Methods for Monitoring Landbirds: A Review Commissioned by Seattle City Light's Wildlife Research Advisory Committee

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National Park Service - Pacific West Region
North Cascades National Park Service Complex
Sedro-Woolley, WA 98284
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North Cascades National Park Service Complex, comprising North Cascades National Park, Ross Lake National Recreation Area, and Lake Chelan National Recreation Area, was established in October, 1968 and is located in northwestern Washington. North Cascades National Park was established to preserve certain majestic mountain scenery, snow fields, glaciers, alpine meadows, and other unique natural features in the North Cascade Mountains for the benefit, use, and inspiration of present and future generations. Ross Lake and Lake Chelan National Recreation Areas were established to provide for outdoor recreation use and enjoyment and to conserve scenic, scientific, historic, and other values contributing to public enjoyment of these lands and waters.

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Purpose of this report

In January 2000 the Wildlife Research Advisory Committee (WRAC) of Seattle City Light awarded North Cascades National Park Service Complex (NOCA) a grant to develop a long-term landbird monitoring plan for North Cascades National Park. The WRAC stipulated that NOCA use part of the grant to review and summarize existing literature on landbird monitoring methods, in order to identify and fully consider the various approaches that might be appropriate for implementation in NOCA and other national parks. This document summarizes our findings.

Long-term natural avian monitoring in the national parks

Long-term monitoring is increasingly recognized as a crucial ingredient in the effective management of natural resources (Noss and Cooperrider 1994). Nowhere is this more true than within the National Park Service. In 1998 Congress passed the National Parks Omnibus Management Act mandating a "program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park system resources." In fulfillment of this directive, the Servicewide Inventory and Monitoring (I&M) Program of the National Park Service (NPS) has launched a major effort "to encourage, coordinate, standardize, and improve natural resource inventory and monitoring projects throughout the 265 parks with significant natural resources" (Anonymous 1999).

NPS guidelines define natural resource monitoring as "long-term systematic repetition of a specific resource survey and the analysis of those data to predict or detect natural and human-induced changes in resource condition, and to determine if natural resource condition objectives are being achieved"(Anonymous, undated). Numerous authors have outlined why natural resource monitoring is important; one of the most concise, broadly applicable statements comes from Davis (1993):

> *"What to monitor, and the appropriate level of accuracy, varies from area to area, but the basic reasons for monitoring are the same everywhere. They are to:*
>
> *-Determine present and future health of natural area ecosystems.*
> *-Establish empirical limits of variation in natural area resources.*
> *-Diagnose abnormal conditions to identify issues in time to develop effective*

mitigation, and
-Identify potential agents of abnormal change."

The NPS considers long-term monitoring "necessary to enable managers to make better informed management decisions, to provide early warning of abnormal conditions in time to develop effective mitigation measures, to convince other agencies and individuals to make decisions benefitting parks, to satisfy certain legal mandates, and to provide reference data from relatively pristine areas for comparison with data collected outside of parks by other agencies" (Fancy, undated).

As numerous authors have pointed out, the first step in designing any monitoring program is to define explicit objectives (Silsbee and Peterson 1991). Fancy and Sauer (2000) recently articulated a hierarchy of four general objectives for park managers interested in initiating avian inventory or monitoring projects:

Objective 1: Document which species occur in the park.
Objective 2: Determine distribution and get a qualitative measure of relative abundance ('abundant', 'common', 'rare') of each species in the park.
Objective 3: Compare relative abundances among species, habitats or areas, or detect trends in population size.
Objective 4: Determine the causes of population trends and differences in abundance among species, habitats, and areas or identify and evaluate management actions to reverse declining trends and increase low population sizes.

These objectives are presented in increasing order of complexity. Objectives 3 and 4 require a substantially greater investment of resources than do Objectives 1 and 2, but they are also likely to provide managers with much more useful information. Indeed, Objectives 1 and 2 alone are probably not appropriate for meeting the long-term monitoring needs of most parks, as they are unlikely to allow detection of non-catastrophic changes over time, or to facilitate scientifically-based management actions even if catastrophic population declines are detected. Objectives 1 and 2 may, however, be appropriate for shorter-term inventory efforts.

Review of established landbird monitoring techniques

As numerous authors have pointed out, there is no ideal monitoring method; different monitoring techniques are appropriate for satisfying different study objectives. Nevertheless, utilizing standardized methods and protocols can facilitate inter-park comparisons, as well comparisons of park data with data from non-park sources. Unfortunately, such standardization does not currently exist (Quinn and van Riper III 1990, Sauvajot et al. 1990). Park monitoring efforts thus must strike a careful balance— they must be flexible enough to allow managers to tailor monitoring techniques to particular park needs, while still being sufficiently standardized to allow for intra- and inter-park comparisons, as well as comparisons with data from surrounding lands that may not be under park management.

Abundance monitoring techniques

The following techniques provide data of varying quality and detail on species occurrence, abundance, and/or density: area searches, linear/strip transects, fixed/unlimited radius point counts, point counts with detectability estimation, and spot mapping. All of these methods are limited to varying degrees by a common set of inherent error sources in counting birds. The majority of count detections are aural, at least in densely vegetated habitats, so birds that are not singing may be essentially uncountable,. Songbirds show enormous variation in song frequency according to such factors as weather conditions, population density, time of day, and stage of reproduction (Conner and Dickson 1980, Diehl 1981, Mayfield 1981, Robbins 1981, Skirvin 1981). In many species unmated males sing more frequently than mated males (Nolan 1978, Best 1981), and whether they are singing frequently or not, the presence of large numbers of non-breeding 'floaters' can greatly skew results (van Riper III 1981). Additionally, the efficiency of even experienced observers decreases significantly as the number of singing birds increases (Bart and Schoultz 1984). For all these reasons, none of the abundance monitoring techniques are perfect. Each technique also has its own additional weaknesses and strengths, which I review and discuss in turn below. I also suggest which of the four previously discussed Objectives can be appropriately pursued using each monitoring technique, and also briefly discuss site selection criteria for implementing each of the methods. Although I don't explicitly state this in the site selection criteria for each method, survey sites for all bird monitoring techniques should be located to coincide with monitoring locations for studies of plants and other animal taxa whenever feasible, so that habitat relations can be studied as thoroughly and efficiently as possible.

Area Searches:

The least regimented of the established methods for counting birds, the area search method simply requires that observers roam freely for a fixed time in a specified area, tallying numbers of each species detected (Lyon 1986, Slater 1994). The method is particularly well suited to projects that rely on volunteer observers (Nur et al. 1999), as it allows variable numbers of observers with diverse skill levels to work together. Because of its informality (observers can behave much as they would during any other day of birding), the method lends itself well to events that combine bird monitoring with public outreach; volunteer observers may wish to participate simply for the fun of it. Furthermore, unlike most other bird-counting techniques, area searches allow rare or secretive species to be actively pursued, perhaps elevating their detection probability (Siegel in preparation).

Area search data also have substantial limitations. Although observers are generally asked to estimate and tally the numbers of individual birds detected, such estimates must be interpreted with great caution. Ensuring that individual birds are counted no more that once can sometimes be difficult even when the observer remains in a fixed location (i.e. during point counts); doing so when multiple observers are moving freely is exponentially harder. Area searches are consequently most appropriate for determining which species are present in a given area, and perhaps qualitatively classifying the relative abundance of each species (rare, common, etc.), but are not appropriate for tracking numbers of birds over time. Even when the objective is simply to generate species lists, area search results may vary substantially with observer skill level and motivation, particularly if the study area includes habitat patches that may be uninviting to some observers (i.e. steep areas, muddy areas, areas dominated by spiny or poisonous plants).

Suitable objectives: 1, 2

Criteria for site selection: Area searches most effectively survey relatively limited, well-delineated areas (Siegel, in preparation). Survey areas may be circumscribed by man-made boundaries (roads, fences, etc.) or natural boundaries (streams, well-defined ecotones, etc.), but in general, clearer borders around the survey area make for more reproducible results. Similarly, observers surveying relatively small parcels of land that can be thoroughly traversed (perhaps repeatedly) during the search will also provide more reproducible data.

Fixed/Unlimited Radius Point Counts without Detectability Estimation:

Point counts require observers to record all birds detected during a fixed amount of time (generally between 3 and 10 minutes) within a pre-determined (usually 50 m) and/or unlimited distance of selected survey points (Hutto et al. 1986, Ralph et al. 1993). The resulting data yield abundance indices, under the assumption that the number of birds detected is proportional to the number of birds actually present.

Like transect surveys (see below), point counts are very cost-effective, and can be implemented across large study areas. Point counts have a major advantage over transect surveys, however, in that bird detections are linked to specific locations, where habitat composition and structure, as well as other ecological variables, can be quantified. Additionally, stationary observers may be better able to focus on birds than observers who are walking, and the practice of counting birds while remaining still for several minutes may be less disruptive of normal bird activity than transect counts, where the observer is continuously moving (Reynolds et al. 1980). An additional advantage of point count data is that they can readily be compared with data from the North American Breeding Bird Survey (BBS), which are obtained from roadside point counts (Droege 1990, Peterjohn and Sauer 1993).

The primary drawback of fixed/unlimited radius point counts, as with any survey method that does not take into account detection probability, is that results may vary widely with observer ability and habitat characteristics (Burnham 1981, Barker and Sauer 1995, Fancy and Sauer 2000). The number of birds counted at a sampling station is the product of the number of birds present and the proportion of them the observer detects. Without accounting for differences in the proportion of birds detected due to differing habitats, observers, or other conditions, the appropriateness of pooling point count results among different observers, or comparing results between different habitats, can be called into question (Fancy 1997, Fancy and Sauer 2000).

Suitable objectives: 1, 2, 3 (although point counts without detectability estimation have been widely used to pursue objective 3, some authors make a compelling argument that they should not be).

Criteria for site selection: Site selection guidelines appropriate for point count studies in national parks are provided by Fancy (2000) and Geissler (undated). Major issues include clear delineation of a sampling frame, incorporation of probabilistic sampling, and targeting extra resources (higher sampling intensity) at areas of special interest.

Point Counts with Detectability Estimation:

Two distinct methods currently exist for adapting point count methods to account for varying detection probabilities associated with different habitats and observers: distance estimation and the double-observer method. In point counts with distance estimation (often called variable circular plots, or 'VCPs'), the observer records the distance to each bird detected; analysis of data can then elucidate detection probabilities of birds at increasing distances from the observer (Buckland et al. 1993). The recently developed double-observer approach requires that two observers simultaneously conduct point counts; detection probabilities are calculated based on the proportion of all birds detected that each individual observer detects (Nichols et al. 2000).

The VCP method yields estimates of detectability, and by extension, meaningful bird density estimates, with only a nominal increase in investment over fixed/unlimited radius point counts without detectability estimation. The double-observer approach may be somewhat more costly to implement, as it requires twice the personnel to survey the same number of points. However, survey protocols in remote wilderness areas often require that observers work in pairs anyway, for safety reasons; in these cases, additional expenses incurred by the double-observer technique may be minimal. In circumstances where personnel is not a limiting factor, the double-observer approach may actually be preferable to the VCP technique, as it avoids errors associated with inaccurate distance estimation (see below). Nevertheless, the double-observer approach has its own set of problems that arise in both field application and data analysis (see Nichols et al. 2000).

VCPs provide substantial advantages over point counts without detectability estimation, and may be somewhat simpler and less costly to implement than double-observer point counts, and have therefore been explicitly endorsed by the National Park Service Inventory and Monitoring Program (Fancy and Sauer 2000). Nevertheless, distance estimation should not be viewed as a panacea for eliminating all important sources of error in conducting point counts. Accuracy of abundance estimates is limited by observer ability to reliably estimate distances; this can be surprisingly difficult, especially in habitats with dense vegetation, high canopy, or rugged topography (DeSante 1986, Hutto et al. 1986, Nur et al. 1999). Relatively modest errors in distance estimation can result in large errors in density estimation (DeSante 1981). Additionally, there may be other detectability issues in bird sampling that neither VCPs nor the double-observer approach can address, such as the existence of unobservable portions of the population being surveyed (e.g. highly secretive females)(Fancy and Sauer 2000).

Suitable objectives: 1, 2, 3

Criteria for site selection: See criteria for fixed/unlimited radius point counts without detectabity estimation.

Transect Counts:

Transect counts include a diverse set of protocols with important distinctions between them. Terminology for the different protocols is quite variable in the published literature, but Verner (1985) provides a thorough clarification and review. Verner (1985) and Franzreb (1981) provide extensive discussions of the assumptions implicit in each of the major versions of the transect method.

Line transects (also called variable-width transects) and strip transects (also called fixed-width transects) require an observer to record all birds detected while walking a fixed route (Emlen 1971). Most line transect protocols require the observer to estimate the perpendicular distance to each bird detected, and consequently allow the calculation of detection probability as a function of distance from the transect. Strip transects require the observer to record all birds detected within a fixed distance of the transect (often 50m), and sometimes additionally require that all birds beyond 50m be recorded separately.

It has been argued that transects provide a more efficient means of counting birds than do point counts (Anderson and Ohmart 1981, Bibby et al. 1992, Fancy and Sauer 2000) as they allow observers to spend more of their field time actually counting birds; a greater effective survey area can be covered, yielding higher detection rates, and consequently, greater precision. On the other hand, overall statistical power of the method is weakened by the fact that it yields fewer independent data points or replicates than point count methods (Nur et al. 1999). Additionally, the method is generally feasible only on relatively gentle terrain, where observers are able to focus their attention fully on birds, rather than on watching their own footing (Anderson and Ohmart 1981, Dawson 1981). Finally, the largest shortcoming of the transect count methods is that they fail to yield associations between individual bird detections and particular points in space. Since the specific locations of individual detections along a transect are generally not recorded, potentially valuable information about habitat associations is lost (Fancy and Sauer 2000). This is particularly true when transects pass through varied habitats. Transect methods are therefore not appropriate for surveying birds in patchy or fine-grained habitats (Anderson and Ohmart 1981, Bibby et al. 1992), or for studies that seek to correlate relatively fine-scale habitat variables with bird occurrence.

Suitable objectives: 1, 2, 3 (if detection probability is incorporated)

Criteria for site selection: If study goals include clarifying bird-habitat relationships, individual transects must be located wholly within a single habitat type.

Spot Mapping:

First described in the literature by Kendeigh (1944), spot mapping as a monitoring technique was later explicitly endorsed by the International Bird Census Committee (International Bird Census Committee 1969), which provided guidelines for its use (Anonymous 1970, Robbins 1970). Although the details of the method have been modified over the years (Svensson 1979 and 1980, Tomialojc 1980) the basic technique is to mark locations, movements, and interactions of individual birds on detailed maps of the study area. Information gathered from multiple visits can be used to map individual breeding territories within the study area.

The spot mapping technique has several distinct strengths. Unlike abundance monitoring techniques that do not incorporate detectability estimation, spot mapping provides density estimates, rather than merely indices of abundance. Additionally, because the technique estimates density of territorial birds, the results may be more meaningful than density estimates produced by point counts with detectability estimation, as the point count estimates may be biased high due to the presence of nonbreeding floaters. Finally, the method can potentially produce more detailed natural history information (i.e. habitat usage, breeding behavior, etc.) than most other monitoring techniques.

Spot mapping also has several important limitations. Because the technique involves multiple visits to the study site, it can be quite expensive per data point (Bibby et al. 1992), a factor that led Nur et al. (1999) to conclude, "[spot mapping] may be better applied to research projects or to high priority areas or species." Additionally, the technique can generally be implemented only in a fairly circumscribed study area, and can therefore be of only limited value if researchers wish to extrapolate results across a large park. Some authors have also cautioned that inferring territory boundaries from the movements and territorial interactions of individual birds can be highly subjective, with resulting density estimates varying widely among observers (Oelke 1981, Verner 1985). Finally, spot mapping is the only abundance monitoring technique discussed here that is applicable solely during the breeding season.

Suitable objectives: 3

Criteria for site selection: Spot mapping studies are usually limited to only a small number of relatively small study plots, because of the substantial time investment necessary to complete the mapping. To provide maximum potential for extrapolating results to the surrounding area, study plots 1) should contain habitat that is representative of the larger landscape, and 2) should be sited using a probabilistic sampling strategy. In some landscapes, satisfying both these conditions can be quite challenging.

Demographic Monitoring Techniques

In addition to measuring avian abundance, the following methods also estimate one or more demographic parameters, such as nesting productivity, post-fledging productivity, recruitment, or survivorship. Monitoring demographic parameters is a crucial component of meaningful landbird monitoring efforts for several reasons. First, environmental stressors and management actions affect demographic parameters directly, without the buffering or time lags that so often affect secondary population trends (Temple and Wiens 1989). Because of the buffering effects of floater individuals and the density-dependent responses of populations, there may be substantial time lags between changes in primary demographic parameters and resulting changes in population size or density (DeSante and George 1994). Second, demographic parameters elucidate the stage(s) in the life cycle at which population change is being affected (DeSante 1992). Such information is particularly important for migratory birds, as it can determine whether management actions should be directed toward a species' breeding grounds, wintering grounds, or both. Finally, monitoring demographic parameters provides information critical for assessing the viability of populations, and for identifying areas of source-sink population dynamics (Donovan et al. 1995). Indeed, because of the vagility of most bird species, local variation in reproductive success may often be masked by recruitment from a wider region (George et al. 1992) or accentuated by lack of recruitment from a larger area (DeSante 1990). Source-sink dynamics may thus make the density of a species in a given area a misleading indicator of population viability (Van Horne 1983, Pulliam 1988).

Constant Effort Mist Netting:

Constant effort mist netting can provide indices of post-fledging productivity, and estimates of adult population size, adult survivorship, and recruitment into the adult population for target species (Baillie 1990, DeSante et al. 1995, Peach et al. 1996, Bart et al. 1999, Silkey et al. 1999). The widespread use of the Monitoring Avian Productivity and Survivorship (MAPS) constant effort mist netting protocol across North America (DeSante et al. 1998, DeSante et al. 2000) allows parameter values to be compared or combined with mist netting results from other areas at multiple spatial scales. The mark-recapture techniques incorporated by MAPS provide the only methodology (other than resighting individually color marked birds-- see nest monitoring with color banding, below) that permits estimation of adult survivorship and recruitment into the adult population. These parameters are critical for providing a full understanding of demography and population dynamics. Additionally, constant effort mist netting allows numerous species to be monitored at the same time, without additional effort, and in-hand examination of birds facilitates collection of additional natural history data.

Like other demographic monitoring techniques, mist netting is a relatively intensive, rather than extensive approach to monitoring, so the spatial extent of the area that can be effectively surveyed is limited. A single MAPS station, with an array of ten 12m mist nets, covers an area of approximately 20-ha, although productivity indices reflect reproductive success from the larger landscape (DeSante et al. 2000). At least four consecutive years of data collection are necessary to produce survivorship estimates for locally resident adult birds, but productivity estimates may be obtained from a single year of data collection. As a general rule of thumb, an average of at least seven individual adult birds per year of each target species must be captured to produce robust survivorship estimates (D. DeSante, pers. comm.). These sample size requirements for parameter estimation makes the technique impractical for monitoring locally rare species. Finally, mist netting is an ineffective monitoring technique for bird species whose habits restrict them to grasslands or to the upper forest canopy.

Suitable objectives: 3, 4

Criteria for site selection: DeSante et al. (2000) provide detailed recommendations for siting constant effort mist netting stations. In general, they suggest that stations be sited in habitat types that are fairly representative of the surrounding landscape, that stations include some edge habitat (such as forest edge, riparian corridor, montane meadow, or power-line right-of-way) to help ensure that large numbers of bird will be captured, and that, to the extent possible, station locations are chosen under a probabilistic sampling strategy.

Nest Monitoring:

Detailed field protocols and pointers for finding and monitoring nests are provided in Martin and Geupel (1993) and Martin et al. (1997). Searching for nests of target species and tracking nesting attempts throughout the breeding season is the only way to effectively estimate nest success rates and to determine proximate causes of nest failures. Nest monitoring facilitates the study of nest-sites or characteristics, and by extension, the elucidation of correlations between nest sites or habitat characteristics and nest success or failure (Best and Stauffer 1980, Li and Martin 1991, Martin 1993, Robinson et al. 1995).

Like mist netting, the spatial extent and habitat diversity of the area that can be effectively surveyed through nest monitoring is somewhat limited. Unlike mist netting, which generally provides post-fledging productivity estimates applicable to the larger landscape (because many of the hatching-year birds caught are dispersing, rather than locally produced individuals), nest monitoring yields fledging success rates that are specific to the study plot—this can be an advantage or a disadvantage, depending on study objectives. Unless all nesting attempts in the study area are monitored, however, the actual reproductive output of the various species cannot be determined. Moreover, nest monitoring is quite labor-intensive, generally requiring that nests be visited at least every 3-4 days (more frequently is even better) to allow for reliable determinations of nest fates (Martin et al. 1997). For this reason the method is generally better suited for testing specific management-related hypotheses than for long-term monitoring in the strict sense.

An additional drawback to nest monitoring is that many studies do not attain large enough sample sizes for robust statistical comparisons. Hensler and Nichols (1981) provide a table of sample sizes necessary to estimate nest survivorship under different parameter values, and conclude that data from a minimum of 20 nests must be pooled to obtain nest survivorship estimates with acceptable precision. Nur et al. (1999) extend the analysis to look at sample size requirements for providing enough statistical power to compare nest survivorship rates among treatments, and conclude that 75 nests per group is a more reliable rule of thumb.

Suitable objectives: 3, 4

Criteria for site selection: Detailed guidelines for siting nest monitoring plots are provided by Martin et al. (1997). As with siting mist netting stations, researchers should use a randomization scheme to randomly choose study plots from all possible sites meeting pre-determined ecological or logistical criteria.

Nest Monitoring with Color Banding:

Referred to as 'total mapping' by Verner (1985), nest monitoring combined with target netting and color banding of breeding individuals and nestlings, and systematic efforts to resight color banded birds is the most thorough means of monitoring individual bird populations. If all nesting attempts are monitored and the fates of fledglings are followed to independence from their parents, this suite of techniques provides the most complete and unbiased measures of demographic parameters of any method (Nur et al. 1999). This method, however, is also extremely labor-intensive, much more so than any other method discussed in this review. For this reason the method is not appropriate for general monitoring programs, but should instead be reserved only for high-priority species or areas (Nur et al. 1999).

Suitable objectives: 3, 4

Criteria for site selection: Site selection criteria for monitoring projects employing nest monitoring and color banding will usually be driven by the particular circumstances requiring such a labor-intensive mode of study.

Conclusions

Table 1 summarizes which Objectives can potentially be attained through each monitoring method discussed in this review. It should be noted, however, that the different methods yield data of substantially different nature and quality, even methods deemed appropriate for the same Objectives. Table 2 provides a summary of the kinds of data yielded by each survey method.

Researchers designing long-term monitoring projects are likely to conclude that no single monitoring method will fully meet their needs; abundance monitoring techniques are relatively inexpensive and can be implemented across very large areas, but provide little information about the causes of population changes that may be detected. In contrast, demographic monitoring techniques can give valuable insight into such causes, but are generally much more expensive per datum, and can only be implemented across relatively small study plots. For these reasons, many authors assert that monitoring programs should ideally incorporate elements of both abundance monitoring and demographic monitoring techniques (Taylor et al. 1985, Verner 1985, Baillie 1990, Nur and Geupel 1993, Ralph et al. 1993, DeSante 1995, Saab and Rich 1997, DeSante and Rosenberg 1998). Integrating spatially extensive abundance surveys with more intensive demographic studies of carefully selected target species or representative locations is likely to yield data of maximum use to park managers interested in both tracking landbird populations over time and implementing appropriate remedial management actions should it become clear that populations are threatened.

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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their developement is in the best interest of all our people. The department also promotes the goals of the Take Pride in America campaing by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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