# Inventory Methods for Waterfowl and Allied Species: *Loons, Grebes, Swans, Geese, Ducks, American Coot and Sandhill Crane*

Standards for Components of
British Columbia's Biodiversity No. 18

Prepared by
Ministry of Environment, Lands and Parks
Resources Inventory Branch
for the Terrestrial Ecosystem Task Force
Resources Inventory Committee

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# Preface

This manual presents standard methods for inventory of waterfowl in British Columbia at three levels of inventory intensity: presence/not detected, relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for groups of species with similar inventory requirements. The series includes an introductory manual (*Species Inventory Fundamentals No. 1*) which describes the history and objectives of RIC, and outlines the general process of conducting a species inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The *Species Inventory Fundamentals* manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in field inventories which involve any of these activities.

Standard data forms are required for all RIC species inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in *Species Inventory Fundamentals No. 1 [Forms]*. This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at: http://www.env.gov.bc.ca/wld/spi/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric

## Terrestrial Ecosystem Task Force

All decisions regarding protocols and standards are the responsibility of the Resources Inventory Committee. The background information and protocols presented in this document are based on the unpublished draft manual, *Preliminary Inventory Manual for Waterfowl and Allied Species in British Columbia*, by Barbara A. Beasley, with information and comments provided by I. Goudie, A. Breault, R. McKelvey, D. Smith, S. Boyd, K. Fry, E. Hennan, L. Thomas, S. Wilson, M. Gebauer, M. Higgs. This draft was then revised by Ken R. Summers with some editing done by Dr. John Smith. Initial drafts of the data forms were made by Brandy Small.

This manual and its associated dataforms were edited to their final versions by Leah Westereng and James Quayle.

# Table of Contents

# List of Figures

# List of Tables

# 1. INTRODUCTION

Waterfowl and allied species - ducks, geese, swans, loons, coots, grebes, and cranes, comprise an important and diverse component of British Columbia's avifauna. Along with the desire to take stock of the province's wildlife resources, there are many reasons to inventory this group of birds:

1. Waterfowl and allied species depend on wetland habitat that is vital for sustaining a healthy environment. Wetlands collect and store runoff and groundwater discharge that is necessary to moderate the effects of drought and flooding, sustain natural vegetation and crops, prevent erosion, and purify water. The soil forming process in river deltas sustains much of our agriculture, and the productive littoral zone supports most of our aquatic food base. There are major threats to the integrity of wetland and coastal habitats in BC due to urban, industrial and agricultural expansion, hydro-electric development, mine development, logging, increased disposal of mineral and chemical wastes and offshore oil and gas exploration. Decisions that alter the environment should only be made after consideration of impacts on the creatures which depend on that environment. By monitoring waterfowl populations we can assess the impact of threats to our wetlands and coastal habitats and then take steps to preserve a healthy environment.

2. Most species in this inventory group are hunted. It is important to monitor their population status so that appropriate harvest limits and regulations can be set.

3. Bird watching is one of the fastest growing outdoor recreational activities in BC, and waterfowl and allied species are among the most attractive and accessible birds for viewing. Monitoring populations and their distributions provides information that can be used to guide people to viewing opportunities.

4. Agricultural and marine aquacultural crops may be severely damaged by foraging waterfowl and allied species. Monitoring the distribution and habitat preferences of birds can provide information that will help alleviate this conflict.

A number of agencies and individuals are involved in collecting data on the distribution and abundance of waterfowl and allied species in BC. The Canadian Wildlife Service (CWS) oversees the conservation of migratory birds, and because most of the habitat on which migratory birds depend is under provincial jurisdiction, the British Columbia Ministry of Environment (MOE) shares this responsibility. Ducks Unlimited Canada is active in improving aquatic habitats for waterfowl, and therefore participates in federal/provincial monitoring programs, as well as their own. University researchers often contribute through their field studies, and many amateur ornithologists (more than 8,000 people in BC) collect valuable data by keeping field notes of their observations, and by participating in volunteer monitoring programs (e.g., Christmas Bird Counts).

With so many different contributors of inventory information, it is important to devise standardized data collection techniques so that information from a variety of sources will be valid (repeatable), comparable and therefore, useful to managers. It is essential that inventory procedures remain consistent over time so that long term trends can be examined. The purpose of this manual is to provide recommendations for applying standardized methods for the inventory of waterfowl and allied species in British Columbia.

# 2. INVENTORY GROUP

The diverse habitats of British Columbia support populations of many species of waterfowl and their allies during some part or all of their life cycles (i.e., breeding, moulting, migrating, and wintering). Abundant wetlands, including small lakes, ponds, sloughs, marshes, bogs, wet meadows, flooded fields, slow-moving streams, ditches, and sewage lagoons scattered along the coast and throughout the interior provide extensive breeding habitat. The long coastline with its many small estuaries, islands, and bays is important for spring and fall migrants. The moderate climate of the south coast and, to a lesser extent, the southern interior supports the highest numbers of wintering species in Canada.

Table 1 summarizes the distribution, habitat preferences, and the general timing of the breeding season and migration movements for each species. These summaries are based primarily on information collected to the end of December 1987 by Campbell *et al.* (1990). Seasonal distribution patterns for each species are clearly presented on map sheets of the National Topographic Grid System in Campbell *et al.* (1990).

Four of the species in this inventory category appear on BC’s Blue List. Trumpeter Swans, Oldsquaw, Surf Scoters, and Sandhill Cranes are considered to be vulnerable or sensitive. The breeding populations of these species are very small within BC. This may mean that suitable breeding habitat is limited but, to date, the nesting populations of these species have not been well studied in BC.

Other species are of special concern because a substantial proportion of the North American, and, sometimes, world's population is found in the province. BC supports 60 to 90% of the world's population of breeding Barrow's Goldeneye (Campbell *et al.* 1990). Over half the North American population of Sandhill Cranes pass through northeastern BC moving to and from their Alaskan breeding grounds. BC is a major migration corridor for large proportions of the North American populations of Trumpeter Swans, Barrow's Goldeneyes, Brant, and Surf Scoters. Approximately 35% of the world's population of Trumpeter Swans winter in southwestern BC (USFWS. and CWS 1990).

Species that are most heavily harvested in BC should be closely monitored. Mallards compose the highest percentage of harvested species in the inventory group. Migrant and wintering Brant and Snow Geese concentrate in a relatively small area of the Fraser River delta where they are subjected to potentially intense hunting pressures. There has been a southward shift in the winter distribution of Brant over the last 15-30 years, thus, there is concern about hunting pressure on BC's wintering birds.

Management policies for North American duck species are based mainly on the population dynamics of Mallards because they are abundant and most easily inventoried (Nichols 1991). Patterson (1979) and Bailey (1981) emphasized the differences among the life history patterns of North American duck species and noted the relevance of these differences to management. For example, Mallards and Blue-winged Teal exhibit relatively low annual survival rates and lack density dependent mechanisms of population regulation (characteristic of r-strategists), whereas Canvasbacks and other diving ducks have higher annual survival rates and exhibit density dependence (characteristic of K-strategists). Sea ducks exhibit extreme K-selection (Eadie *et al.* 1988). It is important that concentrated efforts be made to collect more extensive data on at least some representative species of the K-strategists (Goudie *et al.* 1994).

**Table 1. Status, distribution, habitat requirements and timing of life history events for each species during breeding, migration and wintering periods in BC according to Campbell *et al.* (1990).**

The common and Latin names follow the most recent Check-list of North American Birds (AOU 1983 and seven supplements between 1985 and 1997 as summarized in Campbell 1998). The standardized 5-letter codes for each species name are used throughout BC in field recording and data base systems. Ecoregions according to Demarchi (1995, 1996). Dates for eggs and young correspond to the time when > 50% of the records occurred. Timing of peak migration movements are given for the south coast. Movements through the northern interior tend to be later in spring and earlier in the fall.

Abbreviations for ecoregions: CM = Coast and Mountains; GD = Georgia Depression; SI = Southern Interior; SIM = Southern Interior Mountains; CI = Central Interior; SBI = Sub-boreal Interior; NBM = Northern Boreal Mountains; TP = Taiga Plains; BP = Boreal Plains.

| **Species**<br>**(Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Red-throated Loon<br>*Gavia stellata*<br>B-RTLO<br>(Yellow List) | Along coast from S. Vancouver Isle to Kitsault, Queen Charlotte Isles and Chilkat Pass area. (CM, GD)<br>Nests in small freshwater lakes surrounded by forests or alpine tundra; forages nearby on ocean or large lakes. Nests near water's edge.<br>Eggs: 30 May - 15 June<br>Young: 5-27 July | Flocks of <50 on the south coast, mainly in the Strait of Georgia and Juan de Fuca Strait in shallow, protected inshore waters, e.g., bays, inlets, lagoons and estuaries. Casual throughout the interior scattered on larger lakes and slow moving rivers.<br>Spring movement: late Apr. - early May<br>Fall movement: Sept. - Oct. |
| Pacific Loon<br>*Gavia pacifica*<br>B-PALO<br>(Yellow List) | Teslin Plateau and Liard Basin (NBM, CM) on freshwater lakes and ponds usually surrounded by forests. Nests near water's edge.<br>Eggs: late May - early July<br>Young: late June - early Aug. | Flocks of 100-1000 distributed along coast, especially in the Strait of Georgia (GD, CM) in nutrient-rich areas, e.g., where Pacific herring spawn.<br>Very rare in the interior (SI, SIM, NBM, BP). Prefers deeper waters but frequents bays, estuaries, surge channels and coves.<br>Spring movement: late April-early June<br>Fall movement: Sept. - Oct. |
| Common Loon<br>*Gavia immer*<br>B-COLO<br>(Yellow List) | Widespread throughout BC, most abundant in the Thompson-Okanagan and Fraser plateaus and the Fraser Basin (CM, GD, SI, CI, SIM, SBI, BP, NBM, TP). Nests near water's edge on freshwater lakes in forested and open regions.<br>Eggs: 27 May - 16 June<br>Young: 22 June - 17 July | Flocks of <20 along coast, most abundant at northern end of Strait of Georgia, off Fraser River delta and east end of Juan de Fuca Strait Larger lakes in the interior and protected bays, inlets and harbours on the coast. (CM, GD, SI, CI, SIM)<br>Spring movement: late Apr. - early May<br>Fall movement: early - mid Oct. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Yellow-billed Loon<br>B-YBLO<br>*Gavia adamsii*<br>(Yellow List) | Not known to regularly breed in BC. | Small groups of <7.<br>Along coast mainly in sheltered waters and scattered throughout the interior (CM, GD, SI).<br>Spring movement: late Mar. - May<br>Fall movement: late Sept. - early Dec. |
| Pied-billed Grebe<br>*Podilymbus podiceps*<br>B-PBGR<br>(Yellow List) | Southern coast, southern interior to Quesnel, the Peace Lowlands and rarely in the Fort Nelson Lowlands (GD, CI, SI, SIM, BP, TP). Nests in wetlands with emergent vegetation of reeds, rushes, sedges and grasses<br>Nests built on water attached to emergent vegetation<br>Eggs: 16 May - 10 June<br>Young: 18 June - 20 July | Flocks of <20 in calm marine and freshwater areas near Ladner, Victoria and Vancouver and on larger lakes in the south central interior north to the Chilcotin-Cariboo (CM, SI, CI, SIM, GD).<br>Spring movement: late Mar. - .Apr.<br>Fall movement: late Aug. - Sept. |
| Horned Grebe<br>*Podiceps auritus*<br>B-HOGR<br>(Yellow List) | Widespread east of the Coast Ranges, most abundant in the Chilcotin-Cariboo Basin and Thompson-Okanagan Plateau regions (CI, SI, SIM, BP, NBP, TP). Freshwater lakes and marshes with emergent vegetation. Nests anchored among emergent vegetation in shallow water.<br>Eggs: 12 June -4 July<br>Young: 8 - 28 July | Along coast, especially, Clayoquot Sound, Strait of Georgia, Fraser River estuary, Haro Strait, and in southern interior, especially Okanagan Lake, Kootenay Lake, Lower Arrow Lake and Columbia River. (CM, GD, CI, SI, SIM)<br>Inshore waters along the coast and sheltered areas of larger lakes in the interior.<br>Spring movement: Apr. - May<br>Fall movement: late Sept. |
| Greater White-fronted Goose<br>*Anser albifrons*<br>B-GWFG<br>(Yellow List) | Not known to regularly breed in BC. | Mostly bypasses BC except under poor weather conditions.<br>Mainly coastal and a few records in central southern interior (CM, GD, CI, SI, SIM). Shallow waters of sloughs, marshes, ponds and lagoons, flooded and dry fields, lakes, mud flats and golf courses.<br>Spring movement: mid-Apr. - early May<br>Fall movement: mid-Sept. - mid Oct. |
| Emperor Goose<br>*Chen canagica*<br>B-EMGO<br>(Yellow List) | Not known to regularly breed in BC. | Very rare along the coast (CM, GD).<br>Rocky shores, breakwaters, jetties and spits. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Snow Goose<br>*Chen caerulescens*<br>B-SNGO<br>(Yellow List) | Not known to regularly breed in BC. | Large concentration in inner coastal area of southeastern Strait of Georgia and Puget Sound in marshes off the Fraser River delta (GD, CM). Widespread but scattered (flocks of <10) throughout the central and southern interior (CI, SI, SIM).<br>Estuarine marshes with bulrush rhizomes and agricultural fields.<br>Spring movement: late Mar. - Apr.<br>Fall movement: mid-Sept. - Nov. |
| Ross's Goose<br>*Chen rossii*<br>B-ROGO<br>(Yellow List) | Not known to regularly breed in BC. | Very rare on the inside of the south coast and in the central interior (GD, CI, SI, SIM). |
| Canada Goose<br>*Branta canadensis*<br>B-CAGO<br>(Yellow List) | Widespread throughout BC near any source of permanent water (CM, GD, CI, SI, SIM, SBI, BP, NBM, TP). Inland and coastal wetlands, islands in lakes, tundra, muskeg, agricultural fields, ditches, dykes and sewage lagoons.<br>Nests on ground, in Osprey or Bald Eagle nests, beaver lodges, artificial platforms usually close to water.<br>Eggs: 18 Apr. - 2 May<br>Young: 14 May - 15 June | Throughout southern areas - along coast especially the Fraser Lowlands and southeastern Vancouver Island; in the interior, the Okanagan and Thompson basins and Revelstoke area (CM, GD, CI, SI, SIM, SBI, BP).<br>Anywhere that water and grazing areas are available.<br>Spring movement: late Mar. - mid-May<br>Fall movement : late Oct. - Nov. |
| Brant<br>*Branta bernicla*<br>B-BRAN<br>(Yellow List) | Not known to regularly breed in BC. | Concentrated at Boundary Bay and the east coast of Vancouver Island from Victoria to Campbell River (GD, CM).<br>Estuaries, beaches, bays, lagoons and mudflats near beds of eelgrass.<br>Fall migration occasionally witnessed at sea off Vancouver Island.<br>Spring movement: late Mar. - early Apr. |
| Mute Swan<br>*Cygnus olor*<br>B-MUSW<br>Introduced<br>(Yellow List) | Feral breeding population on southern Vancouver Island from Duncan to Sooke (GD).<br>Lakes and brackish lagoons. Nests on shore, in shallow water, at edge of emergent growth or on artificial platforms.<br>Eggs: 15 May- 7 June<br>Young: 10 June - 20 July | Coastal areas of southeastern and southern Vancouver Island and Gulf Islands in the Strait of Georgia (GD, SI).<br>Lagoons, lakes, estuaries<br>Sedentary. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Trumpeter Swan<br>*Cygnus buccinator*<br>B-TRUS<br>(Blue List) | Small number in the Peace Lowlands and northeastern BC (CM, CI, BP, TP, NBM). Large and small freshwater lakes surrounded by forest.<br>On the edge or among emergent vegetation including bulrushes, sedges, cattail and horsetails.<br>Eggs: 8-21 June<br>Young: 23 June - mid Sept. | From south coast concentrated on Vancouver Island and in the Fraser Lowlands north through Francois Lake region (CM, GD, SI, CI, SIM).<br>Estuaries, agricultural fields, sloughs, lakes, bays along coast. Lakes, marshes, sloughs, ponds, slow moving rivers in the interior.<br>Spring movement: late Feb. - early Apr.<br>Fall movement: late Nov. |
| Tundra Swan<br>*Cygnus columbianus*<br>B-TUSW<br>(Yellow List) | Not known to regularly breed in BC. | Groups of <100 most abundant in Fraser River Delta and Nicomen Slough on coast and in Thompson and Okanagan Valleys in the interior (GD, CM, CI, SI, SIM, BP, SBI). Flooded fields, lakes, and brackish bays, estuaries and inlets on the coast. Open water in lakes and rivers in the interior.<br>Spring movement: mid-Apr.<br>Fall movement: mid-late Oct. |
| Wood Duck<br>*Aix sponsa*<br>B-WODU<br>(Yellow List) | Southern Vancouver Island, Fraser Lowlands, the southern interior, especially Creston, north to Williams Lake (GD, CI, SI, SIM). Mature deciduous woodlands adjacent to lowland ponds, sloughs, slow-moving rivers. Nests in cavities of mature deciduous trees.<br>Eggs: 7 May - 1 June<br>Young: 5 June - 5 July | Resident in Fraser Lowlands and southern Vancouver Island Wintering birds on the south coast and in the Okanagan Basin (GD, CI, SI, SIM, CM).<br>Waterways associated with dense stands of mature forest, emergent vegetation and overhanging brush.<br>Rarely marine.<br>Spring movement: mid-Mar.<br>Fall movement: mid-Sept. |
| Gadwall<br>*Anas strepera*<br>B-GADW<br>(Yellow List) | Central-southern BC from Creston and Grand Forks north to Williams Lake, the Fraser Lowlands and Peace Lowlands (GD, CI, SI, SIM, BP, TP).<br>Wetlands in the grasslands and open forested areas. Coastal brackish marshes, farmlands, sewage lagoons and lakes.<br>Nests on the ground.<br>Eggs: 28 May - 15 June<br>Young: 1 - 24 July | Primarily southeastern Vancouver Island, the Fraser Lowlands and the Okanagan Basin; small numbers along the coast (CM, GD, SI, SIM, CI).<br>Coastal and interior wetlands, flooded fields, lakes, and large slow-moving rivers. Uses deeper and more open waters than other dabblers.<br>Spring movement: late Apr. - May<br>Fall movement: Sept. - Oct. |
| Eurasian Wigeon<br>*Anas penelope*<br>B-EUWI<br>(Yellow List) | Not known to regularly breed in BC. | Mainly along inside southeastern Vancouver Island and the Fraser Lowlands in fall and winter. Spring migrants disperse mainly through the interior (CM, GD, SI, SIM). Wetlands and flooded fields, golf courses.<br>Spring movement: mid Apr. - early May<br>Fall movement: Oct. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| American Wigeon<br>*Anas americana*<br>B-AMWI<br>(Yellow List) | Most abundant in Chilcotin-Cariboo and Peace River parklands; scattered throughout interior, Kootenay and Nechako Lowlands, Peace River, and south coast (GD, CI, SI, SIM, SBI, BP, NBM, TP).<br>Freshwater wetlands and rivers in brushy upland habitats, sometimes far from water. Nests on ground very well concealed often by overhanging shrubs.<br>Eggs: 9-25 June<br>Young: 2 - 22 July | Concentrated on the Fraser River delta. Common along Vancouver Island and in open lakes and rivers in the southern interior (CM, GD, CI, SI, SIM).<br>Estuaries, mudflats, lagoons, shallow bays with seaweeds and eel-grass, agricultural fields, sloughs, marshes, lakes, slow moving rivers, golf courses and airports. Spring movement: March - late April<br>Post-breeding males moult in the southern interior in mid-June.<br>Fall movement: mid Oct. - Nov. |
| American Black Duck<br>*Anas rubripes*<br>B-ABDU<br>(Yellow List) | Feral population near the vicinity of Reifel Island, Ladner and Pitt Meadows (GD). | A small autumn and winter dispersal from local resident populations (GD). |
| Mallard<br>*Anas platyrhynchos*<br>B-MALL<br>(Yellow List) | Widespread, most abundant in the Chilcotin-Cariboo (CM, GD, CI, SI, SIM, SBI, BP, TP, NBM).<br>Wetlands in urban (golf courses, ditches, parks) and rural (agricultural fields, sloughs marshes, lakes, riparian woodlands) environments.<br>Nests on ground concealed by vegetation.<br>Eggs: 29 April - 27 May<br>Young: 22 May - 28 June | Along the coast, major concentration on the Fraser River delta and throughout BC (CM, GD, CI, SI, SIM, SBI, BP).<br>Loaf on estuaries, offshore in bays and inlets, lakes and rivers; forage on flooded fields, tidal marshes and estuaries.<br>Spring movement: mid Feb. - May<br>Fall movement: late Aug. - Dec. |
| Blue-winged Teal<br>*Anas discors*<br>B-BWTE<br>(Yellow List) | South coast east through the southern and central interior and Peace River through Boreal Forest and west to Atlin.<br>Concentrations in Chicotin-Cariboo, Okanagan, Nechako Lowlands and Peace River (GD, CM, SI, SIM, CI, SBI, BP, NBM). Forested and open habitats near small bodies of water.<br>Nests on ground near water.<br>Eggs: 2 - 20 June<br>Young: 5 - 28 July | Migrate mainly through the interior. A few remain on the inner south coast and in the Okanagan Valley and Kootenays in mild winters (CM, GD, SI, SIM).<br>Moulting flocks up to 600.<br>Spring movement: mid-May<br>Summer moult: mid July - mid-Aug.<br>Fall movement: peaks late Aug. - early Sept. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Cinnamon Teal<br>*Anas cyanoptera*<br>B-CITE<br>(Yellow List) | Confined to southern BC - Victoria north to Powell River and throughout the Fraser Lowlands; Kootenays and from southern Okanagan Valley north to Nimpo Lake in the Chilcotin-Cariboo - the centre of abundance (GD, CI, SI, SIM).<br>Wetlands, wet meadows, ditches, sewage lagoons and slow-moving streams. Nests on ground surrounded by vegetation.<br>Eggs: 15 May - 10 June<br>Young: 13 June - 16 July | Rarely winters on south inner coast. Migrates along coast and through interior (GD, CI, CM, SI, SIM).<br>Wetlands with emergent vegetation. In shallow bays and inlets close to cover. Flooded fields, ditches, sewage ponds, willow swamps. In lagoons, estuaries, and bays with eel-grass in marine habitats.<br>Spring movement: late Apr. - mid May<br>Moult - mid July<br>Fall movement: Sept. - Nov. |
| Northern Shoveler<br>*Anas clypeata*<br>B-NOSL<br>(Yellow List) | Most abundant in the Chilcotin-Cariboo and Peace Lowlands. Distributed on the inner south coast and from the southern interior north to Atlin and the Peace River (GD, CI, SI, SIM, SBI, BP, NBM, TP).<br>Open and semi-open habitats in the vicinity of marshes, sloughs, ponds, bogs, lakes, ditches, and slow-moving streams.<br>Eggs: 9 - 14 June<br>Young: 1 - 24 July | Mainly the Fraser River delta and southeastern Vancouver Island. Scattered throughout the southern interior (CM, GD, SI, CI, SIM).<br>Sheltered bays, estuaries, shallow lakes, marshes, and flooded agricultural fields, and especially concentrated at sewage ponds and outfalls.<br>Spring movement: late Apr. - early May<br>Fall movement: Sept. - early Oct. |
| Northern Pintail<br>*Anas acuta*<br>B-NOPI<br>(Yellow List) | Throughout the interior, east of the Coast Ranges and locally on the south coast and the Queen Charlotte Lowlands. Most abundant in the central-south interior, the Peace Lowlands, and the east Kootenay (CM, GD, CI, SI, SIM, SBI, NBI, BP, TP). Drier margins of lakes and wetlands, dry grasslands, shrubby fields, edges of mixed forests, damp meadows, and subalpine bogs.<br>Nest on ground in sparse or low vegetation.<br>Eggs: 19 May - 9 June<br>Young: 16 June - 15 July | Widely distributed. Open waters of the southern interior, and the coast in mild winters. Main migration staging areas at Clayoquot Sound and the Fraser River delta (CM, GD, CI, SI, SIM, SBI, BP).<br>Tidal marshes, shallow foreshore waters, estuaries, exposed eelgrass beds, mudflats, agricultural fields and lagoons on the coast; river banks, flooded fields, ponds, marshes, sloughs, and lakes in the interior.<br>Spring movement: late Feb. - Apr.<br>Fall movement: Sept. - Oct. |
| Green-winged Teal<br>*Anas crecca*<br>B-GWTE<br>(Yellow List) | Southern Vancouver Island, the Fraser Lowlands and northern Queen Charlotte Lowlands on the coast. Widely distributed across the interior (CM, GD, CI, SI, SIM, SBI, BP, TP, NBM).<br>Grassy, brushy, lightly wooded upland areas near fresh water marshes in the interior; sloughs and ponds associated with estuaries on the coast.<br>Nests on the ground in dense cover.<br>Eggs: 20 May 27 June<br>Young: 3 July - 22 July | South coastal BC, especially on the Fraser and Chemainus River estuaries; north coast estuaries; Okanagan Valley and west Kootenay estuaries (CM, GD, CI, SI, SIM, SBI). Tidal mudflats on the coast, shallow marshes and flooded, weedy fields in the interior.<br>Spring movement: mid to late Apr.<br>Fall movement: late Sept. - mid Oct. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Canvasback<br>*Aythya valisineria*<br>B-CANV<br>(Yellow List) | Central and southern interior to Prince George, Vanderhoof and Atlin and throughout the Peace Lowlands. Centre of abundance in Chilcotin-Cariboo (CI, SI, SIM, SBI, BP).<br>Fresh water and alkali lakes, wetlands bordered by dense emergent vegetation, especially bulrush. Nests on water in dense emergent vegetation.<br>Eggs: 27 May - 4 June<br>Young: 28 June - 20 July | The south coast and the southern interior north through the Okanagan valley and west to Kamloops. Occasionally in the Creston valley, along the Queen Charlotte Islands and the north coast (GD, CM, SI, SIM). Coastal marine and freshwater wetlands, most often on lakes in the interior.<br>Spring movement: Mar.<br>Fall movement: Sept. - Nov. |
| Redhead<br>*Aythya americana*<br>B-REDH<br>(Yellow List) | Southeast Kootenays, Creston and the Okanagan valley, widely throughout the Cariboo-Chilcotin, and in the Peace Lowlands (CI, SI, SIM, SBI, BP). On shallow freshwater lakes and wetlands with emergent vegetation. Nests over water in dense stands of emergent vegetation.<br>Eggs: 3 - 22 June<br>Young: 20 June - 19 July. | Mainly in the Okanagan, Creston and Columbia valleys.<br>Also on south coast and rarely on Queen Charlotte Islands (CM, GD, SI, SIM). Mostly on large deep lakes as well as ponds, sloughs, rivers, flooded fields, lagoons and saltwater bays.<br>Spring movement: mid-Feb. - mid May<br>Moulting males - late June<br>Fall movement: Early Sept. - Nov. |
| Ring-necked Duck<br>*Aythya collaris*<br>B-RNDU<br>(Yellow List) | Widespread from the Okanagan and Creston north through the Chilcotin Cariboo to the Peace Lowlands and on the east coast of Vancouver Island and the Fraser Lowlands (GD, SI, CI, SBI, SIM, BP, NBM). Freshwater lakes, marshes, ponds and sloughs often in wooded situations. Nests on land or on water in grass clumps or emergent vegetation.<br>Eggs: 21 May - 18 July<br>Young: 9 July - 7 Aug. | Mainly along south eastern Vancouver Island. Small numbers (mostly males) in Okanagan and Nicola valleys (CM, GD, SI).<br>Lakes, ponds and flooded fields primarily as well as saltwater lagoons, sewage ponds, bogs, and other wetlands.<br>Spring movement: early March - early May<br>Moulting males - mid June - late July<br>Fall movement: late Aug. - mid Nov. |
| Tufted Duck<br>*Aythya fuligula*<br>B-TUDU<br>(Yellow List) | Not known to regularly breed in BC. | Single birds occasionally sighted along southern Vancouver Island and from the Fraser River delta to Harrison Lake (GD, SI). Marine, brackish and freshwater wetlands.<br>Spring movement: Mar. - June<br>Fall movement: Oct. - Nov. |
| Greater Scaup<br>*Aythya marila*<br>B-GRSC<br>(Yellow List) | Not known to regularly breed in BC. | Along the coast especially southern Vancouver Island and the Fraser River delta. Also the Okanagan valley east to the west Kootenays and north to the Thompson Basin, (CM, GD, SI, CI, SIM). Marine and freshwater wetlands.<br>Spring movement: Mar. - June<br>Moulting: early July<br>Fall movement: mid Oct. - Nov. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Lesser Scaup<br>*Aythya affinis*<br>B-LESC<br>(Yellow List) | Rare in the southern interior but increasing northward through the Rocky Mountain Trench and the Thompson-Okanagan Plateau to the Cariboo-Chilcotin and Peace River areas (CI, SI, SIM, SBI, BP, TP, NBM). Freshwater and alkaline lakes, marshes and fields. Most nests concealed in dense grass, agricultural crops, or emergent vegetation.<br>Eggs: 21 June - 12 July<br>Young: 18 July - 4 Aug. | Southern Vancouver Island, Fraser River delta, southern Okanagan valley and the west arm of Kootenay Lake (CM, GD, SI, SIM). Open waters of straits, rocky islets, beaches, bays and harbours, estuaries, lakes, and freshwater marshes.<br>Spring movement: Mar. - early May<br>Fall movement: Sept. - Nov. |
| King Eider<br>*Somateria spectabilis*<br>B-KIEI<br>(Yellow List)<br>Very rare vagrant along the coast | Not known to regularly breed in BC. | Found in 6 areas along the coast: Chatham Sound, Masset, Skidegate Inlet, Port Hardy, Sooke and on the extreme south mainland coast (CM, GD). All records from protected waters of bays, inlets and harbours. |
| Surf Scoter<br>*Melanitta perspicillata*<br>B-SUSC<br>(Blue List) | Peace and Fort Nelson lowlands of northeastern BC (TP, BP). Freshwater lakes surrounded by spruce and muskeg or mature coniferous/deciduous stands.<br>Eggs: 25 June -<br>Young: 22 July - 20 Aug. | Along the coast especially, from White Rock north to the Sunshine Coast. In spring, birds fly from the coast east to the Chilcotin-Cariboo region, Mt. Robson and then northern Alberta (CM, GD, SI, CI). Relatively open but shallower (<6m) waters of straits and protected waters of bays, harbours, and lagoons. Huge flocks where Pacific herring are spawning.<br>Spring movement: Apr. - May<br>Fall movement: late Sept. - Nov. |
| White-winged Scoter<br>*Melanitta fusca*<br>B-WWSC<br>(Yellow List) | Thompson-Okanagan Plateau, Fraser Plateau to the Peace Lowlands and west to Atlin (CI, SI, SIM, BP, TP, NBM). Freshwater lakes and ponds in open country and boreal forest.<br>Eggs: 12 May - 17 July<br>Young: 23 July - 13 Aug. | Two centres of distribution: Hecate Strait and the southern Strait of Georgia. Small numbers winter irregularly in the Thompson-Okanagan (CM, GD, CI). Bays, inlets, channels, estuaries, and occasionally large, slow-moving rivers. Prefers open, deeper waters, especially at shellfish beds.<br>Spring movement: April - May<br>Subadults and post-breeding males moult in July - Aug.; females moult late Aug. - Sept.<br>Fall movement: late Sept. - early Nov. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Black Scoter<br>*Melanitta nigra*<br>B-BLSC<br>(Yellow List) | Not known to regularly breed in BC. | Southern Vancouver Island to Queen Charlottes and Chatham Sound. Rarely seen in the interior (CM, GD, SI).<br>Estuaries, bays, harbours, inlets, sounds and lagoons (where water depths are less than 11 m and near mussel beds), lakes, rivers and sewage ponds.<br>Spring movement: Mar. - May<br>Fall movement: early Sept. - Nov. |
| Oldsquaw<br>*Clangula hyemalis*<br>B-OLDS<br>(Blue List) | One record at White Pass, two records from Blackfly Lake in northwest corner of BC | Strait of Georgia, northern Queen Charlotte Islands, in Chilcotin-Cariboo, Peace Lowlands Okanagan and west Kootenays (CM, GD, SI, CI, SIM).<br>Deeper waters of bays, harbours, along spits, reefs, estuaries, mudflats, larger lakes and rivers.<br>Spring movement: Mar. - May<br>Fall movement: Oct. - Dec. |
| Bufflehead<br>*Bucephala albeola*<br>B-BUFF<br>(Yellow List) | Across interior especially the Peace Lowlands and northern areas of the Boreal Forest (GD, CI, SI, SIM, SBI, BP, TP, NBM). Primarily on lakes and occasionally on rivers, sloughs, and ponds in aspen parklands, interior Douglas-fir forests, open ponderosa pine forests, farmland, and rangeland. Nests in tree cavities near the edge of wetlands.<br>Eggs: 29 May - 10 June<br>Young: 24 June - 18 July | Mainly along coast especially southern Vancouver Island.<br>Also Queen Charlotte Islands and from the Okanagan valley east to the west Kootenays and north to the South Thompson River (CM, GD, SI, SIM, CI). Protected bays, harbours, lagoons, estuaries, lakes, ponds, rivers and sewage lagoons. Flocks of usually < 10 but large concentrations where herring spawn.<br>Spring movement: late Apr. - May<br>Moulting females: July - Aug.<br>Fall movement: late Oct. - Nov. |
| Common Goldeneye<br>*Bucephala clangula*<br>B-COGO<br>(Yellow List) | Uncommon but widespread in the southern third of BC east of the Coast Ranges. Sparse through the Fraser Plateau, Fraser Basin, Peace and Fort Nelson lowlands, and northwestern BC (GD, SI, CI, SIM, SBI, BP, NBM, TP). Lakes, rivers and associated flood plains, sloughs, ponds and creeks, usually with wooded margins.<br>Nests in tree cavities<br>Eggs: 11 Apr. - 2 July<br>Young: 12 June - 13 July | Along the coast, principally around Vancouver Island, the northern Queen Charlotte Islands and adjacent mainland coast. Also in the south Okanagan, South Thompson River and Creston valleys, west Kootenays and Columbia valley (GD, CM, CI, SI, SIM). Estuaries, bays, harbours, lakes, rivers, beaches, marshes. Concentrated where herring spawn in spring.<br>Spring movement: late Mar. - mid April<br>Fall movement: late Oct. - early Dec. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Barrow's Goldeneye<br>*Bucephala islandica*<br>B-BAGO<br>(Yellow List) | Widespread in the southern interior east of the Coast Range. Most abundant in Chilcotin-Cariboo region (CM, CI, SI, SIM, SBI, BP, TP, NBM). Lakes associated with aspen parkland, open ponderosa pine forests, farmland, rangeland and alpine meadows, as well as wetter, closed coniferous forests including sub-alpine regions. Alkaline lakes are preferred.<br>Nests in cavities of trees near the edge of a wetland.<br>Eggs: 20 May - 10 June<br>Young: 21 June - 16 July | Mainly on south and north mainland coast; also along Vancouver Island, Queen Charlotte Islands and interior Okanagan, west Kootenay, and South Thompson River valleys (CM, GD, SI, CI, SIM). Concentrate in areas where herring spawn. and with extensive mussel beds. Bays and fiords with rocky shores, near sources of freshwater and lakes, ponds, rivers and sewage lagoons.<br>Spring movement: March - mid May<br>Moulting females: late Aug. - Sept.<br>Fall movement: late Oct. - Nov. |
| Hooded Merganser<br>*Lophodytes cucullatus*<br>B-HOME<br>(Yellow List) | From Northern Queen Charlotte Islands, Kitsault, Fort St. James and Prince George south through the rest of BC Centre of abundance in southwest (CM, GD, SI, CI, SIM, SBI). Mostly fresh but occasionally brackish water sites, usually with wooded shorelines. Nests in tree cavities.<br>Eggs: 4 - 25 May<br>Young: 7 June - 6 July | Strait of Georgia and the south Okanagan valley (CM, GD, SI, SIM). Estuaries, protected bays and inlets, coastal lakes, marshes, sloughs, lakes, rivers, sewage lagoons and less often, marshes. Common on salmon-spawning streams.<br>Spring movement: late Apr.<br>Fall movement: early Oct. - early Nov. |
| Red-breasted Merganser<br>*Mergus serrator*<br>B-RBME<br>(Yellow List) | Teslin Plateau in extreme northwestern BC and Masset Inlet (CM, NBM). Shores of lakes and rivers in the interior and on marine islands on the coast. Nests on ground on sites heavily vegetated with shrubs or trees.<br>Eggs: 25 June - 16 July<br>Young: 13 July - Sept. | Strait of Georgia and the southern Okanagan valley (CM, GD, SI, SIM). More marine than the Common Merganser. Open and deeper waters in bays, estuaries and inlets; lakes and large rivers.<br>Spring movement: Mar. - May<br>Fall movement: mid Sept. - Nov. |
| Common Merganser<br>*Mergus merganser*<br>B-COME<br>(Yellow List) | Throughout BC except in extremely mountainous areas. Less common and widely scattered in northern BC (CM, GD, SI, CI, SIM, SBI, BP, NBM). Near freshwater along forested shores of lakes, streams, rivers, inlets, and beaver ponds. Nests in tree cavities and on ground in small caves or crevices.<br>Eggs: 20 April - 10 May<br>Young: 15 June - 20 July | Along the coast, northern and southern interior (CM, GD, SI, CI, SIM). Near shore in estuaries, protected bays and inlets, on lower regions of clear rivers with loafing sites. Avoids muddy water and aquatic vegetation.<br>Spring movement - mid Mar. - early May<br>Fall movement: late Oct. - Nov. |

| **Species (Status in BC)** | **Breeding distribution (ecoregions), habitat, and timing of egg laying & brood rearing** | **Non-breeding distribution (ecoregions), habitat, and timing of main migration movements** |
|---|---|---|
| Ruddy Duck<br>*Oxyura jamaicensis*<br>B-RUDU<br>(Yellow List) | Nicola and Okanagan valleys to the east Kootenays, north through the Chilcotin-Cariboo to the Nechako Lowland region and in the Peace River area. Local breeder on Quamichan Lake, Vancouver Island (GD, CI, SI, SIM, BP, TP, SBI). Freshwater wetlands with emergent vegetation such as bulrushes and cattail for nesting cover. Nests over water in emergent vegetation.<br>Eggs: 16 June - 7 July<br>Young: 12 July - 3 Aug. | Widely distributed from southeastern Vancouver Island across the southern third of the province and throughout the Fort Nelson and Peace Lowlands. Centre of distribution in Boundary Bay (CM, GD, SI, CI, SIM, BP). Fresh or salt water bodies at least 2 m deep. Protected bays and lakes with soft mud bottoms and small invertebrates.<br>Spring movement: late Apr. - mid May<br>Fall movement: late Sept. - Oct. |
| American Coot<br>*Fulica americana*<br>B-AMCO<br>(Yellow List)<br>Note: Coot survey methods are also found in manual No. 7, *Inventory Methods for Marsh Birds.* | Southeastern Vancouver Island, the Fraser Lowlands, east across southern BC, north through the Chilcotin-Cariboo and Fraser Basin regions to the Peace Lowlands, Fort Nelson Lowlands, and Liard Basin (GD, CI, SI, SIM, SBI, BP, TP). Freshwater, alkali and brackish wetlands with extensive stands of dense emergent vegetation along the margins. Nests on water in dense stands of emergent vegetation.<br>Eggs: 29 May - 15 June<br>Young: 20 June - 16 July | Along coast, most abundant in southeastern Vancouver Island and the Fraser Lowlands.<br>In the interior from Williams Lake southward especially in the Okanagan valley south of Kelowna (CM, GD, SI, SIM, CI). Fresh, marine and brackish waters where aquatic vegetation provides cover and a food source.<br>Spring movement: Early Apr. - May.<br>Fall movement: mid Sept. - mid Oct. |
| Sandhill Crane<br>*Grus canadensis*<br>B-SACR<br>(Blue List) | Fraser Lowlands, islands along the central mainland coast, Queen Charlotte Islands and from the north Okanagan valley through the Chilcotin-Cariboo to Vanderhoof. Small numbers in Fort Nelson Lowlands (CM, GD, CI, SI, TP). Isolated bogs, marshes, swamps, and meadows.<br>Nests on ground or on water, usually among thick shrubs or emergent vegetation such as hardhack, sweet gale, willows, Labrador tea, bulrushes or sedges.<br>Eggs: 2 May - 25 June<br>Young: 15 June - 15 July | Coastal, interior and northeastern interior migration routes. Stopover points include White Lake, Lac Le Jeune, Bechers Prairie west of Williams Lake and the Kispiox Valley in the interior; Nig Creek, Liard Hotsprings and Cecil Lake in the northeast. Small numbers winter on the Queen Charlotte Islands, Vancouver Island and the Fraser Lowlands (CM, GD, CI, SI, SIM).<br>Flocks up to 5000.<br>Shallow wetlands and margins of lakes, intertidal areas and dry uplands, such as grasslands and agricultural fields.<br>Spring movement: Apr.<br>Fall movement: Oct. |

Note: ducks are sometimes referred to as being in one of the following general groups: Dabbling Ducks, Diving Ducks and Sea Ducks (see glossary for a list of species within these groups).

## 2.1 Special Inventory Considerations for Waterfowl and Allied Species

Within this manual, timing of surveys for waterfowl and allied species in BC is described in terms of the four stages of the lifecycle - breeding, moulting, migration and over-wintering. Different populations of birds in each species are inventoried during each of these stages. Many aspects of waterfowl biology and distribution influence the way in which they should be inventoried at each of these times.

### 2.1.1 Breeding

**Wide Distributions and Low Densities**

In general, populations of breeding waterfowl and allied species are widely distributed across the province, much of their habitat is inaccessible by road, and birds occur at low densities in remote areas. It is costly and time-consuming to inventory the entire breeding range. Therefore, breeding inventories concentrate on accessible areas with the highest densities of birds. These inventories can not be used to provide an unbiased estimate of population size for the entire province, but they are useful for estimating population size within clearly defined areas of specific habitat types.

**Types of Breeding Surveys**

Breeding waterfowl and allied species are commonly surveyed in three ways: (1) breeding pair counts, (2) nest counts, and (3) brood counts. In addition to being able to identify distinguishing characteristics of different age and sex classes, conducting these surveys requires knowledge about the behaviour, operational sex ratio, and nesting habits of each species being surveyed.

***1. Breeding Pair Counts***

- *Territorial Behaviour*: Breeding pair counts are based on the knowledge that established breeding pairs of dabbling ducks localize their activities to one or two ponds (Eng 1986). Thus, counting the number of breeding pairs on each pond repeatedly over the breeding period (from pair bonding until the female is well into incubation) is a valid way to estimate the size of breeding populations. Breeding pair counts are less valid for species that move around in large home ranges (e.g., Canvasbacks, Redheads, Green-winged Teal) during the breeding season. Movements may cause birds to be counted twice and thereby lead to overestimates of the population size.
- *Timing of Counts*: Ideally, pairs are counted after migrants have departed, but before males desert their incubating females. Counts of multiple species should be timed to include the pre-nesting, laying and early incubation stages of the species of interest. This may extend over a period of at least 20 to 30 days to include early- and late-nesting ducks. Dzubin (1969) proposed that lone males, grouped males and males in aerial flights should be included as pairs before a certain date. After that date, grouped males are more likely to be post-breeding males from another location. Different cut-off dates have been established for early nesters (Northern Pintails and Mallards), intermediates (wigeons and Northern Shovelers) and late nesters (Blue-winged Teal and Gadwalls).

- *Operational Sex Ratio:* The "indicated breeding population" is based on the operational sex ratio of the species (Dzubin 1969). For example, only half the grouped males are considered pairs in species known to have 2:1 sex ratios (e.g., Hooded Mergansers, Lesser Scaup). Sugden and Butler (1980) recommend that lone male and pair counts provide the best index to breeding populations for Canvasbacks and total female counts provide the best index for Redheads. Recommendations for counting "indicated pairs" of other duck species await further study. Breeding geese, swans and cranes remain paired throughout the nesting season which extends the time available to survey breeding populations. Lone males indicate pairs only during incubation and males in groups are never considered pairs (Eng 1986).
- *Recording Breeding Pair Counts:* Record the number of pairs, lone males, and males in groups noting the number of males in each separate group.
  - Pairs - The number of pairs presumed to be breeding pairs. Pairs are usually seen close to shore and may exhibit pair-bonding behaviour such as display, courtship, etc.
  - Lone males - The number of resident males that may be defending a territory. These males will commonly be seen repelling conspecific males.
  - Lone females - The number of females feeding intensively between incubation periods. These females are usually seen late in the season.
  - Males in groups - The number of males in an isolated group. For Mallards, these are post-breeding drakes and each individual indicates a breeding pair. These groups are seen late in the season after incubation begins.
  - Mix flock (sex ratios in a mixed flock) - It can be useful to record the number of females and males present where mixed flocks of both sexes are present. This situation is most often seen early in the season.
  - Isolated pair - The number of pairs observed to be isolated from other waterfowl. This is only useful for Goldeneye and Bufflehead. Isolated pairs are usually found near the shoreline and will strongly defend their territory.
  - Immature group - The number of immature males and females observed. This is only useful for some diving duck species such as Barrow’s Goldeneye, Buffleheads, etc.

***2. Nest Counts***

- *Nesting Habitat:* Although it is time-consuming, counting nests can provide estimates of the size of a breeding population in a defined area of habitat. Habitats must be searched thoroughly to find nests that are usually hidden in vegetation. Waterfowl nests in open upland habitat can be found more easily by dragging a cable chain (Higgins *et al.* 1969). Nests near water require searches on foot in chest waders, by canoe or by kayak.
- *Timing of Counts:* Nests are counted by systematically covering nesting areas at specified time intervals to locate early and late nesting birds. Nest searches in dense cover should be conducted while females are still incubating so that flushing females will indicate a nest’s location. Not all pairs initiate laying at the same time and some nests may be destroyed between search periods. Consequently, not all nests are found, while renesting attempts may result in some duplication. Total counts usually represent minimum estimates.

***3. Brood Counts***

- *Index of Annual Waterfowl Production*: Brood counts provide an index of annual waterfowl production, possibly a measure of breeding success, and possibly an index of breeding population size. Gillespie and Wetmore (1974) also suggest that brood surveys provide a better index of an area's capability to support waterfowl than do pair counts. However, the high vulnerability of broods to adverse weather conditions and predation (Breault pers. comm.) reduces the accuracy of brood counts as estimates of either annual breeding population size or habitat capability. Brood surveys provide an index of annual waterfowl production, although multi-year surveys may help answer the question of habitat capability. Brood counts can also provide a measure of annual breeding success if conducted in conjunction with breeding pair or nest counts.
- *Timing of Counts*: There is greater flexibility in the timing of brood surveys because birds are sedentary longer than during spring pair counts (Gillespie and Wetmore 1974). Brood counts should occur after hatching but before fledging. Many species in this inventory group are asynchronous breeders, and each species has its own chronology (refer to Table 1); therefore, the timing and duration of inventories will vary depending on which species are being inventoried.
- *Brood Behaviour and Movements:* Broods are usually more secretive than adults and by the time most broods have hatched, the emergent vegetation is lush and visibility is reduced. Repeated surveys are recommended to increase opportunities for brood detection. However, broods of most waterfowl species move from pond to pond, increasing the likelihood of double counting. Therefore, in repeated surveys, appropriate analytical methods must be used to avoid overestimating population size.
- *Brood Identification*: Gollop and Marshall (1954) recommend that the age of each brood be recorded for waterfowl species so that they can be re-identified on subsequent counts. Ageing the young of asynchronous hatchers, e.g., coots and grebes, is imprecise because young of the same age are usually different sizes. The problem is exacerbated by the fact that some young are preferentially fed. Similarities between the female plumage of different species of waterfowl (e.g., Red-breasted Mergansers resemble Common Mergansers) make it difficult to identify older broods.

### 2.1.2 Moulting

**Timing of Moult**

Waterfowl, grebes, loons, and coots undergo a complete, simultaneous wing moult that leaves them flightless. The moult occurs during the brood-rearing period of geese, the post-breeding period of male ducks and the post-brood-rearing period of most female ducks. Feather regrowth requires three to five weeks depending on the species. Moulting periods are the ideal time to capture birds for mark-recapture studies because they are flightless.

**Habitat and Behaviour of Moulting Birds**

Birds often move to areas away from their breeding grounds to moult. Although little research has been done, it is believed that these areas are rich in food and/or offer good cover for protection from predators. The use of cover by moulting birds makes them more difficult to detect in surveys. High foraging rates of moulting birds can also make it difficult to achieve an accurate count of diving birds. When feeding frequency is high, counts will be more accurate if birds are scanned slowly several times and the highest count used (Breault *et al.* 1988).

**Species Identification**

It can be difficult to identify many species during moult because of their irregular plumage (e.g., male Cinnamon Teal are difficult to distinguish from females after their mid-July moult).

**Site Fidelity**

Moulting sites are known to be consistent from year to year for some species of geese and sea ducks (e.g., Surf Scoters, Savard 1988). This provides an ideal situation for tracking long term trends in the number of birds using specific moulting areas.

### 2.1.3 Migration

**Migration Routes**

Food supplies determine where and when large segments of waterfowl and allied species migrate. Migratory patterns of many species of geese and ducks have changed in response to increased availability of agricultural grains (Bellrose 1976; Fredrickson and Drobney 1979). It is important to consider these changes when interpreting yearly variation in populations at traditional migration stop-over sites.

**Timing of Migration**

Timing of migration is also related to weather, particularly the availability of open water in early spring and late fall. Surveys should be flexibly timed with respect to freezing and thawing in local areas.

### 2.1.4 Wintering

**Wintering Densities**

Wintering birds are concentrated into much smaller areas than at other times in their life cycle therefore, winter is an efficient time to count a large number of birds over a small area. Unfortunately, the potential for error (at least in determining total population sizes) is great (Eng 1986). Flocks of birds that are concentrated in open areas are highly visible but difficult to count, particularly if flocks contain many species of different sizes. Howes (1987) devised a method for estimating numbers of birds in flocks by sight, and aerial photography has been used to increase the accuracy in counting conspicuous species, e.g., geese (Boyd, pers. comm.), swans, and even Canvasbacks (Haramis *et al.* 1985). It is possible to determine the accuracy and precision of observer's estimates of flock size by counting computer simulated flocks (e.g., Hodges 1993).

**Mixed Flocks of Wintering and Migrant Birds**

Flocks of migrants and wintering birds of the same species are often mixed for variable periods of time in the same location (especially along the south coast). Resighting marked birds repeatedly over the winter months is the best way to distinguish wintering birds from migrants.

# 3. PROTOCOLS

The recommended survey types for inventory of waterfowl in British Columbia are summarized in Table 2 (for breeding waterfowl and allied species) and Table 3 (for non-breeding waterfowl and allied species).

**Table 2. Recommended survey type(s) to satisfy different inventory objectives for breeding [1]waterfowl and allied species in British Columbia.**

| Species Group | Recommended Methods | | | |
|---|---|---|---|---|
| | **Obj.*** | **Presence/Not Detected & Relative Abundance** | **Obj.*** | **Absolute Abundance** |
| Loons (except B-YBLO) | PBG<br>PBG | Observation Stations<br>Helicopter Surveys (large or inaccessible areas) | PBG<br>PBG<br><br>N | Observation Stations<br>Helicopter Surveys (for large or inaccessible areas)<br>Nest Counts - Boat |
| Grebes & Coots | G<br>P | Observation Stations<br>Call Playback | N | Nest Counts - Ground or Boat |
| Swans (B-TRUS B-MUSW) | PBG<br>PIBG | Observation Stations (small areas)<br>Transects - Aerial (large or inaccessible areas) | PBG<br>PIBG<br><br>N | Observation Stations (small areas)<br>Transects - Aerial (by helicopter for large or inaccessible areas)<br>Nest Counts - Ground |
| Geese (B-CAGO) | PBG<br>PBG<br><br>I | Observation Stations (small areas)<br>Transects - Aerial (large or inaccessible areas)<br>Helicopter Surveys (large or inaccessible areas) | PBG<br>PBG<br><br>N | Observation Stations (small areas)<br>Helicopter Surveys (large or inaccessible areas)<br>Nest Counts - Ground |
| Dabbling Ducks | PBG<br>BG<br>PBG | Observation Stations<br>Transects - Aerial or airboat<br>Helicopter Surveys (large or inaccessible areas) | PBG<br>PBG | Observation Stations<br>Helicopter Surveys (large or inaccessible areas) |
| Diving Ducks | PBG<br>BG | Observation Stations<br>Transects - Aerial or airboat | PBG | Observation Stations |
| Sea Ducks | PBG<br>BG | Observation Stations<br>Transects - Aerial (large or inaccessible areas) | PBG | Observation Stations |
| Sandhill Cranes | PBG<br>PBG<br>PBG<br>PIBG | Transects - Ground (small areas)<br>Observation Stations (small areas)<br>Transects - Aerial (large areas)<br>Helicopter surveys (large areas) | PBG<br>N | Observation Stations (small areas)<br>Nest Counts - Ground |

* Objective:

- P = breeding pairs; B = broods;
- N = nests; I = incubating adults;
- G = general (total number of birds: including migrants/nonbreeders; or regardless of breeding status or chronology).

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[1] Note: see Table 1 for species that breed in British Columbia.

**Table 3. Recommended survey type(s) and their specific applications for non-breeding waterfowl and allied species in British Columbia.**

| Species Group | Recommended Methods | | | |
|---|---|---|---|---|
| | **Applies to *** | **Presence/Not Detected & Relative Abundance** | **Applies to *** | **Absolute Abundance** |
| Loons | LD<br>C | Transects - Aerial, Boat<br>Observation Stations | L<br>C | Transects - Boat<br>Observation Stations |
| Grebes and Coots | C<br>LD | Observation Stations<br>Transects - Boat, Aerial | C<br>L | Observation Stations<br>Transects - Boat |
| Swans | LD<br>C | Transects - Aerial<br>Observation Stations | C<br>CL<br><br>+ | Observation Stations<br>Airphoto Technique (for concentrated flocks)<br>Mark-resight/recapture |
| Geese | LD<br>LD<br><br>C | Transects - Aerial, Boat<br>Transects - Ground (where roads can be used for transects)<br>Observation Stations | CL<br><br>C<br><br>+ | Airphoto Technique (for concentrated flocks of B-SNGO).<br>Observation Stations - Ground (for B-CAGO and B-BRAN)<br>Mark-resight/recapture |
| Dabbling Ducks | LD<br>LD<br><br>C | Transects - Aerial, Boat<br>Transects - Ground (where roads can be used for transects)<br>Observation Stations | C<br>CL<br><br>L | Observation Stations<br>Transects- Ground (where roads can be used for transects to obtain 100% coverage)<br>Transects- Aerial |
| Diving Ducks | LD<br>LD<br><br>C | Transects - Aerial, Boat<br>Transects - Ground (where roads can be used for transects)<br>Observation Stations | C<br>CL | Observation Stations<br>Transects - Ground (where roads can be used for transects to obtain 100% coverage) |
| Sea Duck | LD | Transects - Aerial, Boat | L | Transects - Boat |
| Sandhill Cranes | D<br>CLD<br>C | Transects - Aerial<br>Transects - Ground (roads for D)<br>Observation Stations | C<br>CL<br>+ | Observation Stations - Ground<br>Transects - Ground<br>Mark-resight/recapture |

* Application:

- C = confined areas (accessible small basins, bays, or other restricted geographical areas), or concentrated flocks;
- L = linear habitat features (shorelines, rivers, etc.);
- D = dispersed or extensive areas (open lakes or ocean; birds scattered through upland areas, inaccessible bogs, widely distributed potholes, etc.);
- + = Mark and resight/recapture techniques are suited to known stable, closed, wintering or resident populations.

Note that access method into a site will depend on terrain, remoteness, and size of study area.

## 3.1 Inventory Surveys

The table below outlines the type of surveys that are used for inventorying waterfowl for the various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

**Table 4. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.**

| Survey Type | Forms Needed | *Intensity |
|---|---|---|
| Transect: Breeding Pair Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl- Breeding Pair Count | • PN<br>• RA<br>• AA |
| Transect: Brood Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Brood Count | • PN<br>• RA<br>• AA |
| Transect: Non-breeding Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Non-breeding Count | • PN<br>• RA<br>• AA |
| Helicopter: Breeding Pair Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Breeding Pair Count | • PN<br>• RA<br>• AA |
| Helicopter: Brood Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Brood Count | • PN<br>• RA<br>• AA |
| Obs. Station: Breeding Pair Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Breeding Pair Count | • PN<br>• RA<br>• AA |
| Obs. Station: Brood Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Brood Count | • PN<br>• RA<br>• AA |
| Obs. Station: Non-breeding Count | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Non-breeding Count | • PN<br>• RA<br>• AA |
| Call Playback | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Call Playback | • PN<br>• RA |
| Nest Count (any method) | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Nest Count | • AA |
| Aerial Photography | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Aerial Photography | • AA |
| Mark-Recapture / Resight | • Wildlife Inventory Project Description Form<br>• Wildlife Inventory Survey Description Form-General<br>• Animal Observations Form- Waterfowl - Capture/Recapture<br>• Animal Observation Form - Waterfowl - Resight | • AA |

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

## 3.2 Sampling Standards

The following standards are recommended to ensure comparison of data between surveys, and to mitigate several sources of bias common in surveys. Individual protocols provide more detailed standards applicable to the method(s) and design recommended.

### 3.2.1 Habitat Data Standards

A minimum amount of habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. As most, provincially-funded wildlife inventory projects deal with terrestrially-based wildlife, standard attributes from the terrestrial Ecosystem Field Form developed jointly by MOF and MELP (1995) will be used. The manual, *Species Inventory Fundamentals* (No.1), contains a generic discussion of habitat data collection and will eventually outline a list of specific requirements for surveys for waterfowl and their allies (Appendix E).

### 3.2.2 Common Sources of Bias in Surveys

*Observer* - Skills, experience and motivation of observers will influence how many birds they detect. For relative abundance between sites in one year, one observer may be used consistently; otherwise, reduce bias by rotating observers, ensuring each site is surveyed an equal number of times by each observer. Use experienced observers or train observers and test their skills to ensure that a consistent standard is met.

*Volunteer Survey Programs - an example.* The way to improve the accuracy and precision of data collected by volunteers is to provide training and feedback. For example, the Burrard Inlet Environmental Action Program (BIEAP) in cooperation with the Vancouver Natural History Society (VNHS) and the Port Moody Squadron organizes volunteers to collect bird survey data in Burrard Inlet four times a year. Volunteers attend a bird species identification workshop a few weeks before each survey. Each survey group is led by an expert birder, and the data are recorded by someone who has been trained before the day of the survey. Detailed guidelines are provided to each crew so that birds can be counted within clearly delineated areas. A social event is held to thank volunteers for their time and effort and survey results are sent to each volunteer in a follow-up letter.

*Effort* - The number of birds detected will increase with sampling effort (i.e., the size of the area sampled and the time spent sampling per unit of area). Effort should be maximized to improve accuracy and standardized so that data from different samples can be compared.

*Density* - It is difficult to count birds and distinguish between species when they occur at high densities. In contrast it may be difficult to detect birds at low densities. More effort or different survey methods may be needed to sample birds at high and low densities.

*Habitat* - It is easier to detect birds in some habitats than others. Different amounts of effort or different survey methods may be needed to sample different habitats.

*Bird Species/Sex/Age Class* - Some species/sex/age classes are easier to detect than others because they are noisier, more conspicuous, breed earlier, or are easier to capture. Some of these factors are discussed in Section 2. Each species/sex/age class may require different survey methods.

*Bird Activity* - The behaviour of birds (e.g., feeding, sleeping, incubating) will alter their visibility. Count birds at times of the day and/or year when they are engaged in activities that make them most visible.

*Time of Year* - Visibility of breeding birds decreases over the summer as vegetation grows. More accurate counts will be obtained early in the season.

*Time of Day* - Activity patterns of birds vary with time of day. Surveys should occur at a standardized time.

*Tidal Rhythm* - Activity patterns of birds vary with the tidal height. Surveys along coastal shorelines and estuaries should occur at a standardized tidal height.

*Weather* - Weather can alter bird activity and the visual acuity of observers. Surveys should occur under standardized conditions and never in poor weather.

### 3.2.3 Weather

**Table 5. Acceptable weather conditions for surveying for waterfowl and their allies.**

| ***Weather*** | ***Ground & Boat*** | ***Aerial*** |
|---|---|---|
| Wind | • <10 km/h ( <3 Beaufort scale) | • Not >25 km/h ( <5 Beaufort scale) |
| Precipitation | • No rain or fog | • No rain or fog |
| Visibility | • >10 km | • Overcast sky preferred |
| Seas | • <1.5 m in height, no whitecaps ( <3 Beaufort scale) | • Smooth ocean surface preferred ( <3 Beaufort scale) |

### 3.2.4 Transportation

**Ground Surveys**

*Advantages:*

- Easier to detect birds and to distinguish species, age and sex classes on the ground than from the air; therefore, counts are more accurate especially for breeding birds, which are more difficult to detect (because they occur at relatively low densities on wetlands partly covered in emergent vegetation); and
- A quiet approach on foot causes less disturbance to birds than an aerial survey.

*Disadvantages:*

- Study area must be accessible by road if vehicles are used;
- Slower method, therefore it is not possible to cover as large an area as covered by air; and
- Birds flushed between basins or observations stations may be double counted.

**Aerial Surveys: Fixed-wing**

*Advantages:*

- Most efficient way to obtain extensive coverage of open habitat; and
- The only way to survey inaccessible regions.

*Disadvantages:*

- Difficult to detect birds from the air (depending on plumage colour and glare) (Stott and Olsen 1972);
- Difficult to obtain accurate estimates of large flock sizes;
- Repeated surveys are highly variable (not precise) (Briggs *et al.* 1985);
- Species, age and sex classes can be difficult to distinguish from the air; and birds may respond to aircraft by flying, diving or hiding, e.g., adult Trumpeter Swans seek cover in tall emergent vegetation and cygnets clump into a tight group which can make it difficult to count individuals (Shandruk and McCormick 1989); Goldeneye and Red-breasted Mergansers consistently flushed when they were approached by low-flying aircraft (Stott and Olsen 1972); loons, grebes, goldeneye and scoters often dive when approached by an aircraft over the ocean (Summers, pers. comm.).

Aerial Survey estimates are very sensitive to transect width, altitude, glare and flight speed; therefore, it is important to conduct surveys consistently (Caughley 1974; Briggs *et al.* 1985).

**Aerial Surveys: Helicopter**

Helicopters can be used (1) as an *alternative survey method* to ground searches, boat searches, or multiple observation stations, or (2) as an *alternative aircraft* to fixed-wing for aerial transect surveys.

As a survey method, helicopters are recommended to survey breeding pairs and broods in locations inaccessible by road (e.g., Boreal Forest, northwest BC). Complete counts by helicopters or from the ground over smaller portions of the study area can be used to derive correction factors for transect surveys made from fixed-wing aircraft.

When used as an aircraft for transect surveys, helicopters enable more accurate counts than fixed-wing aircraft (Shandruk and McCormick 1989). Compared to fixed-wing, the improved visibility, lower flight speed, greater manoeuverability, and variable flight heights of helicopters improve the ability of observers to detect birds (Ross 1985) when used for presence/not detected surveys. For relative or absolute abundance surveys, flight speed and height would be standardized. Unfortunately, the limited range and greater operating costs (at least double the cost of fixed-wing) limit their use in surveys. More information is provided later as to the circumstances under which helicopters are preferred to fixed-wing aircraft for conducting transect surveys.

**Boat Surveys**

*Advantages:*

- More area is covered in a shorter period of time from a motor boat or airboat than from the ground;

- On open water, a boat survey allows a more prolonged or closer view of birds than air or ground surveys, respectively; therefore, it is easier to distinguish species, age and sex classes than from the air or ground;
- In wetlands surrounded by thick emergent vegetation, a canoe or kayak allows better access to birds; and
- It is possible to collect data on habitat characteristics (e.g., sample water quality, invertebrates, temperature) while surveying birds.

*Disadvantages:*

- Birds flushing ahead may be double counted, exaggerating apparent densities (Tasker *et al.* 1984); chance of double counting birds that flush ahead is higher in slow moving boats;
- Birds (e.g., loons) may respond to close approach by flying or diving (boats may disturb birds);
- More time consuming and covers less ground than aerial surveys;
- Can not use high powered scopes because of vibrations and movement; and
- Limited view from low perspective in smaller boats.

### 3.2.5 Survey Design Hierarchy

Waterfowl surveys follow a sample design hierarchy which is structured similarly to all RIC standards for species inventory. Figure 1 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for a survey for grebes and coots using observation stations. A survey set up following this design will lend itself well to standard methods and RIC data forms.

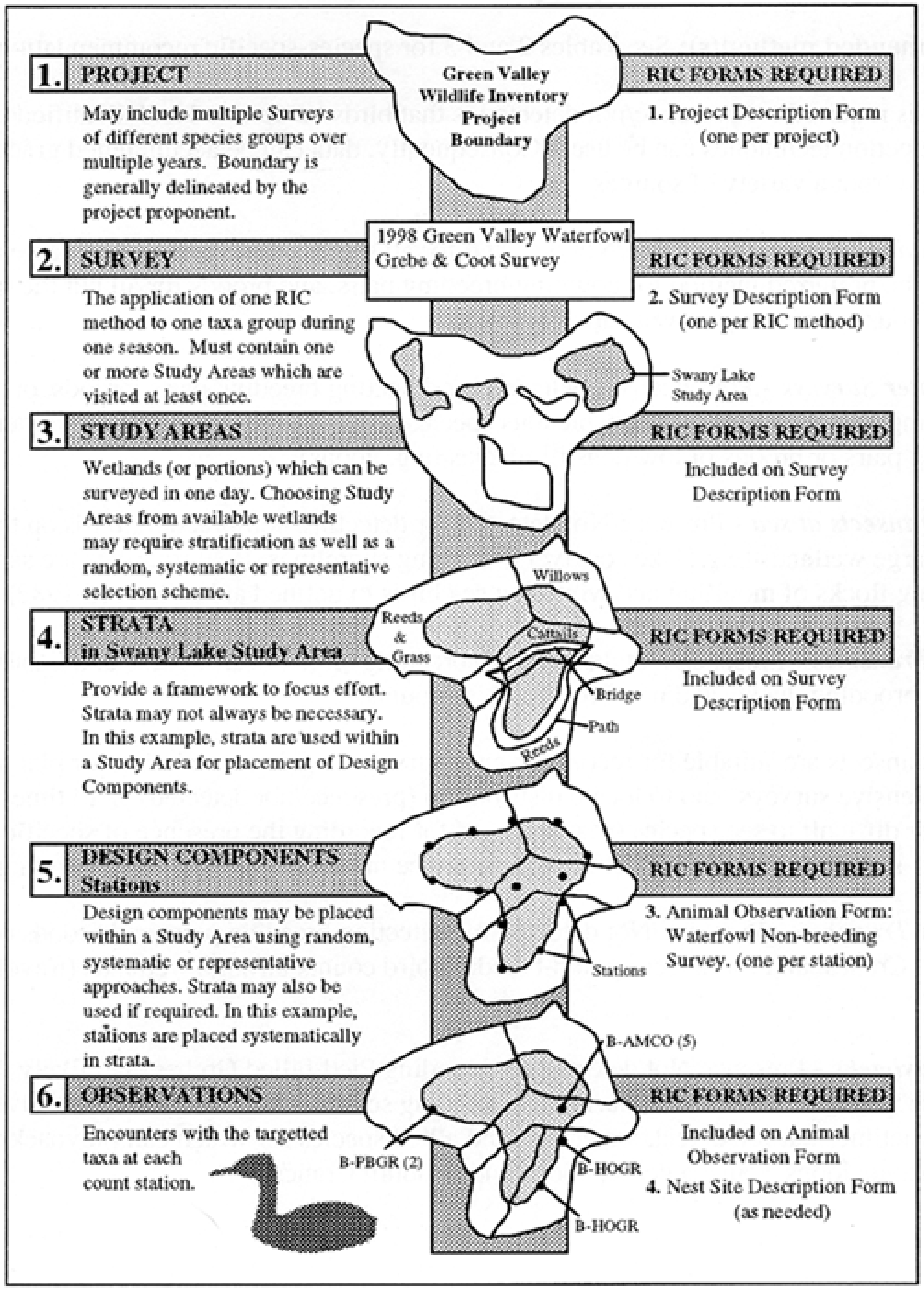


**Figure 1. RIC species inventory survey design hierarchy with examples.**

## 3.3 Presence/Not Detected

**Recommended method(s):** See Tables 2 and 3 for species-specific recommendations.

All that is required for presence/not detected is that birds be detected and identified therefore most detection techniques can be used. Consequently, data can be accumulated gradually over time from a variety of sources.

***Observation Stations*** - Presence/Not detected for all stages of life cycles (see Tables 2 and 3). It is the preferred method for counting breeding pairs, and broods for all but the most conspicuous species (e.g., swans and geese).

***Helicopter Surveys*** - Presence/Not detected for detecting breeding pairs, broods, or incubating adults for the most conspicuous species (e.g., swans, geese, Sandhill Cranes), or breeding pairs or broods of low density species (e.g., loons).

***Boat Transects at sea*** - Presence/Not detected for detecting non-breeding birds on the ocean and in large wetlands (e.g., lakes or rivers) or along shorelines. Boat transects are suitable for surveying flocks of moulting and wintering sea birds in defined areas (Savard 1982).

***Aerial Transects*** - Presence/Not detected for breeding birds (swans, geese and Sandhill Crane), brooding ducks, and non-breeding bird counts.

Aerial transects are suitable for reconnaissance surveys to gain information for planning more intensive surveys, and to locate distribution (presence/not detected) at all times of the year. For difficult to see species (sea ducks) or for recording the presence of specific breeding stages (pairs, broods), a helicopter may be more effective than a fixed-wing aircraft.

***Ground Transects*** - Presence/Not detected for detecting breeding pairs and broods of Sandhill Cranes, and for detecting non-breeding bird counts through wetlands (travelled by foot).

***Call Playbacks*** - Presence/Not detected for breeding Pied-billed Grebes, and likely for other secretive waterbirds vocalizing during the breeding season. Other vocal and secretive, or at least sometimes hard to detect, waterfowl and allied species for which call playback might work include loons, Canada geese, coots, and Sandhill Cranes.

### 3.3.1 Protocol

*For details see the Relative Abundance Section. The notes below are specific to Presence/Not Detected Surveys.

**Sampling Effort**

It may be difficult to detect birds at low densities. More effort may be needed to sample birds at low densities (i.e., increase the size of the area sampled and the time spent sampling per unit of area).

**Field Procedures**

- Observation / Call Playback Stations - All birds are recorded that can be identified from a station (unlimited radius).
- Transects - All birds are recorded that can be identified while travelling along a transect (even those found outside the fixed-width).

**Data Analysis**

- List the species present in the study areas surveyed.
- Plot the occurrence of a species using some map-based units. The size of the map unit depends on whether the habitat is coarse or fine grained with respect to the species' distributions. All map units should be surveyed at a consistent level.
- The analysis with presence/not detected data depends on the objective of the inventory effort. The table below highlights suggested analysis methods for the given RIC objectives.

**Table 6. RIC objectives and analysis methods for presence/not detected data.**

| RIC Objective | Analysis methods | Program |
|---|---|---|
| • Document species range | • Analysis to ensure adequate effort Negative binomial estimate[1] | • See RIC manual No.1, Section 5.2 |
| • Determine habitat associations | • Logistic regression | • Generic statistical analysis software |
| • Detect change in distribution over time | • Use relative abundance methods and regression techniques | • Generic statistical analysis software |

[1] See RIC manual No.1, Section 5, for more details on negative binomial methods.

*Quantifying probability of detection:* The main purpose of these methods is to document species geographic ranges. From a statistical point of view it is important to attempt to quantify the detection probability (as a function of population density, population spatial distribution, detection probability, sampling effort, and other covariates) for a species to allow a general estimate of the optimal amount of effort needed for surveys. Also, if an attempt is made to quantify probabilities of detection, a more statistically conclusive statement can be made about possible reasons for not detecting a species as opposed to a simple “none were found” conclusion. A simple way to estimate probability of detection is through the use of the negative binomial distribution with data from relative abundance surveys. This procedure is detailed in RIC manual No.1, Section 5.

*Documenting changes in species distributions:* If the objective is to detect changes in geographic distributions over time, a more intensive survey regime using relative abundance methods is recommended. This will allow a probability level to be associated with changes in distribution or apparent local extinction. A conclusion that species have become extinct in an area using presence/not detected methods will be difficult given that no estimate of survey precision is possible using current methods. More exactly, it will be difficult to determine if a species is not detected is due to lack of sample efficiency or actual demographic extinction.

*Documenting habitat associations:* If determining habitat associations is an objective, it will be important to document habitat types at the scale of waterfowl home ranges.

## 3.4 Relative Abundance

**Recommended method(s):** See Tables 2 and 3 for species-specific recommendations.

***Observation Stations*** - Relative Abundance for all stages of life cycles (see Tables 2 and 3). It is the preferred method for counting breeding pairs, and broods for all but the most conspicuous species (e.g., swans and geese).

***Helicopter Surveys*** - Relative Abundance for breeding pair counts brood counts, or incubating adults counts for the most conspicuous species (e.g., loons, swans and geese), or breeding pair and broods counts for dabbling ducks in remote areas.

***Boat Transects*** **-** Relative Abundance for non-breeding birds on the ocean and in large wetlands (e.g., lakes or rivers) or along shorelines. Boat transects are suitable for surveying flocks of moulting and wintering sea birds in defined areas (Savard 1982).

***Aerial Transects*** **-** Relative Abundance for detecting for breeding birds (swans, geese and Sandhill Crane), brooding ducks, and non-breeding bird counts on a large geographic scale.

***Ground Transects*** **-** Relative Abundance for detecting breeding pairs and broods of Sandhill Cranes, and for detecting non-breeding birds in wetlands for some species.

***Call Playbacks*** **-** Relative Abundance for breeding Pied-billed Grebes, and likely for other secretive waterbirds vocalizing during the breeding season. Other vocal and secretive, or at least sometimes hard to detect, waterfowl and allied species for which call playback might work include loons, Canada geese, American Coots, and Sandhill Cranes.

### 3.4.1 Overview of Methods

**Observation Stations**

Birds are detected by a stationary observer at each of several wetlands distributed throughout the project area. Wetlands may be chosen systematically, randomly, or randomly throughout stratified parts of the area. Usually the entire wetland is surveyed (this will vary with openness of habitat). If it is not possible to survey the whole wetland, then an adequate number of randomly or systematically placed, independent observation stations can be used to sample the wetland.

*Advantages:*

- Easier to locate wetlands randomly than lay out transect routes randomly;
- A well spaced sample of wetlands will provide more representative data than a few transects in fine-grained habitats;
- A stationary observer has more time to detect and identify birds that are cryptic; and
- Habitat data can be collected at the same time and then is easily associated with the occurrence of individual birds.

*Disadvantages:*

- Density of moving birds is overestimated in surveys where moving birds are included;
- Birds sensitive to observer will be flushed before they can be counted;
- More time-consuming than transects;
- If only part of the wetland is surveyed, relative density estimates of absolute abundance are susceptible to error arising from inaccurate distance estimation, although this can sometimes be corrected by plotting bird locations on airphotos or drawings of the wetland; and
- Relative abundance estimates can be influenced by the effect of differences in vegetation structure between sites on bird detectability.

**Transects**

Birds are detected along a continuous route through the study area. Transects are selected systematically, or randomly throughout stratified portions of the area. The amount of stratification necessary, if any, depends on the habitat diversity and the likelihood that birds will occur in different densities in different habitats. Transects are spaced to avoid recounting the same birds. An observer moves at a speed that enables detection of birds. The transect width must be measured to generate relative estimates.

The ability to see birds must be approximately equal for all portions of a transect and between transects. If this is not the case, then adjustments must be made for the varying ability to see birds in different parts of the transects. Width of sampling area may be divided into two or more zones. There is a trade-off between the number of transects and the length of the transect - numerous short transects offer a more diversified sample and few long transects are easier and more efficient to conduct. There is also a trade-off when considering the width of the transect. Wide transects cover more area and allow for a higher sampling intensity. However, this is offset by the fact that the probability of seeing a bird decreases as one approaches the edge of a wide transect.

Mode of transport along the transect depends on visibility and density of the birds as well as accessibility of the route. For example, an aerial transect is most effective and efficient when conspicuous birds are widely dispersed at low densities in areas that are inaccessible by road or boat.

*Advantages:*

- Most efficient way to gather data in large areas that are relatively uniform;
- Covers lots of ground in a fixed time;
- Generates large samples;
- Able to detect flushing birds as observer approaches;
- Less likely to double count individuals on aerial transects than by other survey methods because you move faster than the birds; and
- Area surveyed is linearly proportional to the lateral distance from the transect. Thus relative density estimates are less susceptible to error arising from inaccurate distance estimation than those calculated from point counts where the area surveyed is proportional to the square of the distance from the observation to the centre of the plot.

*Disadvantages:*

- Poor in small areas or fine-grained habitats;
- Constrained by accessibility depending on mode of transport (e.g., difficult to lay out transects randomly for ground surveys where accessibility is limited);
- Some birds conceal themselves from a moving observer; and
- Some birds in some habitats are difficult to detect when observer is moving.
- The visibility of a bird will tend to decrease with its distance from the transect. To compensate for this, complex estimates involving theoretical or empirical visibility rates can be used.

### Data Analysis for Relative Abundance

#### The main assumptions of relative abundance surveys are:

1. Identical or statistically comparable methods are used when comparison between areas or monitoring trends in one area over time is an objective of inventory effort.

2. Environmental, biological, and sampling factors are kept as constant as possible to minimize differences in survey bias and precision between surveys.

3. Surveys are independent; one survey does not influence another.

If these assumptions are met then each replicate survey should show (on average) the same relative bias allowing calculation of trends and comparison between areas.

However, each assumption should be scrutinized carefully when investigating the applicability of count-based methods, like point counts. Of particular importance is the assumption of equal bias between surveys. Factors such as variable weather and changes in observers can influence whether this assumption can be met.

The quantification of sampling intensity and effort is fundamental to the use of indices and relative abundance measures. This way the assumption of equally bias surveys between areas and over time can be met. In addition, the usefulness of indices depends on the precision of estimates. It is strongly recommend that power analysis procedures be integrated into the study design of all these techniques. As described in *Species Inventory Fundamentals*, manual No.1, Appendix G, programs such as MONITOR, POWER AND PRECISION, and NQUERY are user friendly, and can be easily used in an adaptive fashion to calculate sample sizes needed for the ultimate analysis questions.

If studies are designed appropriately the following general analysis methods can be used (Table 7).

**Table 7. RIC objectives and analysis methods for relative abundance data.**

| **Objective** | **Analysis method**[1] | **Programs**[2] |
|---|---|---|
| • Trends in abundance over time | • Sample methods<br>• Regression techniques<br>• Power analysis | • Generic statistical packages<br>• MONITOR |
| • Comparison in abundance between areas | • ANOVA, method<br>• Power analysis | • Generic statistical packages<br>• Power analysis software |
| • Determine whether habitat modifications have altered population size | • T-test method<br>• Power analysis | • Generic statistical packages<br>• Power analysis software |

[1]See manual No.1, Section 5, for more details on analysis techniques.
[2]See manual No.1, Appendix G, for more detail on software packages.

*Difficulties with count data:* One inherent problem with count data is that they are rarely normally distributed, which makes the application of parametric statistical methods risky, especially if sample sizes are low. Before data are used in parametric tests, the assumption of normality should be tested. Transformations may make frequencies nearly normal in some cases. For a detailed discussion of analysis of count data, see manual No. 1, *Species Inventory Fundamentals,* Section 5. White and Bennets (1996) introduce an alternative method for point count analysis and use songbird counts as an example of this analysis technique.

*Trend analysis:* The basic method for determination of trends is linear regression and associated techniques. There are a variety of refinements to linear regression that can be used with data depending on sampling assumptions and other characteristics of the data. Manual No.1, Section 5, provides a detailed discussion of these techniques.

*Comparison between areas:* Parametric tests and other methods can possibly be used to compare areas if surveys are conducted concurrently. If surveys are conducted non-concurrently (such as in different years), then the results might be biased by population fluctuations. See manual No.1, Section 5, for a thorough discussion of analysis of count data.

*Habitat based inference:* Logistic regression or similar methods can be used to test for habitat associations, but this approach requires that habitat units be the primary sample unit as opposed to population units.

### 3.4.2 Observation Stations

See Tables 2 and 3 for species-specific recommendations.

Relative Abundance for all stages of life. It is the preferred method for counting breeding pairs, and broods for all but the most conspicuous species (e.g., geese and swans). It can also be used to derive correction factors to improve the accuracy of aerial transect surveys of breeding, migrating, or wintering birds (e.g., as done in the annual waterfowl breeding population and habitat survey, USFWS and CWS, 1987).

Foot surveys allow observers to get closer to birds in areas that are not accessible by road, but birds are often more wary of a person on foot than of a vehicle (Summers, pers. comm.).

**Office Procedures**

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant maps of the project area (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate on topographic maps or air photos one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. Generally, a Study Area will be equivalent to a single wetland.
- Determine a suitable sampling design (see next section).
- Determine the number of the Study Areas (wetlands) to be surveyed (sample size).
- Identify shortest routes between observation stations.

**Sampling Design**

- A Project Area may contain one or many wetlands. Each wetland area is considered a Study Area. Generally, each Study Area should be small enough to be surveyed in one day.
- Depending on the size of the Project Area and number of wetlands (Study Areas) it contains, you may:
  - Survey all Study Areas (wetlands) in the Project Area, e.g. for a small, well-defined wetland (Study Area) such as an inlet or bay.
  - Survey only a selected number of the Study Areas (wetlands) in the Project Area. Note that the size of the wetland in each Study Area that is surveyed must be known, or
  - If appropriate, assign each Study Area into a stratum based on habitat type or expected bird densities, then select Study Areas (wetlands) from each stratum to be sampled. Note that the size of the wetland in each Study Area that is surveyed must be known.
- For each Study Area (wetland):
  - Place observation stations at one or more vantage points within each wetland so that entire wetland is surveyed.

- If it is not possible to survey the whole wetland, randomly or systematically place an adequate number of independent observations stations to sample the wetland. Random sampling plans, while producing statistically valid results are not always the most efficient. Further, they are often difficult to carry out in practice. Often systematic surveys with random starts should be considered. Care must be taken to devise a suitable sampling plan which minimizes the mean square error ($bias^2$ + variance) of the estimate. When sampling using observation stations:

    1. A maximum detection radius from the observation station must be set so that the sample area is of a standard, known size. Note that detection distance will vary among species, so detection radius should be set conservatively to allow all species to be counted as accurately as possible within the plot.

    2. Stations must be placed far enough apart so that each station can be considered an independent sample (this will avoid replication of counts).

**Sampling Effort**

- *Breeding Pair Counts:* Each wetland should be surveyed repeatedly during the appropriate daily survey window until required precision is obtained.
- *Brood Counts:* Each wetland should be surveyed every three days during the appropriate daily survey window until required precision is obtained.
- *Non-breeding Bird Counts:* Each wetland/field should be surveyed repeatedly until required precision is obtained.

Care must be taken during the counts to avoid biases as much as possible (e.g. consistent over or under counting). When biases are inherent in the counting *method*, no amount of additional sampling will remove them.

The use of alternating observers may help to average some *observer* biases. Ideally, if several observers are participating in each survey, they should rotate areas between surveys; otherwise, all sites should be surveyed by one observer during a given survey. The order in which basins are surveyed should be rotated between surveys.

**Time of Survey**

- *Breeding Pair Counts:* Crews should survey for breeding pairs after migrants have passed through the area and before males desert incubating females (these times will vary between species).
- *Brood Counts:* Crews should survey for broods after hatch (these times will vary between species).
- *Non-breeding Bird Counts:* Surveys of moulting, migrating and wintering birds should be timed according to the chronology of these events for each species (see Table 1).

**Personnel**

- Map reading, bird identification, and skills to estimate flock size accurately are essential.
- Crew size depends on the extent and thoroughness of the survey.

**Equipment**

- Vehicle, boots/chest-waders, if on foot

- Binoculars
- Spotting scope with window mount and tripod
- Maps and/or aerial photographs
- Night vision telescopes (with high power and high contrast)

**Field Procedures**

- Do not survey in rain, high winds, fog or any other conditions that reduce visibility.
- Survey the entire wetland (Study Area) or selected observation stations.

  1. Total Counts:

  - Observe birds from a vantage point (observation station) along the shoreline of the wetland with binoculars and a spotting scope.
  - Use as many observation stations as necessary to cover the entire wetland.
  - Count by species, all the birds on the entire wetland.

  2. Sample Counts:

  - Observe birds from randomly or systematically placed observation stations along the shoreline of the wetland with binoculars and a spotting scope.
  - Use as many observation stations as necessary to get an adequate sample of the wetland. Stations must be far enough apart so that each station can be considered an independent sample.
  - Count by species, all the birds that are within the predetermined detection radius from the observation station. Birds outside this radius will be counted on a presence/not detected basis only.
- Counting:
  - *Breeding Pair Counts* - Record the number of pairs, lone males, and males in groups noting the number of males in each separate group.
  - *Brood Counts* - Record the number of ducklings and age class of each brood using the system devised by Gollop and Marshall (1954).
  - *Non-breeding Bird Counts* - Record all birds in the surveyed area of the wetland, recording the number of birds in each sex and age class.
  - Count slowly to see diving and resurfacing birds.
  - On each visit count at least three times and record the largest value. This is considered one replicate survey for the wetland.
  - If vegetation obscures part of the area, indicate the proportion of the wetland surveyed (if doing total counts).
- Record wetland characteristics including water level, extent of emergent vegetation and state of surrounding habitat.

**Data Entry**

The Design Components for this survey are observation stations. When digitally entering your survey data, choose ‘Station’ from the ‘Design Component Type’ picklist.

**Data Analysis**

For each Study Area or wetland:

1. If total counts are used:

- *Trends in abundance over time.* Calculate the number of breeding pairs or broods or non-breeding birds (depending on survey type) of each species per wetland at a given time.
  - Each bird count survey of a wetland on a given day is one replicate (all birds counted at all observation stations are summed).
  - Sum the number of birds counted at each replicate survey at a wetland by species, then divide by the number of replicate surveys (birds by species/wetland).
  - Precision is calculated as the square root of the variance around the mean of replicate counts.
- *Comparison of abundance estimates between areas.* Calculate abundance estimates for each wetland by dividing the number of birds by species per wetland by the area of the wetland that was sampled (birds/km$^2$).

2. If sample counts are used:

- *Trends in abundance over time.* Calculate the mean number of birds/station at a given time. Sum the number of each species seen or heard within the set radius from the observation station for all of the stations, then divide by the number of stations sampled.
- *Comparison of abundance estimates between areas*. Calculate birds/km$^2$: divide the mean number of birds/station by the area of the observation sample station.

### 3.4.3 Helicopter Surveys

Relative Abundance in remote or inaccessible areas for any species, but especially for breeding pair counts, brood counts, and incubating adults for the most conspicuous species (e.g., geese and swans), or breeding pair and brood counts for loons and dabbling ducks.

Helicopters are recommended to survey breeding pairs and broods in locations inaccessible by road (e.g., Boreal Forest, northwest BC). Generally, the lower flight speed of and better visibility from helicopters than fixed-wing aircraft improve the ability of observers to detect birds (Ross 1985).

Counts by helicopters or from the ground over smaller portions of the study area can be used to derive correction factors for aerial transect surveys.

Estimates are very sensitive to viewing angle, altitude, glare and flight speed therefore it is important to conduct surveys consistently (Caughley 1974; Briggs *et al.* 1985).

*Example:* Nixon and Majiski (1991) conducted breeding pair surveys in boreal forest wetlands with low waterfowl densities in the Liard Plain and Teslin River Basin. Wetlands were stratified on 1:50,000 topographical maps into three size classes (<1.5 hectares, 1.5-15 hectares and 15-300 hectares). Larger lakes were excluded because it was not feasible to obtain an accurate count. A sample of wetlands within each size class was chosen randomly but most distant wetlands were omitted due to limited time available for the survey. Observers sampled each wetland by circling it in a helicopter. The helicopter would hover while they recorded the number of birds and wetland characteristics. Counts at each wetland were repeated four times at six day intervals starting in mid- to late- May to ensure an accurate estimate of the number of breeding pairs (McKelvey 1989). The mean number of breeding pairs for each species was calculated using the four repeated surveys for each wetland. The relative abundance of breeding pairs was calculated from stratified samples. The results were used to estimate the density of breeding pairs within the entire Liard Plain and Teslin River Basin region. Stratifying by wetland size did not increase the precision of the population estimates because the sample sizes were too small (9 to 30 in each strata). It may have been better to survey more wetlands in each strata and do fewer replicate counts at each wetland.

**Office Procedures**

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant maps of the project area (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate on topographic maps or air photos one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. Generally, a Study Area will be equivalent to a single wetland.
- Determine a suitable sampling design (see next section).
- Determine the number of the Study Areas (wetlands) to be surveyed (sample size).

**Sampling Design**

- A Project Area may contain one or many wetlands. Each wetland area is considered a Study Area. Each Study Area should be able to be surveyed in one day.
- Depending on the size of the Project Area and number of wetlands (Study Areas) it contains, you may:
  - Survey all Study Areas (wetlands) in the Project Area, e.g. for a defined wetland (Study Area) such as an inlet or bay.
  - Survey only a selected number of the Study Areas (wetlands) in the Project Area. Note that the size of the wetland in each Study area that is surveyed must be known, or
  - If appropriate, assign each Study Area into a stratum based on habitat type or expected bird densities, then select Study Areas (wetlands) from each stratum to be sampled. Note that the size of the wetland in each Study Area that is surveyed must be known.
- For each Study Area (wetland) conduct a total count of birds by species.

**Sampling Effort**

- *Breeding Pair Counts*: Each wetland should be surveyed repeatedly during the appropriate daily survey window until required precision is obtained.
- *Brood Counts*: Each wetland should be surveyed every three days during the appropriate daily survey window until required precision is obtained.
- *Non-breeding Bird Counts*: Each wetland/field should be surveyed repeatedly until required precision is obtained.

Care must be taken during the counts to avoid biases as much as possible (e.g. consistent over or under counting). When biases are inherent in the counting *method*, no amount of additional sampling will remove them.

The use of alternating observers may help to average some *observer* biases. Ideally, if several observers are participating in each survey, they should rotate areas between surveys; otherwise, all sites should be surveyed by one observer during a given survey. The order in which basins are surveyed should be rotated between surveys.

**Time of Survey**

- *Breeding Pair Counts*: Crews should survey for breeding pairs after migrants have passed through the area and before males desert incubating females (these times will vary between species).
- *Brood Counts:* Crews should survey for broods after hatch (these times will vary between species).
- *Non-breeding Bird Counts*: Surveys of moulting, migrating and wintering birds should be timed according to the chronology of these events for each species (see Table 1).

**Personnel**

- A pilot with previous aerial survey experience, preferably in the project area. Pilots with no previous survey experience should receive a training flight on a portion of the project area.
- Two highly trained experienced observers with recent practice at estimating numbers.

**Equipment**

- Helicopter (refer to Simpson *et al.* 1993 for logistical and financial considerations in choosing appropriate aircraft)
- Topographic maps (1:20,000 or 1:50,000) for the study area
- 1:5000 air photo maps
- Navigational system (GPS NAD83)
- Tape recorders for each observer, extra tape cassettes and extra batteries
- Intercom and headsets
- Binoculars
- Personal gear including watch, ear plugs, anti-air-sickness devices, warm clothing, sunglasses
- Survival gear
- Window-cleaning rag

**Field Procedures**

***Breeding Pair Counts and Brood Counts***

- Do not survey in rain, high winds, fog or any other conditions that reduce visibility.
- Record numbers of birds on tape-recorders.
- Count by species, all the birds on the entire wetland.
  - *Breeding Bird Counts* - Record the number of pairs, lone males, and males in groups, noting the number of males in each group.
  - *Brood Counts* - Record the number of ducklings and age class of each brood using the system devised by Gollop and Marshall (1954).
  - If vegetation obscures part of the area, indicate the proportion of the wetland surveyed.
- Do not survey more than seven hours per day and take breaks to avoid observer fatigue.

**Data Entry**

- The Design Component for this survey is a block/polygon that contains essentially the entire wetland being surveyed. When digitally entering the survey data, choose ‘Block’ from the ‘Design Component Type’ picklist.

**Data Analysis**

For each Study Area or wetland:

- Calculate the number of breeding pairs or broods or non-breeding birds (depending on survey type) of each species per wetland at a given time.
  - Each bird count survey of a wetland on a given day is one replicate.
  - Sum the number of birds counted at each replicate survey at a wetland by species, then divide by the number of replicate surveys (birds by species/wetland).
  - Precision is calculated as the square root of the variance around the mean of replicate counts.
- Calculate abundance estimates for each wetland by dividing the number of birds by species per wetland by the area of the wetland that was sampled (birds/$km^2$).

### 3.4.4 Transects

See Tables 2 and 3 for species-specific recommendations.

***Ground Transects*** **-** Relative Abundance for detecting breeding pairs and broods of Sandhill Cranes and for detecting non-breeding birds in wetlands for some species.

***Boat Transects*** - Relative Abundance for detecting non-breeding birds on the ocean and in large wetlands (e.g., lakes or rivers) or along shorelines. Boat transects are suitable for surveying flocks of moulting and wintering sea birds in defined areas (Savard 1982). Birds may be counted from a motorboat, airboat, kayak or canoe.

***Aerial Transects*** **-** Relative Abundance for detecting breeding birds (geese, swans and Sandhill Crane), brooding ducks, and non-breeding bird counts breeding bird counts on a large geographic scale.

**Office Procedures**

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant maps of the project area (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate on topographic maps or air photos one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. Generally, a Study Area will be equivalent to a single wetland.
- Aerial: Observers should practice counting birds from the air using computer simulations.

**Sampling Design**

- Stratify habitat, if appropriate, based on expected bird densities (e.g., low, medium, high). Select transect start points from the strata or areas along shoreline - identify start and stop points.
- Transects must have a fixed-width so that relative abundance can be determined.
- Transect length should be determined such that a minimum of 40 birds of each species of interest will be recorded along it (Bibby *et al.* 1992).
- Space transects to avoid recounting the same birds (at least 250m apart in open habitats, Briggs *et al.* 1985). This ensures that each transect is an independent sample.
- Identify shortest routes between samples and refuelling stops.

**Sampling Effort**

- Where practical, transects should be repeated every few days until required precision is obtained.

- Care must be taken during the counts to avoid biases as much as possible (e.g. consistent over or under counting). When biases are inherent in the counting *method*, no amount of additional sampling will remove them.
- The use of alternating observers may help to average some *observer* biases. Ideally, if several observers are participating in each survey, they should rotate areas between surveys; otherwise, all sites should be surveyed by the same observer during each survey. The order in which basins are surveyed should be rotated between surveys.

**Time of Survey**

- Choose time of day and tidal height when birds are most likely to be in open habitats (e.g., 3.4 m (11 foot) tide for aerial surveys in the Fraser River delta, McKelvey *et al.* 1985).
- Aerial - Conduct surveys from two hours after sunrise to two hours before sunset to avoid contrasting and confusing shadows.
- *Non-breeding Birds:* Surveys of moulting, migrating and wintering birds should be timed according to the chronology of these events for each species (see Table 1).
- *Breeding Pairs and Broods:* Aerial surveys of breeding birds (geese and swans) should be timed according to the chronology of these events for each species (see Table 1).

**Personnel**

- Highly trained observers with experience estimating numbers of birds on the water.
- Bird identification and chart/map reading skills.
- Qualified boat operator
- Aerial
  - A pilot with previous aerial survey experience, preferably in the study area. Pilots with no previous survey experience should receive a training flight on a portion of the study area.
  - Two highly trained experienced observers with recent practice at estimating numbers.

**Equipment - Ground**

- Vehicle, boots/chest-waders
- Binoculars
- Spotting scope with window mount and tripod
- Maps and/or aerial photographs
- Night vision telescopes (with high power and high contrast)

**Equipment - Boat**

- Surveys at sea - A boat and motor that is suitable for rough ocean water and allows observers to stand at least 5 m above water at eye level.
- Wetlands - Birds may be counted from a motorboat, airboat, kayak or canoe.
- Navigational equipment (e.g., LORAN-C)
- Binoculars
- Charts/maps/aerial photographs
- Split image range-finder

**Equipment - Aerial**

- Aircraft - helicopter/fixed-wing (refer to Simpson *et al.* 1993 for logistical and financial considerations in choosing appropriate aircraft)
- Topographic maps (1:20,000 or 1:50,000) for the Study Area
- 1:5000 air photo maps
- Navigational system (GPS NAD83)
- Tape recorders for each observer, extra tape cassettes and extra batteries
- Intercom and headsets
- Binoculars
- Personal gear including watch, ear plugs, anti-air-sickness devices, warm clothing, sunglasses
- Survival gear
- Window-cleaning rag

**Field Procedures - Ground**

***Non-breeding Bird Counts***

- Observe birds by walking a transect with binoculars and a spotting scope along the shoreline.
- Count all birds along the transects and record the number of birds in each sex and age class.
- Count slowly to see diving and resurfacing birds.
- Estimate the area of the wetland covered by the fixed-width transects.

**Field Procedures - Boat**

***Non-breeding Bird Counts***

- Record start and stop points of each transect (relative to NAD83).
- Travel at 20 km/h along each transect.
- Two observers scan strips 150 m on each side of the boat (total fixed-width of transect is 300 m).
- Count birds within two distance zones (0-50 m and 51-150 m).
- Lateral boundaries can be estimated with a split image range-finder.
- Only count birds that are on the water and taking off from the water (not flying).
- Record the birds by sex and age class.

**Field Procedures - Aerial**

***Breeding (swans & geese) and Non-breeding Bird Counts***

- Do not survey more than seven hours per day and take breaks to avoid observer fatigue.

- Mark airplane struts at measured distance from the body of the plane to ensure sampling the intended strip width. Use two markers, to account for the range of heights you are likely to fly. For ocean coastline surveys, where the objective is to record all birds in littoral waters (which can vary in width), a transect width is not required.
- Recommended strip width is between 50 and 100 m on each side of the aircraft with one observer seated on each side.
- Fly transects at 135-180 km/h (70-90 knots) approximately 30 to 50 m (100-150 feet) above ground or water. Over open water with low bird densities (e.g. marine habitats), the higher speeds enable more area coverage.
- Record using tape-recorders the numbers of birds flown over within the fixed-width.
- Record species and numbers, and where possible characteristics of birds (e.g., age, sex, plumage, behaviour, group size).
- Transfer data to dataforms immediately after survey is finished.

**Data Entry**

- The Design Component for this survey is transects. When digitally entering the survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist.

**Data Analysis**

- Calculate mean counts for replicate transects (where replicates are possible). Precision is calculated as the square root of the variance around the mean for replicate transects within each strata.
- <u>Relative abundance</u> can be expressed as:
  - Total estimated counts: total number of birds in all the transect sections within a certain location are summed together to give the relative abundance of birds in an area at a given time.
  - Birds in an area: Birds/km$^2$ (divide the number of birds observed by the area surveyed in transect of fixed length and width)
  - Birds per kilometre of survey route (Birds/km)
- Long term annual trends may be analyzed using route-regression analysis (Geissler and Noon 1981, Dickson 1989) although further research may reveal a more appropriate method (Thomas pers. comm.).
- The following strategies should be used if the data are to be used for monitoring of trends:
  - Surveys should be replicated on sequential mornings as discussed previously. This data should be used for power analysis to ensure that sample sizes are adequate to document hypothesized population trends or compare hypothesized differences between areas. See *Species Inventory Fundamentals* manual (Appendix G) for more details on power analysis. In addition standard errors, and coefficients of variation for relative abundance measures should be reported to allow evaluation of the repeatability of measurements.
  - It can be argued that non-replicated transects do not give that much information about the target populations for it is impossible to separate sampling variance from actual variance in population size due to actual biological trends.
  - The analysis of count data requires specialized statistical techniques. See *Species Inventory Fundamentals* manual (Section 5.3) for more details.

### 3.4.5 Call Playback

Relative Abundance for Pied-billed Grebes, coots and other birds that vocalize during the courtship or territorial phase of breeding.

Call playbacks are suitable for detecting secretive breeding species like Pied-billed Grebes (Gibbs and Melvin 1993) which call to establish and defend territories and attract mates. A call playback mimics the presence of an intruder in the territory and results in a vocal or visual display. Relative abundance can be determined if surveys are conducted using a consistent method (consistent bias) and frequently enough to ensure precision. Call playbacks can improve the efficiency and accuracy of nest counts. They are unlikely to work at times of the year when birds are not territorial.

*Advantages:*

- Improves accuracy in counting secretive birds (Gibbs and Melvin 1993).

*Disadvantages:*

- Time consuming;
- May disturb birds;
- Many species do not respond to calls;
- The relationship between the number of calling or responding birds and the actual breeding population is unknown;
- Call playback does not sufficiently sample females or young in a population, therefore it only provides an index of a breeding population; and
- The use of tapes and broadcast equipment introduces an additional source of variation (i.e., in addition to observers, weather etc.).

**Office Procedures**

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant maps of the project area (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate on topographic maps or air photos one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. Generally, a Study Area will be equivalent to a single wetland. Generally, establish Study Areas by stratifying habitat based on expected bird densities (e.g., low, medium, high). Eliminate habitats which are not feasible to survey from the ground (e.g., large lakes).
- Select wetlands from the strata.
- Identify shortest routes between samples (wetlands).

- For each Study Area:
  - Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for areas surrounding the wetland. Determine wetland type using the Riparian Management Area Guidebook (B.C. Min. Environ. and For. Serv. 1995) as a general reference.
  - Identify access points and potential call playback stations for surveys from large scale, colour aerial photographs.
- Prepare a survey tape of the target species' calls.
- Tapes should include, for each species, three series of 20 seconds of calls (c) followed by 30 seconds of silence (s), (except after the last call in a sequence, which should have one minute of silence before the next species), [sequence 20(c1)-30(s1)-20(c1)-30(s1)-20(c1)-60(s1)-20(c2)-30(s2)-etc.]. Each species can be recorded consecutively on one tape. (If you are recording from a commercial CD or tape, do not include the announcement of the species!)
- For comparable results, broadcast tapes should be identical in terms of duration, sequence and quality of calls. Some birds will reply to calls of other species, as well as conspecifics, and so whether they are first or last on the tape will influence the duration of time available for a response. Although it has not been well explored, it is also possible that loud calls may suppress calling of quieter species. It is probably best to be conservative and play calls from quietest species to loudest.
- Tapes degrade with exposure and should be replaced at least once per field season.
- Test the call playback equipment to ensure that it works (see Call Playback Equipment section below). Measure the distance that sounds will be broadcast to determine the area that can be sampled from each broadcast point.

**Sampling Design**

- Random sampling of wetlands, stratified by habitat type if appropriate.
- Randomly choose Study Areas to be surveyed from each of the different strata. The objective here is to strike a balance between maximizing species detections and surveying a sample of habitats which are representative of the Project Area (Gibbs and Melvin 1993).
- For each Study Area, establish Call Playback Stations systematically, either throughout (full plot) or along the edges (half plot) of the habitat(s) of interest.
- A maximum detection radius from the center of the call playback station must be set between 50 and 500 m. Detection distance will vary among species, with most species responding within 100 m and only a few species responding at 500 m. Birds outside the set radius are noted on a presence/not detected basis only. This helps maintain a constant sampling effort and allows for the area surveyed to be standardized.
- Stations should be placed far enough apart so that each station can be considered an independent sample (this will avoid replication of counts), but close enough to ensure proper coverage of the area. Gibbs and Melvin (1993) noted that mean detection distance varied among species with the Pied-billed grebes being detected at up to 500 m.

**Sampling Effort**

- Each Call Playback Station must be visited at least three times during the peak of the breeding season. To ensure sufficient coverage throughout the breeding season, survey visits should be separated by a minimum of 10 days.

**Time of Survey**

- Survey for territorial pairs after migrants have passed through the area and before egg-laying begins (time will vary between species).

**Personnel**

- Crew size depends on the extent and thoroughness of the survey.
- Map reading and bird identification by sound are essential.
- At least one person should be familiar with the collection of habitat data. This will require someone who is familiar with wetland plants and wetland classification.

**Equipment**

- Several copies of appropriate forms for habitat description (see *Species Inventory Fundamentals No. 1*)
- Nest Site Description Forms (used if you find nests during your surveys; these forms and the guidelines for completing them are in the *Species Inventory Fundamentals No. 1* [Forms])
- Vehicle
- Boots/chest-waders if on foot
- Binoculars
- Spotting scope with tripod
- Maps and/or aerial photographs
- Extra batteries
- Call playback equipment. Cassette player and speakers that will broadcast sounds 400m (frequency 40 Hz to 12 kHz, power output of 1.2 watts at 1 kHz), (waterproofing the equipment may be a good idea).

*Call Playback Equipment*

The broadcast of each species' calls should be heard by birds the distance the radius is set at from the point of broadcast. Gibbs and Melvin (1993) utilized a standard maximum sound pressure of 80 dB at one metre from the source to project 100 m. A cruder means of assessing sound level is to subjectively evaluate the sound level at the set distance from the speaker, but there is no way of assuring that you will be hearing what the birds will be hearing. A small portable tape player with two speakers (i.e., a portable stereo) should be sufficient for the purpose of these surveys. An alternative is to use a walkman attached to an amplified speaker. Describe whatever equipment is used by brand name, model name, and power of sound output (these specifications can be found in the owner's manual or from the dealer). Play calls at a maximum volume where there is minimal tape-noise in the background. This usually seems to be a step below maximum output. To keep your hands free during the survey you may want to attach the tape player and speaker to a strap and hang them around your neck.

**Field Procedures**

- Do not survey in wind, rain, fog or any other conditions that would reduce sound transmission or visibility.

- Do nothing for the first two minutes at the station. Give yourself and your surroundings time to settle down now that you have stopped moving. Use this time to listen for any unsolicited calls. Note all locations of calling birds, or birds that you may see within the plot. List the birds outside of the study plot as incidental sightings. Also take this time to record the start time, temperature, cloud cover, wind, etc.
- Hold the speaker at chest height. Broadcast a species' call for 20 seconds, then listen and watch for 30 seconds. Play a series of three calls for each call type. For a full circular plot, broadcast the three calls at $60^0$, $180^0$ and at $300^0$ from your line of travel (this means rotating the speaker 120º after each 20 seconds of call of each species). For a half plot (standing on the edge of a wetland), broadcast the calls at $45^0$, $90^0$ and $135^0$ from the straight edge of the half plot. When a response is elicited, record the approximate location and the sex of the bird on a map of the wetland.
- Wait one minute before playing the series of calls for the next species. Repeat the procedure as above. Ideally, the surveyor should complete call playbacks for the species within the 10 minute visit to the plot, leaving two minutes before the end of the survey to listen for calls. This gives enough time to play calls for up to three different species (not including the initial two minute wait before starting broadcasts).
- Be conservative when counting response. Unless they are simultaneous calls, two responses from approximately the same location should be counted as only one individual.
- Due to potential observer bias and variability, rotate observers among stations to ensure that species are not overlooked or misidentified.

**Data Entry**

- The Design Component for this survey is call playback stations. When digitally entering the survey data, choose 'Station' from the 'Design Component Type' picklist.

**Data Analysis**

- Note that call playback does not sufficiently sample females or young in a population, therefore it only provides an index of a breeding population.
- The standard measure of abundance will be the number of each species seen or heard within the set radius from the centre (station) of the sample plot. (Birds outside of the set radius will be counted on a present/not detected basis.)
- The relative abundance of breeding birds for a given wetland can be given as the mean number of birds per station or mean number of birds per area of the sample plot.
- In the report, include a list of all species detected in the Study Area. Include incidental observations, and a measure of survey effort wherever possible.

## 3.5 Absolute Abundance

Note that a measurement of Absolute Abundance may only account for a specific segment of a population. For example, if the objective is breeding pairs, separate abundance calculations will have to be made for pairs and for other birds recorded. Similarly, if nests are being surveyed, the result will give nest abundance but will not account for birds in the study area that did not build nests.

Note also that results from these methods can be considered estimates of total abundance only if all biases have been eliminated. If this is not the case, then the survey will measure relative rather than absolute abundance. Biases that can not be eliminated should be measured (usually with more survey effort) so that counts can be corrected.

**Recommended method(s):** See Tables 2 and 3 for species-specific recommendations.

***Observation Stations*** **-** Absolute Abundance for all stages of life cycles. It is the preferred method for counting breeding pairs, nests, and broods for all but the most conspicuous waterfowl species (e.g., geese and swans).

***Helicopter Surveys*** **-** Absolute Abundance for breeding pair counts / brood counts for the most conspicuous species (e.g., loons, geese, swans) and when necessary for dabbling ducks in large, inaccessible areas.

***Ground Transects*** **-** Absolute Abundance for non-breeding bird counts, particularly where 100% coverage can be achieved from roads or trails.

***Boat Transects at sea*** **-** Absolute Abundance for detecting non-breeding birds on the ocean and in large wetlands (e.g., lakes or rivers) or along shorelines. Boat transects are suitable for surveying flocks of moulting and wintering sea birds in defined areas (Savard 1982). However, for large and/or dense flocks of birds, boat surveys may yield a count or estimate with a large error.

To achieve absolute abundance, a boat transect must systematically cover an area of interest so as to record all birds or to sample a known proportion of the area. It is most useful in relatively small, well defined areas. If the area being surveyed is along a shoreline, only one transect is required.

***Aerial Transects*** **-** Absolute abundance for swans: breeding pairs, incubating birds, or broods in open habitat. Transects must have a known width so that densities can be calculated.

***Nest Counts*** **-** Absolute Abundance for almost all breeding waterbirds (except ducks). Nest Counts may be conducted using chestwaders or a canoe to search for nests of species that nest over water. These counts are also used for surveying upland ducks breeding in open habitat in confined areas.

***Aerial Photographs*** **-** Absolute Abundance for concentrated non-breeding flocks of large bird species that contrast with their background (swans and B-SNGO).

***Mark-resight/recapture*** **-** Absolute Abundance for non-breeding birds (swans, geese, and Sandhill Cranes). This method is useful only for very specialized kinds of surveys.

### 3.5.1 Observation Stations

See Tables 2 and 3 for species-specific recommendations. Absolute Abundance can be obtained for all stages of life cycles. It is the preferred method for counting breeding pairs, nests, and broods for all but the most conspicuous waterfowl species (e.g., geese and swans).

The close proximity of an observer to the birds means that ground surveys are the most accurate technique for counting birds, especially breeding birds which are more difficult to detect (because they occur at relatively low densities on wetlands partly covered in emergent vegetation). Therefore, with enough time and effort, ground surveys can be used to obtain estimates of absolute abundance. If absolute abundance is the objective, the observer must be confident that enough stations have been used to obtain either complete coverage or enough samples to enable a reasonably accurate extrapolation to account for birds in the unsampled areas.

**Protocols**

*****These techniques are also used for relative abundance surveys. Only differences from the relative abundance survey are listed here. For details on how to conduct this type of survey see section 3.4.2.

**Sampling Design**

- For Absolute Abundance surveys, both the area of the wetlands sampled and the Study Area size must be known. Note that these surveys can only be considered estimates of total abundance if all biases have been eliminated. Biases that can not be eliminated should be measured (usually with more survey effort) and used to correct counts.
- See section 3.4.2, Sampling Design, for remainder of protocol.

**Data Analysis**

For each Study Area or wetland:

- Total counts:
  - Each bird count survey of a wetland on a given day is one replicate (all birds counted at all observation stations are summed).
  - Calculate the number of non-breeding pairs/breeding pairs (depending on survey type) of each species per wetland by summing the number of birds counted at each replicate survey at a wetland by species, then dividing by the number of replicate surveys.
  - Precision is calculated as the square root of the variance around the mean of replicate counts.
  - Calculate birds/km$^2$: divide the mean number of birds/wetland by the area of the wetland.
- Sample counts:
  - Calculate the mean number of birds/station: sum the number of each species seen or heard within the set radius from the observation station for all of the stations, then divide by the number of stations sampled.
  - Calculate birds/km$^2$: divide the mean number of birds/station by the area of the observation sample station.

- Extrapolate the density of birds/km$^2$ determined for a station to the wetland. Calculate the density of breeding pairs of each species per wetland area by dividing the total area of interest by the area sampled. These can be considered estimates of total abundance if all biases have been eliminated. Biases that can not be eliminated should be measured (usually with more survey effort) and used to correct counts.

### 3.5.2 Helicopter Surveys

Absolute Abundance for breeding pair counts / brood counts for the most conspicuous species (e.g., loons, geese, swans) and when necessary for dabbling ducks in large, inaccessible areas.

Detection of birds from the air is relatively poor and counts are inaccurate except for large conspicuous birds at medium densities, e.g., breeding swans and geese. Therefore, air surveys are suitable for absolute abundance estimates for these species only. Counts from helicopters are much more accurate than those from fixed-wing aircraft. Surveys from fixed wing aircraft should not be used to collect data to estimate indices of absolute abundance. Estimates are very sensitive to transect width, altitude, glare and flight speed therefore it is important to conduct surveys consistently.

**Protocols**

This technique is also used for relative abundance surveys. Only differences from the relative abundance survey are listed here. For details on how to conduct this type of survey see section 3.4.3.

**Sampling Design**

- For Absolute Abundance surveys, both the area of the wetlands sampled and the Study Area size must be known. Note that these surveys can only be considered estimates of total abundance if all biases have been eliminated. Biases that can not be eliminated should be measured (usually with more survey effort) and used to correct counts.
- See section 3.4.3, Sampling Design, for remainder of protocol.

**Data Analysis**

Total count for each Study Area or wetland:

- Each bird count survey of a wetland on a given day is one replicate.
- Calculate the number of non-breeding pairs/breeding pairs (depending on survey type) of each species per wetland by summing the number of birds counted at each replicate survey at a wetland by species, then dividing by the number of replicate surveys.
- Precision is calculated as the square root of the variance around the mean of replicate counts.
- Calculate birds/km$^2$: divide the mean number of birds/wetland by the area of the wetland.

*Example:* Nixon and Majiski (1991) conducted breeding pair surveys in boreal forest wetlands with low waterfowl densities in the Liard Plain and Teslin River Basin. Wetlands were stratified on 1:50,000 topographical maps into three size classes (<1.5 hectares, 1.5-15 hectares and 15-300 hectares). Larger lakes were excluded because it was not feasible to obtain an accurate count. A sample of wetlands within each size class was chosen randomly but most distant wetlands were omitted due to limited time available for the survey. Observers sampled each wetland by circling it in a helicopter. The helicopter would hover while they recorded the number of birds and wetland characteristics. Counts at each wetland were repeated four times at six day intervals starting in mid- to late- May to ensure an accurate estimate of the number of breeding pairs (McKelvey 1989). The mean number of breeding pairs for each species was calculated using the four repeated surveys for each wetland. The density of breeding pairs was calculated from stratified samples. The results were used to estimate the population of breeding pairs within the entire Liard Plain and Teslin River Basin region. Stratifying by wetland size did not increase the precision of the population estimates because the sample sizes were too small (9 to 30 in each strata). It may have been better to survey more wetlands in each strata and do fewer replicate counts at each wetland.

## 3.5.3 Transects

See Tables 2 and 3 for species-specific recommendations.

***Ground transects*** **-** Absolute Abundance for detecting breeding pairs and broods (Sandhill Cranes), and for sampling non-breeding birds in wetlands (some species).

***Boat Transects at sea*** **-** Boat transects are suitable for determining Absolute Abundance when surveying flocks of moulting and wintering sea birds in defined areas such as bays or inlets, (Savard 1982). If absolute abundance estimates of larger areas are being attempted, transects must sample a known proportion of the study area.

***Aerial Transects*** **-** Absolute abundance for swans: breeding pairs, incubating birds, or broods in open habitat. Care must be taken to survey transects of a known fixed width so that densities can be calculated.

**Protocols**

These techniques are also used for relative abundance surveys. Only differences from the relative abundance survey are listed here. For details on how to conduct this type of survey see section 3.4.3.

**Sampling Design**

- For Absolute Abundance surveys, counts must be done in a known area, and must sample a known proportion of that area. Note that these surveys can only be considered estimates of total abundance if all biases have been eliminated. Biases that can not be eliminated should be measured (usually with more survey effort) and used to correct counts.
- *Non-breeding Birds:* Use fixed-width, known-length transects in an area of known size.

**Data Analysis**

- Precision is calculated as the square root of the variance around the mean for replicate transects within each strata.
- Long term annual trends may be analyzed using route-regression analysis (Geissler and Noon 1981, Dickson 1989) although further research may reveal a more appropriate method (Thomas pers. comm.).
- Density estimates may be calculated by dividing the number of birds observed by the area surveyed in transects of fixed length and width. Total abundance can be calculated by multiplying the density estimates by the size of the study area. These densities can be used to calculate total abundance only if all biases have been eliminated or corrected for with a more intensive measure.

*Example:*
As part of a larger study to determine the distribution of birds in habitats around Boundary Bay and to estimate the amount of land required to support the current populations of birds, Breault and Butler (1992) used direct counting to estimate the absolute abundance of American Wigeons, Mallards and Northern Pintails on farmlands in the Lower Fraser River delta. Telemetry studies had shown that birds of these species found in Boundary Bay,

Roberts Bank and Sturgeon Bank spent at least a part of every 24 h period in the fields between early November and late March. They counted the number of birds in roadside farmlands from a vehicle driven along the transect survey route one day each week when the tide was high. The open habitat enabled them to count birds in the entire field from viewpoints along the road. They counted the number of birds along the dykes at high tide once each month to estimate the numbers of ducks on Roberts Bank and Sturgeon Bank. Each duck was counted in flocks with fewer than 400 ducks and larger flocks were counted by summing the number of groupings of 100 birds. They calculated the estimated error of their flock size counts by counting the same birds several times. The area of the sampled habitat was determined from satellite images. The numbers of ducks in farmlands during the day was estimated by assuming that the density of ducks in the areas not sampled was the same as the density in the sampled farmland.

### 3.5.4 Nest Counts

See Tables 2 and 3 for species-specific recommendations. Absolute abundance can be obtained for almost all breeding waterbirds (except ducks) by conducting nest counts. The proportion of the area searched must be measured on the ground or from maps or airphotos, if less than 100%.

***Ground transects*** - for detecting nests of upland ducks breeding in open habitat in confined areas. Dragging a chain or rope between two tractors or two people on foot over nesting habitat flushes incubating birds and reveals the location of nests (Higgins *et al*. 1969). Care must be taken to ensure the chain is sufficiently light, or suspended far enough above the ground to prevent damage to nests.

***Foot Searches in Wetlands*** - Searching by wading on foot through the emergent vegetation of the wetland along the shoreline (possibly using chestwaders) is recommended for wet areas.

***Boat Searches in Wetlands*** - used when conducting nest counts for species that nest over water. For deeper wetlands, shorelines may be searched using a canoe for transport.

***Helicopter Surveys*** - In wetlands of known size, do complete searches for incubating birds of conspicuous species which nest in locations visible from the air (e.g., swans). See section 3.5.2 for protocol.

***Aerial Transects*** - Aerial transects by helicopter are conducted for incubating swans or other very conspicuous, widely dispersed birds nesting in open habitat. See section 3.5.3 for protocol.

*Advantages*

- Improves chances of detecting nests in cover.

*Disadvantages*

- May disturb incubating birds and cause abandonment of nests or increase predation;
- Time consuming;
- Difficult to cover representative areas; therefore, biased to surveying most accessible areas; and
- Nests of many species are often concealed and easily missed.

**Office Procedures**

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area.

For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area. Generally, a Study Area will be equivalent to a single wetland.

- For each Study Area:
    - Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for areas surrounding the wetland.

**Sampling Design**

- For Absolute Abundance surveys, both the area of the wetland sampled and the Study Area size must be known. Note that these surveys can only be considered estimates of total abundance if all biases have been eliminated. Biases that can not be eliminated should be measured (usually with more survey effort) and used to correct counts.
- If appropriate, wetlands may first be stratified by habitat type.
- Survey systematically. Conduct total counts of defined areas following a grid pattern or otherwise ensuring complete coverage.
    - If sampling along a transect, use a fixed width narrow enough that nests will not be missed.
    - For ground/water transects also measure the distance from the transect center line to all nests observed, whether in or out of the transect width.

**Sampling Effort**

- Where practical, transects should be repeated every few days until required precision is obtained.
- Care must be taken during the counts to avoid biases as much as possible (e.g. consistent over or under counting). When biases are inherent in the counting *method*, no amount of additional sampling will remove them.
- The use of alternating observers may help to average some *observer* biases. Ideally, if several observers are participating in each survey, they should rotate areas between surveys; otherwise, all sites should be surveyed by the same observer during each survey. The order in which basins are surveyed should be rotated between surveys.

**Time of Survey**

- Ground nest counts should be timed to occur during incubation because flushing hens assists in locating nests in dense vegetation.

**Equipment**

- Dataforms
- Boots/chest-waders
- Upland areas: Vehicle and/or two all-terrain vehicles linked by a drag chain
- Wetlands: canoe if needed

**Field Procedures**

- Do not survey in rain, high winds, fog or any other conditions that reduce visibility or compromise nest survival. Nest counts should not be done in cold weather.
- Nest counts should be timed to occur during incubation because flushing hens assists in locating nests in dense vegetation.

- Nesting structures in known locations (e.g., platforms, nesting islands and artificial nest boxes) can be checked after hatch.
- Grass and low shrub in upland areas:
  - Search by driving two all-terrain vehicles linked by a drag chain or rope over an area (fixed-width transects).
  - Record the distance driven (transect length) and the distance between the vehicles (transect width) so that the searched area can be calculated.
- Wet areas:
  - Search by wading on foot through the emergent vegetation of the wetland along the shoreline (transect along shoreline, possibly using chestwaders).
  - For deeper wetlands, shorelines may be searched using a canoe for transport.
  - Estimate the area of the wetland covered by the survey.
- Markers (e.g. small pieces of white rope) can be added to counted nests to avoid double counting in areas of high density. If multiple nest searches are being done to find new or missed nests or to check nesting success, nests should be marked and numbered.
- A nest is considered successful if at least one embryo sac is found in the nest.
- Count all the nests within the searched area and record the number of eggs in active nests.
- Species can be identified from eggshell and down characteristics of nest remains using Harrison (1978).

**Data Entry**

- The Design Component for this survey is transects. When digitally entering the survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist.

**Data Analysis**

- Long term annual trends may be analyzed using route-regression analysis (Geissler and Noon 1981, Dickson 1989) although further research may reveal a more appropriate method (Thomas pers. comm.).
- Density estimates may be calculated by dividing the number of birds observed by the area surveyed. Total abundance is calculated by multiplying the density estimate by the total habitat area. These can be considered estimates of total abundance only if all biases have been eliminated or corrected for with a more intensive measure.

### 3.5.5 Airphoto technique

See Table 3 for species-specific recommendations. Absolute Abundance can be obtained for concentrated non-breeding flocks of large bird species that contrast with their background (swans and Snow Geese).

Photographs of flocks of large conspicuous birds are taken from an airplane above ground and then birds in the photo are counted later. This technique is suitable for obtaining an accurate absolute abundance estimate of numbers and sometimes age ratios of large conspicuous birds concentrated in a defined area (e.g., Snow Geese, Boyd pers. comm., swans, Sandhill Cranes).

*Advantages:*

- Provides accurate counts of large flocks concentrated in an area that are difficult to estimate by sight from the air or ground.

*Disadvantages:*

- Takes more time than counts from the air e.g., two days to count photos of snow geese in flocks of 40,000; more time if flock sizes are larger (Boyd, pers. comm.).

**Office Procedures**

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant maps of the project area (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate the Project Area on topographic maps or air photos.

**Sampling Design**

- For Absolute Abundance surveys, both the area of the wetland sampled and the Study Area size must be known. Note that these surveys can only be considered estimates of total abundance if all biases have been eliminated. Biases that can not be eliminated should be measured (usually with more survey effort) and used to correct counts.
- Total counts of defined areas, or if photos are extensive, a suitable probability sample of photographs, or defined areas within the photographs.

**Sampling Effort**

- The time it takes to photograph flock(s) in an area(s), plus processing time for counting flocks.

**Personnel**

- A pilot with previous aerial survey experience in the study area.
- One highly trained and experienced observer with experience in taking photographs from the plane.

**Equipment**

- 35 mm SLR auto-wind camera equipped with a 30-110 mm zoom lens
- 35 mm SLR auto-wind camera equipped with a 300 mm lens
- 1600 ASA colour print or slide film for overcast days
- 400 ASA colour print or slide film for sunny days
- Dissecting microscope (12x power)
- Modified pen (a pin attached to a microswitch/digital tallier) for use with print film
- Hand tally counter for use with slide film
- Projection equipment, a large sheet of paper to attach to the wall, and a fine-tipped felt pen for use with slide film
- Air photos of the study area
- Topographic maps of the study area
- Coloured grease pencils and lead pencils

**Field Procedures**

- Weather:
  - Do not survey in winds greater than 25 km/h, in rain or fog.
  - Overcast days are best for discriminating between white and grey birds (adult and young geese/swans).
- Fly at speeds of 130-170 km/h depending on the fixed wing aircraft
- Fly at an altitude of 400 m to minimize disturbance to the birds.
- Upon locating a flock, manoeuvre the airplane to within 200 m and bank for the photo sets. This altitude will ensure good coverage of large flocks, good photo resolution and little interference from clouds.
- Shutter speed should be a minimum of 1/500 s to overcome movement from the airplane vibration (especially given the long lens).
- Take enough photos to cover the entire flocks with 25-50% overlap between photos - only a few photos are needed for small flocks (<500 birds) but > 30 photos are needed for large flocks (>20,000 birds).
- Do not photograph birds in flight because photo-delineation will be more difficult and there will be an increased chance of missing birds and double counting birds.
- If the flock moves prior to or during the photo set, fly > 2 km away, wait for the birds to settle, and then gradually spiral inwards.
- Take flock photos with the 110 mm lens to produce photo scales of between 1:4,000 and 1:6,000.
- Take overview photos with the 30 mm lens to help locate and delineate each flock.
- Take photos with a 300 mm lens randomly throughout the flock to obtain pictures used to estimate age ratios.
- All photos should be automatically inscribed with a number using the camera data back.
- Record flock numbers and their corresponding photo numbers onto maps of the study area along with the exact route flown.

**Data Entry**

The Design Components for this survey are blocks (polygons = Study Area). When digitally entering your survey data, choose ‘Block’ from the ‘Design Component Type’ picklist.

**Data Analysis**

- Counting - print film method (preferred method):
  - Print film on 10.2 cm x 15.2 cm paper at three times normal contrast to help discriminate between grey birds (young) and background features.
  - For overlapping photos, identify common points on adjacent prints and draw lines around the geese to be counted.
  - Entire photos or portions of photos can be used as sample units for age ratios.
  - Count birds in photo under a dissecting microscope (12x power).
  - Punch holes through each goose image with a modified pen (a pin attached to a microswitch/digital tallier) to avoid duplication.
- Counting - slide film method:
  - Project slide onto a large sheet of paper taped to a smooth wall
  - Register the image on the paper to enable realignment
  - For overlapping photos, identify common points on adjacent slides and draw lines around the geese to be counted.
  - Entire photos or portions of photos can be used as sample units for age ratios.
  - Count birds in photo from projected image
  - Mark each counted bird with a fine-tipped felt pen to avoid duplication, and count with a hand tally counter
- Density estimates may be calculated by dividing the number of birds observed by the area photographed if a complete count on the photographs is done. If a sample of photos is counted, or a sample of areas within photos is counted, then appropriate estimates will need to be used based on the method of sampling. These can be extrapolated to estimates of total abundance if the entire population or a known proportion of the population was photographed.

### 3.5.6 Mark-recapture/resight

Use mark-recapture/resight (MRR) techniques for calculating Absolute Abundance for non-breeding birds when counts are not feasible. It is one of the methods recommended for swans, geese, and Sandhill Cranes. It has very specialized and limited application and is a useful census method under only two conditions:

1. to census localized wintering populations of a species where the limits of the range are known and during a period when immigration and emigration are known not to occur (e.g. Swans in the Comox area); or

2. to census resident, nonmigratory populations with a known distribution (e.g. Canada geese on Southern Vancouver Island).

In addition, Mark and Recapture/Resight can be used for two non inventory purposes:

1. Mark-recapture techniques can be used to determine geographic patterns of distribution during migration, calculate indexes of population size and production, or estimate survival and assess harvest pressure on different age/sex classes (Brownie *et al.* 1985; Bibby *et al.* 1992). Therefore they can be much more useful in providing insight into mechanisms of population change than in measuring the actual size of changes.

   These purposes require international cooperation and these kinds of studies are likely to be used only by federal wildlife authorities; or

2. To mark breeding birds for local breeding biology studies.

Because the focus of this manual is inventory methods, mark and recapture will be discussed only in regard to the first two points.

Mark-recapture/resight is recommended for assessing absolute abundance only when counts are not feasible, and only in the special situations listed above. Estimating population size using mark-recapture/resight techniques is based on the assumption that, if a proportion of the population is marked in some way and is then returned to the original population, complete mixing occurs. A second sample is then taken. The number of marked individuals in the second sample should have the same ratio to the total numbers in the second sample as the total number of marked individuals originally released has to the total population. By knowing the number originally caught, the number marked and the number of marked individuals in the second sample, it is possible to estimate the total population.

There are many considerations involved in determining whether mark-recapture/resight is an appropriate technique for estimating population size: (1) it must be possible to catch enough individuals and all individuals should be equally catchable. It is likely that some species/sexes/age classes will be easier to catch than others; (2) it is important that the mark will not harm the bird (e.g., make it more vulnerable to predators); (3) the chances of recapture or resighting must not be affected by the fact that it was caught in the first place. The population should be sampled randomly in recapture/resighting events; (4) marks must be permanent and detectable; and (5) the population must be closed or immigration and emigration must be measured. These assumptions and detailed methods for estimating population size can be found in Bibby *et al.* 1992. Mark-resight recapture requires adherence to these numerous assumptions, large numbers of marked individuals, and high recapture/resight probabilities.

Recapture/Resight/Recovery

Once a large enough proportion of the bird population has been marked (first sample), then the second sample is taken. This may be done by recapturing the birds, or by resight and/or recovery.

*Advantages:*

- Data can be collected over a large window of time.
- Provides extensive information about habitat selection, dispersal and other movements and survival rates.
- Even low returns and low rates of resighting provide information on distribution and habitat use.

*Disadvantages:*

- Tends to require extensive time and effort and is best done on a local scale (does not monitor populations over a large geographic range).
- A large sample of birds (5 to 10% of the estimated population size) need to be banded and recovered/resighted to get good estimates.
- There are numerous assumptions required to calculate population size and survival rates (Bibby *et al*. 1992) that can be violated but they are often not tested.
- Behaviour of many species of birds may make it difficult to read bands and since large numbers of recoveries are necessary, additional markers, such as nasal disks, are essential.
- Marking birds with markers other than bands may increase their mortality or alter their social status.
- Recaptured sample is rarely random **-** some birds may be more vulnerable to recapture than others, and there is a tendency to capture those birds.

There are numerous variations on the MRR method. However, all have common assumptions that must be met, or approximated, in order for subsequent data analysis and abundance estimates to be valid. These assumptions are:

- Demographic and geographic closure (i.e., The sample population is not significantly altered by births, deaths, immigration or emigration during the time of sampling).
- All members of a population must have an equal or known probability of being captured (i.e., Any sample should be representative of the population being sampled).

Only in rare situations are both of these assumptions ever met and for this reason use of this census method is not encouraged. However, if the method is used, it is important that continued efforts be made to approximate the assumptions, if accurate estimates of population size are to be attained. It is possible to minimize the effects of violating assumptions by modifying the general approaches discussed below. It can be useful to review some modifications to the basic formulas in literature such as Eberhardt (1969), Cormack

(1972), O'Farrell *et al*. (1977), Pollock (1982), Krebs and Boonstra (1984), Nichols *et al*. (1984), Kenneth and Anderson (1985), Wilson and Anderson (1985), and Chao (1988).

Other disadvantages of using this method are the complexities of analysing the data. Computer programs such as CAPTURE attempt to integrate all of these formulae into one comprehensive package, but even such programs require considerable expertise to ensure meaningful results. Researchers are advised to consult documents which deal with the suite of models used in CAPTURE, such as Otis *et al.* (1978), White *et al.* (1982), or Rexstat and Burnham (1991). See also the introductory manual, *Species Inventory Fundamentals, No. 1.*

If a density estimate is required then at least four sessions should be conducted in a brief time period (to minimize violations of the assumption of closure). For this reason, recapture of birds, many of which become wary of traps while others are repeatedly caught, is ineffective, so resighting methods must be used. Data from this design can be used with program CAPTURE (see White *et al.* 1982).

As an alternative, the Jolly-Seber model will allow calculation of survival estimates, as well as a population size; however, biologists should be aware that this is not a true measure of density even though it provides a good measure for comparison over time or among areas. Sampling sessions can be conducted with longer durations between resighting periods (i.e., a few sessions each month). Many analysis options exist for the Jolly-Seber model; these are discussed in *Species Inventory Fundamentals, No. 1*.

Both of the designs above can be combined to allow density and survival estimates. This design is called "Pollock’s robust design" and is also discussed in *Species Inventory Fundamentals, No.1*.

### Office Procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Obtain relevant maps of the project area (e.g., 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map which is used to record data should be referenced to NAD83.
- Outline the Project Area on a map and determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Delineate one to many Study Areas within this Project Area. Study Areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.
- Select banding sites in areas that will ensure that the banded sample is representative of the population of interest, e.g., areas where birds concentrate to moult.
- Acquire banding permits and special permits to mark birds.

### Sampling Design

- Non-random. Set-up banding sites in areas that will ensure that the banded sample is representative of the population of interest. If assumptions are met this will allow estimate of population size for a defined area. However, the estimation of standard error will be inaccurate.

**Sampling Effort**

- Band a very large sample of (non-breeding) birds and band different age and sex classes in proportions that allow for comparisons of their recovery rates (see below).
- Distribute banding effort among several sites.
- Sample the population repeatedly over short time intervals (the assumption is that sampling is instantaneous).
- Rapid sampling can be done by organizing a large group of trained volunteers to resight bands over an extensive area on the same day.
- Plan to band in the same areas consistently over several years.

***Time of survey***

- Banding:
  - For inventories of localized wintering populations, band after migration is complete and wintering numbers and distributions have stabilized (between mid November and February in the parts of the province where birds winter).
  - For inventories of resident populations of Canada geese, band flightless moulters and young (usually early June, but may vary locally).
- Resightings:
  - Resightings of wintering populations should occur between mid November and February. Resightings of resident geese can occur between June and February.
  - The location and timing of resightings may depend on local diurnal, tidal, or other bird use patterns.

***Sample sizes***

It is difficult to recommend sample sizes (numbers of observations or animals sampled) which are appropriate for every situation, as this will depend on the level of precision needed. Of course, the larger the sample size is, the more precise the abundance estimates will be. In general, sample sizes can be increased by increasing sampling effort. However, there are always limits to the amount of sampling effort that can be afforded during a study. The solution then becomes a compromise between available resources and levels of precision required to meet the objectives of the study. The simulation modules provided in CAPTURE and NOREMARK can be very helpful in determining the sampling effort needed to get adequate estimates. In addition, Pollock *et al*. (1990) provide sample size tables for the Jolly-Seber model.

It must be remembered that sampling effort will not remove consistent sampling errors or violations of the assumptions of the model, for example, when a non-random sample is recaptured/resighted.

The “robust” study design of Pollock *et al*. (1990) is recommended if density estimates, and survival, and other demographic rates are an objective of inventory efforts. With this design, a series of five-day samples (capture session) are conducted at equal intervals (e.g. every month) during the time period of interest. The data from the five day sessions is used to estimate density using program CAPTURE. (See section on data analysis, and *Species Inventory Fundamentals, No. 1*, Appendix G for more details on program CAPTURE.) In addition, these data are pooled and used with the Jolly-Seber model to estimate survival and other demographic parameters (using JOLLY or JOLLYAGE). This design has the following advantages:

- Theoretically robust estimates of population size and survival are possible.
- Temporary emigration from the study area can be estimated from the data set allowing for further demographic inference, and less biased survival estimates if a subset of the population is not available for resampling in a given period. A new program, RDSURVIV, has been designed for this purpose when the robust design is used (see *Species Inventory Fundamentals, No. 1*, Appendix G).
- The data should also allow further demographic inference and model fitting of survival rates using programs MARK, SURGE, and POPAN (see *Species Inventory Fundamentals, No. 1*, Appendix G).

Methods are available for biologists to determine appropriate sample sizes for the various mark-recapture estimators. It is recommended that project biologists consult the following sources for sample size calculations (Table 3).

**Table 8. Sources for sample size calculation.**

| **Estimator** | **Source for optimal sample size calculation:** |
|---|---|
| Lincoln-Peterson estimator. | Krebs (1989 page 22) |
| Jolly Seber estimates | Pollock *et al*. (1990, page 72)<br>Simulation: POPAN |
| CAPTURE | White *et al*. (1982)<br>Simulation: CAPTURE |

The above references include graphs, and discussions of needed sample sizes for estimators. The determination of optimal sample sizes for program CAPTURE is complex. An easy to use simulation module is available as part of program CAPTURE to allow biologists to explore sample size issues.

### Personnel

- Two or three experienced biologists and a large crew of volunteers for banding.
- Hunters to provide band recoveries where the resighting method is not used.
- A large crew of trained volunteers to resight bands, neck collars, nasal tags, etc.

### Equipment

- Boats to corral moulting birds for banding
- Boots/chest-waders
- Capture equipment: Herring nets, aluminium rods, lead line rigged up for drive-trapping
- Catch boxes and/or capture pen
- Banding tools, e.g., pliers
- Special markers (e.g., plastic leg bands, patagial tags, neck collars, nasal saddles, radio transmitters)
- Binoculars and spotting scope with tripod for resighting bands.

### Field Procedures

- Avoid poor weather when capturing birds.

*Capture and Marking*

- Capture and band the birds (See Protocol at the end of this section for the various capture methods).
- Band a very large sample of birds and band different age and sex classes in proportions that allow for comparisons of their recovery rates.
- Take precautions to reduce mortality in captive sample, i.e., do not let birds suffer from hypothermia or heat prostration.
- Record all relevant information about the bird (e.g., age, sex, status, location) on banding schedules.
- Record the band numbers and/or other marking ID of individuals banded during previous banding efforts

*Recapture/resight*

- Record the number of marked individuals and unmarked individuals in recaptured or resighting samples.
- Record locations of marked and unmarked individuals.
- Sample the population repeatedly over short time intervals (the assumption is that sampling is instantaneous).
- Rapid sampling can be done by organizing a large group of trained volunteers to resight bands over an extensive area on the same day.

**Capture Methods**

**Table 9. Recommended Capture Methods for Waterfowl and their Allies.**

| Species Group | Capture Method |
|---|---|
| Sandhill Crane | Cannon/Rocket Nets when flying, usually decoyed in. |
| Swans | Cannon/Rocket Nets when flying, usually decoyed in. |
| Geese | Drive Traps when moulding and for flightless young. |

***(1) Cannon Net Trapping /Rocket Net Trapping***

- Recoilless rocket cannons with attached nets have been used successfully at Malheur National Wildlife Refuge to capture geese, Sandhill Cranes and other species (McLaury pers. comm.).
- This method requires setting up traps well in advance and baiting birds to get them used to it. This may take several days. Once birds have experienced this method, whether they were caught or escaped, they become very wary, so a site can be used effectively only once for species other than dabblers.
- The body of the rocket cannon is of high strength tubular construction. Welded at the rear of the cannon body is a stabilizer rod which has a 3/16 inch chain attached. This chain is for attaching net leads (Dill, 1967).
- Although the cannon requires no launching tube or rail, a launching rail improves the vertical angle of deployment of the rockets and prevents the rockets from tipping over (McLaury pers. comm.).

- Two types of nets were used with the rocket cannons at Malheur, the entanglement net and the skirt net. It was found that the skirted net worked best for capturing all species. The birds were easier to handle and physical stress while under the net was reduced (McLaury pers. comm.). For more information, see Schemnitz (1980), (especially pages 77-78 of chapter 6 - Capturing and Marking Wild Animals, and chapter 14 - Estimating the numbers of wildlife populations, pages 221-246).

***(2) Goose Wing Trap / Key Hole / Drive Traps***

- This trapping method is used when the goal is to capture a few to several hundred geese with little investment in time and money.
- Trapping is conducted early to mid June (although this depends on where trapping is in province) when the goslings are of considerable size, feathered, yet still flightless. In hot weather, it is important that trapping be done in the early morning to prevent heat stress to the geese.
- The trap consists of any kind of wire pen (in Stanley Park, conveniently located tennis courts are used) and fence wings extending from near the water's edge to the cage entrance (e.g. snow fencing; linked, 4 x 8 foot sections of aluminium-framed wire fencing). The size of the pen depends on the number of birds being captured: small number of geese (<25) should have a pen space at least twice the size required by a group of crowded birds; for larger numbers requiring more processing time, birds should have at least five times the space they require when crowded. Water must be provided in the pen.
- At least two boats are needed to move the geese back onto land into the wings of the trap Exact number of boats will depend on the size of the trap and the number of geese, (one experienced trapper with a canoe can drive and capture up to two dozen geese in places where they are used to people, such as the lower mainland or the Okanagan).
- Ground personal are usually needed to herd the geese down the wings of the trap into the capture pen.
- Once the geese are inside the capture pen the banders may enter the pen and begin banding. The geese should only be approached from one side of the trap to avoid trampling. If large numbers are caught, a subsection should be made in the pen into which a few birds at a time are corralled for processing.

**Data analysis**

The project biologist should be familiar with the different methods of data analysis for mark-recapture inventories before data collection begins. Different assumptions and requirements of the various models will have great bearing on sample design, effort and overall approach.

Section 3.5.7 is a cursory discussion of mark-recapture models. This is included to provide biologists with an overview; however, <u>a greater depth of knowledge will be required to actually carry out a mark-recapture inventory.</u> Prior to commencing, it will be necessary to consult *Species Inventory Fundamentals No. 1* as this manual provides descriptions of many techniques which are generic to species inventory. In addition, the following is a short list of some useful texts and articles. For complete citations see References.

- White *et al.* 1982. In some opinions, this is by far the most readable reference on mark-recapture that is available. Available at: http://www.cnr.colostate.edu/~gwhite/software.html

- Buckland *et al.* 1993. Good text for distance and transect sampling.
- Krebs 1989, (also 1998, 2nd Edition). Good all round discussion of study design, but Chapter 2, Estimating abundance: Mark-and-Recapture techniques, is especially appropriate).
- Pollock *et al.* 1990. A good discussion of the Jolly-Seber model.
- White and Garrot 1990. A good discussion of study design for radio-telemetry estimation studies.
- White 1996. A good discussion of mark-resight estimation procedure.
- Schemnitz 1980. *Wildlife management techniques manual* (especially chapter 14 - Estimating the numbers of wildlife populations, pages 221-246).

## 3. 5.7 Mark/Recapture Data Analysis Methods

There are numerous ways of analysing data from a MRR program. The level of confidence placed in any estimator is largely dependent upon sample size, sample effort and how well the assumptions of the analysis methods are met in the field. Some common methods of analyses found in the literature are summarized below to provide some background information. Many sophisticated and robust methods of analyzing MRR data are available as part of the programs CAPTURE, JOLLY and MARK; all of these are discussed in *Species Inventory Fundamentals*, manual No.1.

***Minimum-Number-Alive Estimator (MNA)***

One of the easiest ways of estimating the abundance of a population from a mark-release-recapture (MRR) program is called the minimum number alive method (MNA). MNA (also called the calendar count or enumeration) is an estimate based on the sum of all individuals known to be alive during a particular capture (trapping) session. An individual is known to be alive during a given capture session if it was captured during that session, or if it was captured before and after that capture session. For example, if an individual is captured during capture session #1 and #3, it can be accurately stated that it was missed (but alive) during session #2.

Although the MNA method is simple to use, this estimator has been criticized as being negatively biased in most situations. For this reason, in a summary, Ritchie and Sullivan (1989) suggest that the MNA estimate should only be used when the trappability of animals is >70%. Several articles have been written on the use of the MNA estimator (Hilborn *et al.* 1976; Jolly and Dickson 1983; Nichols and Pollock 1983; Boonstra 1985; Efford 1992; Hilborn and Krebs 1992). Most of these papers recommend the use of the Jolly-Seber estimator over MNA if trappability is low or unknown.

This approach, also referred to as “saturation trapping” or “enumeration” is generally not the best means of achieving a statistically valid estimate, and is not recommended. The reasons for this are:

- In many cases, a large amount of effort is needed to fully trap a population. In contrast, a valid estimate of population can be gained with less effort by using a ratio estimator, or a closed CAPTURE mark-recapture estimator.
- The assumption that an entire population is trapped or marked cannot be validated and therefore population estimates can be negatively biased (Pollock *et al.* 1990).
- To get an unbiased estimate of density, a population should be geographically closed. To minimize violation of this assumption, sampling should occur in a relatively small amount of time. Saturation trapping usually takes long periods of time, and therefore closure assumptions will be violated unless the researcher is working on an entirely closed system, such as an island.

***Estimation by Asymptotic Capture***

Population abundance can be estimated by intensively trapping and marking a population until no new (unmarked) individuals are captured. This method is essentially a modified (i.e., non-lethal) version of kill trapping where animals are removed until no animals remain. It is generally not recommended as it is subject to criticisms similar to those described above.

***Ratio estimators***

The Lincoln, Petersen, and Schnabel estimators are based on the ratio of marked to unmarked individuals within a population. These estimators assume that the population is “closed” to immigration and emigration. The formulas are based on the assumption that the population size is related to the number of marked and released animals in the same way that the total caught at a subsequent time is related to the number recaptured (Davis and Winstead 1980). White *et al.* (1982) offer excellent discussion of closed models which many be calculated using the program CAPTURE.

The Petersen (or Lincoln-Petersen) estimate is the most basic MRR method. It is based on two sample periods only (i.e., one period of marking animals, followed by a single period of recapture). It is described using the following formulas:

$$\frac{N}{M} = \frac{C}{R} \quad (1)$$

therefore:

$$N = \frac{CM}{R} \quad (2)$$

where:

N = Population Estimate

M = Number of marked and released animals

C = Total number of animals captured

R = Number of marked animals that were recaptured

Lincoln-Peterson estimates are easy to calculate, and the estimator has been shown to be robust to time variation in capture probabilities. However, there are important assumptions associated with this estimator such as equal probabilities of capture between animals, population closure, and no net loss of animal marks between samples. If relative abundance is the objective then violations of assumptions may not be as significant provided that the degree to which assumptions are violated is similar between studies and over time, and therefore the estimator will show a consistent, comparable bias. If absolute abundance is the objective of methods, and animals can be marked individually then the use of the estimators in program CAPTURE is recommended.

Numerous variations on the Petersen Estimate have been developed. The Petersen Estimate is biased in that it tends to overestimate the actual population, especially if the sample is small. In response to this bias, Seber (1982) offers a variation on Petersen’s formula that is less biased, and nearly unbiased if there are at least seven recaptures of marked animals. Another variation, the Schnabel estimate was developed to allow investigators to analyze data from multiple (>2) marking sessions.

### *The Jolly-Seber Estimator*

Like the Lincoln, Petersen, and Schnabel estimators (above), the Jolly-Seber estimator is also based on the ratio of marked to unmarked individuals within a population. However, the Jolly-Seber estimate differs from others in that it recognizes, and attempts to incorporate, the fact that biological populations are generally not “closed”. This “open” model will not provide a true estimate of density, but rather of abundance, as the population is not defined in terms of area. This estimator requires that *at least three* sampling periods be carried out in order to calculate certain variables. Pollock *et al.* provide good discussion of Jolly-Seber models, and the program JOLLY is very useful for simulating MRR or analyzing data.

The formula for the Jolly-Seber estimate of population size is given below.

$$N_t = \frac{M_t}{\alpha_t} \quad (3)$$

where:

$N_t$ = Population estimate just before sample *t*

*t* = Sample period (1,2,3,4,5,......*t* th sample)

$\alpha_t$ = proportion of animals marked

$$\alpha_t = \frac{m_t + 1}{n_t + 1} \quad (4)$$

$m_t$ = Number of marked animals that were recaptured during sample *t*

$n_t$ = Total number of animals captured during sample *t*

$M_t$ = Estimated number of marked animals just before sample *t*

$$M_t = \frac{(s_t + 1)Z_t}{R_t + 1} + m_t \quad (5)$$

$s_t$ = Number of animals released

$s_t$ = ($n_t$ - accidental deaths)

$R_t$ = Number of animals released during sample *t*, or $s_t$ that were recaptured during a later sampling period

$Z_t$ = Number of animals that were not captured during sample *t*, but were captured before and after sample *t*

The Jolly Seber model is also susceptible to biases if unequal capture probabilities are exhibited in the trapped population; however, the survival rate estimate of the Jolly Seber is robust to most forms of capture probability variation, and is therefore a useful alternative for monitoring populations. In addition, there are many modifications to the Jolly-Seber to accommodate age-specific capture probabilities and survival rates (program JOLLY JOLLYAGE and POPAN). If the robust design is used then program RDSURVIV can be used to estimate temporary emigration, and allow more precise survival estimates. Also, the Jolly Seber approach to survival modelling has been modified to allow the testing of biological hypothesis using various model fitting procedures as documented in programs SURGE, and MARK.

However, all of the programs mentioned require advanced statistical knowledge, and project biologists are urged to seek the advice of a qualified biometrician. A summary of useful software is available in *Species Inventory Fundamentals, No. 1*, Appendix G.

Estimates for population size and coefficients of variation were calculated using the Jolly-Seber model in Nichols *et al.* (1981).

# GLOSSARY

**ABSOLUTE ABUNDANCE:** The total number of organisms in an area. Usually reported as absolute density: unit area or volume.

**ACCURACY:** A measure of how close a measurement is to the true value.

**BIODIVERSITY:** Jargon for biological diversity: “the variety of life forms, the ecological roles they perform, and the genetic diversity they contain” (Wilcox, B.A. 1984 cited in Murphy, D.D. 1988. Challenges to biological diversity in urban areas. Pages 71 - 76 in Wilson, E.O. and F.M. Peter, Eds. 1988. Biodiversity. National Academy Press, Washington, DC. 519 pp.).

**BLUE LIST:** Taxa listed as BLUE are sensitive or vulnerable; indigenous (native) species that are not immediately threatened but are particularly at risk for reasons including low or declining numbers, a restricted distribution, or occurrence at the fringe of their global range. Population viability is a concern as shown by significant current or predicted downward trends in abundance or habitat suitability.

**CBCB (Components of BC’s Biodiversity) Manuals:** Wildlife species inventory manuals that have been/are under development for approximately 36 different taxonomic groups in British Columbia; in addition, six supporting manuals.

**CWS:** Canadian Wildlife Service

**DABBLING DUCKS:** May also be referred to as ‘Marsh Ducks’. In BC these include: Wood Duck *(Aix sponsa)*; Green-winged Teal *(Anas crecca)*; American Black Duck *(Anas rubripes)*; Mallard *(Anas platyrhynchos)*; Northern Pintail *(Anas acuta)*; Blue-winged Teal *(Anas discors)*; Cinnamon Teal *(Anas cyanoptera)*; Northern Shoveler *(Anas clypeata)*; Gadwall *(Anas strepera)*; Eurasian Wigeon *(Anas penelope)*; American Wigeon *(Anas americana)*.

**DESIGN COMPONENTS:** Georeferenced units which are used as the basis for sampling, and may include geometric units, such as transects, quadrats or points, as well as ecological units, such as caves or colonies.

**DIVING DUCKS:** In BC these include: Canvasback (Aythya valisineria); Redhead (*Aythya americana*); Ring-necked Duck (*Aythya collaris*); Tufted Duck (*Aythya fuligula*); Greater Scaup (*Aythya marila*); Lesser Scaup (*Aythya affinis*); Common Goldeneye (*Bucephala clangula*); Barrow's Goldeneye (*Bucephala islandica*); Bufflehead (*Bucephala albeola*); Hooded Merganser (*Lophodytes cucullatus*); Common Merganser (*Mergus merganser*); Red-breasted Merganser (*Mergus serrator*); Ruddy Duck (*Oxyura jamaicensis*).

**EWG (Elements Working Group):** A group of individuals that are part of the Terrestrial Ecosystems Task Force (one of seven under the auspices of RIC) which is specifically concerned with inventory of the province’s wildlife species. The EWG is mandated to provide standard inventory methods to deliver reliable, comparable data on the living “elements” of BC’s ecosystems. To meet this objective, the EWG is developing the CBCB series, a suite of manuals containing standard methods for wildlife inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

**INVENTORY:** The process of gathering field data on wildlife distribution, numbers and/or composition. This includes traditional wildlife range determination and habitat association inventories. It also encompasses population monitoring which is the process of detecting a demographic (e.g. growth rate, recruitment and mortality rates) or distribution changes in a population from repeated inventories and relating these changes to either natural processes (e.g. winter severity, predation) or human-related activities (e.g. animal harvesting, mining, forestry, hydro-development, urban development, etc.). Population monitoring may include the development and use of population models that integrate existing demographic information (including harvest) on a species. Within the species manuals, inventory also includes, species statusing which is the process of compiling general (overview) information on the historical and current abundance and distribution of a species, its habitat requirements, rate of population change, and limiting factors. Species statusing enables prioritization of animal inventories and population monitoring. All of these activities are included under the term inventory.

**MARK-RECAPTURE METHODS:** Methods used for estimating abundance that involve capturing, marking, releasing, and then recapturing again one or more times.

**MONITOR:** To follow a population (usually numbers of individuals) through time.

**OBSERVATION:** The detection of a species or sign of a species during an inventory survey. Observations are collected on visits to a design component on a specific date at a specific time. Each observation must be georeferenced, either in itself or simply by association with a specific, georeferenced design component. Each observation will also include numerous types of information, such as species, sex, age class, activity, and morphometric information.

**POPULATION:** A group of organisms of the same species occupying a particular space at a particular time.

**PRECISION:** A measurement of how close repeated measures are to one another.

**PRESENCE/NOT DETECTED (POSSIBLE):** A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

**PROJECT AREA:** An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling for species generally takes place within smaller, representative study areas so that results can be extrapolated to the entire project area.

**PROJECT:** A species inventory project is the inventory of one or more species over one or more years. It has a georeferenced boundary location, to which other data, such as a project team, funding source, and start/end date are linked. Each project may also be composed of a number of surveys.

**RANDOM SAMPLE:** A sample that has been selected by a random process, generally by reference to a table of random numbers.

**RED LIST:** Taxa listed as RED are candidates for designation as Endangered or Threatened. Endangered species are any indigenous (native) species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in British Columbia. Threatened species are any indigenous taxa that are likely to become endangered in British Columbia, if factors affecting their vulnerability are not reversed.

**RELATIVE ABUNDANCE:** The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

**RIC (Resources Inventory Committee):** RIC was established in 1991, with the primary task of establishing data collection standards for effective land management. This process involves evaluating data collection methods at different levels of detail and making recommendations for standardized protocols based on cost-effectiveness, co-operative data collection, broad application of results and long term relevance. RIC is comprised of seven task forces: Terrestrial, Aquatic, Coastal/Marine, Land Use, Atmospheric, Earth Sciences, and Cultural. Each task force consists of representatives from various ministries and agencies of the Federal and BC governments and First Nations. The objective of RIC is to develop a common set of standards and procedures for the provincial resources inventories. [See http://www.for.gov.bc.ca/ric/ ]

**SEA DUCKS:** In BC these include: King Eider (*Somateria spectabilis*); Oldsquaw (*Clangula hyemalis*); Black Scoter (*Melanitta nigra*); Surf Scoter (*Melanitta perspicillata*); White-winged Scoter (*Melanitta fusca*).

**SPI:** Abbreviation for ‘Species Inventory’; generally used in reference to the Species Inventory Datasystem and its components.

**STRATIFICATION:** The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

**STUDY AREA:** A discrete area within a project boundary in which sampling actually takes place. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

**SURVEY:** The application of one RIC method to one taxonomic group for one season.

**SYSTEMATIC SAMPLE:** A sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

**TRANSECT SURVEY:** A method of sampling species abundance by recording all birds observed along a mappable linear route of known length and usually of fixed width. In non fixed-width surveys, the perpendicular distance must be measured/estimated between the line of travel and the birds recorded if the result is to be used to estimate absolute abundance. Where possible, routes are in a straight line, but in many circumstances may follow shorelines, trails, etc. A variety of modes of travel are possible while conducting a transect survey, such as foot, boat, or aircraft.

**TERRESTRIAL ECOSYSTEMS TASK FORCE:** One of the seven tasks forces under the auspices of the Resources Inventory Committee (RIC). Their goal is to develop a set of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia.

**WATERFOWL & ALLIED SPECIES:** Includes ducks, geese, swans, loons, coots, grebes, and cranes.

**WETLAND:** A general term used to describe land that is inundated by surface water or groundwater (includes small lakes, ponds, sloughs, marshes, bogs, wet meadows, flooded fields, slow-moving streams, ditches, and sewage lagoons).

**YELLOW-LIST:** Includes any native species which is not red- or blue-listed.

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