CANADIAN WILDLIFE BIOLOGY & MANAGEMENT

2012: Volume 1, Number 1

ISSN: 1929–3100

Review

Lessons Learned During the Recovery of the Peregrine Falcon in Canada

Geoffrey L. HOLROYD[1] and David M. BIRD[2]

[1] Environment Canada, Room 200, 4999-98 Ave, Edmonton, AB, T6B 2X3 Canada. Email: geoffrey.holroyd@ec.gc.ca

[2] MacDonald College, McGill University, 21111 Lakeshore Road, Ste. Anne de Bellevue, QC, H9X 3V9 Canada. Email: david.bird@mcgill.ca

Abstract

The recovery of the Peregrine Falcon (*Falco peregrinus*) in Canada has spanned almost half a century. The demise of the Peregrine Falcon in North America and Europe was caused by the organochlorine pesticide, DDT. Once this pesticide was banned and captive breeding techniques were improved, large numbers of young falcons were released across southern Canada between 1976 and 1996. The recovery of the Peregrine Falcon was due more to the dedication of those involved and less to recovery plans and legislation that protected this species. Habitat conservation was never a major issue for Peregrine Falcon conservation. This paper discusses the processes involved in the recovery of the Peregrine Falcon in Canada and the lessons learned from this program.

Keywords: Peregrine Falcon, *Falco peregrinus*, recovery, reintroduction, endangered species, toxicology.

INTRODUCTION

The Peregrine Falcon (*Falco peregrinus*) is considered the most widely naturally distributed bird species in the world, being one of only four that currently occurs naturally on all five continents (Temple 1988; White *et al.* 2002). The Peregrine Falcon has been the subject of intense and expensive population recovery efforts spanning the past several decades (Temple 1988; Cade and Burnham 2003). As a result, the species has been successfully reintroduced to eastern North America, with breeding numbers in some states and provinces now greater than ever before (Cade and Burnham 2003).

While the conservation story of the Peregrine Falcon has been told in many places (e.g., Fyfe 1969, 1988; Cade *et al.* 1988; Peakall 1990; Rowell *et al.* 2003), most authors have focused on the number of falcons bred in captivity and released, and produced in the wild, and less on the actual process of this species' recovery. Cade and Burnham's

Correspondence: Geoff Holroyd, Environment Canada, Room 200, 4999-98 Ave., Edmonton, AB, T6B 2X3.
Email: geoffrey.holroyd@ec.gc.ca

(2003) book was unusual in that it focused more on the people involved in the recovery programs across North America. Chapters by Fyfe *et al.* (2003) and Holroyd (2003) in Cade and Burnham (2003) described many of the people, the teamwork and actions involved in the reintroduction effort in Canada. The reintroduction of the Peregrine Falcon into southern Canada is a success story that helps to illustrate many important issues in the conservation of our wildlife heritage. While the story now spans half a century and is not yet over, we will illustrate how this recovery program can teach us broader lessons about the factors that contributed and hindered the Peregrine Falcon reintroduction.

The recovery of any endangered species requires that we must determine the ultimate causes of the decline, not just the proximate causes (Mayr 1961). Proximate causes are those parts of the species' life history that are problematic as shown by its population dynamics. The life history parameters that are cause for concern must then be studied to determine the ultimate causes of the species' decline.

This article reviews many aspects of the Peregrine Falcon recovery program in Canada over the past 40 years and suggests lessons learned from the program that might benefit other conservation programs.

HISTORY OF THE RECOVERY EFFORT

In the 1950s and 1960s, falconers and bird watchers were reporting that nesting cliffs used by Peregrine Falcons were being abandoned (Hickey 1969). Eyries that had been occupied in the eastern USA and Canada south of the boreal forest were silent; a similar situation was occurring in Europe. At the 1965 conference on the status of the Peregrine Falcon, the conclusion was absolute: Peregrine Falcons had disappeared from much of North America and Europe (Hickey 1969). By 1972, Peregrine Falcons in Canada no longer nested south of 60°N, south of the treeline and east of the Rocky Mountains save for a few pairs in northern Alberta, in the southern part of Ungava Bay in northern Quebec (Fyfe *et al.* 1976), and perhaps the east coast of Hudson Bay (Albright and Doidge 1992). In southern Quebec, one pair nesting on a cliff overlooking Lac Lyster may have remained active through the 1970s (Kiff 1988; Bird and Aubry 1972 for details on this nest site). In the eastern USA, Peregrine Falcons had been extirpated (Cade and Fyfe 1970).

After a major conference on the species (Hickey 1969) as well as confirmation by several toxicological investigations on both wild (Kiff 1988) and captive American Kestrel (*F. sparverius*) populations (see review by Bardo and Bird 2009), DDT, an organochlorine pesticide, was determined to be the ultimate cause for the decline (Hickey 1969). This post-WWII insecticide was commonly sprayed on agricultural crops to kill injurious insects as well as against mosquitoes for malaria control. DDT and its primary metabolite, DDE, became biomagnified in the food chain, eventually being stored in the body fat of raptorial birds at the top. When the fat was metabolized, DDE was released into the bloodstream, eventually interfering with an enzyme necessary for of the metabolic release of calcium needed in the egg-formation process (Ratcliffe 1969, 1993; Bird *et al.* 1983). As a result, egg shells were up to 20% thinner than normal, and in many cases, too weak to hold the weight of incubating adults, especially the 1000+ g females. While organochlorine poisoning also resulted in abnormal behaviors (e.g., lessened territorial defense, reduced parental care, etc.) the reproductive capabilities of the Peregrine Falcon pairs decreased significantly, mainly due to broken eggs (Risebrough and Peakall 1988).

The second stage of the story is comparable to causal analysis in decision theory. The cause of the decline was obvious following the sequence of failed nests - unhatched eggs - crushed eggs - thin egg shells - and finally the ultimate cause, DDT. Thus, the conservation effort had satisfied the recommendations of Mayr (1961) to determine the ultimate cause of the species' demise.

Once the role of DDT had been established in the declines of many raptors and fish-eating birds and with no small thanks to Rachel Carson (1962) and her famous book, Silent Spring, the 'decision making process' showed that several steps were required to remedy the dire situation for Peregrine Falcons and other raptors. First, governments moved relatively quickly to ban DDT, i.e., 1970 in Canada and 1972 in USA. However, since DDT and DDE are relatively stable compounds, with a soil half-life up to 30 years, it would be decades before these compounds could disappear from the natural environment. Moreover, even today, DDT is still used in African and Latin America countries as a low-cost solution to combat malaria (van den Berg 2009). Thus, Peregrine Falcons migrating from North America to Central and South America are still faced with DDT and DDE contamination in the food chain.

By 1972, Peregrine Falcon populations in North America were facing imminent extirpation, i.e., only one or two known active pairs south of the tree line east of the Rockies. At that time in North America, three subspecies were recognized (White 1968; White and Boyce 1988). On the west coast and north of the treeline, *pealei* and *tundrius* Peregrine Falcons, respectively, were less exposed to DDT, thus their populations were not as dramatically affected as with the continental *anatum* subspecies which was approaching extirpation. This led to another serious conservation issue with the Peregrine Falcon, a difference in approaches to saving the genetic stock between the Canadians and the Americans.

In an effort to save the genetic basis for the *anatum* subspecies, Richard Fyfe, a biologist with the Canadian Wildlife Service (CWS), began to harvest the last young from nests east of the Rockies. He housed the young birds in a barn on his farm east of Edmonton until a captive breeding facility could be built on the Canadian Forces Base Wainwright about 200 km east of Edmonton (Fyfe *et al.* 2003). Meanwhile, Tom Cade, a falconer and a professor of biology at Cornell University, Ithaca, New York, elected to house and breed pairs of Peregrine Falcons initially borrowed from various falconers who were breeding birds for recreational purposes. While most of these birds were of North American origin, some contained genes from Spanish, Chilean and other subspecies populations (Tordoff and Redig 2001). See below for the ramifications of these different philosophies. As a practicing falconer himself, Fyfe was also aware that these sportsmen had successfully bred Peregrine Falcons and other raptors in captivity. So he hired Phil Trefry, a young falconer from British Columbia, who knew how to handle falcons. Together with Harry Armbruster who had been Richard's field technician, and later Ursula Banasch and Helen Trefry, they learned, improved and implemented the captive-breeding techniques that falconers had pioneered before them (Fyfe *et al.* 2003).

Three other captive-breeding facilities began in Canada in the 1970s. John Campbell, a private falconer, began breeding Peregrine Falcons on his farm south-east of Calgary (Campbell 2003). His pioneering facility, which operated from 1967-1985, raised 85 young that were released across Canada or incorporated as breeding stock at the other Canadian and USA breeding facilities. Lynn Oliphant, a professor at the University of Saskatchewan in Saskatoon, and Paddy Thompson, established a facility called the Saskatchewan Cooperative Falcon Breeding Project. The junior author (DMB) , a professor at McGill University and director of the Macdonald Raptor Research Centre in Montreal, and his technician, Ian Ritchie, also set up a breeding program for Peregrine Falcons aimed at city releases, and at the same time, used their large captive population of American Kestrels as a model species to develop better breeding techniques, e.g., artificial insemination, freezing semen, forced renesting, etc., and to study the effects of toxicants on birds of prey, including Peregrine Falcons. The Saskatoon facility continued throughout the life of the Canadian release program, while the Montreal shut down a few years earlier.

Once captive-bred young were being produced, a technique to release them into the wild had to be established (Fyfe *et al.* 2003). In the first year of releases in Alberta, young Peregrine Falcons were placed in Prairie Falcon (*Falco mexicanus*) nests. However, the technique did not work well due to poor timing synchronicity between the two species as well as concerns about interspecific imprinting (Bird *et al.* 1985). Both American and Canadian programs settled on a technique known to falconers as "hacking", which involves placing nestlings in a box on a cliff or on an artificial structure (Cade *et al.* 1996). Mass-hacks, where 4 or more young were released at once were conducted from 1975 until 1996. Throughout, captive-raised young were placed in the box at about 38 days of age, when they were fully capable of feeding themselves and able to thermoregulate. They were fed dead Coturnix Quails (*Coturnix japonica*) and sometimes other food items, i.e., laboratory Norway Rats (*Rattus norvegicus*) and day-old Domestic Chickens (*Gallus domesticus*), through feeding chutes to minimize the possibility of the young associating humans with the provision of food. When the young were 40-42 days of age, dowels placed on 7-cm centers were removed from the front of the cage to allow them freedom to leave at will. In later designs, the entire dowelled front door could be opened to a horizontal position to serve as a porch for the young to practice wing exercises. The young were free to fly and return to the box for food which was provided for at least an additional 30 days.

Between 1975 and 1996, 1550 young were shipped from Wainwright for release across Canada. During the same interval, 440 and 48 birds from Saskatoon and Montreal, respectively, were sent out for release. An additional 5000 were released in the continental USA (Heinrich 2009). After 21 years of breeding Peregrine Falcons, the Canadian Wildlife Service closed the Wainwright facility in 1996 on the recommendation of the National Peregrine Falcon Recovery Team. The adult falcons were distributed free of charge by the federal government to 7 private breeding facilities with no conditions attached so as to avoid any future financial claims for care.

The take-home lesson here is that we can recover an extirpated species if enough resources are made available to dedicated individuals that are willing to work together towards the common goal.

MONITORING THE RECOVERY

The first Peregrine Falcon that was captive-bred at the Wainwright facility returned to breed in the wild in 1977 (Fyfe *et al.* 1977). This milestone was cause for rejoicing by the Wainwright staff who was under heavy pressure to demonstrate success with this major, relatively expensive program. There were no precedents for such a captive-breeding and release effort, and thus, its success was very much in question. Some Canadian bred-and-released falcons were surviving and returning to breed, but in the USA., e.g., Boston, Massachusetts; Columbus, Ohio; Detroit, Michigan; Cohasset, Minnesota (Tordoff *et al.* 1998; Gahbauer 2008). Meanwhile, Peregrine Falcons released on American soil were showing up as breeders in Canada. For example, the first pair to once again breed on a Montreal skyscraper, in 1984 after the famous Sun Life pair died out in the fifties (Hall 1955 in Herbert and Herbert 1965), was composed of a male and a female released from cliff sites in Vermont and New York. Clearly the falcons did not recognize national boundaries and the reintroduction program had become truly international.

Every five years from 1970 and still continuing, a national Peregrine Falcon survey tallied the number of falcons in southern Canada and representative regions of northern Canada (Rowell *et al.* 2003; Holroyd and Banasch 2012). These surveys cover similar areas each year in all provinces and territories except Prince Edward Island which was never home to nesting Peregrine Falcons historically. In addition to these national censuses, some jurisdictions conducted annual surveys of some or all known pairs in their territory. Most of these surveys included at least the number of territorial pairs and single falcons and their productivity. These surveys provided the critical core information necessary to assess the success of the reintroduction program in southern Canada and the natural population growth in northern Canada in the post-DDT era.

Once release efforts were well underway, the number of Peregrine Falcons in the wild began to increase, albeit slowly (Figure 1). Northern populations that had not received many captive-raised young, grew at an average of 11% per year between 1970 and 2010 (Figure 1). In general, these populations were not as affected by DDT, and the small numbers that had survived into the 1970s provided the founding population for natural growth with no human intervention.

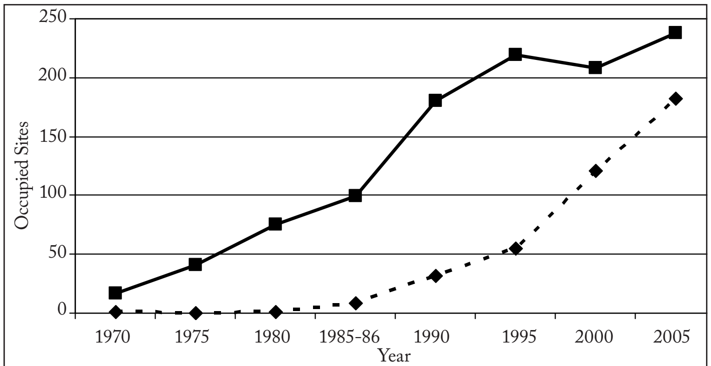

Figure 1. Population of *anatum* Peregrine Falcons in northern (boreal) Canada (solid line) and southern (dashed line) recorded during 5-year surveys.

In the south, population growth was slow in the first 15 years. By 1985, only 8 pairs were nesting in southern Canada. An appraisal of the reintroduction program resulted in significant changes between 1985 and 1990 (Holroyd and Banasch 1990). The Wainwright breeding facility was made more efficient and a further investment of funds resulted in increases in annual production, i.e., over 100 young a year. The review of the release effort between 1976 and 1987 found that 563 young falcons had been released at 24 different sites in southern Canada at an average of 5 (range 1-16) young per area per year (Holroyd and Banasch 1990). However, only 35 had been seen again and half of those were one-year old falcons and many were single falcons with no mate. Since Peregrine Falcons typically breed at two years of age, it was evident that most of the returning falcons were not securing mates for nesting. To enhance their chances, Holroyd and Banasch (1990) recommended that mass hacks of 20 to 30 young per year be released in each area. Since falcons were breeding within 130 km of release sites (263 km for females, and 52 km for males), release areas were defined as being within 250 km of each other. With the increased production from Wainwright, the recovery team agreed to reduce the number of release efforts and focus the releases more strategically. From 1987 to 1991, 50 young per year were released around the Bay of Fundy, and in northern Ontario. From 1992 to 1996, 50 young per year were released in central Alberta. The results of these mass hacks were dramatic increases in the number of falcons breeding from Ontario to the Bay of Fundy and in Alberta (Figure 1). The number of Peregrine Falcons went from 8 pairs in 1985 to 121 in 2000. The analysis of the recovery effort that led to the additional funds to make the recovery program more efficient was similar to the cost-benefit analysis promoted by Baxter *et al.* (2006). The short-term option in 1985 was to continue with a smaller captive-breeding and release program, but in the long term this would end up being more expensive than increasing the size and efficiency of the Wainwright program and conducting mass hacks through partner agencies.

The next concern for the restoration of the Peregrine Falcon was whether the population would sustain itself after 1996 once the mass hacks of captive-bred falcons ended. However, the 2000, 2005 and 2010 national surveys served to confirm that the number of falcons was continuing to increase.

The lessons learned here were that reviews of the recovery program are needed to adapt to the survey results. Specifically, the investment in new facilities in the mid-1980s allowed production to increase, and the strategic move toward mass hacks resulted in falcons returning in more substantial numbers to facilitate pairing and begin a founder population in Alberta and eastern Canada.

THE ROLE OF THE RECOVERY TEAM

The National Peregrine Falcon Recovery Team first met in 1986, more than 15 years after the initial conservation work began. Prior to 1986, the Western Raptor Technical Committee, which was formed by agreement under the Canada Wildlife Act between the federal government and four provincial and two territorial governments, had met for several years to discuss raptor conservation issues and to draft a Peregrine Falcon recovery plan. This committee disappeared with the creation of the recovery team. The recovery program with eastern Canadian provinces had not been initiated through any formal committee, but rather was based on Richard Fyfe's personal contacts.

During the 1986 International Ornithological Congress in Ottawa, a group of interested biologists and managers met with Tony Keith, a senior manager with the CWS in Ottawa who chaired the meeting. Since there was no precedent for a recovery team, the question arose as to who would be invited to sit on this National Recovery Team. One view held that this was a government responsibility so only government employees should sit at the table. However, with two universities, i.e., University of Saskatchewan and McGill University, involved in the captive-breeding and release program, as well as several non-government groups funding and assisting in the releases, it made little sense to exclude them. The accepted philosophy when forming this first Canadian Recovery Team was succinctly stated by Joseph Hickey, an American biologist who had organized the now famous Peregrine Falcon conference in Madison, Wisconsin in 1965, "them that pays plays". The team functioned well to air differences and find consensus on issues surrounding the release of Peregrine Falcons.

While the recovery team had no actual decision-making authority and meetings were primarily an information-sharing exercise, its chief value was to come up with recommendations and promote agency action and collaboration. In more recent years, especially since the federal Species at Risk Act was declared, membership of teams and their functions have been debated periodically by federal staff. The recovery team served as advisor to Environment Canada during discussions of 'residence' and 'critical habitat' (see below). However, the role of the team continued to be to share information, encourage continued conservation and research activities, and to plan and publish the five-year national surveys.

The lesson learned from the formation of the Peregrine Falcon recovery team are those prophetic words stated in 1986, "them that pays plays", with the added proviso that all members have to participate as team players. It is important to recognize that recovery teams do not serve only one agency, nor can they tell any given member what to do. However, recovery teams are indeed a place to share information, to resolve differences to seek common ground and to make collective recommendations. In this regard, the Peregrine Falcon recovery team played a key role in the recovery effort after 1986.

THE RECOVERY PLAN

Conservation efforts to reintroduce the *anatum* Peregrine Falcon were guided by the approved Recovery Plan (Erickson *et al.* 1988) and the annual meetings of the recovery team. The desired effect was to re-establish a self-sustaining population of *anatum* Peregrine Falcons in six management zones across Canada (Figure 2). The initial recovery plan (Erickson *et al.* 1988) was drafted in the midst of the reintroduction program that spanned from 1974 to 1996. At that time, the gene pool was not secure, few Peregrine Falcons were nesting in the wild in southern Canada, and pesticide residues were still a concern.

Issues were prioritized as follows: priority 1.1) population monitoring, 1.2) low productivity as a result of pesticides, 1.3) preserving the gene pool, 2.1) preserving habitat, 2.2) releases (of captive-raised young), 3.1) protecting Peregrine Falcons from human disturbance, 3.2) protection of Peregrine Falcons from predation, 3.3) impacts of disease and other disasters, 4.1) public awareness, and 4.2) research and development of more effective management techniques. The team's activities in subsequent years did not coincide with the priority of actions in the plan. For example, little was done to preserve habitat, while releases and public awareness which were lower priority, were annual events. Monitoring of pesticides was undertaken only in Alberta (Court 1993; G. Court, 2009, Alberta Sustainable Resource Department, personal communication) and British Columbia (Elliott *et al.* 2005).

The recovery plan set two objectives for the six management zones across southern Canada (Figure 2; Erickson *et al.* 1988; Banasch and Holroyd 2004). The first objective was to have a population of 10 pairs nesting in each zone by 1992, and the second objective was to have 10 pairs producing 15 young per year in each zone by 1997. These objectives were exceeded in all zones, giving rise to the decision to terminate captive breeding at Wainwright and end the large-scale releases in 1996.

The recovery team began drafting a revised recovery plan in 1997 after the end of the program of releasing captive-raised young. A recovery strategy was outlined in 2000 and annually updated because of the changing guidelines from the RENEW (Recovery of Nationally Endangered Wildlife) office. With the development of a new Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status report in 2001-02 (Rowell 2002), and the 2007 recommendation to downlist Peregrine Falcons to a Species of Special Concern (Cooper and Beauchesne 2007), the efforts to finalize a recovery strategy waned. A downlisting of Peregrine Falcons would mean that no strategy would be needed, but a management plan would be required instead. The species was downlisted and received the status of "Special Concern" in June 2012 (http://www.gazette.gc.ca/rp-pr/p2/2012/2012-07-04/html/sor-dors133-eng.html).

The lesson learned is that a recovery plan was not actually needed to recover Peregrine Falcon populations. Half of the recovery objectives were ignored or poorly implemented by team members. While the document did provide an opportunity to discuss objectives, members also ensured that their own intentions were covered in the plan. However, with no financial support, the plan could not be implemented in any organized fashion. Efforts to finalize a second plan were stalled

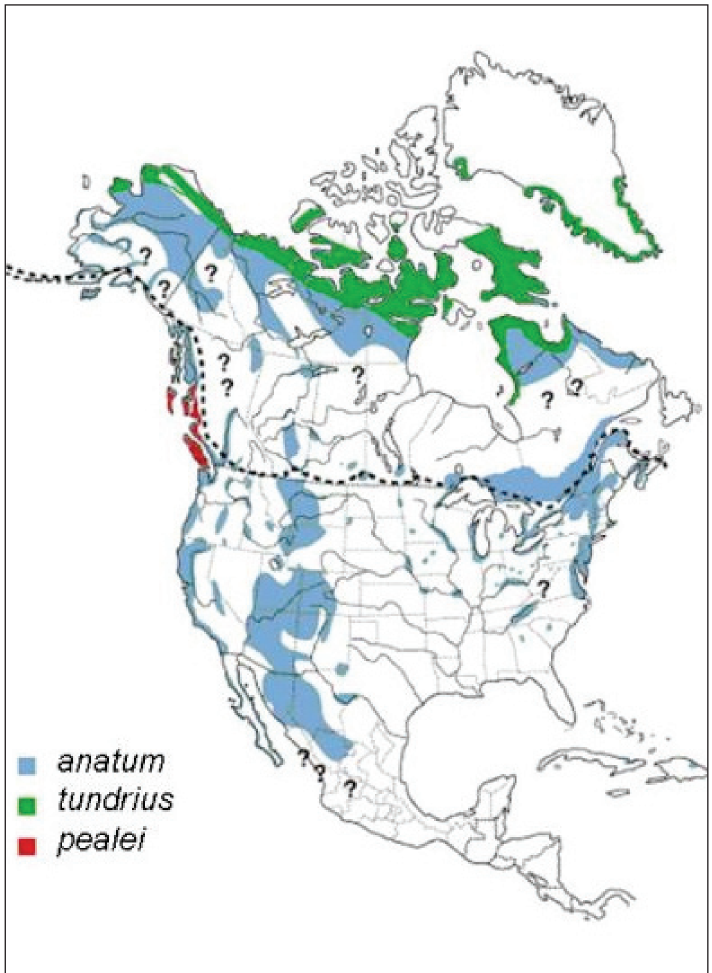

Figure 2. Map of range of peregrine falcons subspecies in North America. (Map: ©Modified from Birds of North America Inc., White *et al.* 2002)

by changing formats and a reclassification of the species recommended by COSEWIC.

COSEWIC CLASSIFICATION OF THE PEREGRINE FALCON

Under the Canada Wildlife Act, the federal, provincial and territorial governments agreed to list species at risk through COSEWIC which was formed in 1977. COSEWIC is composed of representatives from governments, universities and non-government organizations and is supported by taxonomic sub-committees. However, COSEWIC bears no responsibility for recovery efforts.

The Peregrine Falcon was first listed as Endangered by COSEWIC in 1979 (Martin 1979). Twenty years later, COSEWIC downgraded *anatum* Peregrine Falcon to Threatened (Johnstone 1999). In 2002, a status report on *anatum* Peregrine Falcon based on the 2000 national survey (Rowell 2002) caused a stalemate at a COSEWIC meeting because of concern about the taxonomy (Brown *et al.* 2007), the proposed harvest by falconers in the USA (Millsap and Allen 2006), and the fear that downlisting might cause potential loss of revenue sources for some conservation efforts. The conclusion of that meeting was to commission a status report for all three subspecies. In April 2007, COSEWIC recommended the downlisting of *anatum* Peregrine Falcon to Special Concern (Cooper and Beauchesne 2007). Under the new rules of the Species at Risk Act (SARA), this recommendation went to the Minister of Environment who then sought public comments on the recommendation. The formal designation of this change was proposed in the Canada Gazette published on 21April 2012 (http://www.sararegistry.gc.ca/document/default_e.cfm?documentID=2410), and approved on 19 June 2012 (http://www.gazette.gc.ca/rp-pr/p2/2012/2012-07-04/html/sor-dors133-eng.html).

Thus, this next important step in the status of Peregrine Falcons has taken over 10 years to complete after it was first recommended by the recovery team and five years after the recommendation from COSEWIC. This downlisting changed the need for a recovery strategy and designation of critical habitat for a 'threatened' species to a management plan for a species of 'special concern' only.

The lesson learned here is that the listing process was absolutely necessary for all the partners to get involved and the federal government to stay involved in Peregrine Falcon conservation, but in the past decade, the downlisting process has slowed and lagged behind the species conservation status and agency actions.

A LEGAL BASIS FOR THE PEREGRINE FALCON RECOVERY PROGRAM

The recovery of endangered species is a high-profile topic that is subject to federal and provincial/state laws. Specific national and provincial/state laws have been passed to protect and recover species-at-risk in Canada and the Endangered Species Act (1973) in the USA has very strong penalties, has been very controversial, and is long overdue for a review and renewal (Smith and Smith 1997).

In Canada, prior to 2003, endangered species conservation had its history in federal-provincial cooperation. The Canadian federal government was responsible for international wildlife issues, wildlife toxicology, and "order and good government". Canada did not have a national act to conserve endangered species until June 2003 when SARA was passed. Conservation of Canadian 'Species at Risk' (SAR) evolved over the previous 30 years without formal direction from the Canadian parliament. Canada's SAR program developed though agreements of wildlife directors under the Canada Wildlife Act (CWA), which was established in 1973. The CWA enabled legislation with no mandatory actions to initiate regarding SAR, and no direct funding for SAR conservation. The conservation of SAR in Canada was based on cooperative agreements under this act. The CWA did not change the status of Peregrine Falcon management directly. The CWA did allow the Canadian Wildlife Service of Environment Canada to enter into joint wildlife management agreements to conserve Peregrine Falcons and to introduce captive-bred young into the wild.

An additional complication for the Peregrine Falcon recovery program was the fact that raptors were not listed in the Migratory Bird Convention Act of 1917 (MBCA). When the Convention was signed with the USA in 1916, raptors, along with many seed-eating birds, were considered vermin and not worthy of protection. Thus, provincial and territorial governments remained constitutionally responsible for the conservation of raptors and other species not listed in the MBCA. The USA Migratory Bird Treaty Act was amended to conserve raptors, after a treaty was signed with Mexico in 1936 and consequently, raptors were under federal jurisdiction in those two countries. At present, Canada and Mexico do not have a formal convention to jointly protect migratory birds, although the directors of the respective wildlife agencies in the three countries meet annually at the Trilateral Wildlife Meetings.

Most reintroduction projects were organized by provincial wildlife agencies with the assistance of non-government groups and sometimes with the aid of corporate funding. For example, in southern Alberta, the Fish and Wildlife Service (AFWS) took the lead to reintroduce Peregrine Falcons between 1992 and 1996 through a mass hacking program. The first two years of the project were very successful with almost 100 young released (Stubbs 1992; Rowell 1993). After five years, about 250 young had been released by AFWS. Although no formal agreement was in place, CWS was a partner in this release program.

The Accord for the Protection of Species at Risk was signed on 30 September 1996 and updated in 1999 by the federal, provincial and territorial wildlife ministers. Three federal departments signed the Accord: Environment, Fisheries and Ocean, and Canadian Heritage (National Parks). The two-page Accord formed the Canadian Endangered Species Conservation Council which consists of the elected ministers of these agencies. It reaffirmed participation in COSEWIC and committed the governments to "…establish complementary legislation and programs that provide for effective protection of species of risk throughout Canada…" The Council's purpose was to coordinate conservation activities, provide general direction for assessment, and coordinate recovery efforts.

The Habitat Stewardship Program for SAR is the federal program to encourage landowners to become responsible stewards of wildlife on their land. The 2003 SARA is the federal component of the third commitment under the Accord.

The lesson learned here is that specific legislation was not required for the Peregrine Falcon conservation effort undertaken by the federal government. Bilateral agreements under the Canada Wildlife Act sufficed to get agency cooperation to conduct the recovery program. However, as Fyfe *et al.* (2003) pointed out, the establishment of the federal program was due in part to the forward-thinking managers in CWS in the 1970s, particularly Anthony Keith and Ward Stevens. The lack of an international agreement that included raptors did make formal discussions and collaboration on Peregrine Falcon recovery with US agencies more difficult.

BREEDING HABITAT

Habitat loss has been considered a primary cause of endangerment of wildlife in Canada and elsewhere (Ehrlich and Ehrlich 1981; Kerr and Cihlar 2004). The rationale is simple. Wildlife needs habitat to survive and reproduce. Without it, species' populations inevitably decline and ultimately, face the risk of extinction. However, habitat loss is only one cause of decline, since many other factors can cause declines, such as over-exploitation, toxic chemicals, exotic species, and predation (Ehrlich and Ehrlich 1981). As we discussed elsewhere, toxic chemicals were found to be the ultimate cause of the decline of Peregrine Falcons.

The national Peregrine Falcon recovery plan Priority 2.1 was to 'Preserve Habitat' (Erickson *et al.* 1998). The recovery plan called for the preservation of core areas around breeding sites. However, the implementation of this objective eluded the recovery team since many nest sites were in urban areas and others were on or adjacent to private land. The definition of core areas or critical habitat for Peregrine Falcons was never resolved. While conservation of habitat was a priority in the recovery plan, little was in fact accomplished specifically for Peregrine Falcons.

Definition of prey habitat was considered somewhere about half-way through the recovery program. In Wood Buffalo National Park, for instance, Beaver-Johnson (1979) described the diet of the breeding Peregrine Falcons. However, the diet was described for the population as a whole with no reflection of individual diets, seasonal variation, availability of prey, and diet selectivity. Nelson and Myres (1975) and Nelson (1990) noted the dependence of *pealei* Peregrine Falcon on Langara Island, British Columbia on Ancient Murrelet (*Synthliboramphus antiquus*) for food. Little else has been published on Peregrine Falcon diets from southern Canada. Research proposals to define specific foraging areas and habitat use in the breeding season with the use of radio-telemetry were not funded. The second option, i.e., using satellite telemetry to determine locations of breeding Peregrine Falcons in remote areas such as Wood Buffalo National Park, was undertaken but with a minimal number of transmitters each year. The overall objective of such studies was to provide land managers, including provincial agencies, with information on how to define and protect important foraging habitats around nest sites and for dispersing and migrating Peregrine Falcons feed over prairie wetlands and other open-country habitats that fall under the influence of the Prairie Habitat Joint Venture (PHJV). More specific habitat guidelines were never provided to PHJV staff for use in their programs that might have benefited Peregrine Falcons.

Habitat was never shown to be a limiting factor in the Peregrine Falcons' decline. Reintroduced Peregrine Falcons now nest commonly in many Canadian cities on buildings, bridges and in quarries (Cade and Bird 1990; Gahbauer 2008). Thus, conservation of natural habitats seems less important for Peregrine Falcon conservation than for other species at risk. But, as for most other wildlife species, human activities continue to encroach on Peregrine Falcon habitat.

The Species at Risk Act provides protection for species listed as endangered and threatened. Under SARA Section 58(1) "…no person shall destroy any part of the critical habitat of any listed endangered species …..if

(a) the critical habitat is on federal land…..

(b) the listed species is an aquatic species…..

(c) the listed species is a species of migratory birds protected by the Migratory Birds Convention Act, 1994."

Thus, this provision only applied to Peregrine Falcons under (a) on federal land. Since the Peregrine Falcons on federal land are in national parks, their habitats are already protected. Critical habitat also appeared to be a non-starter for Peregrine Falcons since this species nests in many urban habitats that are predominantly composed of concrete and asphalt. Discussions about critical habitat for Peregrine Falcons attempted to resolve the conflict between the need to designate critical habitat and the fact that many Peregrine Falcons nest in cities. One suggestion was that Peregrine Falcons are like airplanes that require airspace and somewhere to land. An alternate suggestion was to designate the two-dimensional area occupied by foraging Peregrine Falcons as critical habitat but under the prescription for habitat destruction allow virtually anything to be done in the critical habitat. This would mean that any activity can be undertaken since the habitat cannot be destroyed based on current Peregrine Falcon habitat use. In either case, no effective habitat protection would occur under SARA. With the downlisting of Peregrine Falcons to Special Concern, the critical habitat provision of SARA does not apply, and the topic is no longer relevant.

However, foraging habitat around nest sites will likely continue to come under the influence of agricultural, industrial and recreational activities. The recent phenomena of drought, global warming and other aspects of climate change may also affect the Peregrine Falcon's food supply, particularly when that prey base is strongly tied to wetland areas. Disturbance of active nest sites was and is still a concern both on human structures that require maintenance, and on cliffs that are also used by recreational climbers (Shank 1989).

The lesson learned here is that research on prey and habitat conservation was not necessary for the recovery of this species. Despite the conclusion that habitat loss is generally a major cause of species declines, it did not play a significant role in the decline of the Peregrine Falcon in most of Canada.

ANTHROPOGENIC NEST SITES

Since there was a history of Peregrine Falcons nesting on tall buildings, e.g., the famous Sun Life pair in Montreal in the 1950s, some conservationists in the Peregrine Falcon recovery program developed an interest in returning falcons to these urban sites. Indeed, the very first hack releases of Peregrine Falcons from buildings in Canada took place in 1976 on the Veterans Hospital in Ste. Anne de Bellevue, Quebec and the O.S. Longman Building in Edmonton, Alberta (Cade and Bird 1990). By 1987, almost half of released young were in urban areas (Holroyd and Banasch 1990), but after that larger rural releases were undertaken and fewer were released in urban areas.

The recovering continental Peregrine Falcon population chose nest sites in both rural and urban habitats. In many cases, historical rural cliff sites such as those along the Red Deer River in Alberta or the shores of Lake Superior in Ontario were re-populated by captive-bred falcons. In other cases, Peregrine Falcons have made ample use of man-made structures, both in rural and urban environments. Throughout the recovery process, concern had been expressed over the number of *anatum* Peregrine Falcons nesting in urban settings or on man-made structures versus natural cliff sites. By 1989, 91% of the returning captive-raised and released falcons returned to a site similar to their release site, i.e., urban versus rural (Holroyd and Banasch 1990). However, even though most releases were from rural cliffs, the 2000 survey data showed that of 162 known territories occupied by territorial *anatum* Peregrine Falcons south of 58°N, 45 (28%) nested on buildings, bridges or industrial towers, while the remaining 117 (72%) nested on natural cliff sites (Rowell *et al.* 2003). A closer look at populations in southern Alberta and southern Ontario in the 2000 survey, where both habitat choices are available, showed a wide variance in figures of 61% and 28% on human structures, respectively. As the number of nesting pairs increased on a limited number of human structures, the proportion of falcons that moved to rural sites were expected to increase. However, by 2009 the reverse was true in southern Alberta, where only two pairs nested on cliffs and 25 pairs nested on structures (G. Court, 2009, Alberta Sustainable Resource Department, personal communication) and in southern Ontario all occupied sites were on structures (Gabhauer 2008; Chikoski and Nyman 2011).

While urban sites may offer a variety of prey, habitat advantages, e.g., more stable "nest ledges", and an absence of natural predators like Great Horned Owls (*Bubo virginianus*) to nesting Peregrine Falcons, they also have their drawbacks (Cade and Bird 1990). The same prey that attracts urban Peregrine Falcons remains a threat to their health as long as avicides and toxic agents like 4-aminopyridine (marketed as Avitrol) are used to control nuisance Rock Pigeon (*Columba livia)* populations. The frequency of deaths from young falling into busy traffic, collisions with buildings mirrored or otherwise, falling down chimney stacks, etc., are higher than those occurring with falcons fledging from natural cliffs. Gahbauer (2008) summarized the various mortalities in urban-nesting Peregrine Falcons and discussed how human intervention had played a role in the success of these birds. Urban Peregrine Falcons are an important contribution to the overall population (Rowell *et al.* 2003; Holroyd and Banasch 1990). Certainly, urban Peregrine Falcons provide a wealth of wonderful opportunities to educate the general public about endangered species, instill a sense of wonderment about Peregrine Falcons in general, and to promote conservation concepts. A plethora of web cams focused on urban Peregrine Falcons still remain popular with many members of the public. Continued monitoring of urban Peregrine Falcons should identify any conservation concerns and provide opportunities for communication with the public.

The lesson learned was that in the end, the Peregrine Falcons decided where they wanted to nest. Despite targeting mass hacks at rural sites, the falcons have chosen to move into urban settings and adopt human-made structures as nesting sites in many parts of southern Canada. The cities of Montreal and Edmonton each now hosts close to 10 pairs of Peregrine Falcons on its buildings and bridges and in its quarries, where historically there was only one or two pairs. Now adopting more than 60 cities in North America, with some large city centers like New York, Toronto, and Chicago supporting over a dozen pairs, these city-nesting falcons appear to be productive, albeit with a fair amount of monitoring especially at fledging time.

DEFINING "RESIDENCE" FOR PEREGRINE FALCONS

Section 33 of SARA (Environment Canada 2003) prohibits damaging or destroying a listed threatened, endangered, or extirpated species' residence. SARA defines residence as: "a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" [s.2(1)].

The prohibition described above comes into effect immediately upon listing for all threatened, endangered, and extirpated species on federal lands, and for species with pre-existing federal jurisdiction on all lands. Species with pre-existing federal jurisdiction includes migratory birds protected under the Migratory Birds Convention Act (MBCA), but not Peregrine Falcons because birds of prey do not fall under this act. SARA also contains a provision to prohibit the destruction of non-federal species' residences on provincial, territorial, and private lands by way of an Order under the federal criminal law power, if the Minister of the Environment deems it necessary to do so [s.34(2), 35(2)]. The description of residence for the Peregrine Falcon includes three types of residences – nest ledges, roost sites and nesting structures (cliff, outcrop, river bank or other natural or artificial structure). This definition is now part of the regulations under SARA. Time will tell if the protection offered by SARA for this species will be effective.

PUBLIC AWARENESS

A key component of the Peregrine Falcon recovery story was communicating related issues to a wide variety of audiences. Briefing notes were frequently submitted by the Edmonton office to senior Environment Canada managers to keep them apprised of the progress of the recovery effort. Press releases and media interviews by staff from all the Canadian breeding centres kept the public not only informed about the progress of the reintroduction effort but about the conservation issues surrounding Peregrine Falcons, including DDT and other pesticides. The recovery team regularly used the Peregrine Falcon as a 'poster' species for toxic chemical issues which echoed the message of Silent Spring (Carson 1962). While the federal government certainly appreciated the high public profile associated with their breeding and release program, it was even more critical for the two non-profit organizations, the Saskatchewan Cooperative Falcon Breeding Project and the Macdonald Raptor Research Centre of McGill University, both of which relied heavily on donations from industry, foundations and private sources.

The federal captive breeding facility was housed just outside the town of Wainwright on a Canadian Forces Base. Both the public and military staff were interested to tour the facility, but with limited CWS staff, time was a factor. So in the mid-1980s, CWS approached the town council and formed a joint Wainwright Wildlife Society with the dual objectives of conserving local wildlife and conducting tours of the breeding facility. The non-profit group received grants to purchase a passenger van and hire summer staff to run scheduled tours onto the base. During the first month each summer, these summer staff would help at the captive breeding facility as part of their familiarization of the Peregrine Falcon story and consequently provided extra help during the busy start to the breeding season. When the Wainwright facility closed, a large party and pig roast was hosted by Phil and Helen Trefry, the staff at Wainwright, to thank the community for its support over the 25-year history.

Another key factor in publicizing the Peregrine Falcon program as well as educating the public was seen in the area of urban releases. Placing young Peregrine Falcons in hack boxes on tall buildings in large city centres, e.g., Montreal, Toronto, Winnipeg, Calgary, Edmonton, etc., and on university campuses, captured the interest of millions of urban-based people. Public enthusiasm over urban Peregrine Falcons was even more heightened when the falcons actually returned to nest on the city buildings, bridges, etc. In many cases, cameras were placed on the nests and video and audio signals sent down to large television screens in building lobbies, e.g., Place Victoria in Montreal, and in Edmonton, even on cable channels. By 2012, web-cams were in operation at various sites across Canada and around the world.

The lessons learned here were that communications to all audiences ranging from government officials to the public-at-large were paramount to the success of the recovery effort, to maintaining support for the programs, and to maximizing benefits of the programs. The Wainwright Wildlife Society continues as a legacy of the breeding facility and its staff. Media still show signs of interest when a new pair of Peregrine Falcons adopts a new building in cities, e.g., the 2009 pair on a tower on the Université de Montreal and a pair in Red Deer, Alberta. Public interest in watching adults and chicks through webcams at numerous nests in Canada and elsewhere has grown with the installation of more sites. We cannot be complacent in our efforts to conserve Peregrine Falcons, but rather should continue to use this raptor as a flagship species for other conservation issues and as an indicator of the ecological integrity of our environment both in Canada and elsewhere.

POPULATION MODELLING FOR PEREGRINE FALCONS

Population models and viability analysis are often touted as necessary to determine the viability of small populations, including Peregrine Falcons (Wootten and Bell 1992). While a population model could have been used to determine whether the production and survival of this species was adequate to predict a self-sustaining or growing population, a proposal in 1994 to develop one for all Canadian populations before the closure of the Wainwright facility was not funded. If such a model had showed that the addition of foster young would be required to help the population, then a supply of captive-raised young would be needed. If that had been the case, the eventual disposal of the Wainwright falcon breeding stock would have allowed for provision for the recipient facilities to provide young for releases.

Simple population models require four numbers: population size, productivity, recruitment to breeding age, and adult survival rate (Grier 1980; Wootten and Bell 1992). Preliminary population models were developed in 1994 and 2001 using data from Wood Buffalo National Park (WBNP) from 1971 to 2001 (Court 1994; GLH, unpublished data). During that time the WBNP population was below 10 pairs until 1993 but then increased to a high of 25 pairs (Figure 3). The majority of young Peregrine Falcons in northern Alberta, in and near WBNP, had been banded for about 20 years. Also, the identity of leg-banded breeding Peregrine Falcons had also been determined for about one-third of the adults between 1990 and 2001. Peregrine Falcons typically breed first in their second year. Recruitment to breeding age (fledgling survival to year 2) is one of the most difficult parameters to measure. Only one estimate existed in the literature. Ratcliffe (1993) determined recruitment, the survival from fledging to breeding age (year 2), to be 0.26 in a British Peregrine Falcon population. The estimated recruitment calculated from northern Alberta data was 0.09 in 1994, and 0.15 in 2001. Annual adult survival was estimated in north-eastern Alberta to be 0.72 (range 68-81%, Court 1994) which was similar to survival estimates of 0.74 calculated for other populations elsewhere (Wootten and Bell 1992).

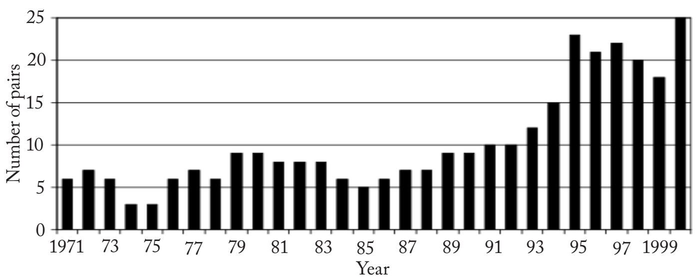

Figure 3. Number of nesting pairs in and adjacent to Wood Buffalo National Park from 1971 to 2000.

Productivity measured as the number of young fledged per territory or nesting attempt varied considerably before 1988, i.e., from 0 to 2.4, but after that year, it was consistently over 1.4 per attempt. These data from north-eastern Alberta up to 2001 were entered into a simple model (Figure 4). The population seemingly declined when the figures from the years prior to 1988, i.e., 1.6 young (S.D. 0.8), were inserted and the probability of population persistence was only 53%. For the time period after 1989, a figure of 1.8 (S.D. 0.3) young produced an increasing population size with a probability of population persistence of 93% (Figure 5). In any case, these figures gave the recovery team some security that if productivity remained above 1.6 with a low S.D., then the population could be expected to survive and even grow. The national recovery plan indicated 1.5 young per pair was necessary to attain population recovery (Erickson *et al.* 1988). More recently, Craig

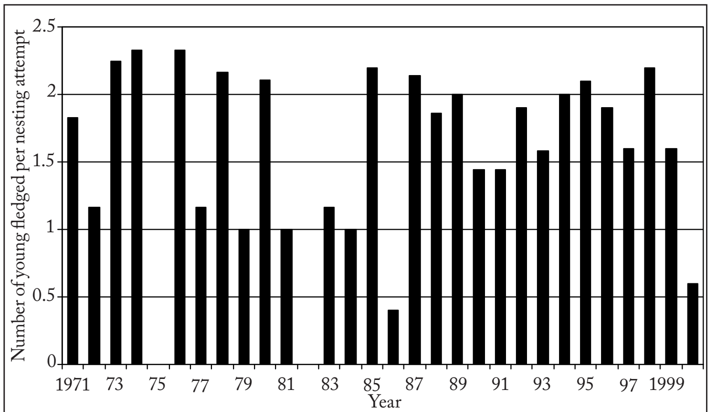

Figure 4. Number of young fledged per nesting attempt by Peregrine Falcons in and adjacent to Wood Buffalo National Park, 1971 to 2000.

et al. (2004) showed in Colorado that as few as 1.1 young per pair may maintain a stable population. Population models were not attempted for any other southern Canadian Peregrine Falcon population.

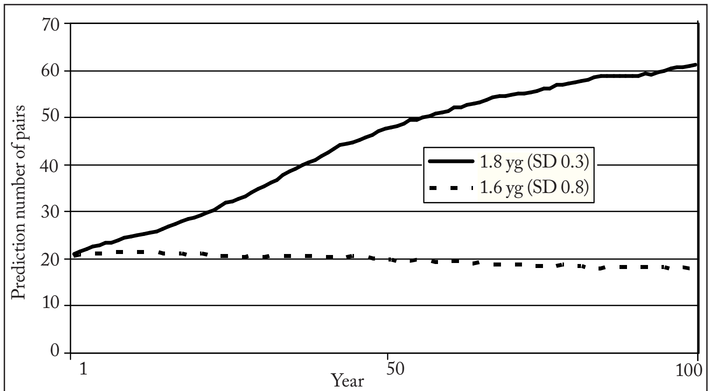

Figure 5. Theoritical model of population viability of Peregrine Falcons in Wood Buffalo National Park with nesting parameters taken from 1971 to 1987 (dotted line) compared with 1988 to 2000 (solid line).

Once the Wainwright facility closed in 1996-97, the supply of captive-raised, young Peregrine Falcons became severely limited. A study of California's Peregrine Falcon population determined that it would decline without the addition of captive-raised young (Wootten and Bell 1992). Apparently high levels of DDT/DDE in southern California were still causing nest failures and preventing the population from maintaining its numbers. If a more precise model had been formulated for Canadian falcon populations, it could have detailed the Peregrine Falcon recovery team's options for dispersal of the young from the Wainwright facility and for the supply of the captive-raised young. However, the simple population model that was created sufficed to bolster the decision to close Wainwright and disperse the breeding stock with no attached conditions, e.g., a supply of young for releases if necessary.

The lesson learned here is that a rigorous population model that included all Canadian *anatum* Peregrine Falcon populations was not needed to recover the population. The populations of Peregrine Falcons have indeed continued to increase in most regions of Canada despite the existence of such a population model. But perhaps the team was fortunate in that regard. If the populations had not continued to increase, then having a more rigorous population model could have indicated where the problem was occurring as well as helping to arrive at the necessary solution.

TOXICOLOGY MONITORING

As stated earlier, the decline of the Peregrine Falcon in North America was caused largely by the use and bioaccumulation of persistent organochlorine compounds, particularly DDT and its metabolite DDE. Summaries detailing contaminants in Peregrine Falcons and their prey up to 1986 showed that environmental levels of several organochlorine compounds were declining by that time.

However, the average level of several organochlorines in Peregrine Falcon tissue and eggs were only slightly below "critical levels" (Peakall *et al.* 1990). In Alberta, from 1980 to 1987, 7 of 56 samples had levels of DDE that exceeded critical levels, and in Yukon birds, five of 8 samples exceeded critical levels (Peakall *et al.* 1990). Eggs collected in 1990-1992 in southern Alberta had lower levels of DDE (mean 6.2 ppm, range 2.4-13.9 ppm) than collections dating back to 1968 (Court 1993).

Egg shell thickness in Rankin Inlet in the 1980s was on average 16% thinner than shells prior to the DDT era (Court *et al.* 1990). Thinning of 18% and/or levels of DDE at 15 mg/kg is generally associated with shell breakage during incubation. Between 1984 and 1992, 15 of 58 clutches had eggshell thicknesses below the 18% figure and all but two were thinner than the pre-DDT era level (Court 1993). Shells from northern Alberta averaged 14% thinner than eggs from DDT-free conditions (Court 1993). Thus, egg shell thinning was still a concern in the early 1990s.

A review of residue levels in prey species between 1980 and 1986 found high levels of contaminants in avian species that feed on aquatic organisms, such as herons (Ardeidae spp.), grebes (Podicipedidae spp.), gulls (Laridae spp.), shorebirds (Charadriformes spp.) and swallows (Hirundinidae spp.) (Baril *et al.* 1990). Gulls collected several years later in southern Alberta in advance of the mass releases, still contained moderate levels of DDE, PCB and Dieldrin (Court 1993). DDE levels in Peregrine Falcon eggs in northern Alberta were below the critical level of 15 mg/kg in 1986-87 (Peakall 1990). Court (1993) found that Peregrine Falcons in southern Alberta had lower residues of DDT, DDE and other chemicals post-reintroduction than historically observed and these levels were below levels that could be expected to cause nesting failure. However, some samples, particularly the eggs laid in Edmonton in 1988 by the female, "Arrow", showed that locally caught prey still contained enough toxins to noticeably contaminate eggs.

The most recent toxicology investigation of Peregrine Falcon prey between 1998 and 2001 found very high levels of DDE in the Okanagan valley where the pesticide was historically heavily used in fruit orchards (Elliott *et al.* 2005).

Lessons learned from the toxicology assessments were that while DDT/DDE levels did decline in regions monitored east of the Rockies, more detailed assessments would have provided a better assessment of the toxicology risks to Peregrine Falcons. Fortunately, the monitoring conducted by AFWS (Court 1993, 2009 Alberta Sustainable Resource Department, personal communication) filled in at least some of the gaps. However, more recent monitoring of toxicology has still not been conducted in most of the populations.

GENETIC ISSUES

One of the issues that was never resolved in the recovery program was the genetic basis of the three subspecies of Peregrine Falcons in North America. Three subspecies are recognized based on physical descriptions (White 1968; White and Boyce 1988), but thus far, this is not supported by modern genetic techniques (Brown *et al.* 2007). The typical *anatum* Peregrine Falcon is medium-sized, with a pinkish or rosy wash on the chest. The *tundrius* subspecies is smaller with a white chest, and the pealei Peregrine Falcon is larger with a dark barred chest. However, numerous falcons are intermediate between *anatum* and *tundrius*, which led to many spirited discussions at conferences regarding the differing philosophies about stocks for release between the American and Canadian programs. Thus, the team recognized the critical need to determine whether the three subspecies could be identified on a genetic basis or at least based on more rigorous morphology.

While it is true that Peregrine Falcons have been restored to North America, there is some doubt that these birds are the same *anatum* genetic stock that once occupied the continent. Whenever a species' population drops to a very low number, there is always concern that the population will lose much of its original genetic diversity if and when it passes through a genetic bottleneck. Stepnisky and Court (2001) compared genetic diversity retained in the southern Alberta population of Peregrine Falcons with the original population of pure *anatum* individuals at the CWS Wainwright Peregrine Breeding Facility. They found that the 1999 Alberta population contained 95% of the genetic diversity of the founding population, and that the population had very little inbreeding and relatively equal founder contribution.

A related question is the genetic origin of falcons that breed in the eastern USA and immigrated to Canada. While the Canadian Peregrine Falcon Recovery Program ensured that only birds of the *anatum* subspecies were used in captive breeding programs, the releases in the eastern USA involved falcons of six other subspecies (*pealei, tundrius, peregrinus, macropus,* and *brookei*) as well as *anatum* (Temple and Cade 1988; Tordoff and Redig 2001). The USA and Canadian-released Peregrine Falcons crossed the border both ways and the species was again becoming 'continental', as it should be.

As mentioned earlier, the first two birds to repopulate a territory in downtown Montreal in 1984 were from eastern USA origins. In the 2000 survey, Ontario reported at least five USA–released adults breeding on the northern side of the border, often paired with Canadian-bred birds (Ratcliff and Armstrong 2000). Similarly, Tracy Maconachie (2000, Manitoba Peregrine Falcon Recovery Program, personal communication) reported that the female Peregrine Falcon that had bred in Winnipeg in the 1990s for more than a decade was a 1989 USA-released bird of mixed subspecies origin. Since a number of Winnipeg young have been sighted in Saskatchewan and Alberta, some of these USA genes may have been transported even further west. During the same time, Canadian-released Peregrine Falcons were breeding in the USA in similar numbers. Thus, it is only logical to assume that a "mixing" of the founding stock between the USA and Canada was and still is occurring. In the final analysis, the philosophy of "a peregrine is a peregrine is a peregrine" was adopted by many, as long as the species recovered. However, perhaps if only to satisfy our own curiosity, DNA-based studies were conducted to determine just how much genetic mixing had occurred.

While some criticized the sample sizes used from some populations, a genetic analysis of historical museum specimens and current wild stock compared the three subspecies pre- and post-releases (Brown *et al.* 2007). Using 12 microsatellite DNA loci, they found no genetic difference between *anatum* and *tundrius* as separate subspecies, but *pealei* remained a distinctly different subspecies even post-release. An additional finding was that *anatum* birds after releases were somewhat different from the *anatum* falcons originally used for the breeding and release program in Canada. Part of that difference is likely attributable to genes from the various exotic subspecies used in the USA program, whose offspring eventually immigrated to Ontario (Tordoff and Redig 2001) where the post-release sample was concentrated. However, the rate of introgression of microsatellites of other subspecies was <1.6% (Brown *et al.* 2007). All in all, these falcons have likely had a minor effect on the genetics of current Peregrine Falcons breeding in southern Canada. There is no evidence that this genetic contamination has crept into the boreal and more northern Peregrine Falcon populations.

The lesson learned here is that the lack of unanimity in the philosophies concerning the genetic origins of the subspecies to be bred and released on either side of the international border led to an inevitable genetic mixing whether one wanted it or not. Since Peregrine Falcons are great wanderers and do not respect international boundaries, the USA- and Canadian-released falcons interbred and now form one continuous population across both nations. Since the genetic study revealed little or no difference between the *anatum* and *tundrius* subspecies, the intermingling of the genes from these release programs has had only a minor impact on the genetics of the reintroduced population.

HARVEST OF MIGRANT PEREGRINE FALCONS

Regardless of the genetic make-up and location of the recovering Peregrine Falcon population, their increasing numbers have precipitated interest from falconry enthusiasts in the USA. This has raised the issue of allowing a harvest of Peregrine Falcons for use in this sport (US Fish and Wildlife Service 2008). Prior to the DDT era, falconers commonly took young falcons from active nests to practice falconry with no apparent impact on the resource. It also must be emphatically noted that falconers played an integral role in the Peregrine Falcon recovery, with many of the propagation and release techniques developed by them strictly for the benefit of this species' conservation (Cade and Burnham 2003).

Still, the harvest issue was a concern for the Canadian recovery team. In a strange twist of events in 2001, the team was caught in the awkward position of voicing its concerns over an American proposal for a harvest of Peregrine Falcons still listed as threatened nationally, while at that same time, the province of Saskatchewan was issuing permits for the take of two passage (young of the year) birds per year. Despite the growing population in most regions of North America, the debate to allow a "take" of wild Peregrine Falcons and how many will continue.

In the autumn of 2009, a harvest of passage Peregrine Falcons occurred in the continental USA, primarily in the eastern states. This allowed take was a modest 36 falcons compared to the original proposal of 250. Although Peregrine Falcons from northern populations are the target of this harvest, southern Canadian nesting Peregrine Falcons could also be caught incidentally. Stable isotope analysis, as previously used on Peregrine Falcons (Duxbury 2004) will be used to approximate the origins of these young of the year. Harvest strategies could end up being modified if the analyses indicate that many young are being harvested from southern populations.

The lesson learned with this issue was that an open dialogue between the two countries was critical for Canadian biologists to express their concerns about the harvest. Through the intervention of the first author as a CWS biologist representing the collective Peregrine Falcon Recovery Teams concerns, the initial harvest was reduced from the proposed 250 per year to 36, a much more acceptable number. Nevertheless, a forum is still needed to continue the dialogue with the USA to protect the interests of southern Canadian Peregrine Falcons.

MIGRATION AND WINTER HABITATS

Once the breeding season ends, the habitat that supports prey populations away from the nest site area and that is used by Peregrine Falcons before they migrate south also must be identified. To this end, Dekker (1980, 1984, 2009) documented the activities of post-breeding Peregrine Falcons feeding on ducks (Anatidae spp.) and shorebirds in the prairies. Gahbauer (2008) and Holroyd (unpublished data) also employed satellite telemetry to study migratory movements of Peregrine Falcons released in both urban and rural environments.

The concern about habitats also extended beyond Canadian borders to the USA and Latin America. As we learned more about the winter habitat needs of the Peregrine Falcons, we realized their dependence on prey in local habitats in the south. Telemetry data indicated that adult birds feed in relatively small 'territories' in winter, and did not range widely during the winter months (GLH, unpublished data). An event in early 2002 in Dominican Republic showed that there is a great deal of public relations work to be done before the Peregrine Falcon can yet be considered "safe". A male falcon wearing a satellite transmitter attached by the Canadian Peregrine Foundation was feeding on pigeons in San Francisco De Macorís, Dominican Republic in the winter of 2001-02. Local pigeon-fanciers were outraged and wanted the falcon summarily shot. Fortunately, local conservationists prevailed and used the falcon's presence to explain the ecology and migration of raptors to the local residents (http://www.peregrinefoundation.ca/programs/trackem/tracklight.html).

Toxicological studies of Peregrine Falcon prey over the years in Latin America have also identified some hotspots on the falcon's wintering range. Henny *et al.* (1982) reported that DDE contamination in migrant Peregrine Falcons was accumulated mostly at their wintering grounds in Central and South America, though levels were sufficiently high to be of reproductive concern for only a small minority of individuals. As said earlier, DDT remains in limited use across parts of Central and South America, and migrant Peregrine Falcons staging or wintering there continued to accumulate toxic residues (Baril *et al.* 1990; Johnstone *et al.* 1996), as a consequence of the high DDE concentrations in certain prey species (Fyfe *et al.* 1990). Samples of prey collected in Latin America found that prey from Peru and Ecuador had the higher concentrations of DDT/DDE compared to Suriname and Costa Rica (Fyfe *et al.* 1990; Banasch *et al.* 1992). However, there were no follow-up actions to reduce pesticide concentrations or use.

The lesson learned about our efforts to learn about toxic chemicals like organochlorines and their impact on migrating and wintering Peregrine Falcons (Fyfe *et al.* 1990; Banasch *et al.* 1992) is that we need to maintain a constant, open dialogue with other countries whose habitats are shared by our Peregrine Falcons. Banning chemicals in our country is definitely useful, but less so if the birds are still being exposed on their migration routes and wintering grounds. The more important lesson learned about migration and winter habitats of Peregrine Falcons is that we have essentially been ineffective in any real conservation actions, with a few exceptions, to conserve falcons and their habitat outside the breeding season in Latin America. At this time, we still do not know the impact of mortality outside the breeding season on Canadian populations.

INTERNATIONAL COLLABORATION

Despite the fact that the American Peregrine Falcon release program, under the direction of Tom Cade at Cornell University, adopted a different philosophy from that of Canada to maintain genetic purity in Peregrine Falcons and were releasing some non-*anatum* falcons, and there were no formal agreements between the two countries to cooperate in the recovery efforts, mutual trust developed between the captive-breeding efforts based upon a shared concern for the resource, i.e., Peregrine Falcons. The lines of communications between biologists in the two countries developed through conferences, workshops and symposia at various international gatherings, most notably the Raptor Research Foundation and the World Working Group on Birds of Prey. Information flowed quite freely among biologists and breeders in Canada, USA and Europe. Staff at the various USA and Canadian captive-breeding facilities knew each other and freely discussed topics of mutual interest as needed. These personal contacts substituted for the lack of formal meetings between the Canadian and USA government wildlife services. Discussions about Peregrine Falcons and other raptors at the Trilateral Meetings of the wildlife directors did occur for two years at the start of the Millennium but were constrained since raptors were not considered migratory birds under the MBCA. Another aspect of collaboration between the Canadian-based breeding programs and the American recovery programs was seen in the sale of captive-bred young to USA organizations for release in their particular geographical regions. This mutually beneficial activity basically provided young *anatum* Peregrine Falcons for release into the USA, while earning money to keep the Canadian breeding programs at the University of Saskatchewan and McGill University functioning.

The lesson learned on international collaboration is that the sharing of information would have likely improved with formal contact between the federal wildlife agencies. However, attendance at annual conferences and telephone calls (no email back then) substituted for formal meetings. Cooperation between the various breeding facilities and release projects was excellent and benefited the recovery of the falcon.

ONGOING MONITORING OF POPULATIONS

A recent concern is the low productivity of Peregrine Falcons in three regions in 2000 and 2005 (the 2010 survey data have not yet been compiled). In those two years, Peregrine Falcons in Yukon, northern Alberta and Labrador in particular experienced very low productivity. In Labrador, the number of falcon pairs dropped from 31 in 1995 to 15 in 2000. Consequently, the number of young produced was greatly reduced. Because the surveys were conducted in July, we do not know if the falcons occupied known sites, failed and left, or, even worse, did not even try to nest. In northern Alberta and Yukon, the pairs arrived in the spring, but many failed to produce young in July. In northern Alberta, 2000 was the first year of low productivity in over a decade of high productivity (Rowell *et al.* 2003).

The lesson learned here was not to rest on one's laurels. While many Peregrine Falcon populations have indeed recovered to healthy numbers, there still remains a myriad of on-going threats to their health and well-being such as new contaminants, e.g.,brominated flame-retardants (Fernie and Letcher 2010; Guerra *et al.* 2011), reductions in prey (Rich *et al.* 2009), and global warming (Franke *et al.* 2010, 2011). Hopefully, continued monitoring, including the 5-year national surveys, will continue to shed light on these new concerns.

CONCLUSIONS

Recovery of Peregrine Falcons was 'easy' compared to those undertaken for other species in decline in Canada. As we stated in the introduction, the recovery of any endangered species requires that we must first determine the ultimate causes of the decline (Mayr 1961). The proximate cause of the Peregrine Falcon decline was the lack of productivity. The ultimate cause was found to be DDT accumulation that interfered with calcium deposition at egg formation that caused eggs to break under the weight of incubating adults. The conservation action that resolved the ultimate cause was to ban DDT in North America. Although it is still in limited use in Latin America where some Canadian Peregrine Falcons spend their winters, its use seems to be limited to indoor residual spraying for disease vector control under the Stockholm Convention (United Nations Environment Programme 2010; Ritter *et al.* 2011; van den Berg 2009).

Another important point is that legislation alone will not prevent the decline of a species or recover it. The recovery of Peregrine Falcons occurred without specific legislation, but did occur with the cooperation of numerous federal, provincial, territorial and non-government agencies. Legislation was important, however, to enact certain conservation solutions, such as banning DDT.

As Sutherland (2000, page 111) succinctly put it, "A failure to diagnose what is wrong is at the heart of much unsuccessful conservation." For instance, habitat loss was not a major factor causing Peregrine Falcon declines, nor was it the ultimate cause. Although Peregrine Falcons obviously need habitat, legislation to protect its habitat alone would not have recovered the species. While SARA does offer habitat protection on federal lands, most Peregrine Falcons in southern Canada nest on private land. Thus, increased socio-economic research is needed to find ways to support landowners who are 'doing the right thing' and acting as responsible stewards for the wildlife that shares their lands.

An international agreement may have helped to get national wildlife agencies committed to the species' conservation and to open dialogue with Latin American countries regarding winter habitat. Holroyd (1993, 1995) suggested that an international agreement was needed to conserve raptors. However, as is seen in the healthy populations of Peregrine Falcons in North America today, their conservation was, in fact, accomplished by parallel action in Canada and the USA without any formal agreement.

Not stressed enough in this article is the dedication of the individuals that were involved in the Peregrine Falcon recovery effort. Cade and Burnham's (2003) book on the Peregrine Falcon recovery in North America focused on 'teamwork and tenacity'. The articles featuring the Canadian recovery effort describe in more detail the efforts of individuals to recover this species in Canada (Campbell 2003; Fyfe *et al.* 2003; Holroyd 2003). Without the commitment of those individuals at all stages of the recovery effort, no amount of legislation or protection would have completed the task at hand. It was very fortunate indeed for the Peregrine Falcon in both North America and Europe that the ultimate cause of its precipitous decline was identified quickly and resolved by a dedicated collection of people whose love for the species caused them to work together on this cooperative program.

Main Lessons

• We can recover an extirpated species if enough resources are made available to dedicated individuals that work together towards the common goal.

• Reviews of the recovery program are needed to adapt to the results of periodic surveys.

• The lesson learned from the formation of the Peregrine Falcon recovery team is that all members have to participate as team players.

• A recovery plan was not actually needed to recover Peregrine Falcon populations.

• The listing process was absolutely necessary for all partners to get involved and the federal government to stay involved in Peregrine Falcon conservation.

• Specific legislation was not required for the Peregrine Falcon conservation effort undertaken by the federal government.

• Research on prey and habitat conservation was not necessary for the recovery of this species.

• In the end, Peregrine Falcons decided where they wanted to nest.

• Communications to all audiences ranging from government officials to the public-at-large were paramount to the success of the recovery effort, to maintaining support for the programs, and to maximizing benefits of the program.

• A rigorous population model was not needed to recover the Peregrine Falcon populations, which continued to increase.

• While DDT/DDE levels did decline in regions monitored east of the Rockies, more details assessments would have provided a better assessment of the toxicology risks to Peregrine Falcons.

• The lack of unanimity in the philosophies concerning the genetic origins of the subspecies to be bred and released on either side of international borders led to an inevitable genetic mixing whether one wanted it or not.

• An open dialogue between Canada and the United States was critical for Canadian conservationists to express their concerns about the harvest of migrant Peregrine Falcons, and to protect the interests of southern Canadian populations.

• We need to maintain a constant, open dialogue with other countries whose habitats are shared by our peregrines. Banning chemicals in our country is definitely useful, but less so if the birds are still being exposed on their migration routes and wintering grounds.

• While many Peregrine Falcon populations have indeed recovered to healthy numbers, there still remains a myriad of on-going threats.

ACKNOWLEDGMENTS

While the authors accept responsibility for any opinions expressed above, they also acknowledge the national community of Peregrine Falcon researchers, managers and enthusiasts who continue to provide interesting and vigorous debate on all aspects of this recovering species' well-being. We thank all those who participate in the National Recovery Team meetings and the recovery efforts across Canada and colleagues in the USA. DMB would especially like to thank his very dedicated partner, Ian Ritchie, for all of his efforts spanning many years in helping the Avian Science Conservation Centre to play a significant role in the recovery of the peregrine. GLH thanks the members of the recovery team which he chaired from 1986 to present, and the staff of the Wainwright facility identified above, who went above and beyond their positions in CWS; all made monumental contributions to the recovery effort spanning four decades. We also appreciate comments on an earlier draft of this manuscript by Elisabeth Beaubien, Marcel Gabhauer, Gilbert Proulx, Helen Trefry and two anonymous referees.

LITERATURE CITED

Albright, D.M., and D.W. Doidge. 1992. Sightings of peregrine falcons (*Falco peregrinus)* at presumed nest sites in eastern Hudson Bay, summer 1985. Arctic 45: 304-305.

Banasch, U., J. P. Goossen, , A. Einstein Riez, , C. Casler, and R. Dominguez Barradas, 1992. Organochlorine contaminants in migrant and resident prey of peregrine falcons *Falco peregrinus*, in Panama, Venezuela and Mexico. Canadian Field-Naturalist 106: 493-498.

Banasch, U., and G.L. Holroyd. 2004. The 1995 Peregrine falcon survey in Canada. Occasional Paper Number 110. Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, Canada.

Bardo, L., and D. M. Bird. 2009. The use of captive American Kestrels (*Falco sparverius*) as wildlife models: a review. Journal of Raptor Research 43: 345-364.

Baril, A., J. E. Elliott, J. D. Somers, and G. Erickson. 1990. Residue levels of environmental contaminations in prey species of the Peregrine Falcon, *Falco peregrinus*, in Canada. Canadian Field-Naturalist 104: 273-284.

Baxter, P. W. J., M. A. McCarthy, H.P. Possingham, P.W. Menkhorst, and N. McLean. 2006. Accounting for management costs in sensitivity analyses of matrix population models. Conservation Biology 20: 893-905.

Beaver-Johnson, L. 1979. Biology and management of peregrine falcons, *Falco peregrinus anatum*, in northeastern Alberta. Prepared for the Alberta Oil Sands Environmental Research Program by the Canadian Wildlife Service, ASOERP Report 80, Environment Canada, Edmonton, Alberta, Canada.

Bird, D.M., and Y. Aubry. 1982. Reproductive and hunting behaviour in *Falco peregrinus* in southern Quebec. Canadian Field-Naturalist 96: 167-171.

Bird, D. M., W. Burnham, and R. W. Fyfe. 1985. A review of cross fostering on birds of prey. Pages 433 438 *in* I. Newton and R.D. Chancellor, editors. Conservation studies in raptors. International Council for Bird Preservation, Technical Publication No. 5, Cambridge, UK.

Bird, D. M., D. Peakall, and D. S. Miller. 1983. Enzymatic changes in the oviduct associated with DDE-induced eggshell thinning in the kestrel, *Falco sparverius*. Bulletin of Environmental Contaminants and Toxicology 31: 22-24

Brown, J. W., P. J. Van Coeverden de Groot, T. P. Birt, G. Seutin, P. T. Boag, and V. L. Friesen. 2007. Appraisal of the consequences of the DDT-induced bottleneck on the level and geographic distribution of neutral genetic variation in Canadian peregrine falcons, *Falco peregrinus*. Molecular Ecology 16: 327–343.

Cade, T. J., and D. M. Bird. 1990. Peregrine falcons, *Falco peregrinus*, nesting in an urban environment: a review. Canadian Field-Naturalist 104: 209-218.

Cade, T. J., and W. Burnham, editors. 2003. Return of the peregrine: a North American saga of tenacity and teamwork. The Peregrine Fund Inc., Boise, Idaho, USA.

Cade, T. J., and R. W. Fyfe. 1970. The North American peregrine survey, 1970. Canadian Field-Naturalist 84: 231 245.

Cade, T. J., J. H. Enderson, and J. Liinthicum, editors. 1996. Guide to management of peregrine falcons at the eyrie. The Peregrine Fund Inc., Boise, Idaho, USA.

Cade, T. J., J. H. Enderson, C. G. Thelander, and C. M. White, editors. 1988. Peregrine falcon populations their management and recovery. The Peregrine Fund Inc., Boise, Idaho, USA.

Campbell, J. A. 2003. Black diamond Peregrines. Page 109 in T. J. Cade and W. Burnham, editors. Return of the peregrine: a North American saga of tenacity and teamwork. The Peregrine Fund Inc., Boise, Idaho, USA.

Carson, R. 1962. Silent Spring. Houghton Mifflin, Boston, Massachussetts, USA.

Chikoski, J., and L. Nyman. 2011. The 2010 Ontario peregrine falcon survey – a summary report. Unpublished report, Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Cooper, J. M., and S. M. Beauchesne. 2007. Update COSEWIC status report on peregrine falcon, *Falco peregrinus*. Prepared for Committee On The Status Of Endangered Wildlife In Canada, Environment Canada, Ottawa, Ontario, Canada.

Court, G. S. 1993. A toxicological assessment of the American peregrine falcons (*Falco peregrinus anatum*) breeding in Alberta, Canada - 1968 to 1992. Occasional report Series No. 10. Alberta Environmental Protection, Fish and Wildlife Services, Edmonton, Alberta, Canada.

Court, G. S. 1994. Population dynamics of American peregrine falcons breeding in northeastern Alberta Canada - 1971 to 1993: An evaluation of the need for continued management. Occasional Report Series 14. Alberta Environmental Protection, Government of Alberta, Edmonton, Alberta, Canada.

Court, G. S., C. C. Gates, D. A. Boag, J. D. MacNeil, D. M. Bradley, A. C. Fesser, J. R. Patterson, G. B. Stenhouse, and L. W. Oliphant. 1990. A toxicological assessment of peregrine falcons, *Falco peregrinus tundrius*, breeding in the Keewatin District of the Northwest Territories, Canada. Canadian Field-Naturalist 104: 255-272.

Craig, G. R., G. C. White, and J. H. Enderson. 2004. Survival, recruitment, and rate of population change of the Peregrine Falcon population in Colorado. Journal of Wildlife Management 68:1032-1038.

Dekker, D. 1980. Hunting success rates, foraging habits and prey selection of peregrine falcons migrating through central Alberta. Canadian Field-Naturalist 94: 371-382.

Dekker, D. 1984. Spring and fall migrations of peregrine falcons in central Alberta, 1979-1983, with comparisons to 1969-1978. Journal of Raptor Research 18: 92-97.

Dekker, D. 2009. Hunting tactics of peregrine and other falcons. PhD Thesis, Wageningen University, Netherlands, and Hancock House Press, Surrey, British Columbia, Canada.

Duxbury, J. M. 2004. Stable isotope analysis and the investigation of the migrations and dispersal of peregrine falcons (*Falco peregrinus*) and burrowing owls (*Athene cunicularia hypugaea*). PhD Thesis, University of Alberta, Edmonton, Alberta, Canada.

Ehrlich, P. R., and A. H. Ehrlich. 1981. Extinction: the causes and consequences of the disappearance of species. Ballantine Books, Random House, New York, New York, USA.

Elliott, J. E., M. J. Miller, and L. K. Wilson. 2005. Assessing breeding potential of peregrine falcons based on chlorinated hydrocarbon concentrations in prey. Environmental Pollution 134: 353–361.

Environment Canada. 2003. Species at Risk Act: an act respecting the protection of wildlife species at risk in Canada. Ottawa, Ontario, Canada.

Erickson, G., R. F. Fyfe, R. Bromley, G. L. Holroyd, D. Mossop, B. Munro, R. Nero, C. Shank, and T. Weins. 1988. *Anatum* peregrine falcon recovery plan. Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, Canada.

Fernie, K., and R. J. Letcher. 2010. Historical contaminants, flame retardants, and halogenated phenolic compounds in peregrine falcon (*Falco peregrinus*) nestlings in the Canadian great lakes basin. Environmental Science and Technology 44: 3520–3526.

Franke, A., M. Setterington, G. Court, and D. Birkholz. 2010. Long-term trends of persistent organochlorine pollutants, occupancy and reproductive success in peregrine falcon (*Falco peregrinus tundrius*) breeding near Rankin Inlet, Nunavut, Canada. Arctic 63: 442–450

Franke, A., J.-F. Therrien, S. Descamps, and J. Bety. 2011. Climatic conditions during outward migration affect apparent survival of an arctic top predator, the peregrine falcon *Falco peregrinus*. Journal of Avian Biology 42: 544-551.

Fyfe, R.W. 1969. The peregrine falcon in Canada. Pages 101-114 in J. J. Hickey, editor. Peregrine falcon populations, their biology and decline. University of Wisconsin Press, Madison, Wisconsin, USA.

Fyfe, R. W. 1988. The Canadian peregrine falcon recovery program, 1967 1985. Pages 599 610 in T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. Peregrine falcon populations: Their management and recovery. The Peregrine Fund Inc., Boise, Idaho, USA.

Fyfe, R. W., H. Armbruster, U. Banasch, and L. Beaver. 1977. Fostering and crossfostering of birds of prey. Pages 183-193 in S. Temple, editor. Endangered birds: management techniques for preserving threatened species. University of Wisconsin Press, Madison, Wisconsin, USA.

Fyfe, R. W., U. Banasch, and H. Armbruster. 2003. The Canadian *anatum* peregrine falcon recovery program. Pages 105-115 in T. J. Cade and W. Burnham, editors. Return of the peregrine: A North American saga of tenacity and teamwork. The Peregrine Fund Inc., Boise, Idaho, USA.

Fyfe, R.W., U. Banasch, V. Benavides, N. Hilgert de Benevides, A. Luscombe, and J. Sanchez. 1990. Organocholorine residues in potential prey of peregrine falcons, *Falco peregrinus*, in Latin America. Canadian Field-Naturalist 104: 285-292.

Fyfe, R. W., S.A. Temple, and T. J. Cade. 1976. The 1975 North American peregrine falcon survey. Canadian Field-Naturalist 90: 228-273.

Gahbauer, M. A. 2008. Breeding, dispersal, and migration of urban peregrine falcons in eastern North America. PhD Thesis, McGill University, Montreal, Quebec, Canada.

Grier, J. W. 1980. Ecology: a simulation model for small populations of animals. Creative Computing 6: 116-121.

Guerra, P., K. Fernie, B. Jimenez, G. Pacepavicius, L. Shen, E. Reiner, E. Eljarrat, D. Barcelo, and M. Alaee. 2011. Dechlorane plus and related compounds in peregrine falcon (*Falco peregrinus*) eggs from Canada and Spain. Environmental Science and Technology 45: 1284-1290.

Heinrich, W. 2009. Peregrine falcon recovery in the continental United States, 1974-1999, with notes on related programs of The Peregrine Fund. Pages 431-444 *in* J. Sielicki and T. Mizera, editors. Peregrine falcon populations; status and perspectives in the 21st century. Tural/Poznan University of Life Sciences Press, Warsaw, Poland.

Henny, C. J., F. P. Ward, K. E. Riddle, and R. M. Prouty. 1982. Migratory peregrine falcons, Falco peregrinus, accumulate pesticides on Latin America during winter. Canadian Field-Naturalist 96: 333-338.

Herbert, R. A., and K. G. S. Herbert. 1965. Behavior of peregrine falcons in the New York City region. Auk 82: 62-94.

Hickey, J. J., editor. 1969. Peregrine falcon populations: their biology and decline. University of Wisconsin Press, Madison, Wisconsin, USA.

Holroyd , G. L. 1993. A raptor conservation strategy for Canada. Pages 195-200 *in* G. L. Holroyd, H. L. Dickson, M. Regnier, and H. Smith, editors. Proceedings of third prairie conservation and endangered species workshop. Occasional Paper 19, Provincial Museum of Alberta, Edmonton, Alberta, Canada.

Holroyd, G. L. 1995. Conservation of prairie raptors. Pages 173-180 in Proceedings of the 60th North American wildlife and natural resources conference. Wildlife Management Institute, Washington, D.C., USA.

Holroyd, G. L. 2003. The return of the *anatum* peregrine to southern Canada, 1985-2000 - a personal perspective. Pages 117-125 *in* T. J. Cade and W. Burnham, editors. Return of the peregrine: a North American saga of tenacity and teamwork. The Peregrine Fund Inc., Boise, Idaho, USA.

Holroyd, G. L., and U. Banasch. 1990. The reintroduction of the peregrine falcon, *Falco peregrinus anatum*, into southern Canada. Canadian Field-Naturalist 104: 203-208.

Holroyd, G. L., and U. Banasch. 2012. The 2005 Peregrine Falcon survey in Canada. Canadian Wildlife Biology & Management 1: 30-45.

Johnstone, R. M. 1999. Update COSEWIC status report on *anatum* peregrine falcon (*Falco peregrinus anatum*). Committee on the Status of Endangered Wildlife in Canada, Environment Canada, Ottawa, Ontario, Canada.

Johnstone, R. M., G. S. Court, A. C. Fesser, D. M. Bradley, L. W. Oliphant, and J. D. MacNeil. 1996. Long-term trends and sources of organochlorine contamination in Canadian tundra peregrine falcons, *Falco peregrinus tundrius*. Environmental Pollution 93: 109-120.

Kerr, J. T., and J. Cihlar. 2004. Patterns and causes of species endangerment in Canada. Ecological Applications 14: 743-753.

Kiff, L. F. 1988. Changes in the status of the peregrine falcon in North America: an overview. Pages 123-129 *in* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White, editors. Peregrine falcon populations: their management and recovery. The Peregrine Fund Inc., Inc., Boise, Idaho, USA.

Martin, M. 1979. Status report on peregrine falcon (*Falco peregrinus*) in Canada. COSEWIC report. B.C. Fish and Wildlife Branch, Victoria, British Columbia, Canada.

Mayr, E. 1961. Cause and effect in biology. Science 134:1501-06.

Millsap, B.A., and G.T. Allen. 2006. Effects of falconry harvest on wild raptor populations in the United States: theoretical considerations and management recommendations. Wildlife Society Bulletin 34: 1392-1400.

Nelson, R. W. 1990. Status of the peregrine falcon, *Falco peregrinus pealei*, on Langara Island, Queen Charlotte Islands, British Columbia, 1968-1989. Canadian Field-Naturalist 104: 193-199.

Nelson, R. W., and M. T. Myres. 1975. Changes in the peregrine populations and its seabird prey at Langara Island, British Columbia. Raptor Research Report 3: 13 31.

Peakall, D. B. 1990. Prospects for the peregrine falcon, *Falco peregrinus*, in the nineties. Canadian Field-Naturalist 104: 168-173.

Peakall, D. B., D. G. Noble, J. E. Elliott, J. D. Somers, and G. Erickson. 1990. Environmental contaminants in Canadian peregrine falcon, *Falco peregrinus*: a toxicological assessment. Canadian Field-Naturalist 104: 244-254.

Ratcliff, B., and T. Armstrong. 2000. Ontario's peregrine falcon survey, 2000. Unpublished report prepared for Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Ratcliffe, D. 1969. Population trends of the peregrine falcon in Great Britain. Pages 239-270 *in* J. J. Hickey, editor. Peregrine falcon populations: their biology and decline. University of Wisconsin Press, Madison, Wisconsin, USA.

Ratcliffe, D. A. 1993. The peregrine falcon. Second edition. T and A.D. Poyser, London, UK.

Rich, T. D., C. Arizmendi, D. W. Demarest, and C. Thompson, editors. 2009. Tundra to tropics: connecting birds, habitats and people. Proceedings of the fourth international partners in flight conference, 13-16 February 2008. McAllen, Texas, USA.

Risebrough, R., and D. Peakall. 1988. The relative importance of the several organochlorines in the decline of Peregrine Falcon populations. Pages 449-462 *in* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White, editors. Peregrine falcon populations: their management and recovery. The Peregrine Fund Inc., Boise, Idaho, USA.

Ritter, R., M. Scheringer, M. MacLeod, and K. Hungerbühler. 2011. Assessment of non-occupational exposure to DDT in the tropics and the north: relevance of uptake via inhalation from indoor residual spraying. Environmental Health Perspectives 119: 707–712.

Rowell, P. 1993. Southern Alberta peregrine falcon reintroduction project 1993 technical report. Alberta Environment, Fish and Wildlife Services, Edmonton, Alberta, Canada.

Rowell, P. 2002. Status report on *anatum* peregrine falcon *Falco peregrinus anatum*. Committee on the Status of Endangered Wildlife in Canada, Environment Canada, Ottawa, Ontario, Canada.

Rowell, P., G. L. Holroyd, and U. Banasch. 2003. The 2000 Canadian peregrine falcon survey. Journal of Raptor Research 37: 98-116.

Shank, C. 1989. Disturbance of falcon nests by rock climbers. The Canadian Alpine Journal 72: 56.

Smith, R. J., and M. D. Smith. 1997. Endangered species protection: lesson Canada should learn from the United States Endangered Species Act. Property Rights Journal 1: 1-36.

Stepnisky, D. P., and G. S. Court. 2001. An evaluation of genetic concerns in a re-introduced population of American peregrine falcons (*Falco peregrinus anatum*) in southern Alberta. Presented at 6th Prairie Conservation and Endangered Species Conference, February 22-25, 2001, Winnipeg, Manitoba, unpublished Alberta Fish and Wildlife report, Edmonton, Alberta, Canada.

Stubbs, P. 1992. Southern Alberta peregrine falcon reintroduction project, 1992 technical report. Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division, Edmonton, Alberta, Canada.

Sutherland, W. J. 2000. The Conservation Handbook – research, management and policy. Blackwell Sciences Ltd., Oxford, UK.

Temple, S. A. 1988. Future goals and needs for the management and conservation of the peregrine falcon. Pages 843-848 *in* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White, editors. Peregrine falcon populations: their management and recovery. The Peregrine Fund Inc., Boise, Idaho, USA.

Temple, S. A., and T. J. Cade. 1988. Genetic issues associate with recovery effort for three endangered raptors. Pages 17-29 in D.K. Garcelon and G.W. Roemer, editors. Proceedings of the international symposium on raptor reintroduction, 1985. Institute for Wildlife Studies. Arcata, California, USA.

Tordoff, H. B., M. S. Martell, and P. T Redig. 1998. Midwest peregrine falcon restoration, 1998 report. Bell Museum of Natural History, St. Paul, Minnesota, USA.

Tordoff, H. B., and P. T. Redig. 2001. Role of genetic background in the success of reintroduced peregrine falcons. Conservation Biology 15:528-532.

United Nations Environment Programme. 2010. Stockholm convention on persistent organic pollutants. Geneva, Switzerland. Available: http://chm.pops.int/Convention/tabid/54/language/en-GB/Default.aspx [accessed 25 March 2012]

US Fish and Wildlife Service. 2008. Final environmental assessment and management plan take of migrant peregrine falcons from the wild for use in falconry, and reallocation of nestling/fledgling take.

wild for use in falconry, and reallocation of nestling/fledgling take. US Fish and Wildlife Service, Division of Migratory Bird Management, Virginia, USA.

van den Berg, H. 2009. Global status of DDT and its alternatives for use in vector control to prevent disease. Environmental Health Perspectives 117:1656-63.

White, C. M. 1968. Diagnosis and relationships of the North American tundra-inhabiting peregrine falcons. Auk 85: 179-191.

White C. M., and D. A. Boyce, Jr. 1988. An overview of peregrine falcon subspecies. Pages 789–810 *in* T. J. Cade, J. H. Enderson, C. G. Thelander and C. M. White, editors. Peregrine falcon populations: their management and recovery. The Peregrine Fund Inc., Boise, Idaho, USA.

White, C. M., N. J. Clum, T. J. Cade, and W. G Hunt. 2002. Peregrine falcon (*Falco peregrinus*). No. 660 in A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, PA., and American Ornithologists' Union,Washington, DC., USA.

Wootten, J. T., and D. A. Bell. 1992. A metapopulation model of the peregrine falcon in California: viability and management strategies. Ecological Applications 2: 307-321.

ABOUT THE AUTHORS

Photo: H. Loney Dickson

Geoff L. Holroyd is a emeritus research scientist with Environment Canada in Edmonton, Alberta, and adjunct professor at the University of Alberta. He has published over 170 technical articles, edited three conference proceedings and published one book. He chaired the Canadian Peregrine Falcon Recovery Team since its inception in 1986 to 2012, was manager of the federal captive breeding facility at Wainwright from 1984 until it closed in 1996, and has conducted research on Peregrine Falcons and Burrowing Owls in western Canada since 1990. His research focuses on the conservation and ecology of species-at-risk and raptors in prairie Canada, Mexico, Spain and elsewhere. He is an honorary life member of the Alberta Society of Professional Biologists and Beaverhill Bird Observatory.

As a Professor of Wildlife Biology and Director of the Avian Science and Conservation Centre of McGill University, **David M. Bird** has published more than 180 refereed papers and supervised over 40 graduate students. His main research interest focuses on raptorial birds, which encompasses virtually all aspects of their biology. As an original founding member of both the Peregrine Falcon and Loggerhead Shrike Recovery Teams, he was highly instrumental in initiating the captive breeding and release program for both species, including pioneering techniques in artificial insemination of falcons. He has also served as Past-President of the Raptor Research Foundation Inc. (RRF) and the Society of Canadian Ornithologists. In 2009 the RRF awarded him the Tom Cade Award for Significant Contributions to Captive Breeding and Conservation.

Photo: Jean Masson

Received 22 February 2012 – Accepted 1 August 2012.