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Low duck populations in the late 1980's and early 1990's prompted unprecedented action from the natural resources community. Agencies and private organizations that were traditionally involved with waterfowl management redoubled their efforts, in the process forming partnerships with groups that were relatively new to the waterfowl management arena. Many resource managers who have had relatively little experience with waterfowl habitat management now find themselves expected to manage duck populations for increased production. Decades of waterfowl research and management experience have provided them with many potential management tools. Unfortunately, the absence of general guidelines for directing waterfowl management actions has put these newcomers to the field at a decided disadvantage. This is particularly true for managers who reside outside of the northern Great Plains, a region that has been the focus of most research on breeding ducks.

This leaflet is intended to orient managers to approaches for identifying the factors that limit duck production. The concepts presented here will assist in making logical management choices in regions where little is known about breeding ducks and their habitat. Although it may serve as interim guidance, this leaflet is not intended to substitute for rigorous, scientific research on waterfowl biology. Readers are urged to use this leaflet as a starting point from which to gather additional knowledge using companion leaflets and technical publications.

The Reproductive Cycle

Although ducks are a diverse group of birds, many dabbling and diving ducks in North America show similarities in general facets of their breeding biology. A basic understanding of the important events and forces that drive reproductive behavior is essential to interpreting premanagement information. The following sections provide a summary of duck breeding biology that, although not strictly accurate for any particular species, is generally representative of the most common North American ducks.

Resource Needs

Most ducks arrive on their breeding grounds from late March to early May. Shortly thereafter they begin to make regular use of wetlands that vary in size, water permanency, and vegetative composition. These wetlands, together with surrounding uplands, constitute the home range of individual pairs. Usually, males become aggressive toward other birds of the same species, defending either wetlands within the home range or space around their mates. These aggressive interactions

cause birds to distribute themselves throughout the breeding habitat.

The need for dietary protein during the prenesting and egg-laying periods causes ducks to seek aquatic invertebrate foods, which may compose 75 to 100% of the hen's diet. Many species maximize food acquisition during this period by capitalizing on the seasonal peaks in aquatic food abundance that differ among wetland types. For example, shallow, temporary wetlands may exist only a few weeks, but during that time they warm quickly and develop invertebrate populations long before permanent ponds. By moving among wetlands and selecting those with the richest invertebrate fauna, ducks are able to quickly acquire the protein necessary for egg production. Thus, small, shallow wetlands contribute as much to ducks during the breeding period as large, permanent cattail marshes. A diverse wetland community is critical to this food acquisition strategy.

Territorial aggression is often initiated when males sight other birds of the same species. This visual spacing limits the number of pairs that an area can support. Habitats with many small ponds on which ducks may isolate themselves, or those with heavy vegetation, bays, or inlets where pairs are visually separated, can reduce encounters between birds and increase pair densities. Wetlands most attractive to dabbling ducks contain about a 50:50 ratio of open water to emergent vegetation. Patches of emergent plants, sparse enough to allow a duck to swim through, are more attractive than large blocks of thick, unbroken vegetation.

Nest Sites

Most diving ducks and some dabbling ducks construct nests over water amid emergent vegetation. In contrast, most dabbling duck nests are made in dead vegetation remaining from the previous growing season. Often, this residual vegetation is found in grassland and shrub habitat located up to a mile from water. Tall, dense grasses or shrubs with low growth forms are usually preferred by dabbling ducks. Islands also provide attractive nesting habitat if adequate vegetative cover is present. Hens explore many potential sites, but select only one to construct a nest. Most ducks lay a single egg each day until a clutch of 9 to 11 eggs is complete.

Incubation

As the clutch nears completion, hens begin an incubation period that ranges from 23 to 30 days for most species, with shorter periods typical of species that lay smaller eggs. Duck nests are often destroyed by mammalian, avian, or reptilian predators. At present, throughout much of the northern Great Plains, predators are abundant, and duck nests are concentrated because nesting cover is limited. Consequently, the percentage of nests that hatch at least one egg (nest success) is often less than 15%. In habitats where nests are dispersed and predators are less common, much higher (40 to 70%) success rates are typical. Most ducks will renest if their initial clutch is destroyed during laying or early in incubation and a sufficient number and diversity of wetlands remain available. In some species, hens that successfully hatch a clutch often return to the vicinity of the successful nest site in subsequent years, and sometimes to the same nest bowl. During incubation, hens leave the nest for a recess three to five times per day. They continue to meet their mates during these recesses until the male leaves his territory and joins groups of other males in preparation for molt. This usually occurs about 1 to 2 weeks into incubation.

Broods

Newly hatched ducklings leave the nest soon after hatching, and may walk through uplands or follow streams to brood-rearing wetlands up to a mile away. Even after reaching a wetland, broods may move among ponds. Ducklings of most species feed almost entirely on aquatic invertebrates until about a month old. Thereafter, ducklings of dabbling duck species gradually increase their consumption of seeds and other vegetation. Because ducklings cannot thermoregulate until they are about 2 weeks old, they are periodically brooded by the hen. Predation and exposure can cause high mortality among ducklings. Contaminants can also cause mortality, either by direct toxicity or, more often, by reducing the abundance of essential invertebrate foods. In many habitats, 20 to 50% of all duck broods are entirely destroyed, and typically only about half of the ducklings in the remaining broods survive. Habitat use by broods differs among species, but is generally related to the need for areas secure from predators and severe weather. Diving duck broods seek security in open water, where they dive to

escape predators. Dabbling duck broods usually prefer dense emergent vegetation.

The Limiting Factor

Contemporary waterfowl management generally uses three approaches for guiding management actions. Actions initiated on an international scale, such as in the North American Waterfowl Management Plan, often originate from broad policy directives such as the need to preserve wetlands or increase nesting success. Other initiatives are guided by computer simulations, such as the Mallard Management Model, that recommend actions based on knowledge of waterfowl biology and factors that suppress reproduction. However, similar guidelines are generally unavailable for managing the scattered, diverse duck breeding habitats of North America. In such habitats, management actions are often guided by the manager's experience and intuition.

Predation, resource limitations, and environmental conditions are factors that may suppress waterfowl populations below their biological potential. However, only one factor is most limiting to populations at any time. Aldo Leopold described the limiting factor as "the one that has to be removed first, and usually the one to which the application of a given amount of effort will pay the highest returns, under conditions as they stand." The effort required to remedy a limiting factor may vary, but until it is removed, activities directed at other, nonlimiting factors will offer relatively little improvement in duck production.

Although many contemporary ecologists view the limiting factor concept as an oversimplification of complex interrelationships, it is nonetheless a useful starting point for considering factors that suppress waterfowl recruitment. Sometimes, a factor that limits duck production can result from deficiencies independent of the breeding habitat, for example, food shortages on wintering areas that prevent the acquisition of fat reserves necessary for successful breeding. Such limitations are usually beyond the control of individual managers. Most factors that are potentially limiting to duck production, however, can be traced to four important requirements of breeding habitat: the ability to attract and retain spring migrants, provide for the resource and social needs of breeding pairs, secure adequate nesting habitat, and provide suitable brood-rearing habitat. Unfortunately, drought, localized agricultural effects, and other dynamic events may cause deficiencies in these requirements to vary annually. Thus, management to correct long-term habitat deficiencies should be based on average habitat conditions. These average conditions should be determined by evaluating premanagement information collected during more than one breeding season.

Because wetland communities are the basic unit in which ducks live and acquire resources during breeding, premanagement information should be gathered independently for each discrete community, not averaged across several isolated wetland complexes. Although waterfowl researchers are beginning to understand the implications of habitat fragmentation for breeding ducks, it is well established that the benefits of small tracts of waterfowl habitat are often swamped by the effects of habitat degradation on adjacent lands. The protocol described here may still be useful for identifying factors limiting duck production, but management to overcome these deficiencies on small tracts of land may be futile in the face of overwhelming external forces.

Obtaining Premanagement Information

Spring Migrants and Breeding Pairs

Information on the number of spring migrants and resident breeding pairs can be obtained through a series of ground counts beginning with the first influx of spring migrants and continuing through the early incubation period. Spring migrant and pair counts, as well as brood counts, should be conducted on a large block of contiguous habitat that is representative of the management area. Ideally, surveys should be conducted two or three times per week, but in no case less than once a week. Because females typically take incubation recesses early and late in the day, nesting chronology and indices to nest success are most readily interpreted if observers restrict their counts to the period between 1 hour after sunrise to 1 hour before sunset. Observers should quietly walk near wetlands but avoid flushing ducks. If birds flush to nearby areas, observers should avoid duplicate counts on these individuals. During the time when spring migrants move through the region, simply tally the numbers of individuals by species and sex. When the number of ducks and the

species composition stabilizes, one may assume that many birds now in the area are beginning to establish home ranges in preparation for breeding. At this time, begin counting male-female pairs and single males, tallying these males as "indicated pairs." These single or "lone" males are usually mates of females who are searching for nest sites, laying eggs, or incubating. For each species, the highest number of pairs plus indicated pairs counted in any census represents the total estimated pairs resident in the wetland community.

Nesting Habitat and Success

The quantity of available nesting habitat is often easy to judge in relation to species requirements. Most diving ducks construct nests over water in robust emergent plants. Map the distribution and vegetative composition of these emergent beds, and note if such areas remain inundated during the incubation period. Cavity-nesting duck species use holes excavated by woodpeckers or created by internal rot in old trees. Note the number and distribution of potential nest trees or actual nest sites and their distances from the wetland. Dabbling ducks and some diving ducks nest in grasses or shrubs adjacent to wetlands. Map the area and distribution of these habitats.

The quality of nesting habitat is difficult to judge for overwater- and cavity-nesting species. However, the height and density of upland sites can be measured using a Robel pole or similar device. Readings obtained at a standardized viewing height and distance can then be compared with minimum standards required by different species. Whenever possible, managers should determine the relative quality of potential nesting habitat.

Duck nesting success is a more indirect index of nesting habitat conditions because it is dependent on the quality and quantity of habitat as well as the density and composition of the local predator community. In grassland habitats, large numbers of nests can often be located using cable-chain drags. In shrubland or wooded areas, hand drags, dogs, or observations of hens returning to nest sites may be necessary to locate nests. When nests are found, note the size of the completed clutch, candle the eggs to determine the stage of incubation, then flag the site by placing a marker at some set distance and direction away from the nest. Excessive disturbance to the nest site must be avoided. Later, revisit the site to determine the fate of the nest. Nests that were abandoned or destroyed by predators will contain whole eggs and pieces of eggshell with membranes firmly attached. Note the condition of the eggs and look for tracks, scats, or other evidence that may suggest the cause of nest failure. Successful nests are typified by shell membranes that are easily separated from shell fragments.

Brood-rearing Period

Begin duck brood surveys when broods of early-nesting species first appear. Surveys should be conducted in early morning (30 minutes before to 1 hour after sunrise) and in late evening (2 hours before until 30 minutes after sunset). Counts conducted at times other than early and late in the day will census only a fraction of the broods present and will be biased towards diving duck species that use open water areas during brood-rearing. Viewers should quietly observe broods, from elevated vantage points if necessary, and note the species, size of the brood (number of ducklings), and age of the ducklings. Be aware that duck broods may move among wetlands, and try to avoid duplicate counts. If movements between wetlands are uncommon and the number of broods per wetland is low, it is often possible to distinguish individual broods based on a combination of species, size, and age. In such cases, note the number of ducklings in a brood on subsequent observations. If a brood is not observed on subsequent surveys and the likelihood of secondary movements to another rearing wetland is remote, record the possibility that the entire brood perished. To obtain data on duckling attrition, individual broods should be observed every 3 to 5 days, particularly when ducklings are young and mortality rates are highest. The most important index to obtain during the brood-rearing period is the number of young remaining in old (prefledging, or class III) broods.

Identifying the Limiting Factor

Attracting and retaining spring migrants, providing resources for breeding pairs, securing adequate nesting habitat, and providing suitable brood-rearing areas are all interdependent activities, wherein each event is dependent on the success of previous events. The following sections provide a basis for identifying deficiencies in this reproductive chain of events by interpreting the

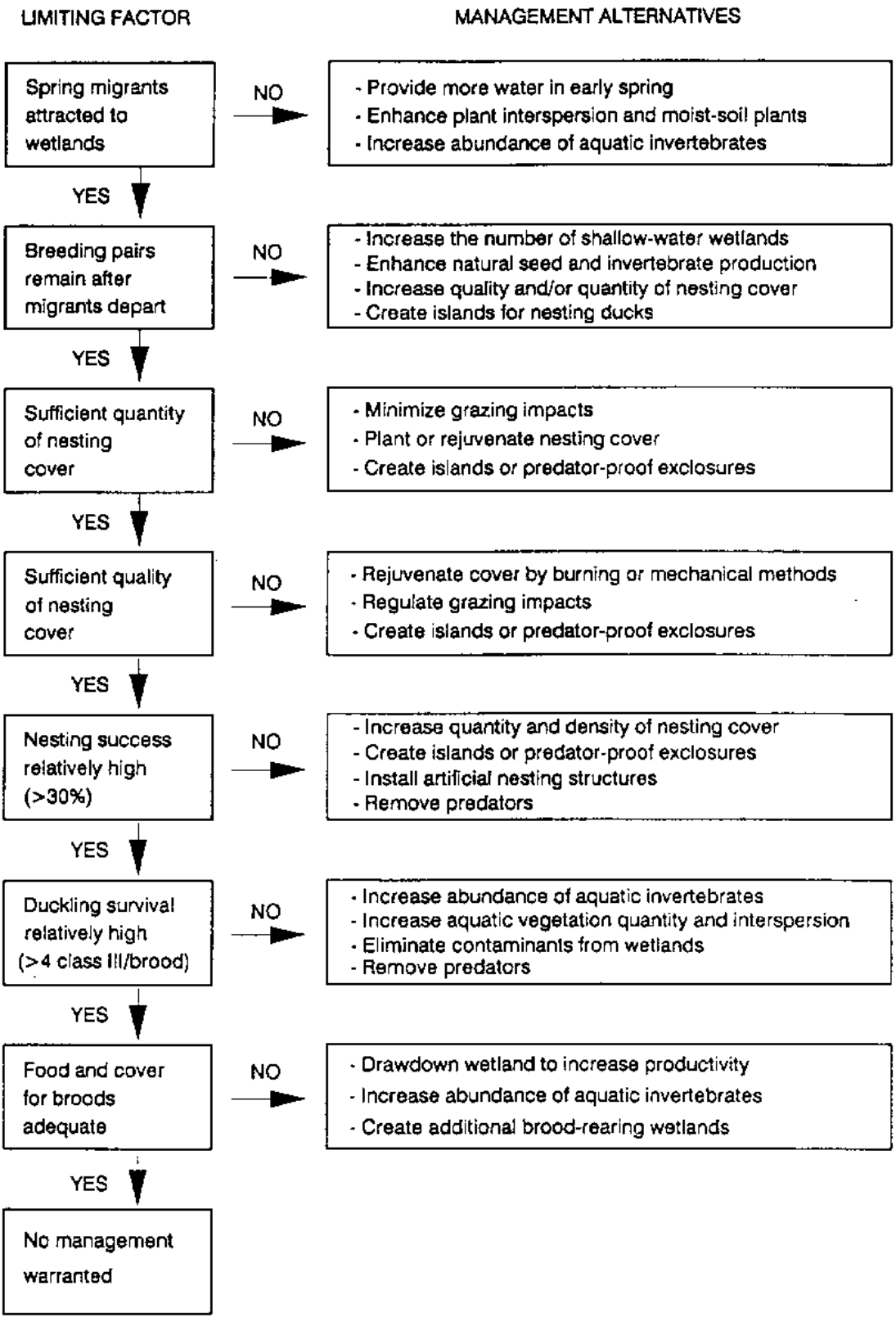

Fig. 1. General management alternatives for addressing factors that limit duck recruitment. Readers should consult technical publications for detailed information on specific alternatives.

premanagement data described above. Once a limiting factor has been identified, general management actions for correcting these deficiencies can be considered (Fig. 1). Readers should consult technical publications for information on which management action is most appropriate and how to implement an action.

Attracting and Holding Spring Migrants and Breeding Pairs

Summarize data on the numbers of ducks present in early spring, looking for evidence of a sharp decline indicative of migrants departing the area and resident pairs remaining behind. If large numbers of migrants were present, but later departed, and those migrants were species that normally breed in the area, consider actions to attract and hold spring migrants.

Examine the number of indicated breeding pairs that remain after migrants leave the area, then determine if the habitat is supporting breeding pairs up to its potential. The key to assessing this potential is knowing how many pairs are attracted to good wetland communities in your geographic area. Comparing pair densities on nearby, high quality breeding habitat provides the best basis for contrast. Historical data also can be consulted. Lacking these data, managers should consult state or federal agencies for area-specific data. For example, curves depicting average breeding pair densities as a function of wetland size and type have been developed for the northern Great Plains (e.g., Cowardin et al. 1988). Wetland complexes that fail to attract adequate numbers of breeding pairs can be managed to increase pair numbers.

Enhancing Nesting Habitat and Nest Success

Emergent vegetation suitable for overwater nesters should be dense, have a height of at least 3 feet above water, and remain flooded during the period of nesting. Suitable emergents should occur in wide bands around the periphery of the wetland or as large islands within the wetland basin. Most cavity-nesting species select nest sites within 200 yards (183 m) of a wetland, although wood ducks (*Aix sponsa*) will use cavities up to 1 mile (1.6 km) from water. If suitable cavities are few or absent within this area, artificial nesting structures can help correct the deficiency. Ducks that nest in upland sites require grasses, legumes, shrubs, or combinations of the above plants within 1 mile of wetlands. Suitable nesting areas should occur in large (more than 40 acres or, 16 ha), unbroken blocks of habitat.

Nesting cover should meet minimal Robel pole indices for height and density (typically, dense at heights of 18 inches—0.5 m—above the ground), and should be secure from grazing and agricultural manipulations until after the incubation period. If density or height is insufficient, several management actions can be used to enhance the quality of nesting cover.

Data on the fate of marked nests should be corrected for exposure, according to the Mayfield correction technique, then average nest success rates should be calculated for the management area. Generally, nest success rates greater than 40% are acceptable in most habitats, whereas rates lower than 15% are usually insufficient to maintain a stable duck population. Lacking direct measures of nest success, managers may obtain qualitative indices of nest loss through "social indices" that rely on the tendencies of many duck species to renest if their initial nests are destroyed. The simplest of these indices is an analysis of the weekly ratios of indicated pairs (lone males) to actual (male–female) pairs during the egg-laying and incubation period for each species. Local populations experiencing low rates of nest loss often exhibit ratios that increase sharply in the first few weeks, then gradually decline from a high level (e.g., 0.2:1, 1.3:1, 3.4:1, 3.0:1, and 2.8:1). Populations experiencing high nest loss may exhibit an increase, followed by a sharp decrease, then a subsequent increase in these ratios (e.g., 0.2:1, 1.3:1, 3.4:1, 1.8:1, and 2.7:1), indicative of unsuccessful hens rejoining their mates in preparation for a second nesting attempt.

Additional evidence of nest destruction may be derived by examining the hatching chronology of duck broods for each species. This is accomplished by back-dating broods to the date of hatch, using information on duckling ages. A frequency distribution of number of broods hatched within 5-day intervals typically depicts a peak of hatch followed by a much smaller, well-defined, second peak from renesting attempts (Fig. 2). Hatching curves that exhibit pronounced renesting peaks or are relatively flat suggest excessive rates of nest loss.

If the quantity and quality of nesting cover are adequate but nesting success is low, try to determine the cause of nest failure. Predation is

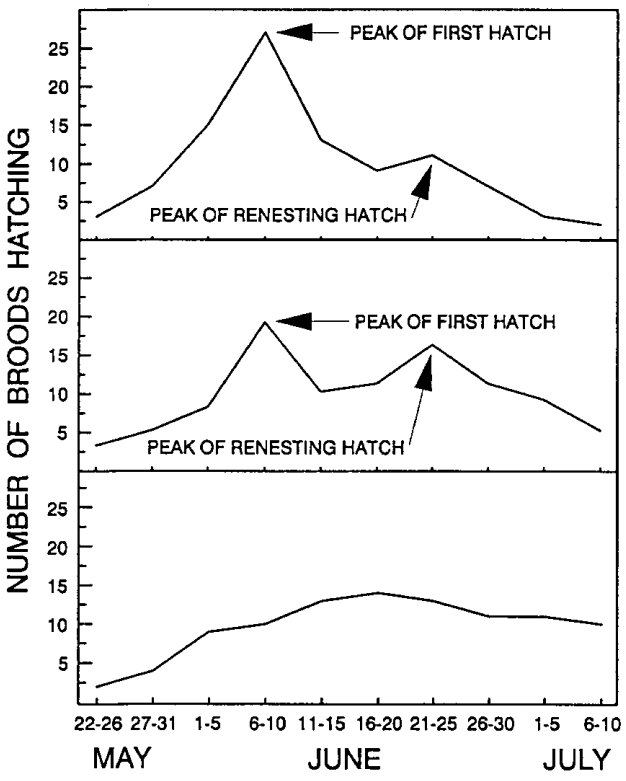

Fig. 2. Hypothetical hatching curves for local duck populations experiencing relatively high (*top*) and low (*middle and bottom*) nesting success during early incubation.

one common reason for nest failure in many habitats, and may be indicated by evidence left at the nest. However, do not discount the possibilities of flooding, destruction from agricultural operations, or exposure to weather. A wide array of corrective actions are available to enhance nesting success, depending on the cause of nest failure.

Improving Brood-rearing Habitat and Duckling Survival

Duckling mortality is indicated either by loss of complete broods or by brood attrition, wherein the number of ducklings in a brood is reduced over time. Mortality caused by exposure, starvation, or death from pesticides or other contaminants often results in the catastrophic loss of entire broods. In contrast, mortality caused by predation may result in a more gradual decrease in brood size. Generally, an average of five ducklings per prefledging (class III) brood is considered acceptable attrition. Supplemental information, such as, from bait stations to identify the presence of predators, invertebrate sampling to gauge the abundance of food, and water quality measures to detect contaminants, may be needed to isolate the causes of duckling mortality. Such supplemental data are usually vital for selecting an appropriate management strategy to enhance brood survival.

Rather than remain in undesirable habitat, broods may move to other wetlands. The quality of brood-rearing habitat may therefore be reflected by the number of resident broods, compared with the number of resident breeding pairs that were in the area, after taking into account nest success rates and renesting activity. If the estimated number of broods occupying a wetland complex is far less than the estimated number believed to have hatched, management may be necessary to enhance the quality of brood-rearing habitat. Often, the root causes of low brood usage and poor brood survival are the same, and a single management action may be used to address both problems.

Other Considerations

Before initiating any management measure, consider whether human disturbance or natural forces have sufficiently altered the ecosystem to warrant intervention. Do not use management tools as "weapons" against a healthy landscape. The waterfowl response to management of such areas will be relatively slight when compared with results of the same effort applied to dysfunctional ecosystems. Unfortunately, however, some of the most important waterfowl breeding habitats in North America have been severely degraded. When managing these habitats, overall objectives should be consistent with the natural values of the ecosystem. Not all wetlands are meant to be breeding habitats. Migratory stopover and wintering areas provide essential resources for ducks, and managers should avoid modifying such areas to create breeding habitat if doing so would impair these other seasonal uses. Although management actions can temporarily alter waterfowl habitats for other than natural uses, they do so only with high cost, intensive labor, and possibly detrimental effects to the ecosystem.

Once a limiting factor has been identified and an appropriate management response is devised, managers should resist the temptation to simultaneously initiate more than one action on a single area. Imposing more than one management treatment complicates evaluations of the

effectiveness of the actions, and often results in no more success than a single treatment that is selected with reasonable forethought.

Lastly, management actions should be evaluated to determine whether the objectives of the project were attained. The same techniques and data analyses used when collecting premanagement information should be employed during this follow-up evaluation.

Suggested Reading

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