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Mallard Use of Elevated Nesting Structures: Fifteen Years of Management in Eastern South Dakota

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Mallard Use of Elevated Nesting Structures

15 Years of Management in Eastern South Dakota

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On the Cover: Flax-lined cylinder with mallard incubating her clutch. Note owl guard on top of cylinder.

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SUMMARY

Mallard (*Anas platyrhynchos*) use of baskets with canopies (structure years [n] = 2,139), cylinders (n = 1,669), and culverts with canopies and partitions (n = 522) was evaluated from 1992 through 2006 in eastern South Dakota. Pre-project nesting data for open-topped baskets were also reported for 1986–1990 for comparative purposes.

Brush (1992–1997) and woven fiberglass (1994–2006) canopies were used to modify nesting baskets. Culverts were also modified with brush (1992-1998) and woven fiberglass (1994-2006) canopies. In addition, culverts were partitioned to provide two, three, or four duck nesting compartments with each compartment occupying a fourth of the culvert nesting space. Space on culverts not occupied by duck nesting compartments (and canopies) on two- and three-compartment models was left open for Canada goose (*Branta canadensis*) nesting.

Nesting cylinders included a plastic tube model (1996–2004) and models with flax straw (1993–2006) or carpet lining (1996–2006) held in place by inner and outer layers of welded wire. All structures were provided with flax straw pre-formed into a nest bowl each spring.

Woven fiberglass structures were easier to maintain than brush structures. Both carpet lined and plastic cylinders were easier to build and maintain than flax lined.

Mallard nest success rates in the three major structure types averaged 91.9% in baskets with canopies, 90.5% in cylinders, and 77.4% in culvert nesting compartments with canopies. Nest baskets with brush canopies averaged 100.0 mallard nests/100 structures while baskets with woven fiberglass canopies averaged 60.3 mallard nests/100 structures. Flax lined (66.6 mallard nests/100 structures) and carpet lined (72.7 mallard nests/100 structures) cylinders were both more productive than plastic cylinders (25.6 nests/100 structures).

Brush and woven fiberglass modified culverts were equally productive for mallards, averaging 130.6 nests/100 structures. Four-compartment culverts were much more productive than two- or three-compartment models. All culverts with mallard nesting compartments had greatly increased mallard production over unmodified culverts.

Adding mallard nesting compartments to culverts had minimal influence in reducing Canada goose use of structures except in woven fiberglass models with four compartments. Canada goose nesting on unmodified culverts greatly reduced mallard use on the same structure. There was no evidence that goose nests on top of the canopy of four-compartment culverts or on the unmodified half of two-compartment brush models had any influence on mallard use of compartments on the same culvert as long as the canopies remained intact. The presence of nesting geese on the unmodified half or fourth of culverts with a partial fiberglass canopy for two or three mallard nesting compartments appeared to reduce mallard use. Culverts with compartments were effective in encouraging multiple nesting, with 36% supporting two or more mallard nests during the same season.

Average production of hatched mallard clutches from a single canopied basket, flax or carpet lined cylinder, or culvert (2–4 canopied compartments) was impressive when compared with expected mallard production per acre from managed upland nesting cover.

Nesting structures do not address the broad-scale habitat problems facing upland nesting waterfowl and other ground nesting birds but may be important in boosting mallard production in extensive areas of the prairie pothole region where upland nesting cover is highly fragmented and/or nest predation rates are severe.

Mallard Use of Elevated Nesting Structures

15 Years of Management in Eastern South Dakota

INTRODUCTION AND LITERATURE REVIEW

Nesting success rates of 15% or better (actual or Mayfield method) are needed to sustain mallard (*Anas platyrhynchos*) populations in the prairie pothole region (Cowardin et al. 1985). Unfortunately, actual nest success in many parts of the northern prairies often averages below this level, making areas potential sinks in terms of population maintenance (Cowardin et al. 1985, Klett et al. 1988, Greenwood et al. 1995). Hoekman et al. (2002) stated that nest success (43% of variation), hen survival during the breeding season (19%), and duckling survival (14%) were the most critical factors driving annual variation in mallard populations.

The major source of mortality in female ducks during the breeding season is predation (Sargeant and Raveling 1992). Over 70% of duck nest failures in prairie regions is attributed to predation, primarily by mammals (Sovada et al. 2001). Increased tillage and fragmentation of grassland nesting cover as well as wetland losses have been linked to increased predation on duck nests and nesting females in prairie habitats (Sovada et al. 2001).

Changes in predator species composition associated with shelterbelts, old buildings, rock piles, silos, culverts, and other human related changes have also increased predation levels on ground nesting birds in the northern prairies (Sovada et al. 1995, Ball 1996). Even federal and state wildlife management areas, such as Waterfowl Production Areas and Game Production Areas, represent isolated grassland patches within the overall landscape. Although programs such as the Conservation Reserve Program (CRP) have helped slow losses of grassland habitats in the northern prairies, considerable destruction of natural grassland areas and replacement with cropland is still occurring (Higgins et al. 2002).

Ideally, the maintenance and restoration of large parcels of grassland habitat would be the most effective way of improving mallard nesting success while at the same time benefiting other ground nesting birds, including most species of dabblers (Anatini) (Ball and Ball 1991, Sovada et al. 2000). However, fragmentation and losses of grassland habitat are still a reality and will continue to negatively influence nesting success rates of mallards and other ground nesting birds.

Tillage and conversion to croplands have destroyed and fragmented tens of thousands of acres of fragile native grasslands in South Dakota's western prairie pothole country in the past decade; these grasslands are important habitat for numerous wildlife species and are particularly important to nesting waterfowl, such as this mallard (inset).

Mallards generally nest in upland areas but are highly adaptable and will also nest on lodged or floating vegetation in a wetland (Krapu et al. 1979) or even in suitable bowl-shaped sites in flooded trees (Cowardin et al. 1967). In eastern South Dakota, a mallard was found nesting in the rotten wood on the top of a wind sheared tree trunk, 12 feet above the underlying grass and shrubs (P. J. Bergmann, personal communication). In west-central Minnesota, one of 10 radiomarked mallards nested on some type of supporting plant matter or vegetation mat above the surface of standing water in a marsh (Maxson and Riggs 1996).

Duck nesting structures were apparently used as early as the mid-1600s in St. James Park in England (Eley Game Advisory Station, 1969 Annual Review as referenced in Johnson et al. 1994b). Woven baskets used in the Netherlands and Denmark provided a nest basket model later used for nesting mallards near the Delta Waterfowl Research Station in Manitoba (Burger and Webster 1964, Bishop and Barratt 1970). At Montezuma National Wildlife Refuge in New York, Cummings (1960) demonstrated that mallards and American black ducks (*Anas rubripes*) would accept a wire basket (with hay added) placed in the crotch of a tree or on the stump of a broken-off tree trunk. In other early studies, mallard nesting cylinders (tunnels) were experimented with by Uhler (1959) and were mentioned as a popular nest design by Burger and Webster (1964), but apparently little information was published in research journals on such early observations. Thompson (1964) reported low level but increasing use of nesting cylinders by mallards in the southwest Lake Erie region and Hopper (1964) found no use of fiberboard nesting cylinders in wetlands in north-central Colorado; cylinders were provided with native hay or straw nesting materials in both studies.

Much of the evolution of mallard nesting structure research and management in prairie-wetland regions is reviewed in Table 1. Early studies documented mallard acceptance of nesting baskets placed in prairie wetlands as well as improved nesting success in these structures when compared with ground nesting birds (Bandy 1965, Bishop and Barratt 1970, Doty et al. 1975, Doty 1979, Lee 1994). Most of these baskets were constructed of galvanized hardware cloth (mesh wire) with steel rods for reinforcement and were generally cone shaped.

Doty et al. (1975) used both galvanized hardware and molded fiberglass baskets in his nesting structure studies (Table 1). Baskets in these studies were generally about

The triangular nesting tunnel (top) and metal cylinder ((bottom) represented early attempts at tunnel type nesting structures (hen houses) (Northern Prairie Wildlife Research Center photo archives).

Wire nesting baskets were generally effective in attracting mallards and, where avian predators were not a problem, provided a safe nesting site; they were largely replaced by fiberglass models in later years (Northern Prairie Wildlife Research Center photo archives).

24 to 26 inches in diameter and 7 to 15 inches in depth and were provided with native grasses, flax straw, or other grasslike material prior to the nesting season.

In the southwestern Lake Erie region, Bandy (1965) studied mallard and black duck use of two cylinder types: wire cylinders lined with straw and those made of metal tubes (Table 1). Doty (1979) used nesting cylinders for mallards in an effort to reduce predation by ring-billed gulls (*Larus delawarensis*). These cylinders were about 2 feet long and 13 to 15 inches inside diameter and were generally made of welded wire formed into a tube and lined with asphalt roofing paper. Doty (1979) also experimented with a structure similar in length to a nesting cylinder but shaped like an oval-mouthed cone on its side. The bottom and canopy were of mesh wire and an aluminum metal sheet was added to the wire canopy to provide visual screening. The covered nest cone developed by Doty (1979) should not be confused with cone-shaped descriptions of most nesting baskets.

Baskets and cylinders were attached to metal pipes that were driven into the marsh substrate to provide support as described in our Methods and Procedures and in other publications (Ball 1990, Zenner et al. 1992). Most authors recommend placing these nest structures about 1 m above the water and in openings within emergent vegetation. Fluctuating water levels greatly influence height of the nesting structures above the water surface from year to year and can sometimes flood the structures or leave them without the protection of standing water around the metal pipe. Mallards are less likely to use nest structures that are not located above standing water.

This covered cone type nesting structure (reconstructed) received relatively high use by nesting mallards in a study by Doty (1979). The overhead cover on original covered cones extended farther toward the back of the nesting material.

The first experimentation with earth-filled concrete culverts was conducted in the 1970s in North Dakota and showed promising results for nesting mallards in years when Canada geese were not using the structures (Higgins et al. 1986).

Use of culverts was first reported by Higgins et al. (1986) in North Dakota. Culverts were of metal or concrete construction, were about 32 inches to 48 inches in diameter, and varied in length from 4 to 6 feet (Higgins et al. 1986, Ball 1990, Zenner et al. 1992). Culvert placement in wetlands and use of fill material is described in our Methods and Procedures. Settling of fill material may occur and more material may need to be added at a later date. Top filling with soil enables growth of volunteer vegetation for nesting cover. Culverts are placed in openings near emergent vegetation but, once in place, are not easily movable if water levels should rise and flood them.

Nesting Canada geese (*Branta canadensis*) are attracted to culverts, making much of the plant cover unsuitable for nesting mallards. Ball and Ball (1991) first reported using a canopy and compartments over culverts to encourage dual use by Canada geese and mallards (Table 1).

Culverts are difficult to install or move compared to other nesting structures, can sometimes tip over due to movement of ice during late winter and spring thaw, and are visually undesirable to some people.

Round hay bales and other elevated structures were compared in Haworth and Higgins (1993), Ray and Higgins (1993), and Johnson et al. (1994a) (Table 1). Bales proved to have moderate to good mallard occupancy but were more accessible to mammalian predators when compared to culverts and open-top baskets. Bales are also rather short-lived (about 2 years) after placement in wetlands. Of the nesting structures, bales were the most readily accepted by redheads (*Aythya americana*).

Hay bales are attractive to nesting mallards but are more accessible to predators and last only about 2 years (Johnson et al. 1994a and others).

Table 1. Review of publications dealing with elevated nesting structures in prairie wetlands showing, where applicable, nest occupancy and nest success rates for mallards.

Citation, place, years data collected	*Structure type*	*Nest occ. (%)*	*Observed nest success %*	*Other notes*
Bandy 1965, southwest Lake Erie region (1964 –1965)	Cylinders	12-72	Not given	Heavy wire cylinders lined with hay similar to those in our study. Also metal pipe cylinders. All were provided with nesting material. Metal cylinders were not used. Most (88%) nesting was by mallards, with some use by wood ducks and black ducks. Occupancy percentage includes all species.
Bishop and Barratt 1970, prairie pothole regions of Iowa (1964–1969)	Open-top baskets	33	87	Both round and square wire baskets. Redheads used 8 baskets, blue-winged teal (*A. discors*) and gadwall (*A. strepera*) used 1 each, and 2 baskets were used by Canada geese.
Doty et al. 1975, South Dakota, Minnesota, Wisconsin, and North Dakota, mainly in prairie pothole region (1966–1973)	Open-top baskets	38	83	Round baskets of galvanized hardware cloth and molded fiberglass. Predation increased toward the end of the study with ring-billed gulls destroying 49% of 114 clutches at one site from 1971–1973; predator loss averaged 23% in main study area in North Dakota. Baskets on stockponds in North Dakota and on wooded wetlands in Minnesota had low use. Smooth brome or barley straw was preferred over flax straw as nesting material.
Doty 1979, Missouri Coteau in North Dakota on federal Waterfowl Production Areas (1974–1977)	Open-top baskets	25	70	Covered cones and cylinders provided more protection from avian predation (ring-billed gulls) than fiberglass baskets. Cones were provided with sheet aluminum attached to the dorsal hardware cloth as overhead cover and were shaped like an oval-mouthed ice cream cone set on its side. Wire cylinders had asphalt roofing paper over the top to provide concealment. All were provided with flax straw.
	Cones	46	84	
	Cylinders	14	73	
Sidle and Arnold 1982, central North Dakota (1980–1981)	Cones	0	0	Covered cones (same type as in Doty 1979) and cylinders were not accepted by mallards. Authors recommended that open-top baskets were still the best option.
	Cylinders	0	0	
Higgins et al. 1986, Woodworth Field Station central North Dakota (1972–1985)	Culverts	92	100	First report on culverts. One concrete culvert observed for 12 years in a small wetland. Canada geese nested on the culvert for 2 years and mallards nested 11 of the next 12 years. All clutches hatched.
Ball and Ball 1991, western and northern Montana (1987–1989)	Culverts	27	71	Competition with Canada geese (36% occupancy) reduced mallard use on culverts without compartments. Half of the culvert was divided into two covered partitions on some 4-foot-diameter culverts, allowing simultaneous mallard and goose nesting. Culverts placed in protected coves or small wetlands did not tip over.
Haworth and Higgins 1993, eastern South Dakota (1986–1987)	Open-top baskets	14	66	Round bales were composed of grasss, sedges, and cattails. Canada geese occupied 6.6% of baskets and 5.5% of bales. Redheads nested on 17.0% of bales.
	Bales	16	36	
Ray 1990, Ray and Higgins 1993, eastern South Dakota (1988–1989)	Open-top baskets	13	79	Redheads occupied 19.2% of the nests on bales. Canada geese nested on 33.3% of culverts, 11.2% of baskets, and 36.8% of bales. Green-dyed nesting material in baskets attracted nesting mallards 10–14 days earlier than normal (nondyed material) but did not increase nest/structure occupancy.
	Culverts	22	92	
	Bales[a]	25	25	

Table 1 continued.

Citation, place, years data collected	Structure type	Nest occ. (%)	Observed nest success %	Other notes
Johnson et al. 1994a, Montana, North Dakota, South Dakota (1987–1989)[b]	Open-top baskets	9	83	Canada goose use of baskets (22.8%), culverts (14.8%), and bales (15.6%) may have reduced mallard use in some cases. Both culverts and bales were more acceptable to mallards than open-top baskets.
	Culverts	24	84	Geese used baskets more than the other structures. Nest success rates were highest on baskets and culverts. All but a few culverts in Montana
	Bales	19	46	lacked canopies and compartments.
Higgins and Vaa 1994, prairie pothole region (1966–1994)	All types			Symposium/workshop proceedings included detailed abstracts or short papers on various research and management programs using elevated nesting structures, primarily in the prairie pothole region. Some of these articles are cited in our report.
Evrard 1996, northwest Wisconsin (1985–1992)	Open and covered-top baskets	6	80	No baskets used in first year but use by mallards increased to 56% in fifth year. Baskets with canopies received almost no use in comparison to those with no top. Several years are needed to evaluate baskets. Bales were short-lived and not productive.
	Bales	4		unknown
Eskowich et al. 1998, Saskatchewan parklands (1994)	Open-top baskets	12	93	Baskets were made of mesh wire.Two types of structures were paired within an average distance apart of 39 feet to allow mallards to make a selection if both were unoccupied. Mallards chose the cylinder type
	Cylinders	70	92	structure first in 98% of cases. Cylinders were made of 2 x 2-inch stucco wire and were 12 inches inside diameter, 24 inches long, and lined with flax straw. Baskets were 24 inches in diameter and 12 inches deep.
Artmann et al. 2001, northeastern North Dakota (1977–1998)	All types			Test of hypothesis that lack of perennial nesting cover would increase use of nesting structures by mallards. Nest structure occupancy was highest in areas with greater amounts of perennial cover in the landscape.
Stafford et al. 2002, eastern South Dakota (1998–1999)	All types			Good to excellent survival of mallard broods produced on nesting structures. Great horned owl (*Bubo virginianus*) predation on ducklings and hens can be serious if nest structures are placed on small wetlands surrounded by trees.
Zicus et al. 2003, western Minnesota (1998–2000)	All type			Mass loss during incubation in mallard eggs from nests in elevated cylinders was 20.6% vs. 15.3% for mallards nesting on the ground.
Chouinard et al. 2005, southern Manitoba (2001–2002)	Cylinders	78[c]	48-99[c]	Occupancy of wire mesh (straw lining) cylinders increased by 56% from 2001-2002. Nesting success dropped from 99% to 48% after year 1 due to corvid predation. Occupancy was evaluated in relation to number of structures and size of small wetlands.

[a] Nest success on bales is for combined mallards (78.9% of nests), redheads, and ruddy ducks (*Oxyura jamensis*) (Ray and Higgins 1993). Occupancy for mallards was estimated by multiplying the proportion of mallards times the occupancy for total ducks on bales (0.79 x 31.6).

[b] Nest occupancy and nest success were calculated from data shown in Tables 1 and 2 in Johnson et al. 1994a.

[c] Occupancy rate is for the second year of a 2-year study (increased 56% after year 1). Occupancy and success are reported for all ducks using cylinders (98% mallards plus 2% redheads and canvasbacks (*Aythya valisineria*) combined).

Recent research has focused on other aspects related to mallard nesting in elevated structures. Artmann et al. (2001) evaluated mallard occupancy rates on nesting structures in relation to availability of perennial nesting cover in the surrounding landscape, testing the hypothesis that lack of perennial cover on the landscape would lead to higher mallard occupancy rates for elevated nesting structures.

Interestingly, use of nesting structures by mallards was highest in areas with greater amounts of perennial nesting cover and lowest in the most highly cultivated areas. Much of this relationship was due to the higher densities of mallard pairs in areas of greater perennial cover. When the number of pairs in the area was controlled statistically (pair density included as within plot covariate), there were no real differences in mallard occupancy rates on structures in relation to proportion of the landscape in perennial cover.

Zicus et al. (2003) found that loss of mass in mallard eggs during incubation was 33% greater in elevated nest structures than in nests located on the ground. Even though mallard nesting success is excellent on elevated structures, it is possible that this loss of weight in the egg stage could compromise post hatch survival. The authors still believed that recruitment gains from elevated structures on wetlands would outweigh any increased duckling mortality due to greater dehydration in eggs.

Stafford et al. (2002, 2004) evaluated survival and movements in mallard broods hatched on overwater nesting structures in South Dakota. They found especially high survival in mallard ducklings ($S = 0.73$) and broods ($S = 1.00$) produced on nest structures in a large marsh (400 ha) characterized by excellent interspersion of emergents. No broods left the marsh. Ducklings hatched on smaller wetlands were more mobile and had lower but still comparatively good duckling and brood survival rates (Stafford et al. 2002).

The influence of number of nesting cylinders and wetland size on duckling production from cylinders placed on small wetlands (0.4–1.5 ha) was evaluated by Chouinard et al (2005). Duckling production (98% mallards) per structure was nearly twice as high with one or two cylinders vs. four cylinders per wetland. Wetland size was not related to duck production per nesting cylinder.

OBJECTIVES

Studies of mallard use and nesting success on elevated structures have generally been of a short-term nature. In this report we evaluated 15 consecutive years of mallard nesting on elevated structures (baskets, cylinders, and culverts) located over standing water in wetland basins in eastern South Dakota. Our objectives were to: 1) determine long-term trends in mallard occupancy and nest success in nesting baskets, cylinders, and culverts, 2) evaluate the effects of various nest structure adaptations for enhancing mallard use and maintaining high nest success rates, and 3) provide managers with various enhancement techniques for mallard nesting structures that have proven productive in this long-term management effort.

MANAGEMENT AREA

Mallard nesting structures were placed on various wetlands or wetland complexes on state Game Production Areas and federal Waterfowl Production Areas in eastern South Dakota. Almost all of eastern South Dakota has a glacial history as recent as 10–12 thousand years ago. Highland areas such as the Prairie Coteau to the east and Missouri Coteau closer to the Missouri River have abundant wetland resources (Johnson and Higgins 1997) and breeding waterfowl (Brewster et al. 1976). Even the James River Lowlands and Minnesota-Red River Lowlands can have abundant natural wetlands and high waterfowl production during wet years (Naugle et al. 2000).

Eastern South Dakota is characterized by a mixed agriculture system dominated by corn, soybeans, and pasturelands. Pastureland is still abundant in portions of eastern South Dakota with rocky or poor soils. However, where better soils occur, tillage is sometimes intensive with little nesting cover remaining.

Much of the taller and denser nesting cover on private lands is associated with conservation provisions of three U.S. Department of Agriculture Farm Act programs: the Conservation Reserve Program (since 1985), Wetland Reserve Program (since 1990), and Grassland Reserve Program (since 2002) (Reynolds et al. 2001, Rewa 2005, Wood and Williams 2005).

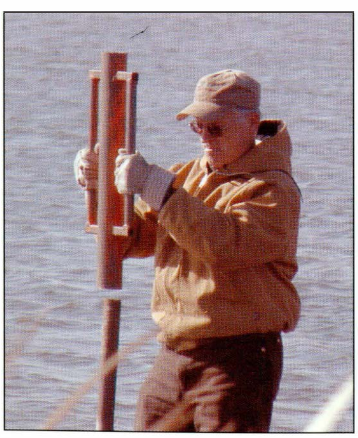
Primary study sites (management sites) included Mickelson Memorial Marsh in Hamlin County, Redetzke Game Production Area in Day County, Sand Lake National Wildlife Refuge and Renziehausen Game Production Area in Brown County, and Oakwood Lakes-Errington Marsh sites in Brookings County. Numerous additional sites included lesser numbers of structures on smaller wetlands. Most nesting structures were erected in palustrine emergent marshes (Cowardin et al. 1979) of which most would be classified as semipermanent (Class IV) or seasonal (Class III) wetlands by Stewart and Kantrud (1971).

Mickelson Memorial Marsh covers approximately 400 ha and is located in eastern South Dakota between Brookings and Watertown. Inset: Mallard ducklings produced in nest structures on this wetland remained on the wetland until fledging and had unusually high survival (S = 0.73) (Stafford et al. 2002).

METHODS AND PROCEDURES

A variety of elevated structures for mallard nesting had either been established previously in eastern South Dakota wetlands or were erected from 1992 through 2006. Structures included nest baskets, nest cylinders (nest tunnels or hen houses), and culverts. Baskets were made of molded fiberglass in the shape of a shallow cone and were 30 inches in diameter and 15 inches in depth. All cylinder types were 24 inches long with an inside tunnel diameter of 12 inches. Lined cylinders were formed from an inner and outer layer of 1 x 2-inch welded wire with flax straw or carpet fitted between the two layers of welded wire. Plastic cylinders were made of corrugated pipe. Flax lined cylinders required more time to construct and maintain than either carpet lined or plastic cylinder types.

Baskets and cylinders were mounted on metal pipe, 1.5 inches in diameter, that had been set in place using a hand-held post driver over thick ice (12–30 inches) in winter or from a boat after ice out. Baskets and cylinders were initially set from 3 to 4 feet above the water.



Metal pipes were driven into the marsh substrate from a boat or through a hole cut in the ice and used as support for cylinder and basket nesting structures (Paul Mammenga in photo).

Most culverts used in our study were 48 inches in diameter, 8 feet in length, and constructed of corrugated metal. Some concrete culverts, 30 inches in diameter and 4 to 6 feet in length, were also used. We preferred metal culverts because of their lighter weight.

An ice auger was used to cut holes in the ice by overlapping the auger holes; the ice was usually too thick for a chain saw with a normal length bar. With a tractor-loader we moved the culverts over the ice and placed them upright in the hole (ice removed). Corrugated metal culverts were light enough that they could be set upright in the ice holes without use of a tractor-loader. Culverts can also be placed in dry wetlands during periods of drought (Higgins et al. 1986, Ball 1990). We used the tractor-loader to level the culvert and set it into place by pushing the base several inches into the bottom sediments.

Ice was lifted out using a tractor-loader and chain.
Inset: Corrugated metal culverts were light and were placed in ice holes by hand.

A tractor-loader was used to level culverts and set them into place, pushing the base several inches into the bottom sediments.
Inset: Culverts were filled with gravel and topped with a layer of soil at the time of installation.

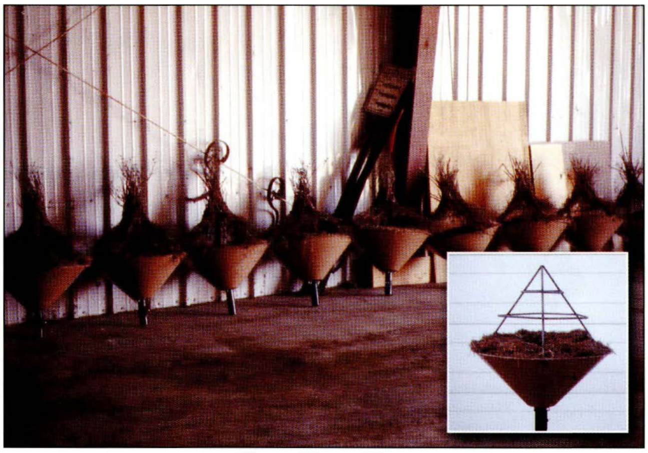
The culverts were filled with gravel and topped with a layer of soil at the time of installation. The soil provided a soft substrate and an initial seed source for volunteer plant growth. We checked that the soil was within about three inches of the culvert rim after settling so ducklings and goslings could escape (Zenner et al. 1992).

Our goal was to place culverts, baskets, and cylinders in open pockets of water in or near emergent vegetation. More detailed information on placement is presented in Ball (1990) and Zenner et al. (1992).

Culverts that tipped over were often difficult to reestablish in an upright position but, where possible, were reclaimed using a tractor-loader over ice. We cut the ice around culverts that had tipped over and used a chain wrapped around one end of the culvert and the tractor-loader to lift and straighten the structure. Metal culverts were easier to lift up and reset than concrete culverts. Once set upright, the culvert base was pressed into the sediments to anchor it again and gravel and soil were added as needed.

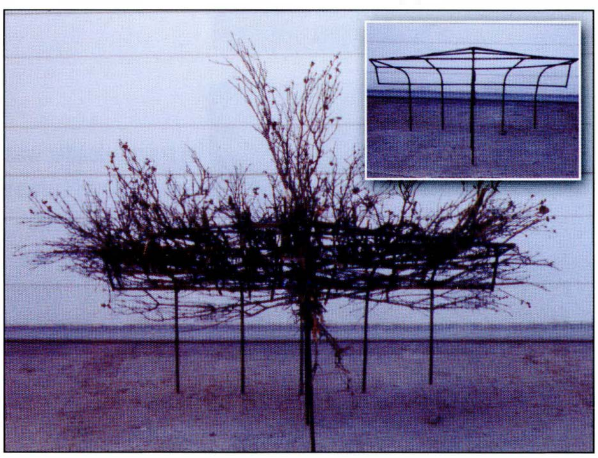
Pipes supporting nest baskets and cylinders sometimes began to tip over or bend due to ice movements and had to be pulled out using a winch on an ATV over ice or from a boat; they were then straightened if bent and reset using a hand-held post driver. Baskets and cylinders no longer located above standing water due to receding water levels were moved to sites over water. Those subject to flooding were relocated to shallower areas in the same wetland basin.

Overhead canopy covers were developed for existing or newly installed nest baskets and culverts (Mammenga 1994). These canopies were either brush (1992–1998), primarily western snowberry (*Symphoricarpos occidentalis*), or woven fiberglass (1994–2006). Partitions made of the same material as the canopy formed two to four nesting



Brush, primarily western snowberry, was attached to a metal frame (inset) to provide canopy cover for nesting baskets.

Right: Fiberglass canopies for baskets provided overhead concealment while allowing the hen three entry or escape routes.



Culvert partitions and canopies of brush were supported by a frame of metal rods (inset). The interwoven brush made the structure appear natural. Metal frames and attached brush placed back to back provided four-compartment models.

Below: Two-compartment culverts were divided so that half of the culvert was left without a canopy for Canada geese and the canopied half contained two mallard nesting compartments. Four-compartment models were created by placing two compartment models back to back.

Brush-modified culverts with four compartments greatly increased mallard occupancy and provided excellent concealment for nesting hens.

compartments to encourage multiple use by concurrently nesting mallards. Culvert partitions and canopies of brush were supported by a frame of metal rods. The interwoven brush made the structure appear natural.

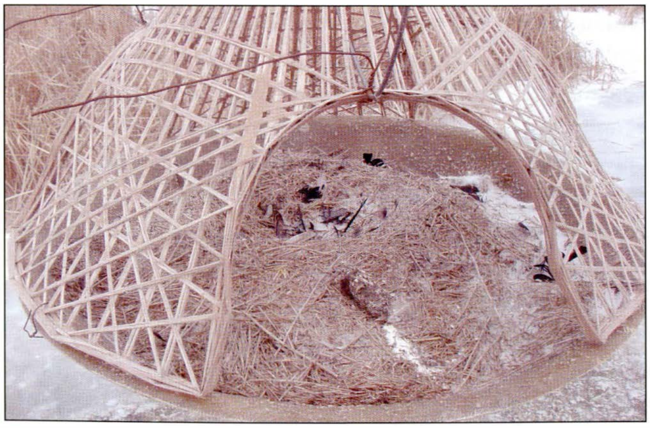
Woven fiberglass canopies and canopies with partitions (for culvert compartments) were made by a private vendor and stockpiled for future needs. Our original vendor is no longer in business but we suggest that these could be constructed by any company that specializes in fiberglass.

Number of compartments on culverts throughout this report refers to canopied compartments built for nesting mallards. Two-compartment culverts were divided so that half of the culvert was left without a canopy for Canada geese and the canopied half contained two mallard nesting compartments. Culverts with four canopied compartments were set up by placing two two-compartment halves back to back; these were used in an attempt to increase multiple nests/structure and to discourage Canada goose nesting. On some four-compartment fiberglass models, Canada geese nesting on top of the canopy eventually flattened and destroyed the canopy above one duck nesting compartment. We removed any damaged canopy material, leaving these culverts with three mallard compartments (three-compartment models) and one open quarter for use by geese.

Our management objective on two-compartment culverts was to enable concurrent use of culverts by both mallards and Canada geese while isolating the goose on a portion of the culvert; three-compartment fiberglass models also fit this objective even though we did not initially plan to create this model.

Flax straw for nesting material was placed in all structures when they were set up in wetland sites. During annual maintenance over ice in winter, we added and built up the flax straw in the baskets, cylinders, and culverts, simulating nests by forming the flax straw into nest bowls. Where mallard nest bowls existed from the previous year, the new flax augmented the previous year's nest bowl without destroying the old nest material or nest bowl shape. Nest bowls from the previous year were nicely shaped by the hen, producing a relatively deep cup and an interweaving of flax straw and feather material.

Nest structures were checked periodically for nesting hens or completed nesting attempts in May, June, and July from 1992 to 2001 and, after 2001, once after the nesting season during late fall and early winter. Ball (1990) indicated that nest structures should be checked soon



Above: Biologists with several years experience in duck nesting studies estimated nest attempts per structure and nesting success from visits in early winter for the years 2002–2006. Prior to 2002, nesting information was gathered by periodic visits to nest structures during the summer.

Left: A mallard nest bowl from the previous summer is visible in this nesting basket. New flax will be added to augment the old nest bowl prior to the nesting season. Note the owl pellet on the edge of the nest bowl, probably from a great horned owl.

after the nesting season before the egg shells and shell membranes from hatched or destroyed clutches begin to deteriorate and cause a loss in accuracy of nesting information. However, when comparing summer and early winter visits, we became convinced that experienced personnel could determine nest use and fate comfortably in most cases if structures were visited by early winter. We may have reduced or lost our ability to identify some consecutive (multiple) nests due to late nest checks from 2002 through 2006 but, in most cases, first and second nesting fates were evident based on egg membranes, shell fragments, and layering of nesting material pulled into the nest bowl by hens. Almost all determinations of nest use and fate were made by P.W. Mammenga and M.E. Grovijahn who each year recorded location, structure type, structure number, date of visit, nesting species (usually mallards), number of eggs, nest status, number of membranes, number of unhatched eggs, cause of failure if known, and, when checking during incubation, approximate stage of the eggs (Weller 1956).

We reported nests/100 structures instead of occupancy because of multiple nests in single structures. Occupancy rates (number of structures with at least one mallard nest) and nests/100 structures by year and for all years combined for all structures are in the Appendix. We reported apparent nest success throughout; these estimates should be close to actual or Mayfield nest success since virtually all nests in structures were located and few nests were destroyed or abandoned (Johnson and Shaffer 1990).

Estimated cost for materials and labor at the time of purchase from 1992–1995

Materials (with their approximate prices during 1992–1995) approximately doubled from original costs by 2006. For example, metal culverts cost $125 in 1992 and $250 in 2006. Costs for personnel also approximately doubled during the period.

Baskets

Fiberglass nest basket $40.00
Pipe with mounting bracket $25.00
Fiberglass canopy for basket $20.00
Wire owl guard (including labor to weld wire). $6.00
Brush canopy option:
    12 ft of 5/8-inch steel framing rod. $2.00
    Labor to weld rods $18.00
    Labor to install brush $12.00
Installation of basket (about 1/2 hour) $15.00

Cylinders

Materials/labor to construct carpet lined cylinder . . $28.00
Materials/labor to construct flax lined cylinder $38.00
Pipes and mounting brackets $25.00
Wire owl guards/cylinder $6.00
Raccoon guard $18.00
Installation labor costs $15.00

Culverts

Metal culverts, 16 ga., 4 ft x 8 ft. $125.00
Paint for top half of culvert. $15.00
Fill gravel $40.00

Options:
Brush canopy (two compartment; four compartment by using two of these back to back)
    40 feet of 3/8-inch metal rod $4.50
    Labor to install brush $24.00
    Labor for welding. $48.00
    Fiberglass canopy (two-compartment) $60.00
    Installation labor, 2.5 hrs, 4 people $150.00

RESULTS AND DISCUSSION

Evolution of our management efforts over 15 years

Management efforts and nest structure manipulations during this 15-year period were an attempt to increase mallard production; this was a management project and was not designed to statistically test research hypotheses. Analysis of project results and comparisons of nest structure types and nest structure manipulations in this manuscript represent post-project efforts to evaluate and present results from this long-term management effort.

Several adaptations to duck nesting structures were made throughout the 15-year period in response to mallard nesting problems we observed and to reports from other managers and researchers about low mallard occupancy of structures lacking overhead cover (Bishop and Barratt 1970, Doty et al. 1975, Haworth and Higgins 1993, Ray and Higgins 1993, Johnson et al 1994a). Ball and Ball (1991) experimented with a few 4-foot-diameter culverts with a canopy and two compartments on half of the structure and found that mallards used the compartments concurrently with Canada geese nesting on the half with no canopy and suggested that additional observations on large culverts with canopies and compartments were needed. Doty's 1979 results using cones (sideways cones, unlike cone shaped baskets) and cylinders also provided evidence that concealment over the top of a nesting structure could increase mallard use (Table 1).

Addition of brush canopies on baskets and brush canopies plus partitions on culverts beginning in 1992 were highly successful in improving mallard occupancy. In later years, more easily managed woven fiberglass replaced brush canopies and partitions.

Our cylinders were lined with flax straw starting in 1993. We continued to use the flax lining but added carpet lined cylinders in 1996 and some plastic models in 1996 in an effort to reduce time spent on lining maintenance.

Great horned owls (*Bubo virginianus*) began to perch on nest basket canopies and on cylinders at some of our sites in the late 1990s. Research on mallard duckling survival from overwater nesting structures in eastern South Dakota had shown that great horned owl predation on ducklings departing nesting structures could be severe on small wetlands surrounded by large trees (Stafford et al. 2002). The owls also could kill mallard females nesting on overwater structures or cause nest abandonment.

Wire owl guards consisting of projecting wires to prevent great horned owls from perching on nest basket canopies were added in 2002; wire guards were added to cylinders in 2004. Percentages of baskets with owl guards by year were 31% in 2002, 50% in 2003, 84% in 2004, 85% in 2005, and 90% in 2006. For cylinders, percentages with owl guards by year were 75% in 2004, 87% in 2005, and 80% in 2006. In 2006, flax hay was attached to the canopies on most of the fiberglass nest baskets using the owl guard wires as attachment sites. Flax on the fiberglass canopies gave these structures an appearance more similar to the brush canopied nest baskets.

Great horned owls learned to use the cylinders with owl guards by perching on the landing platform, gaining direct access to mallard hens and ducklings. Thirteen cylinders that were constructed without any landing platforms had excellent use by mallards, indicating landing platforms were not needed. Thus, most platforms were removed from cylinders in 2005, leaving only 15% with landing platforms.

Direct observation of nest structures as well as owl fecal droppings and pellets indicated that great horned owl use of baskets and cylinders for perching was reduced by use of the wire owl guards and removal of entrance platforms. However, there were no consistent or dramatic changes in nest structure use by mallards or in nesting success after adapting structures to reduce owl use.

These adapted structures were not accompanied by paired control structures. However, we are of the opinion that great horned owls would have caused a reduction in mallard occupancy and nesting success in structures on some wetlands without owl deterrents. The potential positive influence on duckling and hen survival of keeping owls away was evident, based on observations by Stafford et al. (2002).

We fitted metal poles supporting cylinders with metal skirts in a single wetland where raccoons became a problem in 2004. Inset: Cylinder destroyed by a raccoon. Note wire owl guard.

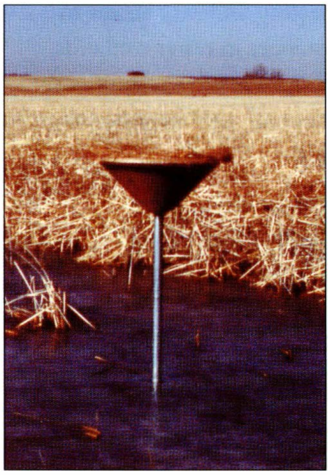
We fitted metal poles supporting cylinders with metal skirts (cones) in a single wetland where raccoons (*Procyon lotor*) became a problem in 2004. In the same wetland, raccoons did not access nest baskets because of their shape and smooth fiberglass construction. Raccoon access to nesting structures was aided in this wetland because of dropping water levels during nesting and easy access to sites with structures. In two instances in other wetlands, raccoons swam directly to nesting structures when rising water levels enabled direct access without climbing the supporting metal pipe.

We attempted to reduce great horned owl use of baskets and cylinders for perching by using wire owl guards and, in later years, removing entrance platforms (cylinders only). Mark Grovijahn is removing the entrance platform.

Nest baskets

Pre-project results for open-topped baskets

Open-topped nesting baskets (no canopy) erected in wetlands in eastern South Dakota averaged only 12.1 mallard nests/100 baskets from 1986 to 1990 (Table 2). Johnson et al. (1994a) noted a similar low rate of use by mallards (8.9%) over the three-state area of Montana, North Dakota, and South Dakota, as did Eskowich et al. (1998) in a 1-year study (12.0% use) in Saskatchewan and McKinnon et al. (1994) in a 3-year study (5-17%) in southern Saskatchewan. In Wisconsin, mallard use of open-topped baskets on federal Waterfowl Production Areas averaged only 5.5% due to extreme low use in the first few years. By the fifth year 56% of open-topped baskets were in use (Evrard 1996). Hanson (1994) noted similar low use (3.8% for all years) of open-topped baskets by mallards in western Minnesota but an increase from less than 1% use to 14.0% use during a 7-year period. Bishop and Barratt (1970), Doty et al. (1975), Doty (1979), and Jones (1994) recorded moderate (25–40%) occupancy rates in open-topped baskets. Nesting success was generally excellent in these studies, but Doty et al. (1975) noted increasing problems with ring-billed gull predation on eggs in some areas. Unusually high use rates of open-topped nesting structures of 44% and 69% and a success rate of 89% were reported for a study area in North Dakota for 1966–67 (Lee 1994).



Fiberglass nesting baskets without canopies averaged only 12 mallard nests/100 baskets on our management sites, much lower than observed after baskets were fitted with brush or fiberglass canopies.

Open-topped baskets on our management areas did not show increasing use with years after placement, as observed by Evrard (1996) and Hanson (1994), nor were gulls, raccoons, or other predators a problem as reported by Doty et al. (1975). Observed nesting success on open-topped baskets from 1986 to 1990 in eastern South Dakota averaged 73.9%. Since few of the open-topped baskets supported more than one mallard during the season, the nests/100 structures in eastern South Dakota was also a close estimate of basket occupancy rates (% of structures used) as reported in most other studies.

Table 2. Nests/100 structures and nesting success for mallards and Canada geese in baskets lacking overhead canopies (open topped) 1986–1990 in eastern South Dakota. Most of the data for 1986, 1987, 1988, and 1989 were originally presented in Ray and Higgins (1993) and Haworth and Higgins (1993).

Year and category	*Baskets (n)*	*Mallards*	*Canada geese*
1986	68		
Nests /100 baskets		19.1	7.4
Nesting success		69.2	80.0
1987	154		
Nests /100 baskets		15.6	5.8
Nesting success		58.3	88.9
1988	132		
Nests /100 baskets		11.4	11.4
Nesting success		80	93.3
1989	126		
Nests /100 baskets		15.1	11.9
Nesting success		78.9	100
1990	165		
Nests /100 baskets		4.2	8.5
Nesting success		85.7	64.3
Combined	645		
Nests /100 baskets		12.1	8.8
Nesting success		73.9	86.2

Canada goose use of open-topped baskets meant for nesting mallards occurred in some studies in the 1960s and 1970s but was generally not a problem because giant Canada goose (*B. c. maxima*) restoration efforts were in an early stage. The highest rates of use by Canada geese (58.3%), and thus competition for open-topped baskets with mallards, were reported by Johnson et al. (1994a) for impounded wetlands in Montana outside the prairie-pothole region. In southern Saskatchewan, Canada geese used 22–39% of open-topped baskets during years 1990–1993 and may have contributed to low rates of mallard use (McKinnon et al. 1994).

Canada goose use of open-topped baskets on our study area from 1986 to 1990 remained low (8.8%) even though nesting geese were abundant in this post goose-restoration period (Table 2; see Haworth and Higgins 1993 and Ray and Higgins 1993). Other substrates in eastern South Dakota, particularly muskrat (*Ondatra zibethicus*) houses and islands, provide suitable nesting sites for Canada geese on many wetlands.

Baskets with brush and fiberglass canopies

Brush and fiberglass canopies were placed on nesting baskets in eastern South Dakota beginning in 1992 and 1994 in an attempt to increase mallard use and reduce Canada goose competition for nest baskets. During the 15 years from 1992 through 2006, numbers of covered nest baskets ranged from 13 in 1992 to 227 in 1998 (Appendix 1). We did not include flooded or other unusable baskets in our summaries.

In all but 4 years, the number of covered nesting baskets equaled or exceeded 140. Baskets available (basket years) over the 15-year span totaled 2,139 (Appendix 1).

Nest success rates in baskets with canopies (cover tops) were excellent, exceeding 90% in 10 of 15 years and 80% in all but 2 years (Fig 1) (Appendix 1). Observed nest success rates for the 1,289 mallard nests in covered baskets averaged 91.9% for the entire 15 years.

Nests/100 baskets generally remained at or above 50 for baskets with canopies during the 15-year period (Fig 1) and averaged 60.3, approximately five times higher than observed during earlier years (1986–1990) in baskets without canopies in the same management areas (Table 2, Appendix 1). Occupancy was slightly lower (56.1%) than nests/100 structures because of some multiple nesting by two mallards in sequence.

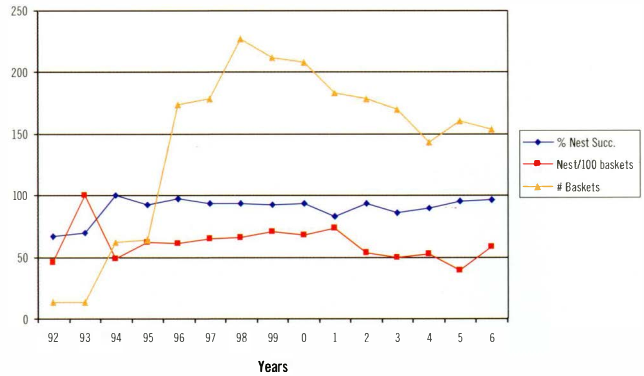


Fig 1. Mallard nest success and nests/100 baskets for structures with covered tops in eastern South Dakota.

When nest baskets with different canopy types were compared, both brush canopies and fiberglass canopies had nest success rates close to 90% in most years (Fig 2) (Appendix 1). For all years combined, nest success was similar for baskets with brush canopies (87.4%) and those with fiberglass canopies (92.3%). In the 6 years that brush covered nest baskets were available, mallard nests per 100 structures reached or exceeded 100 in all but the first year of placement (Fig 3), with 87 nests found during 87 structure years (number of structures available summed over years) (Appendix 1). In comparison, baskets with fiberglass canopies averaged 58.6 nests/100 structures (Appendix 1).

In the 6 years that brush covered nest baskets were available, mallard nests per 100 structures reached or exceeded 100 in all but the first year of placement.

In the 4 years that both structure types were simultaneously in place (1994–1997), nests/100 baskets in brush canopied structures (111.9) was more than double those under woven fiberglass canopies (48.2). However, during that same period, nest basket use increased each year in the fiberglass models while use in brush canopied baskets remained at a static but high level (Fig 3). Brush canopies on baskets appear to be more attractive initially than woven fiberglass to nesting mallards (Fig 3, Appendix 1).

Annual increases in mallard use of baskets with woven fiberglass canopies from 1994 through 1999 were likely related to increasing hen acceptance of the structures and homing of females and their offspring (Doty and Lee 1974).

We suggest that the annual increases in mallard use of baskets with woven fiberglass canopies from 1994 through 1999 were related to hen acceptance of the structures and homing of females and their offspring (Doty and Lee 1974). Because of difficulty in upkeep, brush structures were no longer used after 1997, so we cannot determine how much further occupancy rates would have converged between these two types.

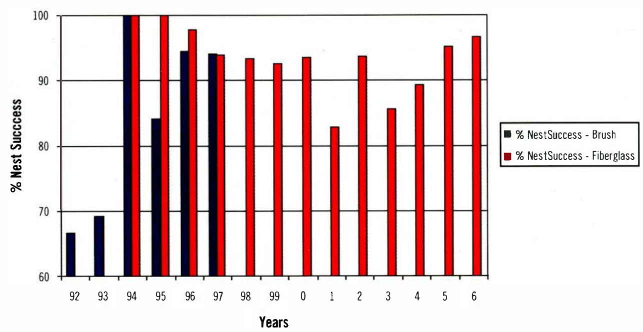


Fig 2. Comparison of mallard nest success baskets with brush or woven fiberglass canopies in eastern South Dakota.

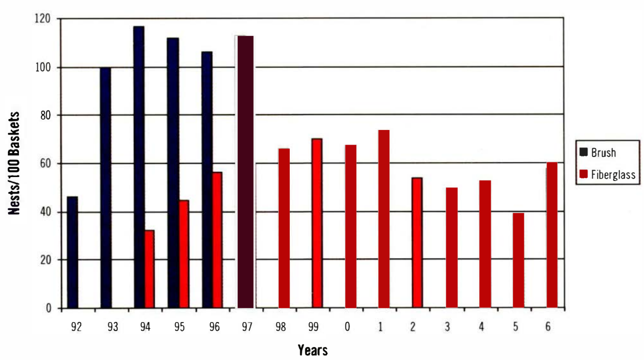


Fig 3. Comparison of mallard use of baskets with brush and woven fiberglass canopies in eastern South Dakota.

Nest cylinders

All cylinder types combined

Our observations on cylinders began in 1993, one year after data collection was initiated on baskets and culverts. Nesting cylinders numbered from as few as 4 in 1993 to as many as 175 in 2002 with a total of 1,669 cylinders available for years combined (Fig 4, Appendix 2). Nesting success averaged 90.5% and never dropped below 81%. Nests/100 cylinders averaged 66.0 while 59.9% (occupancy) of all cylinders were used by nesting mallards (Appendix 2). When two hens nested in the same cylinder during the nesting season the nests were in sequence.

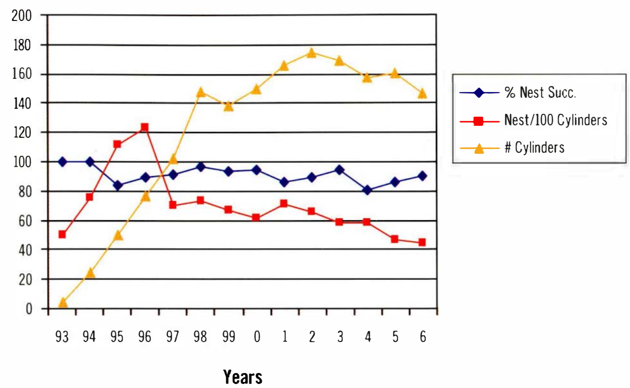


Fig 4. Mallard nest success and nests/100 nesting cylinders (all types combined) in wetlands in eastern South Dakota.

Others have also reported high nesting success rates for mallards using cylinders but mixed results in terms of occupancy. Cylinders with asphalt roofing paper as a covering over the top were studied by Doty (1979) in North Dakota; nest success was relatively good (73%) but the occupancy rate of 14% was considerably lower than what we observed.

Mallard acceptance of cylinders in our study was excellent compared to those in most earlier studies. Wire cylinders with asphalt roofing received only 14% use by nesting mallards in North Dakota (Doty 1979). Sidle and Arnold (1982) observed no mallard nesting in cylinders (204 cylinder years) placed on nine federal Waterfowl Production Areas in North Dakota during 1980–81. However, Kowalchuk et al. (1994) reported mallard use rates for cylinders (hen houses) as high as 83% and nesting

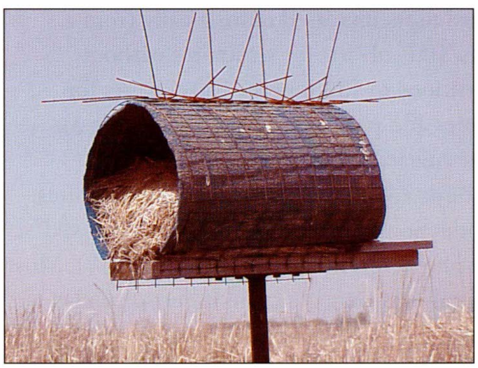
Mallard nests/100 cylinders (all types) averaged 66 with 90.5% of clutches hatching.

success rates of 87% in southern Manitoba. Chouinard et al. (2005), in the prairie parklands of Manitoba, observed peak duck use rates of 78% (98% of nests were mallards) in flax-lined cylinders in the second year of a 2-year study; nest success rates were excellent in the first year (99%) but dropped to 48% in the second year when American crows (*Corvus brachyrhynchos*) and common ravens (*C. corax*) discovered this food source.

Comparison of flax lined, carpet lined, and plastic cylinders

We were interested in the relationship of cylinder type (flax lined, carpet lined, plastic) to nesting success and occupancy. Carpet lined and plastic models could be installed in less time than flax lined. Similar amounts of flax nesting material formed into a nest bowl were made available in the three cylinder types.

Average nesting success for mallards in flax lined (91.0%), carpet lined (89.6%), and plastic (87.0%) nesting cylinders was similar (Fig 5, Appendix 2). The annual variation in nesting success shown for plastic cylinders in Fig 5 reflects the small sample sizes with only 90 plastic cylinders (cylinder years) and 23 mallard nests observed in all years combined.



Mallard nests/100 cylinders averaged 67 for flax lined, 73 for carpet lined (top), and only 26 for plastic (bottom). All three types were provided with equal amounts of flax nesting material.

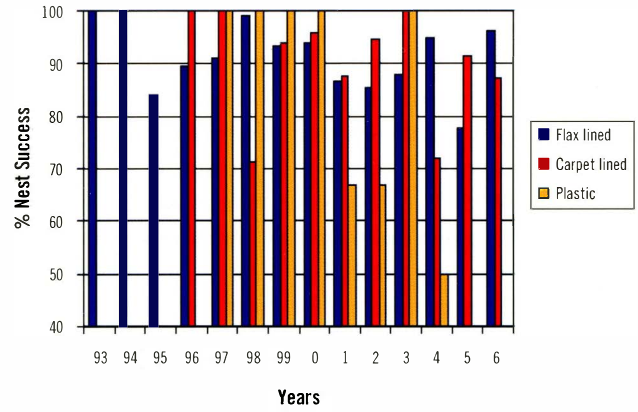


Fig 5. Mallard nest success in relation to type of nesting cylinders placed on wetlands in eastern South Dakota.

Mallard nests/100 cylinders fluctuated considerably but in almost all years was lowest in plastic models (Fig 6); averages were 66.6 for flax lined, 72.7 for carpet lined, and 25.6 for plastic lined (Appendix 2). Occupancy rates in relation to cylinder lining averaged 59.3% for flax, 68.2% for carpet, and 25.6% (no multiple nests) for plastic. Bandy (1965) reported no use of nesting cylinders made from metal tubes but found occupancy rates for straw-lined wire cylinders of 12% to 85% (mostly mallards), depending on year and site.

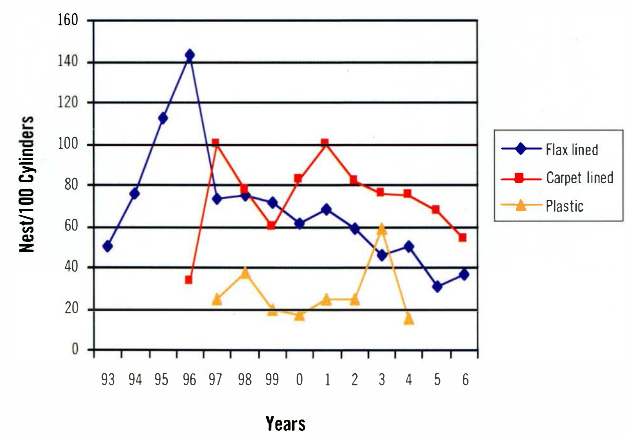


Fig 6. Mallard nests/100 structures in relation to type of nesting cylinders placed in wetlands in eastern South Dakota.

Culvert nesting structures

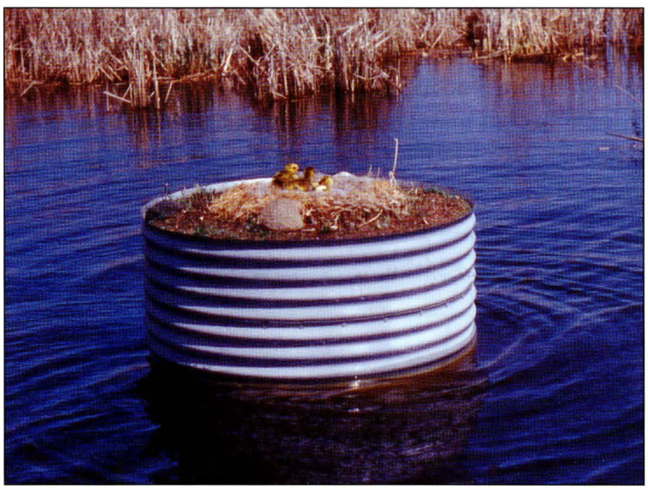
Culverts with and without mallard compartments

Waterfowl use of culvert nesting structures was first observed in North Dakota in 1972 (Higgins et al. 1986). Their use in eastern South Dakota in 1988–1989 was reported in Ray and Higgins (1993). With the exception of a few culverts on wetland impoundments in Montana

(Ball and Ball 1991), nesting culverts in early studies lacked overhead cover (canopies) other than natural vegetation growth and were not partitioned into compartments.

Over a 5-year period (1987–1991) in eastern South Dakota, mallard use of culverts lacking canopies and partitions averaged 9.1 nests per 100 structures with a success rate of 85.7% (Table 3). Canada goose nesting (an average of 48.1 goose nests per 100 culverts) likely inhibited mallard nesting; the geese had a 93.2% nest success rate. As giant Canada geese became more strongly established in South Dakota (1980s) and reached nuisance levels in many areas, the state's emphasis on goose production was reduced.

Overhead canopies and compartments for culverts were built in an attempt to improve mallard production on these structures, as suggested by Ball and Ball (1991). As with the baskets and cylinders, compartments were supplied with pre-formed nesting bowls of flax straw unless the previous year's nest bowl was still present, in which case it was augmented.



Canada goose nesting on culverts without canopies and partitions (an average of 48 goose nests/100 culverts) removed volunteer plant growth and greatly inhibited mallard nesting on those structures.

Table 3. Nests/100 culverts and nesting success (%) for mallards and Canada geese on culverts lacking canopies and partitions from 1987–1991 in eastern South Dakota. Data from 1988 and 1989 were reported previously in Ray and Higgins (1993).

Year and category	*Culverts (n)*	*Mallards*	*Canada geese*
1987	20		
Nests/100 culverts		10.0	5.0
Nesting success		100	0
1988	15		
Nests /100 culverts		20	13.3
Nesting success		100	100
1989	42		
Nests /100 culverts		23.8	40.4
Nesting success		90	100
1990	102		
Nests /100 culverts		4.9	39.2
Nesting success		60	90
1991	129		
Nests /100 culverts		6.2	68.2
Nesting success		87.5	94.3
Combined	308		
Nests /100 culverts		9.1	48.1
Nesting success		85.7	93.2

When the canopies and partitions were added, the number of mallard nests increased dramatically from a mean of 9.1 nests/100 culverts for structures without canopies and partitions to 130.6 nests/100 culverts for those with canopies and partitions (Fig 7, Appendix 3). Mallard nests per culvert increased rapidly in the first few years as the birds adapted to partitioned nesting sites. During peak production years (1994–2000) we observed mallard use at or above 150 nests/100 culverts (Fig 7). Most mallard nests on culverts were concurrent but some also nested in sequence.

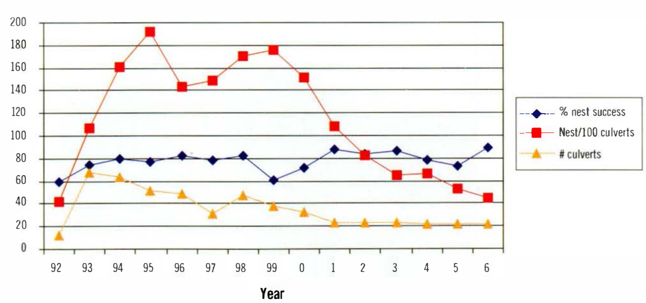
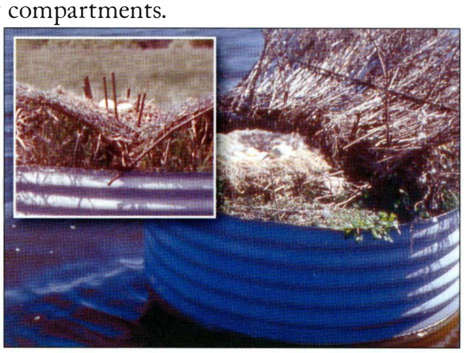


Fig 7. Mallard nest success and nests/100 culverts, 1992–2006, for structures with overhead cover and multiple nesting compartments (from 2–4).

Comparisons of brush and fiberglass canopies and partitions on culverts

Adding brush canopies (1992–1998) and partitioning nesting compartments on culverts improved mallard production from these structures but had little or no influence on goose use (Table 4). Two-compartment culverts for mallards were divided such that one half of each culvert was left without a canopy for use by geese. Canada geese readily used the uncovered portion of brush modified culverts and avoided nesting on top of the canopy.

On brush models with four nesting compartments, all compartments had a canopy to discourage Canada goose use, but geese still used many of these culverts by nesting on top of the brush canopy (Table 4). If openings in the canopy or partition were large enough, a goose would often stretch her head and neck through the canopy or through the partitions to gather nest materials from underlying or adjacent compartments.



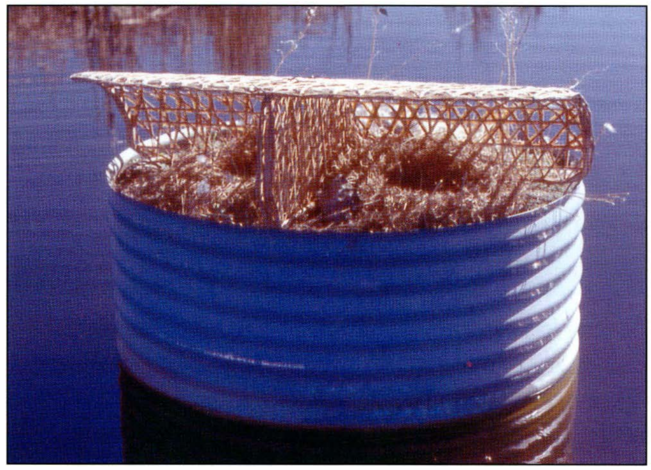
This two-compartment culvert allowed Canada geese to nest on the uncovered portion while mallards nested, either concurrently or sequentially, in the brush canopied compartments. Inset: Geese commonly nested on top of brush canopies of four-compartment models.

Table 4. Mallard and Canada goose nests on culverts with differing overhead cover and numbers of compartments. Most culvert nesting structures reported here were from the Oakwood Lakes area, Sand Lake National Wildlife Refuge, and Redetzke Game Production Area in eastern South Dakota during 1992 through 2006.

Overhead cover (number of compartments)	*Number of culverts*	*Mallard nests/culvert*			*Goose nests/culvert*		
		Mean (SD)	*SD*	*Median*	*Mean*	*SD*	*Median*
Brush (2)	149	1.36	0.95	1	0.69	0.48	1
Brush (4)	36	2.19	1.17	2	0.64	0.49	1
Fiberglass (2&3)[a]	163	0.75	0.77	1	0.90	0.34	1
Fiberglass (4)	71	2.13	1.13	2	0.25	0.44	0
No top (none)	41	0.12	0.40	0	0.88	0.40	1

[a] Fiberglass covered culverts with three compartments were grouped with those with two compartments because of low sample size of the former (41) and similar nests/culvert (3 compartment: $\bar{\chi}$ = 0.63, 2 compartments: $\bar{\chi}$ = 0.79).

Culverts with woven fiberglass canopies and partitions (1994–2006) were evaluated primarily in two- and four-compartment models although some with three compartments (n = 41) were also used. Fiberglass covered culverts with two and three covered compartments occupying half or two-thirds of the culvert were grouped because of the small number of three-compartment models and their similarity to two-compartment models in mallard and goose use rates (see footnote, Table 4).

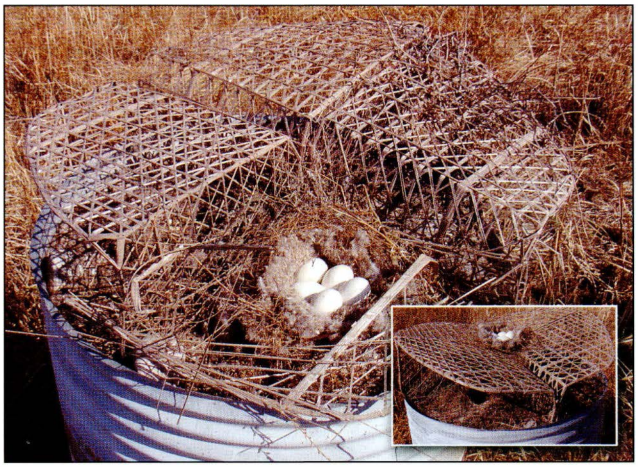


Fiberglass modified culverts with two covered compartments allowed simultaneous use by nesting mallards while a pair of nesting Canada geese used the uncovered half.

Brush adapted culverts with two mallard compartments had more (Kruskal Wallis; $P < .001$) mallard nests per structure than did woven fiberglass with two or three compartments, indicating that brush models may be more effective than fiberglass (Table 4). However, brush and woven fiberglass models with four compartments had almost identical numbers of mallard nests/culvert. Four-compartment structures were clearly the most productive for mallards.

Canada geese nesting on four-compartment fiberglass models, as with four-compartment brush models, built on top of the canopy and used vegetation growing through the canopy to develop a nest bowl and keep the eggs from rolling off. It was not uncommon for one or two eggs to roll off woven fiberglass canopies before the female stabilized the nest.

Goose nesting was considerably reduced on four-compartment fiberglass models when compared to other culvert modifications (Table 4). Over multiple years, nesting Canada geese on some 4-compartment fiberglass models would eventually crush the woven fiberglass canopy above one of the duck nesting compartments, making the underlying nesting compartment unavailable. As noted in Methods and Procedures, the destroyed canopy in these situations was removed and the culvert was then treated as a three-mallard-compartment model with one quarter of the culvert left specifically for goose nesting.



On some four-compartment culverts with fiberglass canopies, Canada geese nesting on top (inset) would eventually break down the canopy over one of the compartments. In these situations the broken fiberglass canopy was removed and the culvert was then treated as a three-compartment model with one quarter of the culvert left specifically for goose nesting.

Does Canada goose use of partitioned culverts influence mallard use?

Mallard nesting on culverts lacking partitions and a canopy was clearly reduced by goose use of the structure (Table 5). However, once partitions were added, Canada goose nesting on the uncovered half of brush model culverts (two-mallard-compartment models) or on top of the canopy (brush and fiberglass four-compartment models) had little influence on numbers of mallards nesting on the structures as long as the canopy remained intact. Reduced mallard use of structures with a nesting goose was only detected on fiberglass two- or three-compartment culverts (Kruskal Wallis: P = 0.013); we are unsure of how nesting geese would have reduced mallard nesting on this culvert model other than using their long necks to steal nesting material from compartments.

Structure use in relation to breeding pair counts

Annual declines in most recent years (2000–2006) in rates of mallard use of baskets, cylinders, and culverts in our management sites were of concern. Culvert use has declined considerably since 1999. Reduced maintenance of culvert canopies and partitions due to de-emphasis of this structure type after 1999, disturbance by Canada geese on two- and three-compartment fiberglass models, and increased disturbance by great horned owls perching on these structures (no owl guards) may have contributed to this decline.

The rapid increases in mallard use of nesting structures from 1992 to 1995 occurred during a period of increase in breeding pair counts and May pond counts; however, it also coincides with an expected increase in nest structure use as mallards adapted to these structures. Mallard use of structures was likely influenced strongly by learning and by homing of adults and their offspring to structures the following year (Fig 8).

Between 1995 and 2001, the association between breeding pair counts and nests/100 structures appears weak or nonexistent. Declines in nests/100 structures (baskets,

Table 5. Mallard nests on culverts with and without Canada geese nesting on the same structure in the same nesting season. Nests reported here were from Sand Lake National Wildlife Refuge, Redetzke Game Production Area, and the Oakwood Lakes area for 1992–2006. Med = median.

Overhead cover (number of compartments)	Culverts with goose nest and nest location: Top[a] (n)	Sect.[b] (n)	Mallard nests on culverts used by geese: Mean	SD	Med	Culverts without goose nest: n	Mallard nests on structures not used by geese: Mean	SD	Med
Brush (2)		102	1.43	0.92	1	47	1.21	1.02	1
Brush (4)	25		2.28	1.30	2	11	2.0	0.77	2
Fiberglass (2 and 3)[c]		144	0.68	0.72	1	19	1.26	0.99	1
Fiberglass (4)	14		2.17	1.21	2	53	2.16	1.10	2
No top (none)	35		0.08	0.37	0	6	0.33	0.52	0

[a] "Top" refers to nesting on top of the brush or woven fiberglass canopy or on unaltered culverts. On fiberglass canopies, vegetation growing through the woven canopy assisted the goose in developing a nest and keeping the eggs from rolling off.

[b] "Sect" includes goose nests on a quarter or half of the culvert lacking an overhead canopy.

[c] Culverts with two and three compartments were grouped for calculations. There were only 41 culvert years for three-compartment culverts.

cylinders, and culverts combined) from 2001 to 2005 were generally accompanied by declines in breeding pair counts for mallards and declines in May pond counts (Fig 8).

Nests /100 structures in 2006 increased along with increases in mallard breeding pairs and wetlands (pond counts). The overall increase in use of nesting structures was tied to an increase in use of fiberglass canopied baskets; use of cylinders and culverts by mallards did not increase in 2006. The camouflaging of fiberglass canopies on nest baskets in 2006 made these baskets look more like the highly productive brush covered baskets used earlier in the project and may have attracted additional mallards.

Declining water levels in wetlands in the last several years have led to development of extensive areas of dense cattail, potentially reducing the interspersion of open water and emergents that may enhance mallard use of structures. Structure use by mallards still remained close to or at 50% even in the poorer years.

Above:
In 2006, flax camouflaging of fiberglass canopies on nest baskets was attempted to potentially improve mallard use of these structures.

Right:
Multiple use of baskets with canopies and cylinders by nesting mallards occurred sequentially but was not common and never exceeded two nests/structure. In comparison, multiple nesting occurred on almost 40% of culverts (with compartments and partitions) and often exceeded two nests/structure.

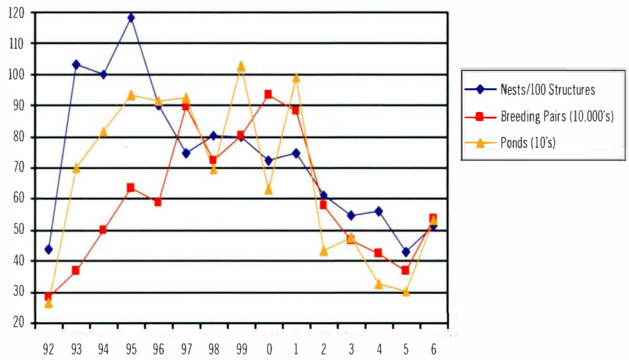


Fig 8. Mallard nests/100 structures in relation to breeding pair counts and May pond counts. Breeding pair counts were from Strata 48 and 49, which are primarily restricted to the eastern half of South Dakota; pond counts were for the entire state (U.S. Fish and Wildlife Service).

Multiple nesting attempts and type of nest structure

All of our nesting structures showed the potential to be used successfully by more than one mallard (Table 6). Multiple use of baskets and cylinders by nesting mallards occurred sequentially and was limited to no more than two hens in one season. Two mallard nests in one season were observed in 12.6% of brush covered baskets (14.5% of baskets used by mallards) and 7.4% of flax lined cylinders (12.6% of cylinders with mallard nests). Chouinard et al. (2005) noted that 4–13% of flax lined cylinders were used twice by nesting ducks and, in one year, two cases of three nests in one cylinder were observed; species was not specified but most were mallards. Culverts often had two concurrent mallard nests, and three or more nests were not uncommon. Over the course of the study (522 culvert years), three mallards nested on single culverts in 56 instances, four in 12 instances, and five or more in 2 instances.

Table 6. Percentage of basket, cylinder, and culvert nesting structures with single or multiple mallard nesting attempts, by overhead cover type or, in cylinders, type of lining. Multiple nests on culverts were often concurrent, but appreciable nesting also occurred in sequence. All structures and compartments were provided flax nesting material formed into a nest bowl each year.

Nest structure type	*Structure years (n)*	*1 nest*	*2 nests*	*≥ 3 nests*
Baskets	2139			
Brush	87	74.7	12.6	0
Fiberglass	2052	50.8	3.8	0
Cylinders	1669			
Flax	1129	51.8	7.4	0
Carpet	450	63.8	4.4	0
Plastic	90	25.5	0	0
Culverts[a]	522			
Brush	272	39.3	29.4	14.0
Fiberglass	250	41.6	15.6	13.2

[a] Culverts include those with two, three, and four compartments. Production in relation to number of compartments is shown in Table 4.

Other bird species nesting on structures

Wood ducks (*Aix sponsa*) nested in 6 (0.3%) of 2,139 baskets with canopies from 1992–2006 and hatched five of these clutches. Redheads will nest in open-topped baskets in low numbers (Bishop and Barratt 1970, Doty et al. 1975, Haworth and Higgins 1993) but they did not use baskets with canopies. Other waterfowl that nested in baskets on rare occasions included blue-winged teal, gadwall, northern pintail (*A. acuta*), and canvasback (Bishop and Barratt 1970, Doty et al. 1975); none of these species used baskets with canopies in our management areas.

In cylinders, wood ducks nested in 30 (2.0%) of 1,669 structures in eastern South Dakota and hatched 24 (80.0%) of the clutches. Interestingly, 10 of 90 (11.1%) plastic cylinders were used by wood ducks while use of hay and carpet lined cylinders was lower at 1.5% and 1.1%.

Wire cylinders lined with grass hay received some use by nesting wood ducks in a study near Lake Erie (Bandy 1965). Artmann et al. (2001) observed no duck species other than mallards nesting in cylinders in northeastern North Dakota. Along with mallards, lesser scaup (*Aythya affinis*), redhead, blue-winged teal, and Canada geese sometimes nested in cylinders in the Saskatchewan parkland region (Eskowich et al. 1998). In southwestern Manitoba, Yerkes and Kowalchuk (1999) recorded redhead use of 4% of 385 nesting cylinders placed in semipermanent wetlands.

Duck use of cylinders in our study was restricted to mallards and wood ducks.

Only one wood duck used a culvert compartment (n = 522). Eight redheads nested on culverts, six (75%) hatched. Redhead use occurred when water levels were within 1 foot or less of the top of culverts, making access easy. All of the redheads nested under a compartment with a canopy. Mallards were the only duck species found nesting on culverts lacking canopies and partitions in 1988 and 1989 in eastern South Dakota (Ray and Higgins 1993).

Canada goose use of culverts has been covered in the section on culverts where possible interaction with mallards is discussed. Canada geese did not use cylinders but did nest in one covered basket for 7 consecutive years. We suspect that the original unmarked female, or possibly offspring hatched on this basket, homed to this structure. The basket was first used by a Canada goose when water levels were unusually high; the goose could swim up and examine the structure by peering through an entrance. The goose was able to repeatedly squeeze through an entrance and yet caused no visible damage to the fiberglass cover. As water levels dropped in subsequent years, a goose continued to use the basket even though flight was required to reach the structure and entrance to the nest would have been difficult.

Augmenting upland nesting cover with nesting structures

Nesting structures such as nest tubs were successfully used in Canada goose restoration efforts (Brakhage 1965). Elevated nesting structures may likewise provide an important management tool for mallards in areas where upland nesting cover is restricted and/or predation rates are severe (Ball and Ball 1991).

Nesting structures were recently included as one of the operational strategy options for improving mallard production in the cropland dominated landscapes of North and South Dakota (Executive Summary, Step-down plan from the Prairie Pothole Joint Venture, 2005).

Nesting success rates for mallards over the 15 years of our study of overwater nesting structures averaged 88.2% for all structures combined. Mallard nests/structure for baskets, cylinders, and culverts combined averaged 0.71 with 60% of all structures being used. At these rates each structure hatched an average of 0.63 mallard nests (success rate x mallard nests/structure).

Management with elevated nesting structures in prairie wetlands may be competitive in terms of cost per mallard produced with management of upland habitat for nesting cover. In the aspen parkland and southern boreal ecoregions in Saskatchewan, from 19 to 35 acres of dense nesting cover

Table 7. Mallard nests hatched/acre of nesting cover and projected acres of nesting cover needed to produce hatched clutches equivalent to average hatched nests/year produced in nesting structures. Average hatched mallard clutches/year in nesting structures were covered baskets (0.55), cylinders (0.60), and culverts with canopies and 2 to 4 compartments (1.01).

Citation	Site and cover	Nest success	Nests/acre	Hatched nests/acre	Structure equivelency: Structure type	Structure equivelency: Acres/nesting structure[a]
McKinnon and Duncan (1999)	Dense nesting cover, Saskatchewan	14.3%	0.20	0.029	Basket	19.0
					Cylinder	20.7
					Culvert	34.8
Kruse and Bowen (1996)[b]	Upland grass cover, Lostwood National Refuge, North Dakota	34.5%	0.10	0.034	Basket	16.2
					Cylinder	17.6
					Culvert	29.7

[a] Average number of hatched clutches for each of the nesting structure categories was divided by estimated hatched nests/acre in other studies to estimate number of acres of nesting cover needed to replace production per individual nesting structure.

[b] Nest success average for the four treatment areas and the area with highest nest densities (control) were used for the data from Kruse and Bowen (1996).

(grass-legume mixture) would be required to produce as many hatched mallard clutches as a single basket, cylinder, or culvert in our study (McKinnon and Duncan 1999) (Table 7).

On Lostwood National Wildlife Refuge, spring grazed, spring burned, summer burned/spring grazed, and control sites had mallard nesting densities ranging from 0.06 nests/acre to 0.10 nests/acre—the highest densities occurred in the control (Kruse and Bowen 1996). At an unusually high nest survival rate of 34.5%, 16 to 30 acres of upland habitat on Lostwood National Wildlife Refuge would be required to equal the average mallard production from a single basket, cylinder, or culvert in our study (Table 7).

MANAGEMENT SUGGESTIONS

Elevated nesting structures (baskets with canopies, cylinders, and culverts with canopies and partitioned compartments) placed in prairie wetlands near emergent cover were highly productive for mallards. Nesting material (flax straw) should be formed into the shape of a nest bowl prior to the nesting season. Where still intact, we recommend keeping the old nest bowl and just enhancing it with additional flax straw.

Mallard production on nesting structures was equivalent to that from considerable acreages managed for nesting cover. However, unlike ground cover, we recognize elevated nesting structures benefit only one or two target species.

Because of the difficulty in maintenance, we recommend woven fiberglass canopies on baskets in preference to brush canopies even though brush canopies may be more readily accepted by mallards; we make the same recommendation for woven fiberglass canopies and partitions on culverts. For cylinders, both flax lined and carpet lined types were highly effective in attracting nesting mallards but plastic models were not. Carpet lining is easier to install and maintain in cylinders than lining with flax straw but the flax lined cylinders (flax nesting material in addition to the lining type) may be more aesthetically appealing.

For both baskets and cylinders, we occasionally had supporting metal pipes bend or lean due to ice movements during late winter and early spring but this represented only about 5% of structures annually. It was not difficult to straighten or move those structures affected by rising water levels or drought.

Eskowich et al. (1998) concluded that nesting cylinders (tunnels) should be used instead of baskets (no canopy) in Saskatchewan as a management tool under the North American Waterfowl Management Plan because of low occupancy rates of nesting baskets. However, our observations show that baskets can be highly productive when appropriate canopies are developed for the structures.

Culverts with multiple compartments under canopies are an attractive option for mallards. These structures are the most productive of all structures we examined, and they can concurrently produce Canada geese without loss of mallard production. We could see no difference in mallard use on brush versus fiberglass canopies on four-compartment culverts; two-compartment brush models appeared to be more acceptable to mallards than combined two- and three-compartment fiberglass models.

Culverts with four canopied compartments (all quarters) were the most productive structures for mallards.

Four-foot diameter culverts provided plenty of space for four canopied compartments for mallards or three covered duck compartments and one open compartment for geese.

Canada geese did not nest on the top of canopies as long as at least one quarter of a 4-foot-diameter culvert was left open for a goose nest. Geese readily nested on brush canopies that covered all four quarters of a culvert but were less likely to use canopies on similar fiberglass models. Geese using portions of the culvert without a canopy (open-topped compartments) or nesting on the top of canopies need nesting material and will steal it by reaching into duck compartments. However, use of multi-compartment culverts by geese, with the exception of two- and three-compartment fiberglass models, did not decrease mallard production on the same structure.

A strong canopy that geese could not crush or destroy could serve as a deterrent to goose damage on four-compartment culverts. If both Canada goose and mallard production are goals, we suggest developing a canopy strong enough to support a nesting goose and shaped to support a goose nest above four underlying mallard compartments.

Canada geese did not nest within canopied compartments on culverts. On culverts without a canopy or compartments, Canada geese, depending on their abundance in the area, can dominate culverts, use much of the natural vegetation growth for nesting material, and greatly reduce mallard use.

Culverts in good working order rewarded our effort with strong mallard output. However, in 15 years of experience with culverts, we encountered some difficulties that have caused us to de-emphasize their use in South Dakota. Once culverts are placed on wetlands and filled with soil it is not practical to move them. Wetland water conditions vary greatly in eastern South Dakota, and many of our once-productive culverts became completely inundated by rising water levels that sometimes turned shallow marshes with interspersed emergents into open-water lakes.

With baskets and cylinders, we were able to move the support pipes to new sites to avoid inundation and to maintain productivity. In contrast, flooded culverts were lost to mallard production and were often tipped over, completely or partially, by the action of ice and water. Once tipped over they were unsightly during low water levels and, if water levels became high again, could even be a danger if motor boats were used on wetlands for duck hunting or fishing.

In North Dakota, Johnson (1992) recommended culverts over other elevated structures despite their initial cost, because of high use rates by mallards and Canada geese, their durability, and reduced maintenance costs. Zenner et al. (1992) warned against placing culverts in sites where water levels fluctuate excessively.

To reduce problems, we recommend culverts be placed in smaller wetlands where water level fluctuations are unlikely to inundate the structure and ice movement is less likely to cause tipping.

As occurred in our study area, water level increases and changes in wetland boundaries can exceed a manager's imagination unless historical information on water level fluctuations is carefully reviewed. Farm buildings and roads in northeastern South Dakota that were inundated by rising water levels beginning in the mid-1990s provided ample evidence of the problem. In many cases, multiple small wetlands that contained attractive patterns of emergent cover were connected by rising water levels into one large lake. This type of flooding can be disastrous to management of culvert nesting structures because they cannot be easily moved as water levels rise.

Early in these management efforts we had placed structures in numerous wetlands, both large and small, and over extensive landscape areas. Over time, we changed our strategy by moving most of our nesting structures to fewer sites to reduce travel and time costs. We chose wetlands or wetland communities with adequate emergent escape cover and invertebrate food sources for ducklings.

Brood survival research provided evidence that a large marsh with good interspersion of emergents, even if isolated from other wetlands, could provide unusually safe brood-rearing habitat for mallards produced on nesting structures (Stafford et al. 2002). Mallard broods produced on numerous baskets and cylinders on a large wetland (Mickelson Memorial Marsh) remained on the wetland, apparently because of the abundance of interspersed emergent cover and invertebrate foods and lack of nearby alternative sites.

We recommend focusing extensive basket and cylinder programs on larger semipermanent wetlands with abundant interspersed emergent cover. This can then be augmented with structures on smaller semipermanent and seasonal wetlands in surrounding areas. While a large wetland with good interspersion of emergent cover can sometimes provide all of the habitat needed to raise young, nearby wetlands enhance the habitat available for brood rearing and provide additional sites for expansion of the nesting structure program. By centering efforts in a few productive areas, travel and time costs can be greatly reduced.

We also recommend starting with a few nesting structures on a particular wetland or group of wetlands to determine if they are going to be used by mallards. After

Dedicated volunteer help can be highly important to nesting structure programs. Stan Lunquist (on left), retired conservation officer for SDGFP, provided uncounted hours of volunteer help in maintaining nesting structures.

evidence of structure acceptance by nesting mallards, the number of structures can be increased.

We recommend starting with nesting structures that have natural-appearing canopies such as flax-lined cylinders or fiberglass canopied baskets with attached flax or other straw to camouflage the top.

We used projecting wires (owl guards) to serve as deterrents to great horned owls perching on baskets and cylinders. Great horned owls will kill ducklings as they depart these nesting structures and will harass or even kill mallard hens. Although we lack experimental evidence, direct observation indicates that owl use was reduced by these wire deterrents.

It may be necessary to remove landing platforms from cylinders if owls learn to land on these. Lack of a landing platform did not deter mallard use of structures that had already been in place and in use during previous years. Metal predator guards around weathered or corroded pipes supporting baskets and cylinders may be needed once this source of food is discovered by raccoons.

As Ball and Ball (1991) and Zenner et al. (1992) remind us, artificial nesting structures do not solve the baseline problems of habitat loss facing waterfowl. Artificial nesting structures in prairie marshes benefit only a few selected species, particularly mallards, and thus represent a narrow approach to a broad conservation problem.

Perennial nesting cover is critical to ensuring successful duck production in the prairie pothole region (Greenwood et al. 1995, Reynolds et al. 2001). Within the prairie pothole region of South Dakota, remaining native rangeland varies from as low as 10% in Union County in the southeast to nearly 50% in Campbell County in the north-central region. Extensive native grasslands in Hand, Hyde, McPherson, and Edmunds counties in South Dakota's western prairie pothole region are experiencing the state's highest levels of sod busting (personal communication, Kurt Forman, U.S. Fish and Wildlife Service, Brookings).

Continued loss of native grasslands along with wetland drainage threatens to destroy the ability of waterfowl populations to bounce back in these and other prairie pothole regions during wet years when water conditions are optimal. These trends in habitat loss require changes in attitudes and the implementation of policies that support better land stewardship and the conservation of wetland, grassland, and, depending on the region, other key habitats. Well-maintained nesting structures can provide a useful management tool for mallards within this broader and more important habitat scenario.

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Appendix 1. Mallard nesting data for baskets with brush canopies (1992–1997) and fiberglass canopies (1994–2006) in eastern South Dakota.

Year	Number of baskets	Number with ≥1 nest	Number of nests	Occupancy (%)[a]	Nests/ 100 baskets[a]	Successful (%)
Brush						
1992	13	6	6	46.1	46.1	66.6
1993	13	11	13	84.6	100.0	69.2
1994	12	11	14	91.7	116.6	100
1995	17	17	19	100	111.8	84
1996	17	16	18	94.1	105.9	94
1997	15	15	17	100	113.3	94
All years	87	76	87	87.4	100.0	87.4
Fiberglass						
1994	50	15	16	30.0	32.0	100
1995	47	18	21	38.3	44.7	100
1996	157	79	88	50.3	56.1	97.7
1997	163	94	98	57.7	60.1	93.9
1998	227	135	150	59.5	66.1	93.3
1999	212	138	149	65.1	70.3	92.6
2000	208	131	140	63.0	67.3	93.5
2001	183	121	134	66.1	73.2	82.8
2002	178	91	96	51.1	53.9	93.8
2003	170	84	84	49.4	49.4	85.7
2004	143	72	75	50.3	52.4	89.3
2005	160	60	62	37.5	38.7	95.2
2006	154	85	89	55.2	57.8	96.6
All years	2052	1123	1202	54.7	58.6	92.3
Both types	2139	1199	1289	56.1	60.3	91.9

[a] Occupancy (%) rates and nests/100 structures are both presented because of multiple nesting in individual baskets. Percent occupancy and nests/100 structures are the same where there was no multiple nesting in individual structures.

Appendix 2. Mallard nesting data for cylinders lined with flax straw (1993–2006), carpet (1996–2006), or plastic (1996–2004) in eastern South Dakota.

	Year	Number of cylinders	Number with ≥1 nest	Number of nests	Occupancy (%)[a]	Nests/ 100 cylinders[a]	Successful (%)
Flax							
	1993	4	2	2	50.0	50.0	100
	1994	25	16	19	64.0	76.0	100
	1995	50	44	56	88.0	112.0	83.9
	1996	66	66	94	100	142.0	89.4
	1997	91	65	67	71.4	73.6	91.0
	1998	131	87	98	66.4	74.8	98.9
	1999	106	68	76	64.1	71.7	93.4
	2000	109	62	67	56.9	61.5	94.0
	2001	122	82	83	67.2	68.0	86.7
	2002	93	52	55	55.9	59.1	85.4
	2003	90	37	41	41.1	45.6	87.8
	2004	77	35	39	45.5	50.6	94.9
	2005	91	28	27	29.7	29.7	77.8
	2006	74	25	27	33.8	36.5	96.3
	All years	1129	669	752	59.3	66.6	91.0
Carpet							
	1996	3	1	1	33.0	33.3	100
	1997	3	3	3	100	100	100
	1998	9	7	7	77.8	77.8	71.4
	1999	27	15	16	55.6	59.3	93.8
	2000	29	23	24	79.3	82.8	95.8
	2001	32	23	32	71.8	100	87.5
	2002	70	56	57	80.0	81.4	94.7
	2003	67	51	51	76.1	76.1	100
	2004	67	46	50	68.7	74.6	72.0
	2005	70	47	47	67.1	67.1	91.5
	2006	73	35	39	47.9	53.4	87.2
	All years	450	307	327	68.2	72.7	89.6
Plastic							
	1996	8	0	0	0	0	
	1997	8	2	2	25.0	25.0	100
	1998	8	3	3	37.5	37.5	100
	1999	5	1	1	20.0	20.0	100
	2000	12	2	2	16.7	16.7	100
	2001	12	3	3	25.0	25.0	66.7
	2002	12	3	3	25.0	25.0	66.7
	2003	12	7	7	58.3	58.3	100
	2004	13	2	2	15.4	15.4	50
	All years	90	23	23	25.6	25.6	87.0
	All types	1669	999	1102	59.9	66.0	90.5

[a] Occupancy (%) and nests/100 structures are both presented because of multiple nesting in individual cylinders. Percent occupancy and nests/100 structures are the same where there was no multiple nesting in individual cylinders as with all plastic cylinders.

Appendix 3. Mallard nesting data for culverts with brush (1992–1998) and woven fiberglass (1994–2006) canopies and partitions in eastern South Dakota

	Year	Number of culverts	Number with ≥1 nest	Number of nests	Occupancy (%)[a]	Nests/ 100 culverts[a]	Successful (%)
Brush							
	1992	12	4	5	33.0	41.7	60.0
	1993	68	54	73	79.4	107.4	74.0
	1994	59	51	98	86.4	166.1	79.6
	1995	47	45	91	95.7	193.6	78.0
	1996	40	34	59	85.0	147.5	79.7
	1997	23	22	33	95.7	143.5	81.8
	1998	23	15	29	65.2	126.1	86.2
	All years	272	225	388	82.7	142.6	78.6
Woven fiberglass							
	1994	4	3	3	75.0	75.0	100
	1995	4	3	7	75.0	175.0	71.4
	1996	8	7	10	87.5	125.0	100
	1997	8	7	13	87.5	162.5	69.2
	1998	24	23	51	95.8	212.5	80.4
	1999	38	32	67	84.2	176.3	61.2
	2000	33	26	50	78.8	151.5	72.0
	2001	23	20	25	87.0	108.7	88.0
	2002	23	16	19	69.6	82.6	84.2
	2003	23	11	15	47.8	65.2	86.7
	2004	21	12	14	57.1	66.6	78.6
	2005	21	8	11	38.0	52.4	72.7
	2006	20	9	9	45.0	45.0	88.9
	All years	250	177	294	70.8	117.6	75.9
	Both types	522	402	682	77.0	130.6	77.4

[a] Occupancy (%) and nests/100 structures are both presented because of multiple nesting on individual culverts.

This brush covered basket on Redetzke Game Production Area in eastern South Dakota was used by one or more nesting mallards in every year of 6 years of operation.

3,000/$1.44 each/7-07