat for any Red Knot DUs.
10	Geological events						
10.1	Volcanoes						Not a measurable threat for any Red Knot DUs.
10.2	Earthquakes/tsunamis						Not a measurable threat for any Red Knot DUs.
10.3	Avalanches/landslides						Not a measurable threat for any Red Knot DUs.
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Changing climates may cause breeding habitat changes, increased predation on breeding grounds, and reduced habitat quality at migration and wintering sites due to sea level rise and ocean acidification, although many effects may occur primarily beyond 3 generations, and some may be beneficial.
11.2	Droughts						Few direct threats anticipated from droughts; ecosystem-level changes related to drying conditions are considered in **11.1 Habitat Shifting and Alteration.**
11.3	Temperature extremes						Not a measurable threat for any Red Knot DUs; ecosystem-level changes related to rising temperatures are considered in **11.1 Habitat Shifting and Alteration.**

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	Increased frequency and especially intensity of storms may cause significant mortality and nest loss, with highest threats posed to fall migrating birds by hurricanes and tropical storms, especially near and while crossing the Gulf of Mexico/Caribbean.
11.5	Other impacts						Other effects of climate change are likely captured by the above sub-categories for all DUs.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							

Appendix 6. Threats calculator table for Red Knot, *rufa* subspecies, southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5)

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	Red Knot, *rufa* subspecies, southeastern USA / Gulf of Mexico / Caribbean wintering population (DU5)			
Element ID			**Elcode**	
Date:	2020-02-12			
Assessor(s):	Guy Morrison (writer), Richard Elliot (Birds SSC co-chair), David Fraser (facilitator), Marie-France Noel (COSEWIC Secretariat), Rosanna Nobre Soares (COSEWIC Secretariat), Yves Aubry (CWS), Louise Blight (SSC member), Mike Burrell (SSC member), Amanda Dey (New Jersey), Scott Flemming (CWS), Marcel Gahbauer (SSC co-chair), Patricia González (Argentina), Andy Horn (SSC member), Jessica Humber (Newfoundland and Labrador), Kevin Kalasz (USFWS), Amie MacDonald (Trent University), Ann McKellar (CWS), David Newstead (USA), Larry Niles (USA), Hayley Roberts (CWS), Paul Smith (SSC member), Don Sutherland (Ontario NHIC), Wendy Walsh (USFWS), Greg Wilson (British Columbia), Paul Woodard (CWS)			
References:	Draft Red Knot update status report (27 January 2020), Draft Red Knot threats calculator (21 January 2020), Recovery strategy and management plan for the Red Knot (*Calidris canutus*) in Canada (ECCC 2017)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	4	0
	D	Low	3	7
Calculated Overall Threat Impact:			High	Medium
Assigned Overall Threat Impact:				
Impact Adjustment Reasons:				
Overall Threat Comments			This was one of five designatable units of Red Knot assessed together on 11-12 February 2020. Generation time was assumed to be approximately 7 years.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Roosting habitat on migration and wintering areas limited by increased housing pressure in E and SE USA and Caribbean.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Roosting habitat on migration and wintering areas in USA and Caribbean limited by pressure from commercial and industrial developments.
1.3	Tourism & recreation areas	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Development of coastal tourist facilities and beach access points in areas used on migration and winter in USA and Caribbean cause disturbance and habitat loss.
2	Agriculture & aquaculture	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops						Not a measurable threat for any Red Knot DUs.
2.2	Wood & pulp plantations						Not a measurable threat for any Red Knot DUs.
2.3	Livestock farming & ranching						Not a measurable threat for this DU.
2.4	Marine & freshwater aquaculture	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	Quality of foraging habitats reduced by clam farming in Quebec, and new aquaculture developments in Delaware Bay.
3	Energy production & mining		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Oil and gas industry production and infrastructure may have local effects on migration stopover and wintering habitats
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Mining and associated infrastructure in the Canadian Arctic may have had past effects in reducing the quality of breeding habitat. Sand mining from E USA beaches may reduce migration habitat quality.
3.3	Renewable energy		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Existing, proposed and developing wind power developments in some areas used on migration and in winter may cause habitat loss and mortality from collisions, but effects are generally unknown.
4	Transportation & service corridors						
4.1	Roads & railroads						Not a measurable threat for any Red Knot DUs.
4.2	Utility & service lines						Not a measurable threat for any Red Knot DUs.
4.3	Shipping lanes						Not a measurable threat for Red Knot DUs; effects of oil spills from shipping considered in **9.2. Industrial & military effluents.**
4.4	Flight paths						Not a measurable threat for any Red Knot DUs.
5	Biological resource use		Negligible	Negligible (<1%)	Unknown	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Hunting for food occurs in parts of the Caribbean, although harvest levels are not well known, but likely low.
5.2	Gathering terrestrial plants						Not a measurable threat for any Red Knot DUs.
5.3	Logging & wood harvesting						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources						Not a measurable threat for any Red Knot DUs; effects of Horseshoe Crab harvest in Delaware Bay are considered in **7.3 Other ecosystem modifications.**
6	Human intrusions & disturbance	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
6.1	Recreational activities	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Increasing disturbance by recreationists has a significant effect on quality of foraging and roosting areas in Magdalen Is., coastal USA (e.g. Florida), the Caribbean, and Panama.
6.2	War, civil unrest & military exercises						Not a measurable threat for any Red Knot DUs.
6.3	Work & other activities		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	Aerial and ground surveys and research may affect birds at migration stop-over sites (Delaware Bay).
7	Natural system modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression						Not a measurable threat for any Red Knot DUs.
7.2	Dams & water management/use	D	Low	Restricted - Small (1-30%)	Slight (1-10%)	High (Continuing)	Management of water levels of inland wetlands in Canadian and US prairies used on spring migration may reduce food availability and roost habitat quality. Infilling of inland sites and altered flow into estuaries, lagoons and deltas may reduce habitat quality of stopover and wintering areas in the Gulf and Caribbean.
7.3	Other ecosystem modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Although harvest of Horseshoe Crab in Delaware Bay has been reduced by management actions, it likely continues to limit availability of its eggs as energy-rich food for spring migrating Red Knot in many years. Beach restoration and management activities in the Delaware Bay area are important in maintaining suitable habitat for Red Knot and Horseshoe Crab.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Not a measurable threat for this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Increased predation and disturbance from recovering Peregrine Falcon populations at migration and wintering areas. Overabundant goose populations may reduce habitat quality at breeding and migration stopover sites. Periodic mortality from toxic algal blooms or shellfish at Gulf of Mexico (Texas) and Caribbean migration stop-over sites and wintering areas.
8.3	Introduced genetic material						Not a measurable threat for any Red Knot DUs.
8.4	Problematic species/diseases of unknown origin						Not a measurable threat for any Red Knot DUs.
8.5	Viral/prion-induced diseases						Not a measurable threat for any Red Knot DUs.
8.6	Diseases of unknown cause						Not a measurable threat for any Red Knot DUs.
9	Pollution	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Unknown	Unknown	High (Continuing)	Untreated sewage in coastal migration stop-over and wintering sites, such as the Caribbean, may have undetermined toxic effects on Red Knot.
9.2	Industrial & military effluents	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	Risk of oil spills in coastal areas used on migration or in winter, including the Gulf of St. Lawrence, E USA, and the Gulf of Mexico, have potential for periodic serious impacts on birds and their habitats.
9.3	Agricultural & forestry effluents		Unknown	Unknown	Slight (1-10%)	High (Continuing)	Red Knot and its prey may be exposed to toxic agricultural rice field effluents in Trinidad and other locations, on migration or in winter.
9.4	Garbage & solid waste						Not a measurable threat for any Red Knot DUs.
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Most Red Knot are likely exposed to airborne pollutants at some point in their life cycle, but it is unclear whether any of them may affect this DU.
9.6	Excess energy						Not a measurable threat for any Red Knot DUs.
10	Geological events						
10.1	Volcanoes						Not a measurable threat for any Red Knot DUs.
10.2	Earthquakes/tsunamis						Not a measurable threat for any Red Knot DUs.
10.3	Avalanches/landslides						Not a measurable threat for any Red Knot DUs.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Changing climates may cause breeding habitat changes, increased predation on breeding grounds, and reduced habitat quality at migration and wintering sites due to sea level rise and ocean acidification, although many effects may occur primarily beyond 3 generations, and some may be beneficial.
11.2	Droughts		Unknown	Large (31-70%)	Unknown	High (Continuing)	Increasing droughts may reduce quality of prairie wetlands used as stopover habitat by northbound migrants in northern USA and central Canada.
11.3	Temperature extremes						Few direct threats anticipated from droughts; ecosystem-level changes related to drying conditions are considered in **11.1 Habitat Shifting and Alteration.**
11.4	Storms & flooding	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	Increased frequency and especially intensity of storms may cause significant mortality and nest loss, with highest threats posed to fall migrating birds by hurricanes and tropical storms. Although most birds do not cross the Gulf of Mexico/Caribbean, they are present in this high risk area throughout fall and winter.
11.5	Other impacts						Other effects of climate change are likely captured by the above sub-categories for all DUs.
Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008).							