The North American Trumpeter Swan Survey: retain or find something new?

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Abstract

The Trumpeter Swan *Cygnus buccinator* is a charismatic species, important to many North Americans, and estimating demographic parameters – including abundance and distribution – is a basic requisite for the conservation and management of its populations. From 1968 to 2015, the primary population survey for Trumpeter Swans was the North American Trumpeter Swan Survey (NATSS), which was exceedingly useful for determining trends in abundance and range expansion following near-extirpation of the species in the first half of the 20th century. The NATSS also had some shortcomings, however, which limited its utility as an index of the swans' status, and the NATSS has been suspended indefinitely. To help inform decisions as to whether the NATSS should be reinstated, or an alternative monitoring programme developed, we here review the strengths and drawbacks of the NATSS as well as those of other operational surveys and monitoring programmes. For instance, the Waterfowl Breeding Population and Habitat Survey, the Mid-Winter Waterfowl Survey, the Breeding Bird Survey, the Christmas Bird Count, and eBird data also cover large areas of the Trumpeter Swans' range during certain (albeit different) periods of the year, and several have been mentioned as possible alternatives to the NATSS for assessing the status of Trumpeter Swan populations in North America, but each also has some limitations. We discuss the types of data that each of these monitoring efforts generate, and whether any might provide information sufficiently useful for managing Trumpeter Swan populations and their habitats effectively. We hope that this critique will not only be useful to federal, state and provincial agencies as they develop monitoring programmes for revision of management objectives, but that it will help to stimulate the development of updated strategies for Trumpeter Swan conservation.

Key words: breeding bird survey, Christmas Bird Count, *Cygnus buccinator*, eBird, Mid-Winter Waterfowl Survey, Trumpeter Swan, Waterfowl Breeding Population and Habitat Survey.

Assessment of the status of any wildlife species is critical for informing decisions about appropriate conservation measures, with an estimate of population size or density being a key component in determining its conservation status and whether a management programme is required (Williams *et al.* 2002). Understanding how or to what extent abiotic and biotic factors, as well as conservation or management actions, affect population abundance therefore is a central pursuit of wildlife managers (Williams *et al.* 2002; Sauer & Knutson 2008). Numerous methods have been used to ascertain wildlife abundance (Thompson *et al.* 1998; Williams *et al.* 2002; Pierce *et al.* 2020). Before selecting a specific approach, however, managers need to clarify their objectives and to weigh the value of potential data in relation to the management decisions that need to be made, in order to ensure that the data gained match the information required (Pollack *et al.* 2002).

Following the near extirpation of the Trumpeter Swan *Cygnus buccinator* by the early 20th century, resulting from unregulated harvest largely for the feather trade, numerous efforts (*e.g.* bird translocations, supplemental feeding programmes, habitat management) were initiated to restore its populations. In 1968, the North American Trumpeter Swan Survey (NATSS) was established to provide information on population size, productivity and distribution of the species (Office of Migratory Bird Management 1981; Groves 2017). The survey was repeated in 1975 and conducted at 5-year intervals thereafter, through to 2015. The NATSS was the only continent-wide survey which focussed on Trumpeter Swans, and was primarily an aerial survey conducted by state, provincial and federal agencies, with assistance by non-governmental organisations and private individuals (Groves 2017).

From the outset, the NATSS has helped managers assess the progress of restoration efforts for the three Trumpeter Swan populations currently recognised by management and conservation groups in North America – the Pacific Coast, the Rocky Mountain and the Interior populations – toward population goals contained within Flyway Management Plans, which varied not only between flyways but within flyways as the swans' status changed over time (*e.g.* Subcommittee on the Interior Population of Trumpeter Swans 1998). In response to financial and logistical constraints, survey objectives were modified for the 2015 NATSS with abundance estimates receiving priority, the productivity objective being dropped, and the birds' distribution retained as a secondary objective (Groves 2017). Initial discussions regarding the objectives and future of the NATSS commenced in 2015 and resulted in the formation of the International North American Trumpeter Swan Survey Steering Committee (Steering Committee). The Steering Committee was composed of staff from the U.S. Fish and Wildlife Service (hereafter USFWS), Canadian Wildlife Service (CWS), State and Provincial wildlife agencies, and The Trumpeter Swan Society. Although the Steering Committee was formed and tasked with identifying objectives and the future direction of the survey, a full discussion and review of the NATSS has not occurred (Groves 2017).

Difficulties (*e.g.* securing aircraft, personnel and funds) in completing the entire survey occurred during each survey (Groves 2017). For the proposed 2020 NATSS, the spread of COVID-19 made planning for the effort particularly difficult due to travel restrictions. Additionally, critical partners in the survey effort reduced or withdrew their support of the survey, in recognition that information from the NATSS was not critical to inform current management decisions (Environment and Climate Change Canada Wildlife and Monitoring Assessment Committee, unpubl. recommendation, July 2019). Further, the broadening distribution of Trumpeter Swans across much of their range increased the projected cost of the monitoring effort. Because these issues were not likely to be overcome, and an incomplete survey would result in less useful information, the NATSS Steering Committee recommended in January 2020 that the survey be suspended indefinitely (International North American Trumpeter Swan Survey Steering Committee, unpubl. memorandum 27 January 2020).

Trumpeter Swans are a federal trust species under the Migratory Bird Treaty (39 Stat. 1702), meaning that the federal governments of the signatory countries collectively have the ultimate responsibility for their management and conservation. Because the Trumpeter Swans' range extends to the USA and Canada, these responsibilities have been delegated to the USFWS (USA) and Environment and Climate Change Canada (Canada). Updates of Trumpeter Swan goals and management plans, which are now pending and historically relied on information from the NATSS, will necessitate renewed discussion about the monitoring needed to measure progress toward objectives specified in these plans. Thus, we offer this initial examination of the NATSS and several other existing surveys or monitoring efforts as possible alternatives to the NATSS. We also briefly consider acquiring data that might inform a variety of Trumpeter Swan management decisions and provide recommendations about assessing the status of Trumpeter Swan populations.

Methods

We used the objectives from the 1968–2015 NATSS, which were to estimate abundance, productivity, and distribution of swans in late summer–early autumn (Groves 2017), as the basis for our review of the NATSS. We examine the extent to which the NATSS met those objectives as well as funding and logistical considerations. We also review how the NATSS met some assumptions regarding survey methodology, specifically the two primary sources of variation in surveys – detection probability and spatial variation (Pollock *et al.* 2002; Williams *et al.* 2002).

Other surveys or monitoring programmes that may be considered as alternatives or complements to the NATSS are also described, our criteria for including them being that any alternative had to be national in scope (*i.e.* covering the USA and Canada, to encompass the Trumpeter Swans' distribution) and likely to continue into the foreseeable future. The monitoring efforts that met those criteria were: (1) the Waterfowl Breeding Population and Habitat Survey (WBPHS); (2) the Mid-Winter Waterfowl Survey (MWS); (3) the Breeding

Bird Survey (BBS); (4) the Christmas Bird Count (CBC); and (5) eBird. For each of these, we review the types of data that they provide, whether they could reasonably meet NATSS objectives, and pertinent funding or logistical considerations.

Results

North American Trumpeter Swan Survey

The NATSS was the only survey directed specifically at assessing Trumpeter Swan status at population and continental scales and has been used to help track progress towards various conservation objectives (Groves 2017). Primarily an aerial survey, it was conducted over most of the Trumpeter Swans' range and covered all three populations, *i.e.* the Interior, Rocky Mountain and Pacific Coast Populations. The survey has been conducted since 1968 and produced population- or flock-specific data, with flock being considered as an aggregation of swans that may or may not be genetically similar to a larger group of swans but is largely geographically separated and often managed independently from the population. For example, the High Plains flock is an aggregation of birds of the Interior Population, but has a different geographical range, its own unique demographic characteristics, and been managed differently from other segments of the Interior Population. For much of the survey's history, counts were treated as censuses. In some survey areas productivity information (*i.e.* number of grey birds (cygnets) *vs.* white birds) was collected, at least in some years. The survey has been useful in gauging large-scale population trends and changes in swan distributions, most of which have shown dramatic increases in Trumpeter Swan numbers over time attributable to translocation efforts (*e.g.* Monnie 1966; Gale *et al.* 1987), natural population growth and range expansion. Without the NATSS, managers would have been largely uninformed about the rate or level of population trajectories and extent of range expansion. For such goals or information needs, at both the population and flock levels, the NATSS would still be useful if continued.

Despite its directed nature and historical utility, there are, however, several features of the NATSS that limit its usefulness for assessing the current status of Trumpeter Swans. First, survey design, timing and methods were not always consistent spatially or temporally within or across population survey units (Groves 2017). Additionally, survey protocols changed within some population survey units with changes in the spatial extent of the areas surveyed (Groves 2017). Thus, estimates of the numbers and trends of Trumpeter Swans recorded across the different spatial scales are not directly comparable, and only those limited to areas and years that used similar survey methods can be considered robust. Nonetheless, in attempting to provide an overall picture of the status of the species for each survey year, data from all Trumpeter Swan populations were combined to obtain an overall "total" for North America. Whilst this combined "total" likely is a reasonable reflection of gross Trumpeter Swan population trajectories, it should be recognised that it is statistically inappropriate

to combine disparate data in this way for generating abundance estimates (Pierce *et al.* 2020).

From a statistical standpoint, most of the surveys were treated as censuses and were represented as absolute counts of swans. Although in later years, portions of the survey had a statistically sound sampling frame (*i.e.* aerial transects were made over known or suspected swan ranges and habitat; Hawkings 2005), we are unaware of associated detectability assessments that would make these estimates statistically reliable (Pollock *et al.* 2002). We know of only one paper that investigated detectability during a Trumpeter Swan-specific survey (Bart *et al.* 2007). Whilst that study indicated that the overall detectability of swans was high (0.93), extending those results to other areas and seasons may not be appropriate (*e.g.* where other swan species may occur). Another source of variability in population surveys is temporal changes in survey coverage (Pollock *et al.* 2002; Williams *et al.* 2002). Trumpeter Swan surveys that have a statistical sampling frame likely have accounted for this, but census surveys may not. Indeed, Groves (2017) acknowledged that not all areas were covered in the 2015 survey, nor in previous surveys as well. Further, because swans are expanding their range both through natural pioneering and due to translocation efforts (*e.g.* reintroductions to the Flathead Indian Reservation and to Blackfoot Valley; Olson 2022), not all areas containing swans were surveyed during each survey. There was no agreed-upon, standardised process for expanding survey coverage to account for these range expansions, likely resulting in counts that were biased low to an unknown extent. Obtaining a population census or estimate should be directed at a defined population over a defined space and time (Pollock *et al.* 2002; Williams *et al.* 2002). In this case, because of increases in swan populations, the spatial definition of the population likely changed with each successive survey.

Another limitation with the NATSS is its periodicity. Despite the objectives of the NATSS not requiring more frequent or annual assessments of swan status, the periodic nature of the survey presented other issues. For species that demonstrate relatively slow population growth and those that are not harvested or otherwise have individuals removed from them (*e.g.* to alleviate crop depredation issues), reliable estimates may not be needed on an annual basis for management decisions. If population abundances change relatively slowly, periodic surveys may be adequate; however, increasing the time between surveys increases the risk that management decisions could be delayed, either resulting in a population declining to a level that makes it harder to recover that population, or increasing to levels that can cause conflicts with other interests (*e.g.* agriculture, bird-aircraft strike hazards and public health/disease concerns). Annual monitoring has in the past allowed managers to respond relatively quickly to changes in population status, such as harvest restrictions for Atlantic Brant *Branta bernicla hrota* and the Atlantic Canada Goose *Branta canadensis* population when their abundances declined (Atlantic Flyway Council 2008; Roberts *et al.* 2021). Similarly, regulation changes were

made with the sudden increase in Aleutian Cackling Geese *Branta hutchinsii leucopareia* numbers, allowing the take of more birds in response to their population growth (Pacific Flyway Council 2006). Although professionals working with swans may notice a decline at local scales, given the periodic nature of the NATSS detecting a large-scale population decline may be elusive. Therefore, reliance on periodic surveys may involve a substantial risk, especially for species that are not abundant.

Another important issue facing the NATSS is funding for the survey, particularly for federal agencies because these agencies must submit annual budget requests to congressional appropriations committees. Surveys conducted annually actually are easier to get funded, as those reviewing appropriations see them each year. In contrast, periodic surveys result in a large increase in budget requests in some years, not only increasing scrutiny of their purpose but also often triggering requirements for reductions elsewhere in the budget request to offset costs. With the rising cost of conducting the NATSS over time, due to a combination of inflation and increases in swans' abundance and geographic range, such trade-offs have become more difficult in recent years. Finally, federal agencies typically are not allowed to "bank" funds over several years to avoid such issues; they usually need essentially to spend their entire budget each year or risk a reduced budget the following year, because a perceived "surplus" is viewed as the budget being too generous.

In summary, the NATSS provided a large-scale indicator of population trends for Trumpeter Swans, which was range-wide and population-specific. Moreover, despite there being no formal design for including new areas, the survey did at least periodically reveal the expansion of swans into new areas, allowing the documentation of changes in the species' range. It did however give only an index of abundance; its results therefore should not be interpreted as reliable estimates of population size, and statistically valid measures of precision were not available. Also, because the results provided only a periodic index to abundance and not population estimates, they could inform only a narrow range of management decisions and limited the ability to assess the effectiveness of those decisions. If reinstated, the periodic nature of the survey would continue to present both logistical and funding problems, requiring a much higher level of coordination than occurred historically, to ensure that the survey would be conducted in a consistent manner and during prescribed timeframes.

Given the preliminary nature of this review and the large number of component surveys that make up the NATSS (*e.g.* the High Plains Flock Survey, the Fall Survey of the USA breeding segment of the Rocky Mountain Population and the Alaska Trumpeter Swan Survey), we did not attempt to assess each of the partners' individual survey efforts. Nonetheless, we expect that there may be challenges with consistency in logistical matters such as observers, platforms (different types of aircraft used), coverage or other factors that may make estimates or counts less consistent. This may merit additional

assessments by the agencies involved with NATSS component surveys.

Waterfowl Breeding Population and Habitat Survey (WBPHS)

The WBPHS has been conducted operationally by the USFWS, CWS and numerous partners since 1955. The survey is conducted annually (except in 2020 and 2021 due to COVID-related issues) during April–June and covers the major breeding habitats of most waterfowl species nesting in the USA and Canada. The WBPHS is an aerial survey, but also has a ground-based component that was incorporated to address annual detectability of birds. In more remote areas where ground-based surveys are not practical, averages of years where helicopter-based detectability estimates were conducted are used when generating estimates (Smith 1995). The survey has undergone several reviews (*e.g.* Bowden 1973, 1984), resulting in a sound sampling and statistical design that provides annual estimates of species' abundances with associated measures of precision. A complete description and review of the survey was provided by Smith (1995).

Although the overall design of the WBPHS was not developed to generate estimates at taxonomic units below the species level, the scale at which data are collected (*i.e.* 18-mile segments; Canadian Wildlife Service and U.S. Fish and Wildlife Service 1987; Smith 1995) allows for the post-stratification of survey areas that can be used to generate estimates at finer scales of bird abundance (*e.g.* the Rocky Mountain and Hi-Line populations of Canada Geese; U.S. Fish and Wildlife Service 2022). Thus, a similar approach could potentially be used to generate population-specific estimates for Trumpeter Swans, as well as an overall estimate of their abundance. Although the current Standard Operating Procedures (SOP; Canadian Wildlife Service and U.S. Fish and Wildlife Service 1987) for the survey do not differentiate between Trumpeter and Tundra Swans *Cygnus c. columbianus* (observations are simply coded as "swans"), breeding range maps (Baldassarre 2014) for both species suggest there is little overlap between the species during the survey timeframe, reducing the potential for Tundra Swans confounding the estimates.

The WBPHS does not, however, encompass the entire Trumpeter Swan breeding range (see U.S. Fish and Wildlife Service 2022) and may not sample swans well within parts of the survey range. Preliminary analyses suggest that within the Canadian provinces, variances of abundance estimates are fairly high (J. Dooley, U.S. Fish and Wildlife Service, unpubl. analyses). Imprecise estimates make management decisions more difficult because the current state of the system is unclear, and the ability to measure responses to management actions also is poor. Many Trumpeter Swan breeding areas fall outside the current boundaries of the survey, including northwestern British Columbia, the Yukon Territory, and many states in the continental USA. Although some states (*e.g.* Minnesota, Wisconsin, Michigan, Oregon) conduct breeding waterfowl surveys within the timeframe of the WBPHS and use similar methods, many others do not (*e.g.* Iowa,

Indiana, Nebraska, Wyoming, Idaho). Further, even for states that do conduct breeding waterfowl surveys, areas covered by the surveys may not align with distributions of breeding Trumpeter Swans (see USFWS 2022 and Baldassarre 2014 for WBPHS transect areas and breeding distributions of swans, respectively). Thus, even those surveys would need to be modified to sample Trumpeter Swans more effectively, at least for the years in which Trumpeter Swan population estimates are desired. Modifying the WBPHS and state surveys to provide a better estimate of Trumpeter Swan abundance would be a costly endeavour to address concerns about only one species. Finally, any productivity data collected (which also would require a change to the SOP) would be greatly biased because the first broods typically are not observed until early to mid-June (Shea *et al.* 2013; Mitchell & Eichholz 2020), by which time the survey is nearly completed.

To summarise, the WBPHS potentially could provide statistically sound population-specific estimates of abundance for Trumpeter Swans on their breeding grounds, particularly in the Prairie Pothole Region. These data would be useful for assessing population status and responses to habitat changes in their nesting areas. However, the areas covered by the survey would need to be expanded to include more Trumpeter Swan breeding areas to ensure unbiased results, and sampling intensity may need to be increased in some areas to produce reasonable measures of precision. Doing so would require additional financial and other resource commitments, which would have to be determined.

Mid-Winter Waterfowl Survey (MWS)

The MWS was initiated in the 1930s (Crissey 1984) and is the longest running survey of waterfowl in North America. Although not targeted at Trumpeter Swans, the MWS is directed at waterfowl and does include swan counts. The MWS is a mostly an aerial "cruise" survey with some ground-based sections that historically has been coordinated and conducted across the USA and areas of Canada each year in early January (Soulliere *et al.* 2013). Its primary objectives are to monitor relative changes in the birds' abundance and distribution, and also their association with different habitats, but it does not provide a defined sampling framework that would permit statistically rigorous estimates of population size (Smith *et al.* 1989; Heusmann 1999; Soulliere *et al.* 2013). MWS data have, however, been used for some harvest management decisions and non-breeding waterfowl habitat conservation planning, and the survey provides the only population assessment information for some species of waterfowl (Smith *et al.* 1989; Soulliere *et al.* 2013). Additional strengths of the MWS are that it is conducted annually, includes most of the important waterfowl habitats in North America during winter, is coordinated among jurisdictions, and has been conducted for > 75 years.

As with the NATSS, however, the MWS also has design limitations, including a lack of statistical framework, precluding measures of precision for counts of birds, and lack of detectability assessments or correction factors to assess accuracy. The MWS has been criticised for differences in field methods among areas (*e.g.* use of aerial

surveys in some areas *vs.* ground counts in others), frequent changes in survey personnel, variability in experience of survey personnel, variation in survey effort, and changes in the areas surveyed within states (Eggeman & Johnson 1989; Heusmann 1999; Soulliere *et al.* 2013). Yet despite these flaws, counts of American Black Duck *Anas rubripes* from the MWS had similar trends as an aerial transect survey with greater statistical rigor (Conroy *et al.* 1988), suggesting the MWS may reasonably reflect changes in abundance of these birds.

The MWS is conducted annually and covers the vast majority of wintering areas of Trumpeter Swans. The possibility of obtaining some index of productivity (ratio of adults:juveniles) also exists from aerial or ground surveys in the MWS, although additional data would need to be collected to differentiate cygnets (grey birds) from adults and subadults (white birds). Given the need for MWS data to address certain objectives such as the assessment of population status for some species of waterfowl and establishment of hunting regulations for some populations – *e.g.* the Eastern Population Tundra Swans (Atlantic, Mississippi, Central, and Pacific Flyway Councils 2007) and Atlantic Brant (Atlantic Flyway Council 2002) – continuation of the MWS seems likely at least in some areas of the USA (however, see Heusmann 1999). With some suggested improvements, the MWS could produce more reliable survey results (see Soulliere *et al.* 2013). Nevertheless, the MWS has several major shortcomings for assessing the status of Trumpeter Swans. Most significantly, support for and conduct of the survey has diminished substantially in recent years. Because the MWS data are used explicitly in management decisions for only a few species, and because both federal and state agencies have faced increasing costs for the survey and budgetary constraints, the survey is not conducted as extensively as in the past. The Atlantic Flyway no longer conducts a flyway-wide coordinated effort; they conduct surveys only in areas where Tundra Swans and Brant occur in winter. The Pacific Flyway also no longer conducts a flyway-wide coordinated survey, and several states in the Mississippi Flyway likewise no longer conduct the survey. Only the Central Flyway continues the MWS in the way in which it was conducted historically. Thus, the MWS would need to be reinvigorated substantially to provide reliable information on swan abundance and trends. Arguments for increased efforts expended largely (or solely) to assess Trumpeter Swan status therefore probably would not gain much support from agency personnel under extant budget conditions.

Assuming that the MWS could be increased from its present scope and conducted as it was historically, another significant issue is that during winter Trumpeter Swans coexist with Tundra Swans in many areas, and the two species cannot be differentiated reliably by aerial survey crews. Thus, counts could include both Trumpeter and Tundra Swans and may not provide sound indices for either species; additional effort would need to be expended (*e.g.* ground surveys, or lower-altitude surveys where species could be identified) to obtain defensible species-specific results. Although not undertaken historically, the spatial nature of the data collected during

the MWS could, however, permit development of population-specific (*i.e.* Pacific Coast, Rocky Mountain and Interior) counts of Trumpeter Swans, assuming that Trumpeter and Tundra Swans could be differentiated in the survey or where there is little overlap in the winter distributions of the two species.

In summary, while a reconstituted MWS may provide some general indication about swan population trends, it would not provide reliable species-specific (*i.e.* Trumpeter *vs*. Tundra) counts without survey modifications. Breeding area distribution information would not be available and productivity information would require changes in survey protocols. Such changes would necessitate additional financial and logistical burdens to conduct the survey, even beyond those associated with the survey as it was conducted historically. Nonetheless, discussions about aligning objectives for Trumpeter Swans population data with the MWS might prove useful.

Breeding Bird Survey (BBS)

Concern about the status of nongame birds, arising from the effects of habitat loss and other stressors (*e.g.* pesticide use) on their populations during the 20th century, resulted in the BBS being initiated in 1966 as a means of monitoring trends for a wider range of bird species (Sauer *et al.* 2013). Begun in the eastern USA and southeastern Canada, the scope of the survey quickly grew to the remaining areas of the USA and much of southern Canada by 1968 (Sauer *et al.* 2013). Alaska also had BBS routes along its limited road system, and additional routes were added in remote regions of the USA and northern Canada in the 1990s (Sauer *et al.* 2017). The survey continues to expand and > 4,000 routes currently exist.

The BBS is a roadside survey conducted annually in June (although May and July counts are permitted in some areas) by observers (largely volunteers) who can identify birds both by sight and vocalisations. All birds heard or seen within a 400 m radius of each stop along the routes are counted by observers, and additional information (*e.g.* weather) also is collected (Sauer *et al.* 2017). The resulting point-count data provide information suitable for analysing population trends for individual species, their relative abundance, and other informational products (*e.g.* maps of bird abundance trends), but do not provide information sufficient to estimate absolute abundance. Analyses of the point-count data have changed over time with the advent of additional computing capability and development of improved statistical models. Current analyses of population trend information use log-linear hierarchical model fit using Bayesian methods (Sauer *et al.* 2017).

Trumpeter Swans were not among the species that were typically included in the BBS analyses following initiation of the survey, because the paucity of routes in areas which they inhabit means that there were only limited data available. Recently, however, Sauer *et al.* (2017) have developed analytical methods to generate trend estimates for species with northern distributions, including Trumpeter Swans, where additional years of data and additional routes now provide sufficient information for analysis. From the trend estimates available for 1993–2014, credibility

scores for Trumpeter Swan abundance at the continental level indicate they were questionably or poorly monitored by the BBS (Sauer *et al.* 2017). Moreover, BBS data would need to be post-stratified to assess trends for each population. Results of population-level analyses therefore would likely be even less credible than the BBS continental estimates, because the number of routes where Trumpeter Swans are observed for each individual population would be smaller.

Christmas Bird Count (CBC)

The first CBC was in 1900 and is similar to the BBS in being an annual survey, undertaken largely by volunteer counters across North America (www.christmasbirdcount.org). Anyone can volunteer to assist in counting birds. The National Audubon Society leads the effort but has many partners throughout the western hemisphere, which conduct counts in several countries. In contrast to the BBS, the birds are counted in their wintering areas, with observations made between 14 December and 5 January of each winter. Groups of birders count birds within a 24 km diameter circle, and individuals within each group follow specified routes within the circle to record all birds seen. In addition to those counted along specified routes, birds also are counted at birdfeeders within the circle.

Like the BBS, the counts from the circles provide abundance indices which can be analysed across space and time to assess trends in numbers, and give an index of changes in population size. Absolute abundance cannot be estimated from the data. Indices can also be generated using hierarchical models, but generally are more complex because of the additional variables that should be taken into account (*e.g.* potential for birds to be counted more than once by observers within a circle, birder expertise, amount of area surveyed, non-random placement of circles (Stewart 1954; Bock & Root 1981; Sauer & Link 2002)).

Given that the CBC is conducted during winter, the geographical boundaries of the wintering range for each of the Trumpeter Swan populations would need to be determined, and the data post-stratified to generate population-specific trends in abundance for swans within these areas. This delineation of population boundaries, along with selecting the appropriate count data for the trends analyses, would likely require significant resources at the outset, and there would be ongoing costs in updating the analyses each year. We cannot speculate about the reliability of the results at this time.

eBird

A relatively new database of bird observations is eBird, a project of the Cornell Laboratory of Ornithology (https://ebird.org/home). This is another citizen science programme where birders upload their sightings to an electronic database. The Cornell Laboratory warehouses the data, and scientists from the Laboratory and elsewhere develop analyses to determine bird distributions, migration patterns and other demographic information.

Geographic coverage of observations likely includes much of the Trumpeter Swans' range; however, birds breeding in the far northern areas of North America probably are not well covered. Additionally,

there is no survey design for this monitoring programme. Rather, individual birders choose where to observe birds and whether to enter their observations, so analyses and any conclusions about bird demographics are contingent on the temporal and spatial efforts expended by volunteers. Although current eBird records may provide some useful data on the distribution and densities of Trumpeter Swans in certain areas and during various parts of their annual cycle, estimates of bird abundance cannot be generated from that information. However, new analyses and models continue to be developed as the database grows, and at some future date the capability to estimate bird abundance directly from eBird data may be possible. Meanwhile, eBird records are perhaps presently most useful for helping to describe range expansion by Trumpeter Swans, as birders report the species with increasing frequency in new areas.

Discussion

Our review of the NATSS and other broad-scale surveys and monitoring programmes conducted in the USA and Canada, summarised in Table 1, suggests that none of those other efforts currently can generate the results historically provided by the NATSS. Two surveys (WBPHS and MWS) have the potential to generate range-wide, cohort-specific estimates of abundance and perhaps population-specific estimates. However, they would require supplemental coverage in certain geographic areas, or a re-design of the survey, to produce relatively unbiased and precise estimates. The other extant monitoring efforts currently produce only indices to trends in abundance over time and space, and not estimates of abundance (Table 1). Further, much analytical work would need to be conducted to determine the sufficiency and reliability of the trend information generated specifically for Trumpeter Swans, particularly at the population level.

Although none of these efforts individually supply the information the NATSS provided, new analytical techniques that combine data from extant monitoring efforts may be able to do so. For example, Zimmerman *et al.* (2017) integrated ground plot survey data with BBS data to estimate Wood Duck *Aix sponsa* abundance in the Atlantic Flyway. Similarly, Howell *et al.* (2022) combined eBird data with structured survey data to estimate abundance of Mottled Ducks *Anas fulvigula* along the coast of the Gulf of Mexico. Similar efforts may enable reliable abundance and trend estimates for Trumpeter Swans at useful spatial and temporal scales, although considerable work would be needed to assess this. Those efforts would require funding and personnel support from federal and state agencies, and a commitment to providing those resources over the long-term.

The importance of management objectives

Caughley (1977:12) stated "*Estimates of abundance have no intrinsic value and they should never be considered ends in themselves.*" The purpose of any population survey therefore needs to flow from a clear identification of the conservation and management objectives and decisions that the data are being collected to help inform, which may in turn relate to national or international

legislation or agreements of which a country is a signatory (*e.g.* Ramsar Convention 2017). Lack of explicit objectives – or perhaps a more common occurrence in wildlife management, changes in objectives associated with changes in population status, societal values, or other aspects of the management environment – necessitate periodic reassessment of monitoring programmes.

In the absence of broad agreement about the main objectives for Trumpeter Swan conservation, regarding their population size and other demographic measures, identification of key management decisions is lacking. We suspect that objectives, and thus the most pressing management information needs, may differ among populations. For instance, for the rapidly expanding Interior Population, the greatest information need may be related to their geographic expansion during the non-breeding period, habitat use, and the adequacy of habitat for continuing flock expansion while minimising potential crop depredation. For the U.S. breeding segment birds of the Rocky Mountain Population, abundance, productivity and studies directed towards obtaining a better understanding of demographic limitations (Oyler-McCance *et al.* 2007; Ransler *et al.* 2010) may be more vital. For the Pacific Population, swan distribution and investigations about mitigating known problems of lead poisoning (*e.g.* Degernes *et al.* 2006; Smith *et al.* 2009), powerline collisions and disease might be seen as important.

A new NATSS or something else?

The relatively sudden decision to suspend the NATSS indefinitely has produced a serious information gap in the assessment of the status of Trumpeter Swans in North America. The Trumpeter Swan management community, and particularly the USFWS and CWS, have a responsibility at least periodically to assess the status of the species. Because the NATSS is unlikely to be resurrected (at least as it was conducted historically) due to funding constraints and other concerns, we encourage the Trumpeter Swan management community to expeditiously elucidate explicit management objectives for each management population and the species overall, as the basis for renewing Trumpeter Swan monitoring programmes.

Once the responsible agencies and stakeholders have renewed objectives for monitoring in place to help inform specific management decisions, we can then turn back to the characteristics of existing operational surveys and judge how those might help address information needs for Trumpeter Swan conservation. For instance, if one of the objectives was simply to chronicle range expansion, some combination of e-bird, Trumpeter Watch (The Trumpeter Swan Society 2022) and the WBPHS might be adequate. Perhaps some focused observations by mid-continent National Wildlife Refuge staff could reveal useful patterns about habitat use in areas of pioneering and increasing Trumpeter Swans. For surveys where cygnets could be easily identified from adults, readily incorporated into survey protocol and recorded by observers (*e.g.* MWS, CBC), indices of annual productivity (ratios of white/grey swans in early winter) might also yield important clues as to future population

growth in certain areas. Another option worth exploring could be the use of Bayesian integrated models (*e.g.* Arnold *et al.* 2018; Riecke *et al.* 2022) to estimate demographic parameters of Trumpeter Swan population units simply by systematically monitoring adult/cygnet ratios during the post-breeding period, and thus obviate the need for traditional population surveys. Annual aerial surveys may be warranted for monitoring aggregations of birds that are near or below numerical objectives, such as the USA breeding segment of the Rocky Mountain Population. Certainly, if any Trumpeter Swan populations were to be exposed to increased hunting mortality (*e.g.* U.S. Fish and Wildlife Service 2019), regular sampling of the status of those breeding flocks would be a high priority and require something at least as frequent and informative as the NATSS.

Many migratory bird species should be monitored because of status concerns, take limits, and other reasons, but annual information to make management decisions is not necessary in all cases. While the use of periodic surveys to monitor populations potentially has several issues, it can be a useful tool for measuring the status of some species. Funding such surveys has created issues in the past, given that they are not in annual budget requests. However, potential solutions to fund such monitoring programmes exist. One way would be to fund the survey annually at a level that would monitor a geographic portion of the Trumpeter Swans' range. Each year, a different geographic portion of the range would be surveyed, until after a relatively short period of years the entire range would be surveyed. Then, assuming minimal abundance changes in each of the areas over that period of time, the survey results could be combined to generate a count of swans for that period. Alternatively, a separate budget item could be developed to fund periodic surveys, with those funds being used for a different species each year in a rotational framework. A number of species could fall into such a category, including Trumpeter Swans. Each year, a different species would be monitored using the funds from the periodic survey budget. That idea had been discussed internally by the U.S. Fish and Wildlife Service's Migratory Bird Program over a decade ago, but was not pursued at that time (U.S. Fish and Wildlife Service draft memorandum, 22 June 2010).

Conclusion

In summary, our review of existing surveys suggests that each potential alternative to the NATSS may have some utility for Trumpeter Swan monitoring (Table 1) but they need to be reconsidered once management objectives and data needs are reviewed, identified and agreed upon. The desirable sequence would seem to be to: a) clarify objectives for each of the populations; b) identify essential information for anticipated management decisions that may vary regionally; and c) determine monitoring strategies that will provide data for how those needs might be met. Without first clarifying objectives and decisions, we – and others – cannot evaluate effectively whether the present operational surveys or a combination thereof have the characteristics to serve those needs or how

Table 1. Attributes of surveys that include Trumpeter Swans in North America, summarising: (a) the frequency, (b) type of abundance measure, (c) whether productivity (cygnets counted or not) is recorded, (d) distribution (effectiveness of detecting individuals in new areas) and (e) whether the survey covers the Trumpeter Swans' range comprehensively in either summer or in winter.

Survey*	**Survey attribute**					
	Initial Year	**Frequency**	**Abundance**	**Productivity**	**Distribution**	**Range-wide**
NATSS	1968	Periodic – 5 years	Count/Estimate	Some areas	Good	Yes
WBPHS	1955	Annual	Estimate	No	Fair	No
MWS	1935	Annual	Count	Some areas	Poor	Yes
BBS	1966	Annual	Index	No	Fair	Yes
CBC	1900	Annual	Index	No	Fair	Yes
eBird	2002	Annual	Index	No	Fair	Yes

*NATSS = North American Trumpeter Swan Survey; WBPHS = Waterfowl Breeding Population and Habitat Survey; MWS = Mid-Winter Survey; BBS = Breeding Bird Survey; CBC = Christmas Bird Count.

they may be modified to do so. Perhaps an entirely different information set is needed to assess population status and support habitat conservation planning, suggesting that a new approach should be pursued instead.

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Photograph: Trumpeter Swans on the Kenai River, Alaska, by Craig Ely.