



Government of Northwest Territories Gouvernement des Territoires du Nord-Ouest

Critical Breeding Periods for Raptor Species of the Northwest Territories

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ABSTRACT

Raptors can be more sensitive to disturbance during the breeding period compared to other periods. We used information from literature and unpublished phenological data collected from 1970s to 2010s to determine the critical breeding periods for each of the NWT's 15 raptor species in each of the territory's major eco-climatic regions. The critical period was defined as beginning two weeks prior to egg-laying and one week after the end of the nestling period. Each raptor species has different initiation and duration of critical breeding periods. These periods also differ by latitude and habitat. This information can be used to draft guidelines for restrictions on activities around raptor nests. We recommend that breeding period charts should be updated in a decade or so to adjust for earlier phenology with a changing climate. We recommend that particular efforts should be taken to estimate age of nestlings during each nest visit to allow for better estimates of breeding phenology.

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INTENT

Raptor species are sensitive to human disturbance during their breeding period (Newton 1979). Certain disturbance activities are often restricted in the vicinity of raptor nests during this critical time period. However, many of the Northwest Territories (NWT's) raptor species have intrinsic differences in the initiation and duration of breeding activity as well as differing responses to local environmental conditions.

The intent of this report is to provide a general summary of the critical breeding period for each of the NWT's raptor species in each of the territory's major ecoregions. This information can be used as targeted guidelines for restrictions on human activities around raptor nests.

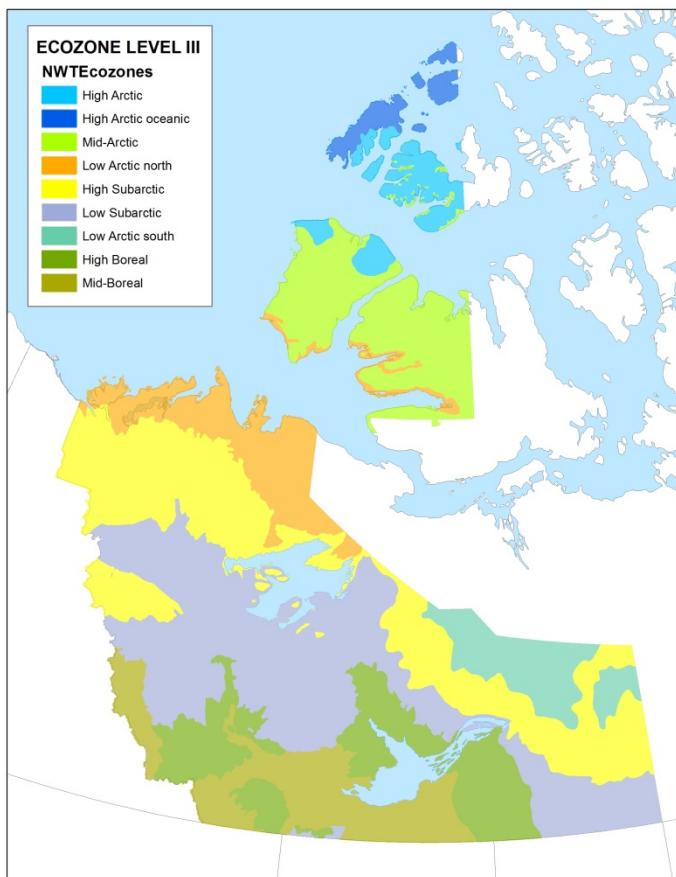


Figure 1. Level III ecoregions of the NWT.

Ecoregions

We present estimates of breeding phenology for each of the NWT's level III ecoregions (Ecosystem Classification Group 2007, 2008, 2010, 2012, and 2013). We have combined High Arctic oceanic into the High Arctic ecoregion resulting in eight ecoregions of interest (Figure 1). The NWT classification is a refinement of the continental approach taken by the United States Environmental Protection Agency (US EPA) and the Commission on Economic Cooperation (Wiken et al. 2011). Because it does not match the Nunavut (NU) classification, we were unable to utilize relevant data from NU; i.e., from ecoregions that straddle the NWT/NU border.

METHODS AND APPROACH

In studies entailing extensive raptor field surveys, the most objectively measurable date in the raptor breeding cycle is the date of hatch. This can be calculated by subtracting the estimated age of young in the nest from the date of observation. Age of nestlings can be roughly determined by observation (often using known date photographs; e.g. Moritsch 1983) or more accurately estimated by a regression on flight feather (usually 7th primary) length (e.g. Poole 1989).

Other events in the raptor breeding cycle are more difficult to determine in field studies entailing infrequent visits to nest sites. Date of arrival from migration can only be roughly estimated because birds do not become firmly associated with a nest site until an unknown time after arrival and one to several weeks prior to actual egg-laying. Accurately determining date of egg-laying and fledging requires daily observation of nests, which is possible only in intensive field studies. By contrast, determining hatch date by aging nestlings can be done for many nests over a wide area, but is less accurate than direct observation.

There is a wide literature on the phenology of raptor breeding which has been most extensively summarized in the Birds of North America Online (BoNA). For each species, BoNA provides an image of an annual calendar wheel summarizing peak and extreme dates of breeding, migration and molt. However, these reviews cover the species' entire breeding range and considerable subjective interpretation is usually required to predict critical dates in the various NWT ecoregions.

Fifteen species of raptors are known to occur within the NWT (Table 1). Owls were excluded from this analysis due to limited phenology data for these species in the NWT. Data on breeding phenology in the NWT are limited for most raptor species. However, the NWT and NU have amassed a large body of data into the NWT/NU Raptor Database providing the location and various reproductive parameters for raptor nests observed from the 1970s to the present. Enough data to undertake statistical analysis of breeding phenology in differing Ecoregions were available for only a few species (e.g. peregrine falcon, gyrfalcon, golden eagle, rough-legged hawk). For these species, earliest, 1st quartile = Q1, 2nd quartile = median, 3rd quartile = Q3 and latest hatch dates were determined for each ecoregion for which data exist. From the range in hatch dates, dates for egg-laying were determined by subtracting published average incubation periods from hatch date. Dates for fledging were estimated by adding published average nestling periods to hatch dates.

Raptor species are sensitive to disturbance early in the nesting cycle, although this sensitivity varies with many indeterminable factors (Newton 1979). Consequently, we have considered the onset of the critical period to commence two weeks prior to the median initiation of egg-laying. We also include an extra week to the critical period at the end of the breeding cycle because recently fledged young initially usually do not stray far from the

nest because of their limited flight capabilities (e.g. Poole and Bromley 1988). The two weeks added prior to egg-laying and the one week added after estimated fledging provide a reasonable buffer to address inaccuracies, yearly variation, and possible outliers in the data.

Table 1. NWT raptor species with their AOU code name. Species are presented in the 1998 AOU taxonomic sequence (American Ornithological Union, nd).

Common Name	Scientific Name	AOU Code
Turkey Vulture	<i>Cathartes aura</i>	TUVU
Osprey	<i>Pandion haliaetus</i>	OSPR
Bald Eagle	<i>Haliaeetus leucocephalus</i>	BAEA
Northern Harrier	<i>Circus cyaneus</i>	NOHA
Sharp-shinned Hawk	<i>Accipiter striatus</i>	SSHA
Northern Goshawk	<i>Accipiter gentilis</i>	NOGO
Broad-winged Hawk	<i>Buteo platypterus</i>	BWHA
Swainson's Hawk	<i>Buteo swainsoni</i>	SWHA
Red-tailed Hawk	<i>Buteo jamaicensis</i>	RTHA
Rough-legged Hawk	<i>Buteo lagopus</i>	RLHA
Golden Eagle	<i>Aquila chrysaetos</i>	GOEA
American Kestrel	<i>Falco sparverius</i>	AMKE
Merlin	<i>Falco columbarius</i>	MERL
Gyrfalcon	<i>Falco rusticolus</i>	GYRF
Peregrine Falcon	<i>Falco peregrinus</i>	PEFA

OCCURRENCE OF RAPTOR SPECIES IN NORTHWEST TERRITORIES ECOREGIONS

NWT Environment and Natural Resources (ENR) have developed a geodatabase to map the presence of each bird species using a set of density indices in each level IV ecoregion (Chowns 2012). The geodatabase used indices to quantify densities as follows:

- 0 = absent
- 0.5 = presence expected
- 1 = occasional
- 2 = rare
- 3 = localized
- 4 = common
- 5 = abundant

For each raptor species, the mean density indices for the eight level III ecoregions (Table 2, Figure 2) were calculated as the mean score over all level IV ecoregions in the level III ecoregion weighted by the areas of the individual level IV ecoregions.

Table 2. Summary of mean area-weighted density for 15 NWT raptor species in eight level III NWT ecoregions.

Species	High Arctic	Middle Arctic	Low Arctic North	Low Arctic South	High Subarctic	Low Subarctic	High Boreal	Middle Boreal
Turkey Vulture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Osprey	0.0	0.0	0.0	0.0	1.3	2.4	1.5	2.2
Bald Eagle	0.0	0.0	1.3	1.0	2.4	3.6	3.9	3.6
Northern Harrier	0.0	0.0	1.3	1.2	1.6	1.8	2.3	2.6
Sharp-shinned Hawk	0.0	0.0	0.2	0.0	1.1	1.1	1.4	2.5
Northern Goshawk	0.0	0.0	0.6	0.3	1.2	1.9	2.7	2.6
Broad-winged Hawk	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7
Swainson's Hawk	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.1
Red-tailed Hawk	0.0	0.0	0.0	0.0	0.6	1.5	1.6	2.0
Rough-legged Hawk	1.3	3.0	2.8	2.1	2.6	2.2	2.2	1.8
Golden Eagle	0.0	0.1	2.1	1.2	2.5	1.8	2.2	1.7
American Kestrel	0.0	0.0	0.5	0.0	1.6	1.7	3.1	3.4
Merlin	0.0	0.0	1.4	0.6	1.7	1.9	2.4	2.2
Gyrfalcon	0.7	1.3	2.5	1.7	1.7	1.0	0.5	0.6
Peregrine Falcon	1.6	1.9	2.5	1.9	2.5	1.9	1.5	1.5

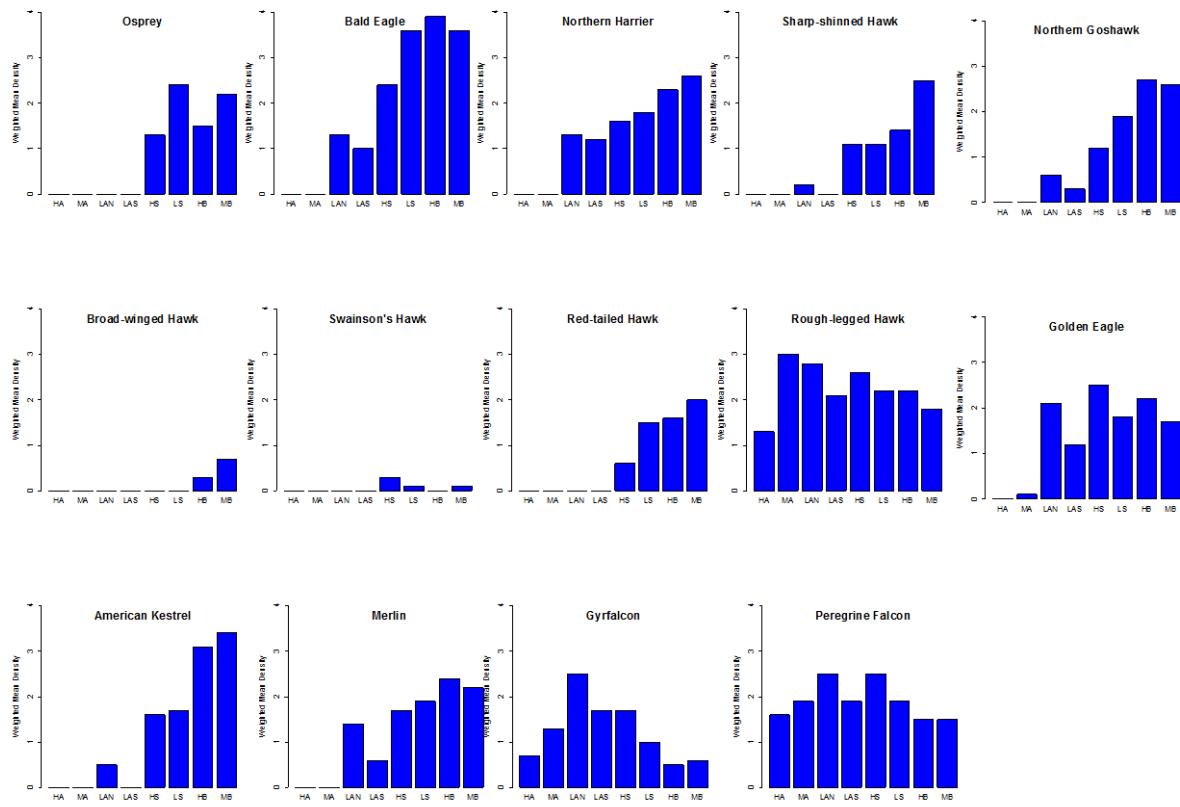


Figure 2. Mean raptor species density index for level III ecoregions weighted by area. See Methods for details of computation. From north to south: HA = High Arctic, MA = Mid-Arctic, LAN = Low Arctic North, LAS = Low Arctic South, HS = High Subarctic, HB = High Boreal, MB = Mid-Boreal.

Appendix 1 shows the density of 14 NWT raptor species (turkey vulture excluded; see below) in each of 162 level IV ecoregions.

RAPTOR BREEDING PHENOLOGY IN THE NORTHWEST TERRITORIES

Turkey Vulture (TUVU)

There are no records of TUVU in the NWT/NU Raptor Database. TUVUs are considered to be "rare/accidental" in the NWT (Avibase nd). TUVUs will not be considered further in this report.

Osprey (OSPR)

OSPRs occur in the four most southerly of the eight NWT level III ecoregions (Table 2, Figure 2). There are 20 OSPR observations in the NWT/NU Raptor Database of which 19 are in the NWT. However, only one allows determination of hatch date (3 July in the High Boreal ecoregion).

The only published information for phenology of OSPR breeding in the NWT is Poole (1985) and Shank (1990) who aged nestlings in six years at sites in the High Boreal ecoregion. Hatch dates ranged from 25 June – 16 July.

From this information and the one empirical observation from the NWT/NU Raptor Database, we estimate a median hatch date of the 1st week of July for the High Boreal ecoregion. We estimate egg-laying dates from a mean incubation period of 39 days (Poole 1984 in BoNA) and fledging dates from a mean nestling period of 55 days (Poole 1984 in BoNA) (Table 3).

Table 3. Critical breeding period for OSPRs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May	June	July	August	September
High Arctic (NP)					
MidArctic (NP)					
Low Arctic North (NP)					
Low Arctic South (NP)					
High Subarctic (ESTIMATED)		E E E E E	E N N N N N N N N N N		
Low Subarctic (ESTIMATED)		E E E E E	E N N N N N N N N N N N N		
High Boreal		E E E E E	N N N N N N N N N N N N		
MidBoreal (ESTIMATED)	E E E E E	N	N N N N N N N N N N N	N	

Bald Eagle (BAEA)

BAEAs occur in the six mainland NWT level III ecoregions (Table 2, Figure 2). There are 134 BAEA records in the NWT/NU Raptor Database of which 126 are in the NWT. Of the NWT records, only ten have sufficient information to allow determination of breeding phenology. Note that sample sizes are limited for the High Subarctic and Mid-Boreal (Table 4).

Egg-laying date was determined by subtracting an incubation period of 35 days (review in BoNA) from the median hatch data and date of fledging was estimated by adding 80 days (Bortolotti 1986) to the median hatch date (Table 5).

Table 4. Earliest, Q1, median, Q3, and latest dates for egg-laying, hatch and fledging by BAEAs in NWT ecoregions. Data from the NWT/NU Raptor Database.

Ecoregion	Laying Date					Hatch Date					Fledging Date					N
	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	
High Arctic (NP)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mid-Arctic (NP)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Low Arctic North (NO DATA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Low Arctic South (NO DATA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
High Subarctic	08-Apr	07-May	12-May	18-May	26-May	13-May	11-Jun	16-Jun	22-Jun	30-Jun	01-Aug	30-Aug	04-Sep	10-Sep	18-Sep	6
Low Subarctic (NO DATA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
High Boreal (NO DATA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Mid-Boreal	03-Apr	15-Apr	27-Apr	03-May	08-May	08-May	20-May	01-Jun	07-Jun	12-Jun	27-Jul	08-Aug	20-Aug	26-Aug	31-Aug	3

Table 5. Critical breeding period for BAEAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	April	May				June				July				August			September
High Arctic (NP)																	
MidArctic (NP)																	
Low Arctic North (ESTIMATED)						E	E	E	E	E	N	N	N	N	N	N	
Low Arctic South (ESTIMATED)						E	E	E	E	E	N	N	N	N	N	N	
High Subarctic						E	E	E	E	E	N	N	N	N	N	N	
Low Subarctic (ESTIMATED)						E	E	E	E	E	N	N	N	N	N	N	
High Boreal (ESTIMATED)						E	E	E	E	E	N	N	N	N	N	N	
Mid-Boreal						E	E	E	E	E	N	N	N	N	N	N	

Northern Harrier (NOHA)

The NOHA occurs in all six of NWT's mainland ecoregions with densities that decline with increasing latitude (Table 2, Figure 2). There are only two records of NOHA in the NWT/NU Raptor Database.

We know of no published literature on NOHA breeding phenology in the NWT. Initiation of egg-laying may be influenced by microtine abundance (Simmons et al. 1986). Most of the research has been done in Wisconsin where the species exhibits a very wide two-month window in hatch dates ranging from 21 May to 20 July with a peak in late June/early July (Schmutz and Schmutz 1975). The one NWT observation was an un-aged nestling observed on 3 July in the High Boreal ecoregion. The incubation period averages about 31 days with the nestling period averaging 35 days (review in BoNA).

Due to the lack of data, the estimate for the NOHA critical breeding period is very preliminary (Table 6).

Table 6. Critical breeding period for NOHAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May			June			July			August		
High Arctic (NP)												
Mid-Arctic (NP)												
Low Arctic North (ESTIMATED)				E	E	E	E	E	N	N	N	N
Low Arctic South (ESTIMATED)				E	E	E	E	E	N	N	N	N
High Subarctic (ESTIMATED)				E	E	E	E	E	N	N	N	N
Low Subarctic (ESTIMATED)				E	E	E	E	E	N	N	N	N
High Boreal (ESTIMATED)			E	E	E	E	E	N	N	N	N	
Mid-Boreal (ESTIMATED)		E	E	E	E	E	N	N	N	N	N	

Sharp-shinned Hawk (SSHA)

SSHA occurs in five of the NWT's eight level III ecoregions with densities declining with latitude (Table 2, Figure 2). There is only one SSHA record in the NWT/NU Raptor Database.

We know of no information on the breeding phenology of SSHAs in the NWT. Known breeding chronologies are from Oregon, Utah and New Brunswick and are quite variable (review in BoNA). Consequently, we can only roughly estimate the critical period for the five NWT ecoregions. The length of the breeding season is estimated by calculating an egg-laying date as 32 days before hatch and fledging as 24 days after hatch (review in BoNA).

The critical breeding periods should therefore be considered as uncertain (Table 7).

Table 7. Critical breeding period for SSHAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May			June			July			August		
High Arctic (NP)												
Mid-Arctic (NP)												
Low Arctic North (ESTIMATED)					E	E	E	E	N	N	N	N
Low Arctic South (NP)												
High Subarctic (ESTIMATED)					E	E	E	E	N	N	N	N
Low Subarctic (ESTIMATED)				E	E	E	E	N	N	N	N	
High Boreal (ESTIMATED)				E	E	E	E	N	N	N	N	
Mid-Boreal (ESTIMATED)				E	E	E	E	N	N	N	N	

Northern Goshawk (NOGO)

NOGOs occur in six of the eight NWT level III ecoregions, but are common only in the two boreal ecoregions (Table 2, Figure 2). There are only two NOGO records in the NWT/NU Raptor Database and neither provides information allowing determination of breeding phenology.

NOGOs lay eggs in late April to early May in both Alaska (BoNA) and British Columbia (BC) (Chytyk and Dhanwant 1999, in COSEWIC 2013). In BC, hatch is in the last week of May and the 1st week of June (Chytyk and Dhanwant 1999, in COSEWIC 2013). The mean incubation period is about 32 days (review in BoNA) and the mean nestling period is about 40 days (Cramp and Simmons 1980, Boal 1994). Based on these data, we very roughly estimate the critical breeding period of NOGOs (Table 8).

Table 8. Critical breeding period for NOGOs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	April	May	June	July	August
High Arctic (NP)					
Mid-Arctic (NP)					
Low Arctic North (ESTIMATED)		E E E E	N N N N N		
Low Arctic South (ESTIMATED)		E E E E	N N N N N N	N	
High Subarctic (ESTIMATED)		E E E E	N N N N N N		
Low Subarctic (ESTIMATED)		E E E E	N N N N N N		
High Boreal (ESTIMATED)		E E E E	N N N N N N		
Mid-Boreal (ESTIMATED)		E E E E	N N N N N N		

Broad-winged Hawk (BWHA)

BWHAs are at the northern limit of their range in the NWT and occur only rarely in the Mid- and High Boreal ecoregions (Table 2, Figure 2). BWHA are considered as "rare/accidental" in the NWT (Avibase nd). There are only two BWHA records in the NWT/NU Raptor Database indicating that un-aged nestlings were present on 23 June and 11 July.

We know of no published literature describing BWHA breeding phenology in the NWT. However, Rusch and Doerr (1972) indicate that the mean BWHA hatch date is 2 July for central Alberta. The mean incubation period is 30 days and fledging occurs in five to six weeks (mean = 39 days) (reviews in BoNA) (Table 9).

Table 9. Critical breeding period for BWHAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May				June				July				August				
High Arctic (NP)																	
Mid-Arctic (NP)																	
Low Arctic North (NP)																	
Low Arctic South (NP)																	
High Subarctic (NP)																	
Low Subarctic (NP)																	
High Boreal ESTIMATED)					E	E	E	E	N	N	N	N	N	N	N		
Mid-Boreal (ESTIMATED)					E	E	E	E	N	N	N	N	N	N			

Swainson's Hawk (SWHA)

According to the NWT avian density index, SWHAs occur in very low densities in three NWT level III ecoregions (Table 2, Figure 2). There are no records of SWHA in the NWT/NU Raptor Database. BoNA states "Status in Alaska, Yukon, and NWT needs clarification, though it appears that small and all-but-apocryphal breeding populations may have always existed in a few localities." We suggest that the species is as uncommon in the NWT as to not require special protection.

However, if SWHAs are detected, the most likely breeding phenology is that shown in Table 10, based primarily on the phenology in Saskatchewan (BoNA).

Table 10. Critical breeding period for SWHAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May			June			July			August		
High Arctic (NP)												
MidArctic (NP)												
Low Arctic North (NP)												
Low Arctic South (NP)												
High Subarctic (ESTIMATED)			E	E	E	E	E	N	N	N	N	N
Low Subarctic (ESTIMATED)			E	E	E	E	E	N	N	N	N	N
High Boreal (NP)												
MidBoreal (ESTIMATED)		E	E	E	E	E	N	N	N	N	N	

Red-tailed Hawk (RTHA)

RTHA is a largely southern species found in four NWT ecoregions with density declining from south to north (Table 2, Figure 2). There are 14 RTHA records in the NWT/NU Raptor Database. Of these, 12 occur in the NWT, but none allows determination of breeding phenology. We know of no published information on breeding phenology specifically for the NWT. The most applicable information is from central Alberta (Luttich et al. 1970) where incubation initiates between 12 April and 26 May (mean = 1 May) and hatch occurs between 27 May and 5 June. Fledging occurs between 11-20 July. These data are extrapolated for the four NWT ecoregions (Table 11).

Table 11. Critical breeding period for RTHAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	April	May	June	July	August
High Arctic (NP)					
Mid-Arctic (NP)					
Low Arctic North (NP)					
Low Arctic South (NP)					
High Subarctic (ESTIMATED)		E E E E	N N N N	N N N N	
Low Subarctic (ESTIMATED)		E E E E	N N N N	N N N N	
High Boreal (ESTIMATED)		E E E E	N N N N	N N N N	
Mid-Boreal (ESTIMATED)		E E E E	N N N N	N N N N	

Rough-legged Hawk (RLHA)

RLHAs occur in all eight NWT level III ecoregions with densities generally increasing with latitude. There are 741 RLHA records in the NWT/NU database of which 254 are in the NWT. Of the NWT records, 37 allow determination of hatch date. Date of egg-laying was determined by subtracting an incubation period of 31 days from hatch date while date of fledging was estimated by adding a nestling period of 40 days to hatch date (review in BoNA) (Table 12).

BoNA notes that RLHA breeding phenology is strongly affected by latitude and nest-ledge characteristics as well as by yearly differences in temperature and dates at which nest ledges become snow-free. Data from the NWT/NU Raptor Database is puzzling in indicating that hatch dates are two weeks earlier in the Low Arctic North and South than in other ecoregions. However all of these data are from a single year in one specific area for each ecoregion, suggesting a possible year effect.

Table 12. Earliest, Q1, median, Q3, and latest dates for egg-laying, hatch and fledging by RLHAs in NWT ecoregions. Data from the NWT/NU Raptor Database.

Ecoregion	Laying Date				Hatch Date				Fledging Date				N			
	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	
High Arctic	13-Jun	17-Jun	18-Jun	19-Jun	21-Jun	13-Jul	17-Jul	18-Jul	19-Jul	21-Jul	22-Aug	26-Aug	27-Aug	28-Aug	30-Aug	4
Mid-Arctic	10-Jun	15-Jun	16-Jun	21-Jun	25-Jun	10-Jul	15-Jul	16-Jul	21-Jul	25-Jul	19-Aug	24-Aug	25-Aug	30-Aug	03-Sep	18
Low Arctic North	22-May	22-May	26-May	29-May	06-Jun	21-Jun	21-Jun	25-Jun	28-Jun	06-Jul	31-Jul	31-Jul	04-Aug	07-Aug	15-Aug	10
Low Arctic South	-	-	-	-	-	-	-	30-Jun	-	-	-	-	-	-	-	3
High Subarctic	-	-	-	-	-	-	-	15-Jul	-	-	-	-	-	-	-	2
Low Subarctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
High Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mid-Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Because of the uncertainties arising from the data and intrinsic variability RLHAs show in breeding dates, Table 13 should be considered as a very rough guide.

Table 13. Critical breeding period for RLHAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May			June			July			August			September	
High Arctic (ESTIMATED)					E	E	E	E	N	N	N	N		
Mid-Arctic (ESTIMATED)					E	E	E	E	N	N	N	N		
Low Arctic North (ESTIMATED)				E	E	E	E	N	N	N	N	N		
Low Arctic South (ESTIMATED)				E	E	E	E	N	N	N	N	N		
High Subarctic (ESTIMATED)		E	E	E	E	N	N	N	N	N	N	N		
Low Subarctic (ESTIMATED)		E	E	E	E	N	N	N	N	N	N	N		
High Boreal (ESTIMATED)	E	E	E	E	N	N	N	N	N	N	N	N		
Mid-Boreal (ESTIMATED)	E	E	E	E	N	N	N	N	N	N	N	N		

Golden Eagle (GOEA)

GOEAs occur in seven of the NWT's eight ecoregions (Table 2, Figure 2). There are 1,709 GOEA records in the NWT/NU Raptor Database. Of these 481 occur in the NWT. Of the NWT records, 59 contain sufficient information to determine breeding phenology. However, there are enough data to draw conclusions only for the Low Arctic North and High Subarctic ecoregions (Table 14). We used a mean incubation period of 43 days (review in BoNA) and a nestling period of 64 days (USGS unpublished in BoNA).

Table 14. Earliest, Q1, median, Q3, and latest dates for egg-laying, hatch and fledging by GOEAs in NWT ecoregions. Data from the NWT/NU Raptor Database.

Ecoregion	Laying Date					Hatch Date					Fledging Date					N
	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	
High Arctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mid-Arctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Low Arctic North	20-Apr	30-Apr	05-May	10-May	17-May	01-Jun	11-Jun	16-Jun	21-Jun	28-Jun	04-Aug	14-Aug	19-Aug	24-Aug	31-Aug	50
Low Arctic South	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
High Subarctic	19-Apr	26-Apr	30-Apr	06-May	19-May	01-Jun	08-Jun	12-Jun	18-Jun	01-Jul	04-Aug	11-Aug	15-Aug	21-Aug	03-Sep	7
Low Subarctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
High Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mid-Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table 15. Critical breeding period for GOEAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	March	April	May	June	July	August	September
High Arctic (NP)							
Mid-Arctic (ESTIMATED)			E E E E E E N N N N N N N N				
Low Arctic North			E E E E E E N N N N N N N N				
Low Arctic South (ESTIMATED)			E E E E E E N N N N N N N N				
High Subarctic			E E E E E E N N N N N N N N				
Low Subarctic (ESTIMATED)			E E E E E E N N N N N N N N				
High Boreal (ESTIMATED)			E E E E E E N N N N N N N N				
Mid-Boreal (ESTIMATED)			E E E E E E N N N N N N N N				

American Kestrel (MAKE)

AMKEs are found in five of the eight Level III ecoregions with density declining dramatically with increasing latitude (Figure 2, Table 2). There are 17 observations of AMKEs in the NWT/NU Raptor Database of which all occur in the NWT, but none allow determination of breeding phenology.

We know of no published information on breeding phenology in the NWT. The most relevant information would appear to be from Saskatchewan where egg-laying occurs from April 30 – June 19 (mean = *ca.* May 20) (Figure 5 in BoNA, from G.R. Bortellotti, unpublished). Hatching and fledging dates have been calculated by adding 30 days for both incubation (Bird and Palmer 1988 in BoNA) and fledging (review in BoNA). The BoNA account notes that the breeding phenology of AMKE is correlated with latitude, so we have suggested a somewhat later breeding phenology in the NWT than in Saskatchewan (Table 16).

Table 16. Critical breeding period for AMKEs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	May			June			July			August		
High Arctic (NP)												
Mid-Arctic (NP)												
Low Arctic North (ESTIMATED)				E	E	E	E	N	N	N	N	
Low Arctic South (NP)												
High Subarctic (ESTIMATED)				E	E	E	E	N	N	N	N	
Low Subarctic (ESTIMATED)				E	E	E	E	N	N	N	N	
High Boreal (ESTIMATED)				E	E	E	E	N	N	N	N	
Mid-Boreal (ESTIMATED)				E	E	E	E	N	N	N	N	

Merlin (MERL)

MERLs occur in six of NWT's eight level III ecoregions and generally decline in density with increasing latitude (Table 2, Figure 2). There are 23 MERL observations in the NWT/NU Raptor Database of which 20 occur in the NWT. Only one allows determination of hatch date.

We know of no published literature describing the breeding phenology of MERLs in the NWT. In Saskatoon, MERLs lay eggs between late April and late June (Sodhi et al. 1992) while the egg-laying is usually completed by the third week of May in Montana (Becker and Sieg (1985) and near Mount Denali, Alaska (Laing 1985). These data allow only a very rough estimation of breeding phenology in the NWT (Table 17).

Table 17. Critical breeding period for MERLs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	April			May			June			July			August		
High Arctic (NP)															
Mid-Arctic (NP)															
Low Arctic North (ESTIMATED)					E	E	E	E	N	N	N	N	N		
Low Arctic South (ESTIMATED)					E	E	E	E	N	N	N	N	N		
High Subarctic (ESTIMATED)				E	E	E	E	N	N	N	N	N			
Low Subarctic (ESTIMATED)				E	E	E	E	N	N	N	N	N			
High Boreal (ESTIMATED)		E	E	E	E	N	N	N	N						
Mid-Boreal (ESTIMATED)	E	E	E	E	N	N	N	N							

Gyrfalcon (GYRF)

GYRFs are present in all eight of the NWT's level III ecoregions with a peak density in the Low Arctic North. There are 1,441 GYRF observations in the NWT/NU Raptor Database. Of the 312 records that allow determination of breeding dates, 248 occur in NU and 64 in NWT (Table 18). We have calculated egg-laying date as 35 days before hatch (Cade and Weaver 1976 in Poole and Bromley 1988) and fledging as 47 days after hatch (Poole and Bromley 1988) (Table 19). In Table 18, the very late breeding dates for the Low Arctic South ecoregion are based on only three observations and are probably unreliable.

Table 18. Earliest, Q1, median, Q3, and latest dates for egg-laying, hatch and fledging by GYRFs in NWT ecoregions. Data from the NWT/NU Raptor Database.

Ecoregion	Laying Date					Hatch Date					Fledging Date					N
	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	Earliest	Q1	Median	Q3	Latest	
High Arctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mid-Arctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Low Arctic North	09-Apr	01-May	06-May	11-May	16-Jun	14-May	05-Jun	10-Jun	15-Jun	21-Jul	30-Jun	22-Jul	27-Jul	01-Aug	06-Sep	48
Low Arctic South	23-May	23-May	26-May	28-May	02-Jun	27-Jun	27-Jun	30-Jun	02-Jul	07-Jul	13-Aug	13-Aug	16-Aug	18-Aug	23-Aug	3
High Subarctic	06-Apr	18-Apr	22-Apr	24-Apr	15-May	11-May	23-May	27-May	29-May	19-Jun	27-Jun	09-Jul	13-Jul	15-Jul	05-Aug	13
Low Subarctic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
High Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mid-Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Table 19. Critical breeding period for GYRFs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	March			April			May			June			July			August	
High Arctic							E	E	E	E	E	N	N	N	N	N	
Mid-Arctic							E	E	E	E	E	N	N	N	N	N	
Low Arctic North							E	E	E	E	E	N	N	N	N	N	
Low Arctic South							E	E	E	E	E	N	N	N	N	N	
High Subarctic							E	E	E	E	E	N	N	N	N	N	
Low Subarctic							E	E	E	E	E	N	N	N	N	N	
High Boreal							E	E	E	E	E	N	N	N	N	N	
Mid-Boreal							E	E	E	E	E	N	N	N	N	N	

Peregrine Falcon (PEFA)

PEFAs are present in significant densities in all NWT level III ecoregions (Figure 2, Table 2). There are 7,223 PEFA records in the NWT/NU Database of which 2,875 occur in the NWT. A total of 218 of these records contain adequate information to determine hatch date (Table 20).

Date of egg-laying was calculated by subtracting an incubation period of 34 days from hatch date (Burnham 1983, review in BoNA). Adding a mean nestling period of 38 days (Steenhof and Kochert 1982) to hatch date provided an estimate of fledging date (Table 21).

Table 20. Earliest, Q1, median, Q3, and latest dates for egg-laying, hatch and fledging by PEFAs in NWT ecoregions. Data from the NWT/NU Raptor Database.

Ecoregion	Laying Date								Hatch Date								Fledging Date								N	
	Mean	67% confidence early	67% confidence late	95% confidence early	95% confidence late	Mean	67% confidence early	67% confidence late	95% confidence early	95% confidence late	Mean	67% confidence early	67% confidence late	95% confidence early	95% confidence late	Mean	67% confidence early	67% confidence late	95% confidence early	95% confidence late	Mean	67% confidence early	67% confidence late	95% confidence early	95% confidence late	
High Arctic	-	-	-	-	-	18-Jul	13-Jul	24-Jul	06-Jul	30-Jul	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	
Mid-Arctic	14-Jun	07-Jun	20-Jun	02-Jun	26-Jun	07-Jul	30-Jun	15-Jul	22-Jun	25-Jul	14-Aug	07-Aug	22-Aug	30-Jul	01-Sep	18-Aug	31-Aug	13-Aug	06-Sep	7						
Low Arctic North	03-Jun	27-May	11-Jun	19-May	21-Jun	07-Jul	01-Jul	10-Jul	27-Jun	14-Jul	12-Aug	08-Aug	17-Aug	04-Aug	21-Aug	22-Aug	20-Aug	30-Jul	01-Sep	107						
Low Arctic South	01-Jun	28-May	06-Jun	24-May	10-Jun	05-Jul	25-Jun	15-Jul	15-Jun	25-Jul	12-Aug	02-Aug	22-Aug	23-Jul	01-Sep	08-Aug	02-Aug	14-Aug	27-Jul	20-Aug	34					
High Subarctic	01-Jun	22-May	11-Jun	12-May	21-Jun	05-Jul	25-Jun	07-Jul	19-Jun	13-Jul	08-Aug	02-Aug	14-Aug	27-Jul	20-Aug	-	-	-	-	-	-	-	-	-	41	
Low Subarctic	28-May	22-May	03-Jun	16-May	09-Jun	01-Jul	25-Jun	07-Jul	19-Jun	13-Jul	08-Aug	02-Aug	14-Aug	27-Jul	20-Aug	-	-	-	-	-	-	-	-	-	15	
High Boreal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	
Mid-Boreal	15-May	08-May	22-May	01-May	29-May	18-Jun	11-Jun	25-Jun	04-Jun	02-Jul	26-Jul	19-Jul	02-Aug	12-Jul	09-Aug	18-Aug	31-Aug	13-Aug	06-Sep	15						

Table 21. Critical breeding period for PEFAs in NWT level III ecoregions. The egg incubation period is designated with E's while the nestling period is indicated by N's.

Ecoregion	April	May			June			July			August			September		
High Arctic (ESTIMATED)						E	E	E	E	E	N	N	N	N	N	
Mid-Arctic						E	E	E	E	E	N	N	N	N	N	
Low Arctic North					E	E	E	E	E	N	N	N	N	N		
Low Arctic South				E	E	E	E	E	N	N	N	N	N	N		
High Subarctic			E	E	E	E	E	E	N	N	N	N	N	N		
Low Subarctic			E	E	E	E	E	N	N	N	N	N	N	N		
High Boreal (ESTIMATED)		E	E	E	E	E	E	N	N	N	N	N	N	N		
Mid-Boreal		E	E	E	E	E	N	N	N	N	N	N	N	N		

SUMMARY

Table 22 summarizes estimates of the critical breeding period of each of the NWT's raptor species in each of the eight level III ecoregions. The critical period is defined as beginning two weeks prior to the calculated or estimated median egg-laying date and one week after the calculated or estimated median fledging date. Instances of breeding outside these defined critical periods are to be expected, but should not be common.

The database used to create critical breeding period charts include nesting observations encompassing five decades (1970s to 2010s). All ecoregions in the NWT are warming rapidly (ENR 2011). It may be expected that timing of some critical breeding events may change in the future for raptor species in the NWT. These changes may occur at different rates in different ecoregions (Carrière and Matthews 2013). We recommend that the critical breeding period charts provided in this report be re-estimated for each species and ecoregion in ten or 20 years using database records from the latest four decades to confirm critical dates or to adjust them if appropriate. Researchers should put particular emphasis on recording estimated age of nestlings to allow more accurate estimation of the breeding phenology.

Table 22. Summary of the critical breeding period for NWT raptors in each level III ecoregion. "NP" indicates that the species is not present in the ecoregion.

	High Arctic	Mid-Arctic	Low Arctic North	Low Arctic South	High Subarctic	Low Subarctic	High Boreal	Mid-Boreal
Osprey					3rd wk May - 2nd wk September	3rd wk May - 2nd wk September	2nd wk May - 1st wk September	1st wk May - 4th wk August
	NP	NP	NP	NP				
Bald Eagle			1st wk May – 4th wk September	4th wk April - 3rd wk September	4th wk April - 3rd wk September	3rd wk April - 2nd wk September	2nd wk April - 1st wk September	2nd wk April - 1st wk September
	NP	NP						
Northern Harrier			4th wk May – 4th wk August	4th wk May – 4th wk August	3rd wk May - 3rd wk August	3rd wk May - 3rd wk August	2nd wk May - 2nd wk August	2nd wk May - 2nd wk August
	NP	NP						
Sharp-shinned Hawk			1st wk June - 3rd wk August	NP	1st wk June - 3rd wk August	4th wk May - 2nd wk August	4th wk May - 2nd wk August	4th wk May - 2nd wk August
	NP	NP						
Northern Goshawk			1st wk May – 2nd wk August	1st wk May – 2nd wk August	4th wk April - 1st wk August	4th wk April - 1st wk August	3rd wk April - 4th wk July	3rd wk April - 4th wk July
	NP	NP						
Broad-winged Hawk							4th wk of May - 4th wk of August	3rd wk of May - 3rd wk of August
	NP	NP	NP	NP	NP	NP		
Swainson's Hawk					3rd wk May - 4th wk August	3rd wk May - 4th wk August	NP	2nd wk May - 3rd wk August
	NP	NP	NP	NP				
Red-tailed Hawk					1st wk May - 2nd wk August	4th wk April - 1st wk August	3rd wk April - 4th wk July	3rd wk April - 4th wk July
	NP	NP	NP	NP				
Rough-legged Hawk	1st wk September	1st wk September	1st wk June - 1st wk September	3rd wk May – 3rd wk August	3rd wk May - 3rd wk August	2nd wk May - 2nd wk August	1st wk May – 1st wk August	1st wk May – 1st wk August
Golden Eagle			4th wk April - 1st wk September	3rd wk April - 4th wk August	2nd wk April - 3rd wk August	2nd wk April - 3rd wk August	1st wk April - 2nd wk August	4th wk March - 1st wk August
	NP							
American Kestrel				4th wk May – 3rd wk August	3rd wk May - 2nd wk August	3rd wk May - 2nd wk August	2nd wk May - 1st wk August	2nd wk May - 1st wk August
	NP	NP	3rd wk August	NP				
Merlin				2nd wk May – 1st wk August	2nd wk May – 1st wk August	1st wk May - 4th wk July	4th wk April - 3rd wk July	4th wk April - 3rd wk July
	NP	NP						
Gyrfalcon	4th wk April - 2nd wk August	4th wk April - 2nd wk August	3rd wk April – 1st wk August	2nd wk April - 4th wk July	2nd wk April - 4th wk July	1st wk April - 3rd wk July	4th wk March - 2nd wk July	4th wk March - 2nd wk July
Peregrine Falcon	4th wk May- 1st wk September	4th wk May- 1st wk September	3rd wk May – 3rd wk August	2nd wk May - 3rd wk August	3rd wk May - 3rd wk August	3rd wk May - 3rd wk August	1st wk May - 2nd wk August	4th wk April - 1st wk August

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LITERATURE CITED

American Ornithology Union. nd. List of the 2,008 birds species (with scientific and English names) known from the A.O.U checklist area. (Accessed January 2016) <http://americanornithology.org/sites/default/files/files/imce-img/AOUchecklistTin-Falcon.pdf>.

Avibase—Bird Checklists of the World. nd. (Accessed January 2016) <http://avibase.bsc-eoc.org/checklist.jsp?region=cant&list=howardmoore>.

Becker, D.M. and C.H. Sieg. 1985. Breeding chronology and reproductive success of Richardson's Merlin in southeastern Montana. *Raptor Research* 19:52-55.

Bird, D.M. and R.S. Palmer. 1988. American Kestrel. Pages 253-290 in *Handbook of North American birds*. Vol. 5: diurnal raptors. Part 2. (Palmer, R. S., Ed.) Yale Univ. Press, New Haven, CT.

Birds of North America Online (BoNA). (P. Rodewald, Ed.). Ithaca: Cornell Laboratory of Ornithology; Retrieved from The Birds of North America Online database: <http://bna.birds.cornell.edu/BNA/>. (Accessed January 2016)

Boal, C.W. 1994. A photographic and behavioral guide to aging nestling Northern Goshawks. Pp. 32-40 in W.M. Block, M.L. Morrison, and M.H. Reiser (editors). *The northern goshawk: ecology and management: proceedings of a symposium of the Cooper Ornithological Society, Sacramento, California, 14-15 April 1993. Studies in Avian Biology No. 16*. Cooper Ornithological Society, Camarillo, CA.

Bortolotti, G.R. 1986. Influence of sibling competition on nestling sex ratios of sexually dimorphic birds. *The American Naturalist* 127:495-507.

Burnham, W. 1983. Artificial incubation of falcon eggs. *Journal of Wildlife Management* 47: 158-168.

Carrière, S, and Matthews, S. 2013. Peregrine falcon surveys along the Mackenzie River, Northwest Territories, Canada. Environment and Natural Resources, Government of the Northwest Territories. File Report 140. 55pp.

Cade, T.J. and J.D. Weaver. 1976. Gyrfalcon X peregrine hybrids produced by artificial insemination. *Journal of the North American Falconers' Association* 15:42-47.

Chowns, T. 2012. Bird ecoregion-based distribution in the Northwest Territories (Draft version). Produced for the Department of Environment and Natural Resources, Government of the Northwest Territories.

Chytyk, P. and K. Dhanwant. 1999. 1998 Northern Goshawk (*Accipiter gentilis laingi*) population inventory of the Queen Charlotte Islands/Haida Gwaii – final report. B.C. Min. Environment, Lands and Parks, Wildlife Branch, Smithers, BC. 41pp.; *in* COSEWIC 2013.

COSEWIC. 2013. COSEWIC assessment and status report on the Northern Goshawk *Accipiter gentilis laingi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 56pp. (Accessed January 2016.)
www.registrelep.gc.ca/default.asp?lang=En&n=99FC419D-1#_doc.

Cramp, S. and K.E.L. Simmons. 1980. Osprey. Pages 265-277 *in* The birds of the Western Palearctic. Vol. 2: hawks to bustards. Oxford University Press, Oxford, UK. *in* Birds of North America Online.

Ecosystem Classification Group. 2007 (rev. 2009). Ecological Regions of the Northwest Territories – Taiga Plains. Environment and Natural Resources, Government of the Northwest Territories. 137pp.

Ecosystem Classification Group. 2008. Ecological Regions of the Northwest Territories – Taiga Shield. Environment and Natural Resources, Government of the Northwest Territories. 146pp.

Ecosystem Classification Group. 2010. Ecological Regions of the Northwest Territories – Cordillera. Environment and Natural Resources, Government of the Northwest Territories. 245pp.

Ecosystem Classification Group. 2012. Ecological Regions of the Northwest Territories – Southern Arctic. Environment and Natural Resources, Government of the Northwest Territories. 170pp.

Ecosystem Classification Group. 2013. Ecological Regions of the Northwest Territories – Northern Arctic. Environment and Natural Resources, Government of the Northwest Territories. 157pp.

Environment and Natural Resources (ENR). 2011. NWT State of the Environment – Highlights 2011. Environment and Natural Resources, Government of the Northwest Territories. 56pp. Accessed 24 May 2016.

Laing, K. 1985. Food habits and breeding biology of Merlins in Denali National Park, Alaska. Raptor Research 19: 42-51.

Luttich, S.N., D.H. Rusch, E.C. Meslow, and L.B. Keith. 1970. Ecology of red-tailed hawk predation in Alberta. Ecology 51: 190-203.

Moritsch, M.Q. 1983. Photographic guide for aging nestling prairie falcons. US Department of Interior, Bureau of Land Management, Boise, Idaho. 15pp.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD. 399pp.

Poole, A.F. 1984. Reproductive limitations in coastal ospreys: an ecological and evolutionary perspective. Unpublished Ph.D. dissertation Boston University. Boston, MA. *in Birds of North America Online*.

Poole, K.G. 1985. Artificial nesting platforms for ospreys near Yellowknife, Northwest Territories. NWT Wildlife Service, Government of the Northwest Territories. File Report No. 50. 34pp.

Poole, K.G. 1989. Determining age and sex of nestling gyrfalcons. Raptor Research 23:45-47.

Poole, K.G. and R.G. Bromley. 1988. Interrelationships within a raptor guild in the central Canadian Arctic. Canadian Journal of Zoology 66:2,275-2,282.

Rusch, D.H. and P.D. Doerr. 1972. Broad-winged hawk nesting and food habits. Auk 89:139-145.

Shank, C.C. 1990. Nesting platforms for ospreys on the Snare Transmission Line: update for 1985-1987. NWT Wildlife Service, Government of the Northwest Territories. Manuscript Report No. 28. 16pp.

Schmutz, J.K. and S.M. Schmutz. 1975. Primary molt in *Circus cyaneus* in relation to nest brood events. Auk 92:105-110.

Simmons, R., B. MacWhirter, P. Barnard, and G.L. Hansen. 1986. The influence of microtines on polygyny, productivity, age, and provisioning of breeding northern harriers: a 5-year study. Canadian Journal of Zoology 64:2,447-2,456.

Sodhi, N.S., P.C. James, I.G. Warkentin, and L.W. Oliphant. 1992. Breeding ecology of urban merlins (*Falco columbarius*). Canadian Journal of Zoology 70:1,477-1,483.

Steenhof, K and M.N. Kochert. 1982. An evaluation of methods used to estimate raptor nesting success. Journal of Wildlife Management 46:885-893.

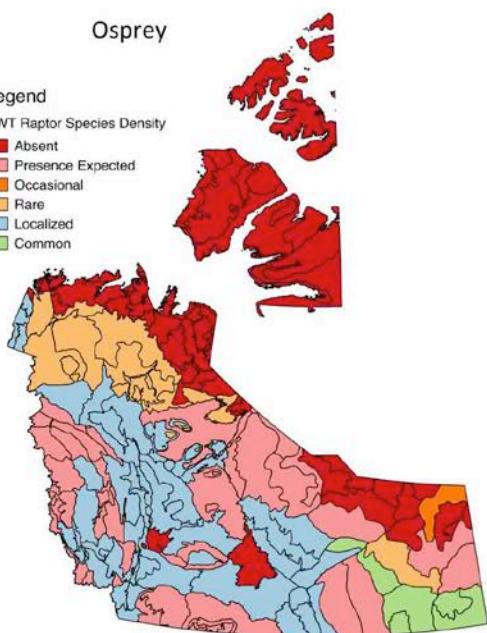
Wiken, E., F.J. Nava, and G. Griffith. 2011. North American terrestrial ecoregions—level III. Commission for Economic Cooperation, Montreal, Canada. (Accessed January 2016.) ww3.cec.org/islandora/en/item/10415-north-american-terrestrial-ecoregions-level-iii-en.pdf.

APPENDIX 1. DENSITY MAPS FOR NWT RAPTORS

Osprey

Legend

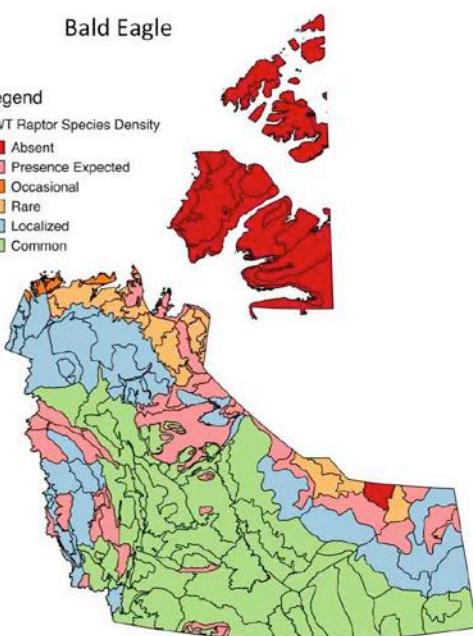
NWT Raptor Species Density
Absent
Presence Expected
Occasional
Rare
Localized
Common



Bald Eagle

Legend

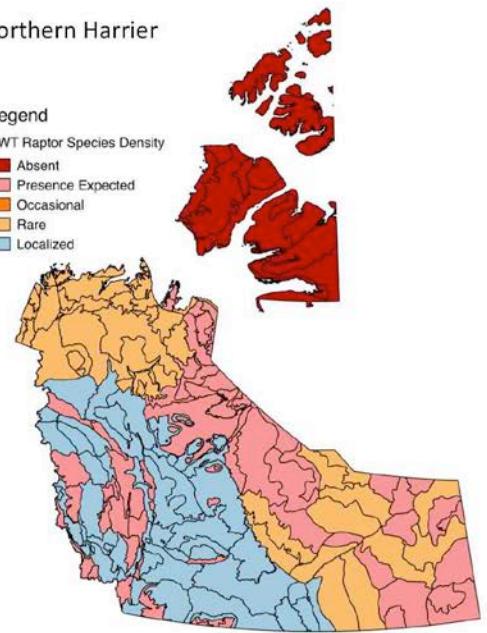
NWT Raptor Species Density
Absent
Presence Expected
Occasional
Rare
Localized
Common



Northern Harrier

Legend

NWT Raptor Species Density
Absent
Presence Expected
Occasional
Rare
Localized



Sharp-shinned Hawk

Legend

NWT Raptor Species Density
Absent
Presence Expected
Occasional
Rare
Localized
Common

