Declines of Greater and Lesser Scaup Populations: Issues, Hypotheses, and Research Directions

Summary Report of the Scaup Workshop
9-10 September 1998, Jamestown, ND

U.S. Department of Interior
U.S. Geological Survey
Northern Prairie Wildlife Research Center
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INTRODUCTION

The combined breeding population of greater (Aytha marila) and lesser scaup (A. affinis) is larger than that of any other diving duck species and greater than that of most dabbling ducks in North America (U.S. Fish and Wildlife Service 1998). Scaup are the most widespread of North American diving ducks (Tribe Aythini), extending from northern tundra in Alaska and Canada in summer to southern Mexico in winter (Austin et al. 1998). Greater and lesser scaup are not counted separately because they are difficult to distinguish during aerial surveys, so distinguishing specific trends is not possible. Lesser scaup are estimated to constitute 89% of the continental scaup population (Bellrose 1980, Austin et al. 1998). During the 1970s and early 1980s, the combined scaup population ranged from 5 to >7 million (Figure 1). Scaup and most other North American waterfowl species experienced population declines during the prairie drought in the late 1980s and early 1990s. From 1986 to 1993, most principal duck species, including scaup, were below goals of the North American Waterfowl Management Plan (NAWMP; U.S. Fish and Wildlife Service 1986, 1998).

Water conditions in the prairie pothole region improved markedly in 1994 and generally have remained good through 1998 (U.S. Fish and Wildlife Service 1998). Populations of all principal duck species except scaup have increased since 1993. By spring 1997, only scaup and northern pintail (Anas acuta) populations remained below NAWMP goals and their respective long-term averages. Although the pintail population has increased, the scaup population has continued a nearly steady decline since the mid-1980s. In spring 1998, the breeding scaup population was 3.47 million, a 16% decline from 1997, and the lowest recorded since surveys began in 1955 (U.S. Fish and Wildlife Service 1998).

On average, 7% of scaup were counted in Tundra, 25% in Prairie-Parklands, and 68% in Boreal Forest biomes during 1955-97 (Afton and Anderson, in review) (Figures 2 and 3). Thus, drought or habitat degradation in the Prairie Pothole Region should have less direct effect on the continental breeding scaup population than on other diving ducks such as canvasback (Aytha valisineria) or redheads (A. americana), which predominantly occur in the Prairie Pothole Region. Many studies have evaluated relationships of waterfowl populations with conditions in the Prairie Pothole Region, but no study has examined similar relationships in the boreal forest. Low densities of breeding scaup (relative to the Prairie Pothole Region) and difficult field logistics have limited studies conducted in the Boreal Forest biome.

Concerns about the declining combined population have led to increasing interest and research efforts on greater and lesser scaup. Afton and Anderson (in review) and the U.S. Fish and Wildlife Service (FWS) (Allen et. al. 1999) have evaluated scaup population data based on breeding and wintering ground surveys and band return data. Rocque and Barclay (1999) have examined greater scaup survival rates and populations in the Atlantic Flyway. The Institute of Wetland and Waterfowl Research of Ducks Unlimited, in cooperation with the Louisiana Cooperative Fish and Wildlife Research Unit, is developing a research...
The U.S. Geological Survey's Northern Prairie Wildlife Research Center hosted a workshop on 9-10 September 1998 to provide biologists the opportunity to share information on scaup and to discuss research needs and opportunities for collaboration. Dr. James K. Ringelman, Ducks Unlimited Inc., was facilitator. Forty-five biologists participated, including biologists from U.S. Geological Survey research centers and cooperative research units; U.S. Fish and Wildlife Service's Office of Migratory Bird Management, Office of Research Coordination, and Alaskan refuges; Environment Canada; Ducks Unlimited's Institute of Wetland and Waterfowl Research; Ducks Unlimited Canada; universities; Long Point Waterfowl and Wetlands Research Fund; and state representatives of the Atlantic, Mississippi, and Central Flyways (see Appendix I).

Over 2 days, workshop participants reviewed knowledge about greater and lesser scaup, examined potential problems facing the species, identified information and research needs, and

Figure 2. Annual estimates of breeding greater and lesser scaup (combined) in the Tundra (strata 8-11), Boreal Forest (strata 1-7, 12-25, 50, and 77), and Prairie-Parkland biomes (strata 26-49, and 75-76). From Afton and Anderson (in review).

initiative on scaup. Other biologists plan to publish previously collected data or are considering new research.

Figure 3. Traditional survey strata for the annual Waterfowl Breeding Population and Habitat Survey in North America, with strata classified as in the Tundra, Boreal Forest, or Prairie-Parkland Biome.
formulated a strategy for addressing some of these needs. Accordingly, this report summarizes knowledge of scaup ecology and populations, issues of concern, and recommendations reached by participants, with a complete reporting of recommendations developed by 4 discussion groups. Information from oral presentations and abstracts at the workshop are included in the introductory material (below) and as supportive material for recommendations. The U.S. Geological Survey did not edit the substance of results and recommendations contained herein.

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REVIEW OF CURRENT KNOWLEDGE

POPULATION STATUS AND TRENDS

Breeding Populations

The combined breeding population of scaup has fluctuated markedly since the Waterfowl Breeding Ground Population and Habitat Survey (hereafter referred to as Breeding Ground Survey, BGS) was initiated in 1955 (Figure 1). The population declined during the 1960s, increased during the 1970s and early 1980s, then in 1984 began a nearly steady decline to record lows in 1998. During 1978-97, the population declined by 150,491 scaup per year (Afton and Anderson in review). In separate analyses of BGS data, Allen et al. (1999) found no linear trend in numbers from 1955 through 1987, but noted a significant decline since 1987.

Discerning whether both species are declining is problematic because of the lack of species-specific information. Allen et al. (1999) assumed strata 8, 9, 10, and 11 in Alaska and stratum 13 in the Northwest Territories contained primarily greater scaup, and that all other strata contained primarily lesser scaup. Those strata thought to contain primarily greater scaup had stable populations during 1955-98, with an increase during 1988-98, but populations in other strata (containing primarily lesser scaup) in the boreal forest have declined since 1988 (Allen et al. 1999). Independent analyses by M. MacCluskie, A. Afton, and M. Anderson (unpubl. data; hereafter referred to as MacCluskie et al.) indicate similar trends. However, knowledge about the proportion of greater versus lesser scaup in each surveyed strata, or at smaller substrata scales, is poor and often based on old information, and there are concerns that proportions have shifted in some areas.

The combined breeding scaup population has not declined uniformly across the breeding range. The Boreal Forest population (BGS strata 1-7, 12-25, 50, and 77) has declined markedly, whereas the Prairie-Parkland population (strata 26-49 and 75-76) has increased 50% during 1993-97. The Tundra population (strata 8-11)
remained relatively stable during this period (Figure 2; Afton and Anderson in review). Within the surveyed areas, populations have significantly declined during the last 20 years (1978-97) in central and northern Alberta, northeastern British Columbia, and in Northwest Territories (combined, an area which hosts an average of 52% of the continental breeding population), and in southern Alberta, Montana, and western Dakotas.

MacCluskie et al. further refined these analyses by examining breeding population data at the transect level for 14 strata. Of those, 10 strata (strata 3, 4, 12-18 and 20) contained at least one transect with a significant positive or negative slope. Generally, scaup counted at the transect-level for strata east of the continental divide show a decline beginning about 1980. Stratum 12 (Old Crow Flats) shows significant increases in scaup numbers since initiation of surveys. Strata from interior Alaska (Strata 3 and 4) have mixed trajectories with some transects showing increasing and others decreasing populations. For transects with significant negative slopes, the decrease in scaup primarily is due to fewer groups and pairs and not to fewer lone males counted. The increase in Stratum 12 is due to increased number of groups since the early 1970s.

MacCluskie et al.'s analyses indicate that the decline of scaup is widespread in the western Canadian boreal forest and is not restricted to a few strata. The cause(s) of the decline in this region does not appear to be affecting populations in interior Alaska, or in boreal forest habitat west of the continental divide. Analyses by MacCluskie et al. are ongoing and will include comparisons with population trends of other waterfowl (e.g., American wigeon [Anas americana], green-winged teal [A. crecca], and scoters [Melanitta spp.]) that breed in boreal forests.

Biases in the BGS for scaup population estimates have not been adequately addressed (see Austin et al. 1998, Afton and Anderson in review). Scaup are among the latest migrants to move north in spring, and their migration may be delayed during cold springs. The BGS, designed primarily for mallards (Anas platyrhynchos), is conducted in mid-May (U.S. and southern prairie-parkland areas) to early June (northern strata), when some scaup are still migrating to breeding areas. Some scaup may be counted multiple times, i.e., in southern regions and again in northern areas. Without extensive mark-resighting or telemetry studies, evaluating this bias is difficult. Biologists suspect that in some years, particularly those with delayed migration due to cold or inclement weather, this bias results in large standard errors or, more seriously, in high population estimates for some strata (see also Austin et al. 1998, Afton and Anderson in review). Weekly waterfowl surveys in south-central North Dakota (1957-97) indicated a trend toward earlier chronology of scaup migrations and a weak relationship between peak scaup numbers and temperature (J. Austin, D. Granfors, M. Johnson, and S. Kohn, unpubl. data). These data and other observations (Afton and Anderson in review; D. Kay, Ducks Unlimited Canada, pers. obs.) also indicate that BGS counts are conducted in some years when migrant birds are still in the area.

Waterfowl production and habitat surveys, conducted during 1-21 July in prairie-parkland areas and 8-22 July in boreal forest areas (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1987), are poorly timed to estimate scaup production. Most scaup clutches hatch from mid-July through August (Austin et al. 1998), so most scaup production is missed in surveys conducted before late July, particularly in wet years.

**Winter Populations**

On average, 40% of scaup counted during midwinter surveys were in the Mississippi Flyway, 39% in the Atlantic Flyway, 14% in the Pacific Flyway, and 6% in the Central Flyway during 1955-97 (Afton and Anderson, in review). Midwinter counts of scaup have declined over this period (Figure 1), with declines in Atlantic and Mississippi Flyways accounting for most of the change. Long-term trends by state are mixed. Afton and Anderson (in review) noted that midwinter survey totals are strongly affected by number of scaup.
recorded in Louisiana, and these counts are influenced by weather, which occasionally prevents completion of surveys. Midwinter counts have substantial error and biases (Crissey 1975), and comparisons among years or states are not recommended (Eggeman and Johnson 1989). However, such counts provide an indicator of long-term trends and changing waterfowl distributions not otherwise available.

Analyses of the Christmas Bird Count (CBC) data indicate that lesser scaup numbers during 1955-95 were stable (Allen et al. 1999), but greater scaup numbers declined 3.2% per year. However, numbers of greater scaup in the CBC have increased in the Atlantic Flyway during 1988-95. The only changes in CBC data for all scaup occurred around the Great Lakes, where they showed a 4.8% per year decline from 1955 through 1987 and a 3.5% decline per year for 1955-95. From 1988 through 1995, scaup numbers on the Great Lakes increased by 16% per year. This reflects a change in distribution associated with their exploitation of zebra mussels (Dreissena polymorpha) (Wormington and Leach 1992; C. Custer and T. Custer, pers. comm.).

Distribution of migrating and wintering scaup has shifted in the past 20 years probably because of changes in food resources. Such shifts could change exposure of scaup to harvest and also to contaminants. Rocque and Barclay (1999) and P. Castelli (New Jersey Div. Fish, Game, and Wildlife, pers. comm.) noted that numbers of wintering greater scaup have declined along the Long Island Sound, Connecticut, and New Jersey coast. These declines could be due to changing food resources, habitat, or disturbances. Food resources for scaup have increased in parts of the Great Lakes because of expansion of zebra mussel populations, but may have declined in some riverine or coastal areas because of contaminants, sedimentation, or other factors affecting invertebrate communities. Declines in migrant scaup numbers using the Illinois and Mississippi Rivers were attributed to degraded habitat quality — reduced food resources, water levels, and water quality (Mills et al. 1966, Bellrose et al. 1979, Korschgen 1989; S. Havera, Illinois Natural History Survey, pers. comm.). Wetland degradation also has affected coastal marshes of Lake Erie, the Detroit River, and southern Gulf coast. Changing nutrient and sediment loads in the Mississippi River have caused a large (up to 9,000 km²) hypoxia zone in the inner continental shelf near the Mississippi Delta, an area once used by wintering scaup; such areas now have low densities of fish and invertebrates (Turner and Rabalais 1994). This region may have once provided significant food for wintering scaup. Biologists know that scaup occur far off shore (e.g., off the Louisiana coasts), but these areas are not surveyed because of logistical difficulties and expense.

Harvest and Age and Sex Ratios

Harvest.—Harvests of greater scaup in the U.S. (1961-97) and Canada (1974-97) have declined. Harvest of lesser scaup also declined in Canada since 1974 (Allen et al. 1999). The Canadian declines may be linked to declining number of hunters there since 1974. Harvest of lesser scaup in the U.S. was variable but has increased in the most recent 4-5 years, likely due to longer seasons, more liberal bag limits, and increased hunter participation. Nonetheless, during 1988-97, harvest of scaup relative to population size was the lowest of all common duck species for which there are spring survey and harvest data (Allen et al. 1999). Scaup are lightly harvested compared to more r-selected species of ducks, suggesting that hunting has not played a significant role in their decline (see also Afton and Anderson in review).

Age ratios.—Age ratio (immatures to adults) of greater scaup in the U.S. harvest did not change during 1961-97; the mean ratio was 1.4 (Allen et al. 1999). For lesser scaup, the age ratio in the U.S. harvest averaged 1.46 and declined 1% per year during that period. Afton and Anderson (in review) found similar declines, with the greatest declines in the Mississippi Flyway. In Canada, age ratio for greater scaup was highly variable but showed no trend. Age ratio of lesser scaup there also was highly variable but declined about 1.5% per year during 1969-96 (Allen et al. 1999).
Sex ratios.—Afton and Anderson (in review) reported increased sex ratios of lesser scaup (more males relative to females) for both adults and immatures in the U.S. harvest. They interpreted this as evidence that reproductive success has declined and/or female survival rates have declined relative to male survival rates. Furthermore, if age ratio of males has declined and sex ratio has increased, female survival seemingly must have decreased.

BREEDING ECOLOGY

Distribution of Studies

Of the 2 scaup species, lesser scaup have received the most intensive study during the breeding season. Whereas lesser scaup often have been the principal focus of studies (Rogers 1962, Trauger 1971, Hammell 1973, Hines 1977, Afton 1983, Austin 1983), mostly in the Prairie-Parkland biome, few studies (Munro 1941) have focused on breeding biology of greater scaup, likely because of their low densities and remote breeding locations. Both species were part of studies of multiple waterfowl species. Austin et al. (1998) reviewed breeding biology information for lesser scaup, including comparisons of nest success and clutch size among grassland, parkland, and boreal forest regions. Most knowledge of breeding biology of lesser scaup came from 2 parkland areas: near Erickson in southeastern Manitoba (Rogers 1962, 1964; Hammell 1973; Afton 1983, 1984, 1985, 1993; Afton and Ankeny 1991; Afton and Hier 1991; Austin et al. 1998) and St. Denis National Wildlife Area (NWA) in central Saskatchewan (Dawson and Clark 1996, R. Clark, unpubl. data). Knowledge of lesser scaup breeding ecology in boreal forests is far less extensive, and comes largely from 2 areas in the Northwest Territories (Yellowknife Study Area [YKSA]; and Great Slave Lake; Trauger 1971, Nudds and Cole 1991, Fournier and Hines 1996, M. Fournier and J. Hines, unpubl. data) and from 3 areas in Alaska (Yukon Flats, Yukon-Kuskokwim Delta, and Copper River Delta; Grand 1995; D. Esler, P. Flint, and B. Grand, unpubl. data). Low breeding densities, access, and other logistics make extensive research in the boreal forest difficult and expensive.

Studies of Basic Breeding Ecology and Recruitment

Prairie-Parkland.—Breeding ecology of lesser scaup has been intensively studied at Erickson during 1958-61 (J. Rogers), 1970-71 (G. Hammell), and 1973-77 (A. Afton). J. Austin studied postbreeding ecology of female lesser scaup there in 1981-82. R. Clark (unpubl. data; Dawson and Clark 1996) studied breeding populations and reproductive biology of lesser scaup at St. Denis NWA, Saskatchewan, during 1982-98. He found no trend in annual median breeding population size (pairs plus lone females) during that period. Timing of nesting (upland nests) did not vary annually, and median initiation dates were similar to that in other parkland areas (Austin et al. 1998). Nest success, estimated in 1980 and during 1989-98, ranged from 3.5% to 28%, and was typically <15%, which is lower than average scaup nest success for the Prairie-Parkland biome (Austin et al. 1998).

Female lesser scaup have a lower reproductive rate than most other ducks, and reproductive success is age-related in both the Prairie-Parkland and Boreal Forest biomes (Trauger 1971; Afton 1983, 1984); this also is likely true for greater scaup. Scaup recruitment in prairie-parkland declines during dry years due to low nest success and increased proportions of nonbreeding 1- and 2-year-old females (Rogers 1964; Afton 1983, 1984).

Boreal forest.—Number and productivity of lesser scaup on the YKSA, a 38-km² study area in the Northwest Territories, were monitored in 1962-65 (R. Murdy), 1967-70 (D. Trauger), and 1985-98 (M. Fournier and J. Hines). M. Fournier and J. Hines conducted parallel studies of greater and lesser scaup on nearby Great Slave Lake during 1991-98. These studies show significant annual variations in local numbers and reproductive success of scaup. During 1991-98, nest success averaged 37% for lesser scaup at YKSA and 72% for both species at Great Slave Lake (sample sizes there were small). Nesting studies are difficult in this region as it takes >1 person-day to find 1 nest. Egg hatchability was high (76-89% on Greater
Slave Lake; 94-97% on YKSA), but hen success, as measured by brood:pair ratios, was highly variable and averaged 22.7% during 1985-98. Long-term pair and brood counts on the YKSA indicate that both declined between 1962-65 and 1985-98, but the brood:pair ratios have not changed. Nudds and Cole (1991) reported similar results when comparing data from the 1960s and 1980s in the YKSA.

In Alaska, B. Grand (Grand 1995, unpubl. data), D. Esler, P. Flint, and T. Fondell (unpubl. data) collected data on nesting biology, nutrient-reserve dynamics, and exposure to lead for greater and lesser scaup during 1990-98 on the Yukon-Kuskokwim Delta, Yukon Flats, and Copper River Delta. Clutch sizes were similar among 3 Alaska study sites, and nest success was moderate to high relative to that of other waterfowl. Scaup were the last ducks to initiate nests at all 3 locations. In the Yukon-Kuskokwim Delta, greater scaup were among the last ducks to begin nesting each year and frequently renested. Clutch volumes of first nests were similar or larger than those of sympatric nesting geese. Nutrients for lesser scaup clutch formation in Alaska are derived from reserves stored before arrival, reserves stored on the breeding area, and foods consumed during egg formation (B. Grand, D. Esler, P. Flint, and T. Fondell, unpubl. data). Nesting scaup rarely ingested lead shot, unlike eiders (Somateria spp.) and oldsquaw (Clangula hyemalis) nesting there (Flint et al. 1997).

Duckling Survival

Duckling survival has been estimated only in Erickson in 1977-80 (Afton 1984) and St. Denis in 1992 (R. Clark, unpubl. data), using multiple counts of broods attended by marked hens. In Erickson, average survival rate during the first 20 days posthatch was 0.675 (SE=0.049, n=39 broods; Afton 1984). In St. Denis NWA, duckling survival rate was 0.38 during the first 48 days post-hatch and was lower for young ducklings (first 15 days posthatch; 0.401) than for older ducklings (16-48 days; 0.955) (n=11 broods; Dawson and Clark 1996). Ducklings from larger eggs had higher survival rates than those from smaller eggs, as did those hatching later in the breeding season (Dawson and Clark 1996). However, preliminary analyses (R. Clark, unpubl. data) suggest that female recruitment (i.e., females entering the breeding population the following spring) is higher for early-hatched ducklings.

Duckling survival has not been studied in boreal forests or tundra. Nudds and Cole (1991) suggested that duckling survival, based on rate of within-year decline in brood sizes, did not change between the 1960s and 1980s in the YKSA.

No duckling or brood survival data exist for greater scaup.

Annual Survival and Philopatry

L. Reynolds (unpubl. data) assessed band recovery and survival rates for lesser scaup. Most data sets provide recovery and survival estimates only for the 1950s and 1960s; there have been insufficient lesser scaup bandings to estimate survival since 1978. Seven reference areas were established by combining degree blocks with similar distributions of recovered lesser scaup: 3 preseason areas (north Alaska, south Alaska, and Alberta), 3 postseason areas (North Atlantic Coast, South Atlantic coast, and Louisiana), and 1 spring-migration area (Michigan). Recovery rates (0.90-5.80%) generally are lower for lesser scaup than for other ducks. Survival rates ranged from 0.427 to 0.866 for females and 0.524 to 0.817 for males, with most estimates falling between 0.57 and 0.71. Reynolds found no effect of very restrictive hunting regulations during the 1961 and 1962 seasons on male survival in 2 reference areas. He cautioned that the preponderance of nonsignificant tests for geographic, temporal, and sex differences in survival should be interpreted cautiously because of large standard errors for many estimates and consequently low statistical power of those tests. He recommended that low recovery rates and poor model fit from past band-recovery data be considered in planning future banding efforts of lesser scaup. Assuming a 1.65% recovery rate for both sexes, 70% male survival, 60% female survival and a coefficient of variation of 0.05,
then total bandings needed for a 5-year study are 3,300 males and 4,100 females.

Lesser scaup are highly philopatric to natal and breeding areas (Afton, pers. comm. in Johnson and Grier 1988), and likely this is true of greater scaup. R. Clark, A. Afton, and J. Rotella (unpubl. data) analyzed mark-recapture data for lesser scaup marked at Erickson (1977-81) and St. Denis NWA (1989-98) using Program MARK to estimate philopatry and annual survival of lesser scaup females. At Erickson, models indicated that all surviving adult females returned the following year because resighting estimates were 1.0, and annual survival rate estimates were as high or greater than those derived from independent analyses (0.46-0.57) based on banded birds (above). Annual survival of marked females averaged 0.56 for yearlings and 0.57 for adult females, implying that natal philopatry also was strong. On St. Denis NWA, annual survival of adult females was ~0.68, with much annual variation, and breeding philopatry appeared virtually complete.

In Alaska, nest site fidelity and annual survival estimated from recapture of leg-banded greater scaup females was high (>70%) (B. Grand, P. Flint, D. Esler, and T. Fondell, unpubl. data).

Long-term declines in reproductive success or survival, combined with strong philopatry of breeding females, may have contributed to long-term population declines in some areas. It is unclear to what extent reproductive success and local recruitment are limited by factors on breeding areas (e.g., food resources, nesting habitat, nest or hen success, duckling survival), or on migration and wintering areas (e.g., contaminants). If scaup from a given breeding area share migration and wintering areas, limiting factors such as contaminants, food resources, or harvest pressure may be more important in long-term population trends for a breeding area than if a population has diverse migration and wintering areas. This highlights the need for better data on affiliation of scaup among breeding, migration, and wintering areas.

Habitat

Amphipods and pond characteristics in the Parkland.—Amphipods, primarily Hyalella and Gammarus spp., are a primary food of migrating and breeding scaup and for ducklings (reviewed by Austin et al. 1998). Hunters and biologists have long noted that scaup usually are found on wetlands with amphipods, but this relationship has never been quantified. D. Lindeman and R. Clark examined relationships among amphipod abundance, pond morphometry, and lesser scaup numbers in 12 sites in southern Saskatchewan (Lindeman and Clark in review). Because scaup frequently nest within wetland margins and are the only diving duck that nests in uplands (Austin et al. 1998), Lindeman and Clark also examined the role of wetland margins and upland habitats. Use of wetlands by breeding scaup was positively correlated with presence of amphipods, pond area, and absence of wetland margin impacts. Abundance of Hyalella, the more common of 2 main amphipod species in all but ephemeral wetlands, often was a key factor affecting abundance of breeding scaup and occurrence of ducklings. Because of the dominance of amphipods in scaup diets, particularly of ducklings, factors affecting amphipod abundance and relationships between amphipods and scaup also need to be examined in boreal forests.

Climate changes.—Productivity of lesser scaup in prairie-parklands is reduced during drought, largely due to low nest success and nonbreeding by younger females (Rogers 1964; Afton 1983, 1984). Afton and Anderson (in review) hypothesize that prairie drought may affect scaup breeding in boreal forest by reducing availability of food during spring migration and thus acquisition of nutrient reserves for breeding. If so, the recent long-term drought in the Prairie-Parkland biome may have contributed to the decline in the continental population. Examination of nutrient-reserve dynamics of lesser scaup breeding in Erickson, Manitoba, indicated that lipid reserves limit clutch size in lesser scaup (Afton and Ankney 1991). Afton and Ankney (1991) also concluded that food availability may limit lipid storage by breeding females and be an important factor affecting
clutch size in lesser scaup. These conclusions were supported by an Alaskan study of lesser scaup nutrient-reserve dynamics (see above). Thus, changes in food resources on migration and breeding areas could reduce reproductive success. New research linking feeding ecology, nutrient dynamics, and breeding is needed to examine cross-seasonal effects, and to assess impacts of habitat alteration, including human- and climatic-driven changes.

Recent and anticipated long-term climate changes in the parkland and boreal forest also may affect scaup. Analyses by Larson (1994) and Sorenson et al. (1999) indicate that wetlands in the parklands are vulnerable to increased temperatures that are predicted in global climate models; wetland numbers and depths likely would decline with increased temperatures. The Boreal Forest ecosystem is expected to experience the greatest warming from global climate change (Environment Canada 1995, Rouse et al. 1997). Boreal areas of northwestern Canada already have experienced temperature increases of 2.3-2.4°C over the past 51 years (Environment Canada 1997). Given predictions of significant changes in hydrology, temperature, and precipitation patterns, effects on both biomes may be serious. Changes in wetland habitats and food resources used by scaup, due to climate change, could affect the continental scaup population. However, the magnitude and direction of changes of habitat or food resources in the Boreal Forest ecosystem, and the long-term effects to scaup populations, are unknown. Because amphipods are a key food of scaup, they may be a significant link in the relationship between scaup and climate change. To better understand the sensitivity and response of boreal wetlands to climate change, and to understand whether climate change will positively or negatively affect scaup, we need (1) more detailed examination of existing data, and (2) models that relate climate change to wetland characteristics and associated resources.

MacCluskie et al. are examining BGS data relative to climate data to assess correlations between past changes in temperature or precipitation on scaup populations in boreal forest strata.

CONTAMINANTS

Contaminants have caused population declines in a number of avian species, such as brown pelicans (Pelecanus occidentalis), peregrine falcons (Falco peregrinus), and double-crested cormorants (see Keith 1996, Blus 1996, Peakall 1996 for reviews). Contaminants can affect populations directly, by causing mortality or impaired reproduction, or indirectly, by reducing food availability or quality available to a population. Organochlorine compounds, such as DDT and its metabolites, and dieldrin (Blus 1996, Peakall 1996) have adversely affected avian populations. Trace elements, such as mercury, selenium, and lead, also are detrimental to birds (Paine 1996, Thompson 1996, Heinz 1996). Finally, newer organophosphate and carbamate insecticides have caused avian mortalities, but effects are more often local.

The Great Lakes area is known for environmental contamination problems (Government of Canada 1991). Because of migration shifts by scaup to and through the Great Lakes and longer stopovers there since the zebra mussel invasion (Wormington and Leach 1992), migrant and wintering scaup may be more exposed to contaminants (cf. Austin et al. 1998, Afton and Anderson in review). Potential contaminant exposure in the Great Lakes may be exacerbated by the filtering capabilities of zebra mussels, which may bioaccumulate more contaminants than do other traditional scaup food items. Most persistent organochlorine chemicals have declined in the Great Lakes since the 1970s (Government of Canada 1991). This trend also is evident in tissues of lesser scaup from western Lake Erie/Detroit River area (Smith et al. 1985; C. Custer and T. Custer, unpubl. data). Persistent organochlorines in tissues of lesser scaup have dropped approximately 10-fold in the Detroit River area.

Long Island Sound and adjacent waters also are heavily polluted, based on contaminant levels in sediments, shellfish, and finfish (Grieg et al. 1977, Grieg and Sennefelder 1985). This region has historically been an important wintering area for scaup (Bellrose 1980), but scaup numbers
there have declined (Merola and Chasko 1989, Barclay and Zingo 1993). Studies on organic and heavy metal contaminants in scaup indicate they are accumulating contaminants through the food base (J. S. Barclay, unpubl. data).

Selenium is an essential element, and normal concentrations in birds living in fresh water are 4-10 ug/g (ppm, dry weight; Heinz 1996). Lesser scaup collected from western Lake Erie and lower Lake Michigan in 1991-92 contained exceptionally high selenium concentrations. The lowest mean levels of selenium in lesser scaup livers were 2 to 4 times background levels (C. Custer and T. Custer, unpubl. data). Only 1 of 34 livers was in the normal range for selenium. Selenium can impair reproduction via embryo abnormalities and mortality, reduce growth and survival of young, cause pathological changes in tissues, and can cause adult mortality. Ten ppm (dry wt) or greater in the liver of laying females is associated with reproductive impairment in some avian species, and 33 ppm in livers is considered harmful to birds (Heinz 1996). Fourteen of 34 liver samples in the Custers' study were above 33 ppm. Selenium concentrations in these scaup were equivalent to those reported in diving ducks from San Francisco Bay, California, an area known to be contaminated with selenium (Hothen et al. 1998).

Concentrations of other trace elements (Cd, Hg, and Mn) in lesser scaup collected from Lake Erie and Lake Michigan (C. Custer and T. Custer, unpubl. data) were elevated but not at levels indicative of problems. These 3 trace elements also were elevated in liver samples of greater scaup collected in Florida (1990-92; T. Michot, W. Benson, and J. O'Neil, unpubl. data) and in Long Island Sound (J. S. Barclay, unpubl. data); selenium concentrations in those samples, however, were within normal levels. Greater scaup from Florida also showed elevated levels of cadmium (kidney) and arsenic relative to redheads and buffleheads (Bucephala albeola) from Florida or Louisiana/Texas. Differences among species appeared to be related to diet differences (T. Michot and L. Reynolds, unpubl. data), or contaminants accumulated away from that wintering site.

Whether selenium or other contaminants are affecting scaup health, behavior, or reproductive success is unknown. No studies have examined contaminant levels in migrant scaup once they have left the Great Lakes or on the breeding grounds. Such data are needed to assess whether high selenium concentrations, accumulated in the Great Lakes, affect scaup reproduction. This could be determined from a collection of eggs that are analyzed for appropriate chemicals. Additionally, the effects of high selenium concentrations on survival and migration patterns of scaup in the Great Lakes are unknown. This question is less tractable, but could be addressed with a combination of techniques such as satellite telemetry and/or banding.

**SUMMARY OF ISSUES**

Following presentations on the issues discussed above, workshop participants generated a list of issues (not prioritized) to aid further discussions (Table 1). Participants grouped these issues into 4 main questions, similar to hypotheses outlined in Afton and Anderson (in review) for detailed discussion on how to direct future research and survey efforts:

1. Has reproduction or survival of scaup changed sufficiently to cause population declines and, if so, what is the cause(s)?

2. Have changes in the western Canadian boreal forest resulted in reduced reproductive success of scaup?

3. Have physiological changes, including nutrient acquisition patterns and contaminants, affected reproductive success of scaup?

4. What information is needed to manage greater and lesser scaup separately?

The sections below summarize the discussions and recommendations from each discussion group. Group leaders were R. Clark, B. Pollard, C. Custer, and J. Lawrence, respectively.
Table 1. List of issues generated from presentations and discussions during the Scaup Workshop.

- Contaminants - breeding
- Contaminants - winter/migration
- Contaminants - nutritional impact
- Adequacy of winter surveys
- Adequacy of breeding surveys
- Changes in migrational routes and resources
- Are population declines real?
- Detection of future declines
- Reproductive success
- Breeding habitat changes
- Annual survival (adult females), seasonal partition of survival
- Predation
- Changing food resources - quality and quantity
- Proportion of greater and lesser scaup by strata
- Changes in boreal forest habitat
- Boreal forest fire impacts
- Banding samples - survival rates
- Role of hunting mortality
- Standardized harvest survey data in US and Canada
- Climate change
- Nutrient reserve acquisition (timing, location)
- Disease / parasites / health
- Change in population as function of vital rates
- Postbreeding ecology
- Site fidelity (breeding and winter)
- Differences between boreal forest and prairie birds in their breeding ecology, breeding parameters, and nutrient dynamics
- Coincidence of population changes in similar species
- Compare to similar species with stable populations
- Disturbance factors, affecting access to food resources, etc.; including boating, hunting activities
- Appropriateness of NAWMP goal

1. HAS REPRODUCTION OR SURVIVAL OF SCAUP CHANGED SUFFICIENTLY TO CAUSE POPULATION DECLINES, AND IF SO, WHAT IS THE CAUSE(S)?

Basic rates associated with population dynamics—births, deaths, immigration, and emigration—were briefly reviewed. Factors affecting birth rates include number of eggs produced, egg fertility and hatchability, nest success, renesting rates, and duckling survival. Birth rate may be affected by population age and sex ratios, body size and condition, timing of breeding, renesting effort, and environmental variables, both biotic (e.g., food, predators) and abiotic (e.g., weather conditions). Mortality differs among age and sex cohorts, during different components of the annual cycle, and may be attributable to different annually varying factors such as hunting, disease or catastrophic events. Fidelity of yearling and adult female lesser scaup to a breeding location is strong (see Breeding ecology: annual survival and philopatry above). Little is known about reproductive or survival rates of lesser scaup except for those breeding in a few prairie-parkland and boreal forest areas. Thus, there are several hypotheses to account for population declines based on changes in vital rates. For clarity, however, we grouped them into breeding and nonbreeding hypotheses.

Breeding Season Hypotheses

Productivity may decline because of changes to boreal forest habitats, contaminants, or nutrition. Potential mechanisms are manifold, but most likely are lowered duckling survival, reduced nest success, or both, assuming that previous models and observations of duck population dynamics apply (Johnson et al. 1987, Carlson et al. 1993, Flint et al. 1998). It is unknown whether relatively small changes in survival or nest success, acting singly or in combination, would cause population declines observed in BGS data; these analyses have not been performed. Female condition and clutch size also may be important, so contaminant or nutrient acquisition hypotheses need to be considered. Alternatively, survival of breeding females may have declined. Modification of boreal forest habitat may have altered predator-prey relationships or increased natural mortality in other ways. We think it unlikely that subsistence hunting of scaup has increased substantially.

Rather than separate reproduction or survival into various components, a preferred approach is to study individually marked female scaup so that reproduction and survival can be determined concurrently. Capturing and marking females before breeding would allow assessment of the
contaminant hypotheses because their contaminant levels could be measured or randomly-selected females could be dosed with contaminants suspected to impair reproductive success. Moreover, marked birds can be resighted in future years, providing further data about survival and breeding site fidelity. Below is a phased approach for studying reproduction and survival of scaup on selected breeding areas:

**Phase 1:** Pinpoint areas where scaup populations have declined most, where they have remained stable, and where they are increasing.

**Phase 2:** Conduct preliminary study(ies) to determine feasibility (logistics, costs, etc.) of acquiring data from individually marked (breeding success, survival, diet [using stable isotopes of blood], molting) or unmarked (nutrient acquisition, diet, molt) scaup.

**Phase 3:** Develop a *preliminary* model of population dynamics using published data and information acquired in phase 2.

**Phase 4:** Randomly select study sites based on information obtained in phases 1 and 2, involving replicate sites in each trend category, or as a minimum, contrasting areas of decline with those that are stable or increasing.

**Phase 5:** Obtain data for 4-5 years on each site. Each year, (1) predict and then measure population change, then (2) refine and update the population dynamics model, while (3) testing hypotheses about underlying causes of population change.

**Nonbreeding Season Hypotheses**

Studies of survival, diet, and nutrient or contaminant acquisition on nonbreeding areas must be done concurrently with breeding studies to provide better data about causes of scaup population declines. It is crucial to simultaneously evaluate whether nonbreeding season mortality has risen and, if it is due to hunting or another cause. It also is essential for correctly interpreting results of breeding season studies (e.g., roles of nutrients or contaminants). Changes to molting, migration/staging, or wintering areas may affect survival or future reproduction. Likewise, impacts of hunting or natural mortality may influence population size. The role of hunting in adult female survival is uncertain but may have increased in relative importance because harvest of adult scaup (including females) has remained stable in the Mississippi flyway (where most scaup are shot) despite population declines and a lower ratio of immatures:adults in the harvest. Finally, strong fidelity of breeding scaup populations to the same migration and wintering areas could cause declines on breeding grounds if mortality or contamination of food resources on migration or wintering areas has risen.

Investigations are needed at important migration or wintering sites. Specific research questions about the nonbreeding period are examined below, followed by a general approach to address them. Contaminant problems are covered elsewhere (see Issue 3), but there is potential for collaborative research.

*How does annual and overwinter survival of scaup vary with age-sex cohort, and what role does hunting play?* Banding scaup in boreal forest locations and wintering areas would eventually answer this question. There are many benefits to this approach, but there will be costs and delays in acquiring data, and it would not yield information on natural causes of mortality. One alternative is to mark large numbers of scaup on migration and/or wintering areas with satellite transmitters and determine survival rates and causes of mortality; this, too, is costly but would yield precise results quickly. Another favored possibility is to combine the 2 approaches, using radio-telemetry to rapidly provide reliable information about smaller samples of scaup in specific areas and using band recovery analyses to derive estimates from larger samples marked over a broader geographic area. Preliminary analyses of harvest data (Afton and Anderson, in review) indicate that studies of adult females would be most valuable. Feasibility of using satellite transmitters should be pursued, as they would provide more complete information about
molting, staging and wintering locations, local movements and mortality.

What is the fidelity of breeding scaup to specific migration sites and wintering areas, and how does this relate to overwinter mortality, including hunting losses? Declines of scaup in mid-boreal areas of western Canada may be related to fidelity to winter or migration sites if mortality on wintering areas exceeds productivity (and adult survival) on breeding areas. Answering philopatry and mortality questions may be accomplished by annually banding scaup in the same breeding and wintering areas and recapturing birds over time. The advantages are that other information can be acquired from captured birds, other species could be banded, and exact locations of marking are known, but disadvantages include cost and long delays before sufficient data are available for analyses. Previous banding data could provide preliminary information on winter philopatry.

Alternatively, philopatry could be evaluated by applying stable-isotope techniques to feathers of hunter-shot or trapped scaup, thereby delineating affinities of breeding scaup (from the deuterium isotope signal) to specific migration or wintering areas (from where the bird was shot/captured). This approach can quickly provide answers to questions about (1) general breeding origin (primarily latitude) of hatch-year scaup and possibly about female fidelity to specific migration and wintering sites, (2) general molting areas (latitude) of adult male scaup, and (3) breeding philopatry of scaup shot by hunters in different migration and wintering areas. The main advantage of this approach is that answers would be obtained relatively quickly for certain cohorts (e.g., breeding origin of hatch-year scaup; molting location of adult males).

Disadvantages include cost (initial refinement of the existing isotope model and development of cheaper analytical methods), and lack of specific information about breeding origins. However, the information obtained on breeding origins likely would be sufficiently precise to test the main question posed above.

2. HAVE CHANGES IN WESTERN CANADIAN BOREAL FORESTS RESULTED IN REDUCED REPRODUCTIVE SUCCESS OF SCAUP?

Sources of Possible Landscape-Level Impacts

The boreal forest herein refers to Alaska, Yukon, Northwest Territories, northeastern British Columbia, northern Alberta, northern Saskatchewan, and northern Manitoba, including the Saskatchewan River Delta. We considered 9 possible landscape-level impacts to breeding scaup:

Fire.—The northern boreal forest has evolved as a fire-dependent ecosystem, not only in North America (Kronenberg et al. 1998, Larsen 1997, Lee et al., 1997, McCullough et al. 1998), but throughout the circumpolar boreal ecozone (e.g., Conrad and Ivanova 1997, Stocks et al. 1998). Fire is perceived to play a significant role in determining the structural complexity of boreal mixed-wood ecosystems (Kronenberg et al. 1998, Lee et al. 1997). Estimates of fire frequency in the ecosystem vary, but fires typically are viewed as having occurred on a relatively frequent (i.e., ≤100 yr) interval (Kronenberg et al. 1998, Larsen and McDonald 1998, Lee et al. 1997). Due to the extent of fires across this landscape and size of individual fires (often thousands of hectares), effects of fire on waterfowl habitat is potentially widespread.

Alterations in fire frequency have occurred in this century as fire suppression activities increased to protect merchantable timber resources (Conrad and Ivanova 1997, Thompson et al. 1998). Furthermore, enhanced fire suppression has resulted in a shift in fire extent and severity in recent decades (Thompson et al. 1998). Climatic changes may increase fire frequency, either by increased fire probabilities or changes in vegetation (Kronenberg et al. 1998). Changes in climate also have been projected to alter fire frequency and intensity (Stocks et al. 1998, Thompson et al. 1998). Whether fires affect reproductive success of scaup is presently unknown. A review of fire history would determine if fire frequency and extent have changed during periods and in areas of scaup population declines. Assessment of the
interaction between fire and scaup reproductive success would be warranted if a correlation was detected between areas of declining scaup numbers and fire frequency or extent.

Logging.— In the Northwest Territories, logging activity is minimal and likely has little impact on scaup populations. However, logging recently may have had an effect in northeast British Columbia, northern Alberta, northern Saskatchewan, and northern Manitoba, especially in the past 10 years. It is during this period that technological development has allowed and promoted harvest of aspen (Populus tremuloides) and balsam poplar (P. balsamifera) in these areas. Additionally, government attitudes toward development of resources in the boreal mixed-wood region have resulted in the recent expansion of logging activities (Province of Alberta 1998). Exploratory analyses of remotely-sensed data in the boreal mixed-wood region of east-central Alberta (Lac LaBiche) confirm the recent expansion of logging activity (Dr. I. Creed, University of Western Ontario, pers. comm.). Broad-scale, long-term declines in scaup populations probably are not a result of logging activities in the boreal mixed-wood ecosystem given their recent (i.e., since 1990) development. Whether logging affects nesting habitat or wetland quality is unknown. Certainly, the agricultural transition zone has recently expanded northward in concert with logging activities along the southern edge of the boreal forest, particularly in central Alberta. This expansion may be contributing to declines in scaup populations there. The extent of conversion of boreal mixed forest to agriculture could be examined using LANDSAT-TM images, and assessed relative to breeding waterfowl survey data. However, this area is insufficiently large to have caused range-wide declines observed for scaup.

Climate.— The Boreal Forest ecosystem is predicted to experience the greatest warming due to global climate change (Environment Canada 1995, Rouse et al. 1997). Most anticipated effects on ecosystem processes are linked to changing biogeochemical processes of plant growth and soil, changes in vegetation distribution patterns, and changes in net primary productivity (Plöchl and Cramer 1995). However, few studies have examined potential response of non-peat wetlands to climate change in this ecosystem (e.g., Marsh and Lesack 1996). Given predictions of significant changes in hydrology, temperature, and precipitation patterns, potential effects on boreal wetland ecosystems likely will be broad-scale and significant. The magnitude and direction of changes and long-term effects on scaup populations are not known. We recommend retrospective analyses to assess potential effects of climate change on wetland extent and quality in the boreal ecosystem.

Oil and gas developments.— Exploration and development for oil and gas has been widespread across the region, but effects are mostly localized. Exploration effects are largely transitory, but oil and gas extraction facilities come with permanent infrastructure, including roads and well pads.

Acid rain.— Contrary to the situation documented for wetland-dependant wildlife in eastern boreal ecosystems (Hansen 1987, Longcore et al. 1993), acidification in western Canadian boreal forests is anticipated to be localized and minimal (ADPR 1989). Acid neutralizing capacity (ANC; the ability of soils and bedrock to ameliorate acidic deposition) in much of the western boreal ecosystem generally is moderate to high (Anonymous 1988), largely due to extensive glacial overburden found there. Furthermore, wind patterns resulting in the long-range transportation of SO2 and NOx emissions from high volume sources common to northeastern North America (Haines 1981) are not common to the western boreal ecosystem. Thus, point source deposition is of greater importance in this region. Wetlands located in areas immediately downwind of industrial sources (e.g., metal smelting facilities in Thompson and Flin Flon, MB) that lack sufficient ANC may be affected, but these effects are anticipated to be localized.

Hydro-electric development.— At present, we are unaware of large-scale projects planned for the western Canadian boreal forest region. Significant local effects on wetlands and
wetland-dependant wildlife are possible, but past developments are unlikely to have caused range-wide declines in the scaup population.

**Mining.**—Mining occurs largely outside of traditional waterfowl survey areas, and effects usually are localized. Past activities are not presumed to be sufficient to have resulted in the significant declines observed in the scaup population. Several new mining interests have been developed in areas of the Northwest Territories, but minimal impacts to scaup habitat are anticipated.

**Predators.**—There is no evidence of changes in predator communities or predator efficiency that suggest scaup are suffering increased losses to predation. However, rigorous data to test this are not available.

**Confounding aspects of prairie drought cycles.**—We hypothesize that prairie drought may contribute to lower reproductive success of scaup (see discussion above under Breeding biology: climate change; Afton and Anderson in review). During prairie drought, wetland availability and quality are markedly reduced. This could cause shifts in scaup distribution during spring migration as they seek suitable wetland habitat, and reduced availability of food; these factors might affect acquisition of nutrient reserves. Reproductive success of boreal scaup could be reduced if they were not able to acquire sufficient nutrient reserves during spring migration. The significance of prairie-parkland food resources to scaup breeding farther north is unknown.

**Reproductive effort in prairie-parkland and boreal forest habitats.**—Comparison of data collected in the YKSA (Trauger 1971), Alaska (B. Grand, D. Esler, P. Flint, and T. Fondell, unpubl. data), and Erickson, Manitoba (Afton 1984) suggests basic reproductive parameters of lesser scaup were similar among boreal and parkland areas. Data are lacking for scaup breeding in tundra and for other boreal forest areas. Additional studies in a range of areas, conducted simultaneously to examine within-year differences, would enable biologists to determine whether reproductive effort and success differ between scaup breeding in prairie-parkland and boreal forest, especially in areas where the population is declining. Studies should compare several reproductive parameters including clutch size, nesting effort, nest and hen success, role of nutrient reserves, and duckling survival.

There are several constraints to addressing these issues. First, we need to clarify where, specifically, the largest declines have occurred. We recommend a continuation of the work initiated by MacCluskie et al. and D. Caswell. This information is particularly critical for development of intensive studies of breeding biology and to directly assess effects of habitat changes noted above. We lack comparative information on temporal and spatial patterns of spring and fall migration of Boreal Forest and Prairie-Parkland populations. Possibly, differences in these factors lead to differential hunting pressures, exposure to contaminants, and differential scaup reproductive success and recruitment. Banding, mark/resighting, and telemetry studies could address these issues and better describe spatial and temporal patterns of migration.

**Recommendations**

The following recommendations are not prioritized.

1. Examine reproductive effort and success of scaup along a north-south gradient, extending from the western Canadian boreal forest to the prairie-parkland. Field work should be done simultaneously on several areas to allow comparisons within years. Such a large-scale effort will require time to secure cooperators, funding, and the necessary support. This work would include:
   a. Intensive site work to assess basic reproductive biology, including nest and hen success, nesting effort, clutch size, role of nutrient reserves, and duckling survival.
b. Broad-scale monitoring, such as pair/brood counts and brood size, to assess spatial and temporal trends in reproductive success.

2. Explore opportunities to develop linkages with experts in climate change research and ongoing projects (e.g., BOREAS program, the Mackenzie River study, or other efforts targeting the Boreal Forest ecosystem). Identify someone to explore potential effects on boreal habitats as related to scaup.

3. Explore fire history (past 20-50 years), including extent over the long term, in provincial and territorial records. Where possible, conduct investigations at the BGS substrata scale. Assess fire history relative to climate change implications.

4. Examine logging activities and habitat changes at BGS substrata scale relative to scaup populations to assess whether logging activities have contributed to the decline in scaup populations. This work should be implemented pending analyses of where scaup population declines are occurring.

3. HAVE PHYSIOLOGICAL CHANGES, INCLUDING NUTRIENT ACQUISITION PATTERNS AND CONTAMINANTS, AFFECTED REPRODUCTIVE SUCCESS OF SCAUP?

Contaminants and nutrient acquisition are closely interrelated through feeding and food resources. Here, we examine each separately and present recommendations within each section.

Contaminants

We proposed 2 hypotheses to assess whether contaminants have contributed to the decline of lesser scaup populations. Because the consensus was that reduced recruitment was likely contributing to the scaup decline, hypothesis formation began there. We recommend a tiered approach; thus, if problems are identified at the first tier, research should test hypotheses on Tier Two, and so on. We only identified Tier One questions for some hypotheses. Subsequent Tier Two hypotheses may be developed as needed.

H_1: Contaminant concentrations in eggs are affecting reproductive success.

Problem statement: The only recent contaminant data are from migration and wintering areas; consequently, it is unknown whether concentrations of contaminants persist until scaup reach their breeding grounds at levels that affect reproduction.

Tier 1: Determine concentrations of organochlorine and trace elements in scaup eggs and determine whether they are at levels indicative of reproductive problems.

Sampling design: Determine concentrations in eggs collected from: (1) areas where populations are declining and areas where populations are stable or increasing, (2) major breeding areas, and/or (3) locations where existing studies are under way. One egg per clutch would be randomly collected from 5-10 nests per site. Possible contaminants are persistent organochlorines, trace elements (especially mercury and selenium), polycyclic aromatic hydrocarbons, dioxins, and furans.

Another possibility would be to collect more than 1 egg per clutch and artificially incubate eggs so that hatching success can be determined; bioindicators such as ethoxyresorufin-O-dealkylase (EROD), oxidative stress, or polycyclic aromatic hydrocarbons levels in bile could be measured. Egg quality could be assessed in freshly laid eggs.

Tier 2: If significant levels of contamination are found in eggs, assess contaminant levels in females and effects of contaminant levels on hatching success and duckling growth and survival. Investigations would include:

- Examine contaminant levels in nesting females. Collect nesting females to
determine how contamination in the liver and carcass of each female relates to contamination concentrations in her clutch. Because of remoteness of scaup nesting sites, it may be more efficient to collect females and clutches when addressing Tier 1.

- Use the sample egg method to quantify contamination of a sample egg and assess hatching success of the remaining eggs in the clutch.
- Measure duckling growth and survival rates relative to contamination levels.
- Examine behavioral effects of contaminants through studies of captive scaup.
- Assess where scaup are accumulating contaminants by examining affiliations among breeding, migration and wintering areas, using banding, color-marking, or satellite telemetry.

Tier 3: Mode of action and true tests of hypotheses. Once effects are observed in field situations, design studies to test those hypotheses. These studies would be true tests under more controlled and repeatable circumstances. These studies could be parallel laboratory and field studies and could:

- Examine depuration rates of selected contaminants.
- Examine effects of contamination on immune responses.
- Examine effects of contamination on thermoregulation.
- Examine interactions between nutrients and food availability and contaminant effects.
- Examine interactions between parasites and diseases and contaminant effects.
- Examine effects of contamination on vitamin depletion.
- Examine effects of contamination on lipid dynamics.
- Examine effects of contamination on salt gland function.

- Develop assays or tests that might assist in studies.
- Model the above as needed.

H₀: Contaminant concentrations affect propensity for nonbreeding.

Problem statement: Recruitment may be reduced because some proportion of scaup are not breeding. Nonbreeding could happen at 2 geographic scales: scaup may arrive at breeding sites but not breed, or scaup may not arrive at breeding sites to attempt to breed (see Afton 1984). Causes for nonbreeding could include contaminants, food or nutritional constraints, or habitat degradation. Studies would require that other factors be teased apart from effects of contaminants, which will be challenging.

Tier 1: On a small geographic scale, use mark/recapture, mark/resight, and telemetry techniques to determine whether nonbreeding is occurring and what proportion of the population is affected. Proportion of nonbreeding would be compared among sites with differing contaminant concentrations or among sites with differing productivity. A blood sample could be taken to quantify contaminant exposure for comparison among individuals. Few data are available to interpret contaminant concentrations in waterfowl blood, but such data could be collected in captive studies.

Tier 2: Design captive studies to test whether some chemical contaminants delay or deter breeding and determine mechanisms for mode of action.

Methods to determine proportion of the population which are not breeding on a larger geographic scale are unavailable or logistically very difficult. Additionally, what level of nonbreeding is normal has only been documented at Erickson (Afton 1983, 1984). Techniques for assessing nonbreeding on a larger scale need to be developed.
Nutrient and Food Limitations

Relationships among food availability, nutrient availability, intake rates, daily food and nutrient requirements, body mass and condition, and reproductive performance are complicated. These relationships are not static but vary according to the annual cycle, sex, and extrinsic factors such as temperature and competition. Information on feeding ecology, food availability, and nutrient acquisition during spring migration, and how these relate to breeding effort and success is limited (Afton unpubl. data). Changes in food availability and quality on wintering and migration areas may differentially impact scap breeding in different regions (cf. Afton and Anderson in review). These issues can be most readily addressed through standard approaches such as collection of feeding scap. Stable isotope analyses also can provide insight into foraging ecology (Chamberlain et al. 1997).

Hypothesis: Reproduction is limited by food resources/nutrient reserves on winter, spring migration, and/or breeding areas.

Problem statement: Food resources, nutrient availability, and/or nutrient reserves during any portion of the life cycle could limit lesser scap reproduction. When or where critical reserves for breeding are acquired by female scap, and flexibility of scapuaced with changing food resources or habitat, is largely unknown, particularly in coastal areas.

Tier 1: Collect scap throughout the annual cycle and determine lipid, protein, and ash content of carcasses and other tissues as appropriate. Collection of female scap is of higher priority than collection of males. Research could compare among flyways, among populations that breed east versus west of the Continental Divide, or between boreal forest and prairie-parkland populations.

Tier 2: Determine whether stable isotope ratios can be used to answer nutrient or food resource questions or identify breeding areas. Stable isotope patterns in tissues can be used to reflect diet changes over time. For example, liver tissue (half-life=2.6 days) turns over approximately 4 times faster than muscle tissue (half-life=12.4 days), and over 600 times faster than bone collagen (half-life 173 days) (Hobson and Clark 1992). Stable isotope ratios in these tissues can be used to determine whether a diet shift has occurred over that time frame. Deuterium isotopes in bird feathers can help determine the region where diet was raised. To use this technique in adults, detailed knowledge of molt patterns would be needed.

4. What information is needed to manage greater and lesser scap separately?

Separation of the 2 species in surveys and other data sets is important for addressing the decline in scap populations and would allow setting separate NAWMP population goals and deriving management strategies. We reviewed the various data sets and considered the information required to facilitate separate management.
Examination of Issues

Waterfowl Breeding Population and Habitat Survey.—Additional analysis of BGS data can lead to improvements in survey design. Analyses should examine social groupings, distribution and timing of the survey, and consider re-stratification of the survey for scaup. Biologists noted that increasing numbers of ring-necked ducks (Aythya collaris) seemingly correspond with declining numbers of scaup in some areas. This relationship should be examined to see if improved ability of aerial survey crews to separate scaup and ring-necked ducks contributed to an apparent change in numbers. Analyses also should compare breeding population estimates of scaup to species with a similar breeding range (e.g., wigeon, bufflehead [Bucephala albeola], goldeneye [Bucephala clangula, B. islandica]). Detailed reports of pilot-biologists, containing information on ice-out dates and habitat and survey conditions, should be reviewed because they may contain information on accuracy of annual scaup population estimates.

The BGS, which is timed for mallards, provides only a rough index of scaup population numbers. A new June survey that could provide a better scaup population estimate should be evaluated. This would require recensusing some May survey routes at a time appropriate for scaup.

Separation of Species during Waterfowl Surveys.—The most important need was a practical way to separate the 2 species during BGS. Separation of the species cannot be made effectively from aircraft because they tend not to fly for fixed-wing aircraft and dive or hide when low-flying helicopters approach. The only method to assess species composition in the surveyed areas is a ground survey from Hudson Bay to the west coast of Alaska. We recommend first conducting a pilot ground study to sample an area thought to contain mostly greater scaup and several areas containing a mix of the 2 species. We did not evaluate logistics or discuss survey design. Sampling would require accounting for the patchy distribution of the 2 species among habitats. Some information probably could be gathered on national wildlife refuges in Alaska. The ground survey would require a coordinator to plan the study and work with the aboriginal groups and others to arrange access.

It would be valuable to review recent and historical reports (e.g., general bird and wildlife surveys, impact statements, etc., many of which are unpublished) for areas within the scaup breeding range, particularly the boreal forest. These may contain information on distribution of each species.

Also needed is review of waterfowl migration and winter survey data, including individual state migration surveys, Great Lakes surveys (e.g., Long Point, ON), midwinter surveys, and other surveys. Two new surveys that may be useful are a coordinated Great Lakes survey and improved Gulf Coast surveys, specifically in Louisiana and Florida. Many scaup use these areas during fall and winter. J. Goldsberry suggested that greater and lesser scaup could be separately counted from survey aircraft in fall and winter based upon wing stripe pattern when ducks are flushed. New or expanded surveys could be further justified based on other species that are either poorly surveyed or which may have declining populations, such as scoters, oldsquaw, and mergansers (Merganser spp.). These surveys should be coordinated with Sea Duck Joint Venture efforts.

The Parts Collection Survey data, and possibly state or refuge bag check data, should be reviewed in more detail in terms of distribution, age, and sex. Additional sampling of hunters in the Parts Collection Survey specifically to obtain scaup (which are often shot late in the hunting season) would bias species composition data obtained and thus is not recommended. However, additional bag checks or special wing surveys in selected areas may provide information on species composition, age, and sex.

Banding/Marking.—Potential banding areas could be identified using GPS locations from the BGS to locate concentrated breeding areas. It would be difficult to band large numbers of breeding ducks or broods. Molting birds can be banded,
but their breeding area is unknown. A program should be designed to band scaup in all representative parts of the range to allow for differences in migration/winter areas and population parameters. It is a low priority to band in migration/winter areas, unless annual survival estimates are needed for these areas. It may be useful to collect new banding data and compare with older data from certain areas.

It is important to tie major breeding and molting areas for each species with migration, wintering, and harvest areas. Satellite transmitters attached to scaup on winter or breeding areas would provide information more quickly than a banding program, but sample size and costs would be concerns. Scaup marked with satellite transmitters during winter could provide data on multiple counting or undercounting of scaup during the BGS.

Investigators should assess condition of individual birds when marking because this can have an important influence on survival (Pace and Afton 1999). Banding may be the only way to obtain information necessary for developing a population model for scaup. There should be a cost/benefit analysis of banding versus marking birds with satellite transmitters to determine which method provides the most useful information for management, given limited research dollars.

**NAWMP Goal.**—In 1986, NAWMP established a goal of 6.3 million breeding scaup (both species combined) by the year 2000 (U.S. Fish and Wildlife Service 1986); this was based on the estimated average number of scaup present during 1970-79 (6,305,195). The number of breeding scaup has not met this goal since 1984. Rather than consider the appropriateness of the current NAWMP population goal for the combined scaup population, we believe we should move quickly towards new and separate goals for each species. We recommend that the NAWMP goal be reviewed and separate goals for each species be determined by 2005.

**Separate Management.**—The information described above is needed to effectively manage these species separately. It would be difficult to manage harvest of the 2 species separately even if population monitoring data are available, although this could be attempted where the species are geographically separated during a portion of the hunting season.

**Recommendations**

We recognize that the activities listed below may run concurrently, with topics from 1-5 not given in priority order. Within each list, a high priority item is identified that should begin soon.

1. Review of available data (*complete a, b, & c by 1999*)
   a. BGS data: scaup and associated species (High priority)
   b. Harvest information (Medium priority)
   c. Winter survey data (Low priority)
   d. Compilation of all relevant scaup data (Low priority)

2. Separation of species in BGS (*initiate 2000, complete 2005*)

3. Examination and improvement of survey precision (*initiate 2000, complete 2005*)
   a. BGS (i.e. timing, re-stratification) (High priority)
   b. Harvest surveys (measure of recruitment) (Medium priority)
   c. Migration/winter (Low priority)

4. Banding/Marking
   a. Link breeding/migration/winter areas (High priority) (*initiate by 1999*)
   b. Survival/recovery estimates - modeling data (Medium priority)

5. NAWMP Goal - Review and determine separate goal for each species (2005)
CONCLUSIONS

The consensus of workshop participants was that scaup populations have declined. BGS numbers are down and age ratio in harvest for lesser scaup has declined, indicative of poor recruitment. Analyses of BGS data by MacCluskie et al. indicate that the scaup decline occurred primarily in Canada's western boreal forest, east of the continental divide. This is the primary breeding range for lesser scaup. Whether greater scaup breeding there also are declining is unknown.

Various factors may be contributing to these declines, and extensive research and analyses are needed to identify them. Contaminants, lower female survival, and reduced recruitment due to changes in breeding-ground habitat or food resources are believed to be the primary factors contributing to the scaup decline. These factors are not mutually exclusive and likely interact across seasons. The range of issues and of geography involved makes addressing these hypotheses complex.

Several themes were repeated in discussions and recommendations. These highlight research and information needed to address the hypotheses examined here and in Afton and Anderson (in review).

- **Continue detailed examination of existing data.**—Much information remains in the BGS, harvest, and other data sets. These need to be examined for biases, errors, and patterns, including possible changes over the past 20-30 years. Such evaluations could lead to improved surveys and assessments of population trends. Retrospective analyses of these data sets with other information, such as habitat or climate changes, could provide insight into these issues.

- **Determine affiliations of scaup among breeding, migration, and wintering grounds.**—This information is critical to understanding cross-seasonal influences of food resources, nutrient-reserve dynamics, contaminants, and the role of recruitment and seasonal survival in regional population changes. Although banding data provided some insight into the flyway distributions of scaup, these distributions patterns likely have shifted in the past 20 years due to changing food resources on migration and wintering areas. Therefore, a key research priority must be to determine movements and associations of greater and lesser scaup among wintering, migration, and breeding areas. Extensive summer banding on breeding grounds and telemetry (including satellite telemetry) would provide this information but these will be difficult and likely expensive.

- **Develop separate population estimates for greater and lesser scaup in surveys.**—Although most evidence suggest that lesser scaup are declining, we cannot discern whether greater scaup breeding in the western Canadian boreal forest also are declining. Clarification of each species' distribution in surveyed areas will be important for long-term monitoring and conservation of each species, and also for understanding factors contributing to the continental decline. Although we often consider greater and lesser scaup as very similar ecologically, they differ in breeding ecology, feeding ecology, distribution, and other aspects. Separation of the 2 scaup species in migration and midwinter surveys is needed to better delineate their distribution and exposure to hunting and contaminants and to examine food resources issues.

- **Improve estimates of survival.**—Clearly needed are extensive banding and mark/resighting studies to address breeding success, philopatry, and seasonal and annual survival rates. These studies are most needed on breeding areas to examine factors contributing to differential population dynamics among areas. Banding and marking can help us examine the role of contaminants and harvest in the population decline. Improved survival
estimates are critical for determining harvest policies, assessing population trends, and modeling population dynamics.

- **Examine reproductive success across a range of areas.**—Most research was conducted before the start of the population decline. New studies, particularly in the Boreal Forest biome, are needed to examine reproductive success in areas where populations are declining and compared to sites where populations are stable or increasing. Such studies will allow assessment of the role of reproduction in the current decline, and of the factors contributing to any decline in productivity.

Two actions would help guide future efforts and reduce redundancy: (1) a website or periodic newsletter, to keep participants and others interested in scaup informed about current research plans, activities, and opportunities for collaboration, and (2) a designated coordinator for some studies, particularly examination of existing survey and harvest data and banding studies. Work by Allen et al. (1999) and Afton and Anderson (in review) provide a baseline for additional analyses.

Several participants suggested that a conservation plan, as done for sea ducks, and an on-going working group would be valuable to provide information on scaup issues to concerned individuals and groups. A workshop focusing on scaup should be conducted at the Second International Duck Symposium at Saskatoon, Saskatchewan, in the fall of 2000.

Effective conservation of North American waterfowl requires cooperation and communication among agencies and organizations in the U.S., Canada, and Mexico. This workshop is the first step in focusing research directions and stimulating communication and partnerships among diverse groups concerned with scaup conservation and management. All of the recommendations presented here will require funding, commitments of personnel time and other resources, and partnerships and cooperative studies. We encourage all involved with scaup to keep others informed of their activities, and to seek opportunities for collaboration and interactions. We challenge the U.S. Fish and Wildlife Service, U.S. Geological Survey, Canadian Wildlife Service, Flyway Councils and Technical Committees, and private conservation organizations to commit personnel and funding necessary to begin answering research and information needs identified at this Workshop. These steps should begin immediately to address possible causes of scaup population declines. With scaup showing a long-term decline of ~150,000 birds per year, the need for immediate action is clear.

**LITERATURE CITED**


Thompson, I. D., M. D. Flannagan, B. M.
Wotton, and R. Suffling. 1998. The effect
of climate change on landscape diversity:
an example in Ontario forests. Envir.
Trauger, D. L. 1971. Population ecology of
lesser scaup (Aythya affinis) in subarctic
118pp.
Coastal eutrophication near the Mississippi
U.S. Fish and Wildlife Service and Canadian
Waterfowl Management Plan: a strategy for
cooperation. U.S. Fish Wildl. Serv.,
U.S. Fish and Wildlife Service and Canadian
procedures for aerial waterfowl breeding
ground population and habitat surveys in
Fish Wildlife Serv.
Waterfowl population status, 1998. U.S.
Concentrations of migrant diving ducks at
Point Pelee National Park, Ontario, in
response to invasion of zebra mussels,
106:376-380.
## APPENDIX I. Participants at the Scaup Workshop, 9-10 September 1998, Jamestown, ND.

<table>
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APPENDIX II. List of abstracts, by author, distributed at Scaup Workshop.


Barclay, John S., and Deborah A. Rocque. When Greater Scaup Are "Lesser" Scaup.


Grand, Barry, Paul Flint, Dan Esler, and Tom Fondell. Lesser and Greater Scaup Studies Conducted by the Alaska Biological Science Center.


Richard Jeffery, Glen A. Fox and Sean W. Kennedy, Michael Fournier, and John S. Barclay. Polycyclic Aromatic Hydrocarbons (PAHs) and Other Contaminants in Mussels: a Potential Cause of Decline of Scaup Populations.

Krapu, Gary L., and David A. Brandt. Some Reproductive Traits of Lesser Scaup Breeding in North Dakota.


Michot, Thomas C., William H. Benson, and James M. O'Neil. Trace Element Concentrations from Greater Scaup and Other Diving Ducks Wintering in Apalachee Bay, Florida, Seagrass Beds.

