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Introduction

Malheur National Wildlife Refuge (NWR), Harney County, Oregon, is an important breeding area for Pacific Flyway Waterfowl. Trumpeter swans *(Olor buccinator),* Canada geese *(Branta canadensis),* and 14 species of ducks nest at Malheur NWR. The refuge is one of the most important redhead *(Aythya americana)* nesting areas in the western United States. Malheur NWR was established by President Theodore Roosevelt in 1908, primarily as a nesting area for migratory birds. The refuge also serves as an important migration stop for thousands of waterfowl and other migratory birds. Originally the refuge was called Malheur Lake Reservation and included only Malheur, Mud, and Harney Lakes. The 60,000 acre (24,280 ha) Blitzen River Valley was added in 1935, primarily to help protect the water supply for Malheur Lake. The 22,000 acre (8,900 ha) Double-O Ranch was acquired in 1941 and smaller parcels have been added more recently. Relatively complete records have been kept of annual waterfowl production estimates at the refuge since 1942. The objectives of this paper are to summarize those historical records, describe apparent trends, and discuss some of the factors that may influence waterfowl production at Malheur NWR.

Description of Malheur NWR

Malheur NWR is comprised of approximately 183,000 acres (74,100 ha) of shallow marshes, irrigated meadows, brush-grass uplands, alkali flats, and brushy alkali uplands. The refuge is 27 miles (43 km) wide and 41 miles (66 km) long. The elevation averages 4,100 feet (1,250 m). The climate is characterized by warm, dry summers and cold winters. Maximum temperatures seldom exceed 90°F (32°C) in the summer and subzero temperatures are recorded in most winters. The surfaces of most lakes and ponds are usually frozen from December through mid-February, but snow depths rarely exceed 6 inches (15 cm). Average annual precipitation is 9 inches (23 cm), occurring mainly from November through January with a smaller peak in May and June.

The principal sources of water are the Silvies and Blitzen rivers and Silver Creek (see Figure 1). The Silvies River originates in the Blue Mountains and empties into the north side of Malheur Lake. Silver Creek also originates in the Blue Mountains, but flows through the Double-O Ranch into the west side of Harney Lake. The Blitzen River arises on Steens Mountain, southeast of the refuge. It provides water for the Blitzen Valley before entering Malheur Lake. The Blitzen River is the

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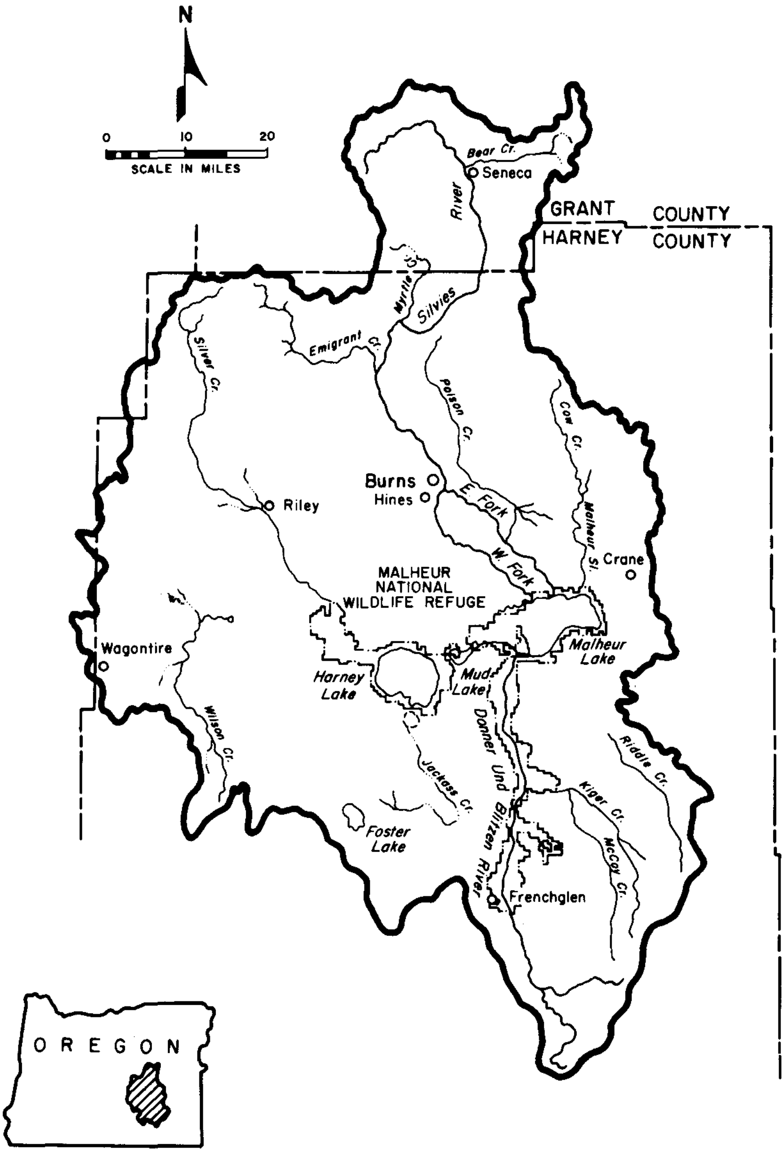

Figure 1. Map of the Harney Basin, Oregon, including Malheur National Wildlife Refuge.

largest source of inflow to Malheur Lake. From October 1971 through September 1973 the Blitzen River provided 57 percent of the inflow, the Silvies River provided 20 percent, 17 percent came from direct precipitation, and 6 percent came from Sodhouse Spring (Hubbard 1975).

Malheur Lake is one of the largest freshwater marshes in the western United

States. It ranges from less than 10,000 surface acres (4,000 surface ha) of water in dry years to over 60,000 surface acres (24,300 surface ha) in years with high runoff. Water depths range from 1 to 6 feet (0.3 to 2 m) with an average of 3 feet (1 m). Hardstem bulrush *(Scirpus acutus)* is the dominant emergent plant and sago pondweed *(Potamogeton pectinatus)* is the most important submergent plant. The western section of Malheur Lake is a series of natural ponds separated by a network of low islands and peninsulas. The center section, the deepest area of the lake, is predominantly hardstem bulrush interspersed with open water. The eastern section is the most alkaline and has the best stands of sago pondweed in most years. For more details on the hydrology of Malheur Lake see Hubbard (1975). Duebbert (1969b) reviewed the ecology of Malheur Lake.

At one time Mud Lake was a shallow marsh between Malheur and Harney Lakes. A channel and dike were constructed through the marsh. Although a couple of small marshes remain, most of Mud Lake is wet meadow or agricultural fields.

Harney Lake is the sump of the closed Harney Basin. Water often enters Harney Lake through Silver Creek, but a majority of the inflow enters from Malheur Lake through Mud Lake. Harney Lake ranges from zero to 30,000 surface acres (0 to 12,100 surface ha).

The Blitzen River Valley is flat, long and narrow. Small ponds and sloughs are interspersed among irrigated meadows and drier uplands. Most of the water in the valley wetlands originates from snow melting on Steens Mountain. When runoff is sufficient, ponds and sloughs are filled in the spring from runoff water diverted from the river through a complex system of canals, dams and dikes.

The Double-O Ranch is the westernmost section of Malheur NWR. This area receives inflow from Silver Creek and much of the area is watered by springs.

In addition to hardstem bulrush, common emergents at Malheur NWR are broad-fruited burreed *(Sparganium eurycarpum),* broad-leafed cattail *(Tyhpa latifolia),* Baltic rush *(Juncus balticus)* and alkali bulrush *(Scirpus maritimus).* Submergents are dominated by pondweeds *(Potamogeton spp.),* coontail *(Ceratophyllum demersum),* water milfoil *(Myriophyllum exalbescens)* and bladderwort *(Utricularia vulgaris).* Uplands are covered with big sagebrush *(Artemesia tridentata),* rabbitbrush *(Chrysothamnus spp.)* and black greasewood *(Sarcobatus vermiculatus).* These shrubs are interspersed with Great Basin wild rye *(Elymus cinereus),* alkali wild rye *(E. triticoides)* and salt grass *(Distichlis stricta).*

Methods

Annual waterfowl production estimates were reported in refuge quarterly or annual narrative reports, or annual production summaries. These reports are on file at the headquarters, Malheur NWR. Methods of estimating duck and goose production have varied through the years. From 1942 through 1945 estimates were based on general field observations; no standardized sampling procedures were used. From 1946 through 1952, production estimates were based on nest success from nesting studies. No standardized routes were used for breeding pair or brood counts. There was a dearth of information from 1953 through 1955. Production was based on general observations during routine field activities. From 1956 through 1960 production estimates were based on pair, nest, and brood observations from sample plots checked twice a month during the breeding and brooding season.

Those results were supplemented with general observations during aerial, boat, and ground surveys. From 1961 through 1967 estimates were based on random ground and aerial surveys of breeding pairs and random brood counts on the principal brooding areas.

Beginning in 1968, breeding pairs and broods were censused along standard aerial, boat, and ground routes and nesting success was determined from sample plots. Production estimates from 1968 through 1971 were based on extensive brood counts. From 1972 through 1980 production estimates for ducks and geese were calculated by multiplying the breeding pair estimate × nest success × mean brood size just prior to fledging.

Trumpeter swan production was determined by an actual count of cygnets just prior to fledging. Currently, a combination of aerial and ground surveys is used to determine the number of swan pairs, nests, broods, and cygnets.

Malheur Lake acreages were derived from staff gauge readings at the mouth of the Blitzen River (Refuge files). Readings recorded prior to April 1972 were converted to surface acreage using the table in Piper et al. (1939). Subsequent readings were converted using a table developed as a result of a U.S. Geological Survey hydrology study (Hubbard 1975). Sago pondweed beds were mapped from the air or by boat. Acreages were determined by using a polar planimeter or a "dot" method.

Grazing was reported in animal unit months (AUMs). One animal unit month is the amount of forage consumed by an adult cow in 30 days.

Data Limitations

Because of the changes in methodology through the years, waterfowl production estimates at Malheur NWR are difficult to interpret. Those changes sometimes coincided with changes in biologists and reflected a continuing effort to refine sampling techniques. The estimates were never intended to be interpreted as precise measurements of annual waterfowl production. They were calculated to provide general trend information. Production estimates at Malheur NWR are made difficult by the expanse of the area, limited access, and large fluctuations in water availability. These limitations prevent analyses of the data in any depth. I have assumed that the trends exhibited by these estimates reflect the actual historical trends in waterfowl production at Malheur NWR.

Results

Annual waterfowl production estimates from 1942 to 1980 averaged over 51,000 birds. Production was the highest in the 1940s averaging over 100,000 birds per year (Table 1). Between 1948 and 1954, production declined precipitously (Figure 2). Annual production averaged less than 44,000 birds in the 1950s and was even lower in the 1960s when less than 25,000 birds were fledged annually. A moderate upward trend followed during the 1970s when annual production increased to almost 33,000 birds. The highest annual estimate, recorded in 1948, was 150,950 waterfowl and the lowest was 6,900 reported in 1959.

Duck Production

Ducks comprised over 95 percent of the waterfowl produced annually at Malheur NWR. An average of over 48,000 ducks was produced annually, with a high of

Table 1. Average annual waterfowl production during four periods from 1942 to 1980 at Malheur National Wildlife Refuge.

Species	1942–1950	1951–1960	1961–1970	1971–1980
Gadwall	37,556	19,431	6,682	5,840
Mallard	32,556	5,518	3,457	4,592
Redhead	9,256	8,149	3,870	7,552
Cinnamon/blue-winged-teal	9,588	4,412	4,800	6,953
Pintail	7,278	587	926	1,139
Ruddy duck	5,044	969	866	2,823
Northern shoveler	3,478	1,093	627	1,187
American wigeon	455	146	685	706
Green-winged teal	867	237	238	486
Canvasback	266	241	350	420
Lesser scaup	589	298	227	156
Common merganser	152	103	90	53
Canada goose	4,267	2,480	1,381	1,237
Trumpeter swan	—	2.7	9.8	12.5
Total waterfowl	111,352	43,667	24,209	33,157

146,950 in 1948 and a low of 5,610 in 1959. Of the ducks produced from 1942 to 1980, 79 percent were dabblers and 21 percent were divers, but these proportions were quite variable (Figure 3). For example, in 1959 about 2 percent of the ducks produced were divers, but in 1979 almost 46 percent were divers. More gadwall *(Anas strepera)* were produced than any other species from 1942 to 1980 (Table 2). The next five most productive ducks were mallard *(Anas platyrhynchos)*, redhead, cinnamon/blue-winged teal *(Anas cyanoptera/Anas discors)*, pintail *(Anas acuta)*, and Ruddy duck *(Oxyura jamaicensis)*. Cinnamon and blue-winged teal are lumped because of the difficulty in distinguishing between females of the two species during field censuses. Ratios of male teal suggest that 90 percent or more are cinnamon teal. Other ducks that nested included northern shoveler *(Anas clypeata)*, American wigeon *(Anas americana)*, green-winged teal *(Anas carolinensis)*, canvasback *(Aythya valisineria)*, lesser scaup *(Aythya affinis)*, common merganser *(Mergus merganser)*, and ring-necked duck *(Aythya collaris)*. Broods of ring-necked ducks were observed in 1964, 1971, and 1980 (Marshall and Duebbert 1965, Cornely et al. 1981). They apparently do not nest every year and are not common when they do nest.

In the 1970s the ranking of ducks in order of mean annual production was different than the long term ranking above. For the period 1971 to 1980, ranking was as follows: (1) redhead, (2) cinnamon/blue-winged teal, (3) gadwall, (4) mallard, (5) ruddy duck. During that period the production of redhead, cinnamon/blue-winged teal, American wigeon, and green-winged teal was above the long term average.

Since 1942, production trends have been similar for most duck species (see Table 1). Except for American wigeon and canvasback, the highest production reported

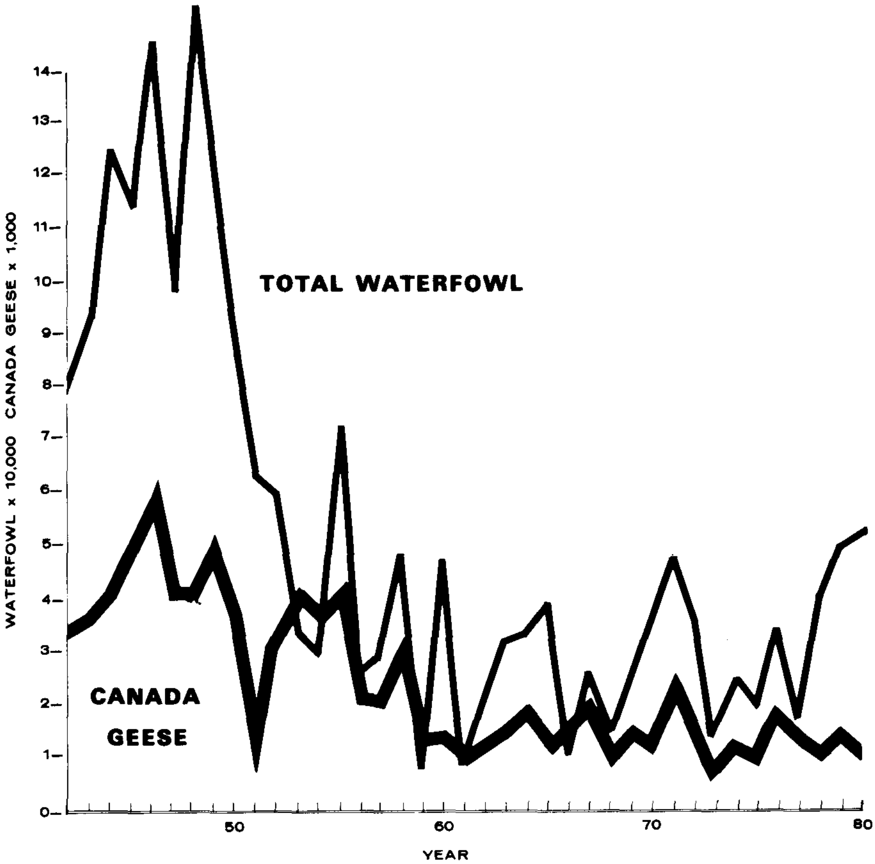

Figure 2. Total waterfowl production and Canada goose production at Malheur National Wildlife Refuge, 1942–1980.

for each species was in the 1940s. The first record of canvasback nesting in the Harney Basin was not until the late 1930s. Every species declined in production during the 1950s. Mean production declined again in the 1960s as production of nine species declined, one was unchanged, and four increased. Production of American wigeon and canvasback reached new highs in the 1960s. In the 1970s the average production of most duck species was higher than in the 1960s. Production of American wigeon and canvasback was the highest ever, but that of gadwall, lesser scaup and common mergansers was the lowest on record. The species that suffered the greatest decline in production between the 1940s and the 1970s were mallard, gadwall and pintail.

Canada Goose Production

Production of Canada geese at Malheur NWR was highest in the 1940s and declined through the 1950s and 1960s (Figure 2, Table 1). Unlike production of

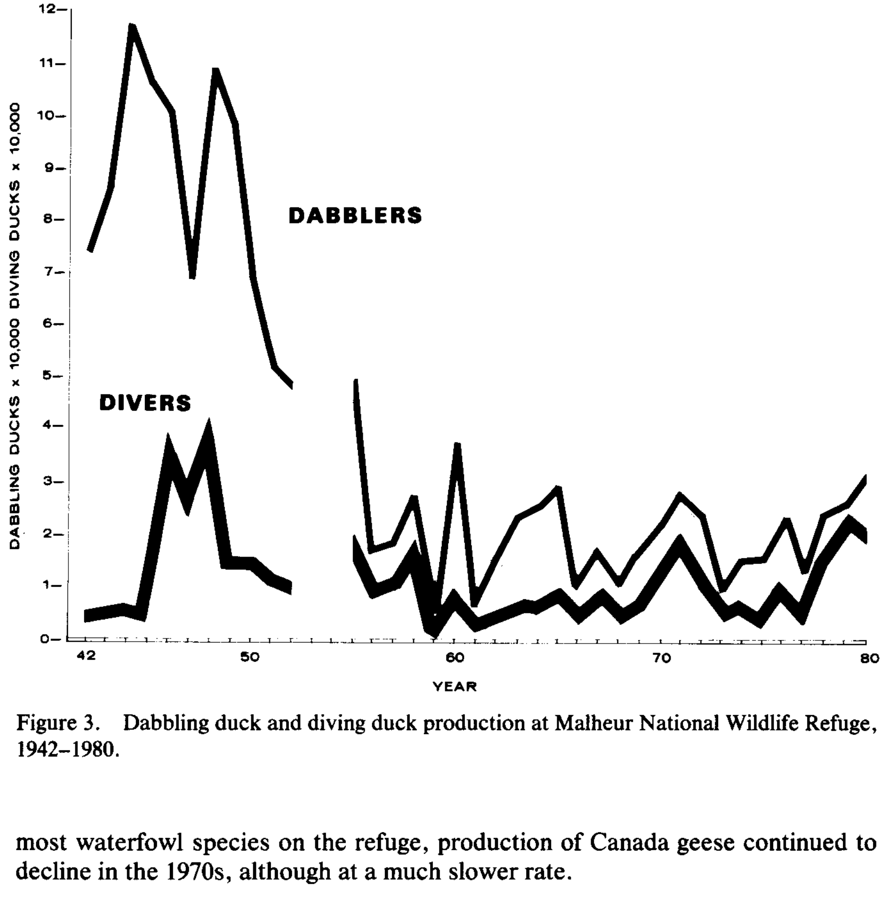

Figure 3. Dabbling duck and diving duck production at Malheur National Wildlife Refuge, 1942–1980.

most waterfowl species on the refuge, production of Canada geese continued to decline in the 1970s, although at a much slower rate.

Trumpeter Swan Production

There are no historical records of nesting trumpeter swans at Malheur NWR. Transplants from Red Rock Lakes NWR, Montana were initiated in 1939 and continued until the first brood was observed at Malheur NWR in 1958. From 1958 through 1980, 239 cygnets were fledged at Malheur NWR. Mean brood size was 2.9 and the mean number of successful broods was 3.6 annually. Mean annual trumpeter swan production gradually increased through the 1960s and 1970s (Tables 1 and 2).

Discussion

Because waterfowl are migratory, conditions and events many miles away as well as locally may influence production at Malheur NWR. Because numerous factors may be invloved and many of them may be interrelated, direct cause and effect relationships are difficult to identify and analyze. Conditions and events that occur outside Malheur NWR and some local factors are beyond the control of the

Table 2. Range and average annual production of 14 waterfowl species during 1942–1980 at Malheur National Wildlife Refuge.

Species	High production	Year	Low production	Year	Mean
Trumpeter swan	33	1979	0	1959, 1961 1977	10
Canada goose	6,000	1946	680	1973	2,548
Gadwall	45,000	1948, 1949	2,000	1959	16,648
Cinnamon/blue-winged teal	17,120	1949	1,100	1957	6,463
Mallard	50,000	1944	600	1959	11,287
Pintail	20,000	1944, 1945	0	1959	2,507
Northern shoveler	8,000	1948, 1949	0	1959	1,528
American wigeon	2,051	1980	50	1950, 1959	508
Green-winged teal	2,000	1948	30	1955, 1962	458
Redhead	30,000	1946	100	1959	7,100
Ruddy duck	15,000	1948	10	1959	2,434
Canvasback	1,400	1980	0	1959, 1961	332
Lesser scaup	2,000	1948	0	Several	310
Common merganser	1,000	1944	0	Several	98

refuge staff. Other factors may be modified to some degree by refuge management activities.

Off-refuge Factors

The quality and quantity of wintering habitat, food availability at migration stops, and hunting, disease, and other mortality at wintering areas or during migration may influence the numbers and condition of waterfowl that nest at Malheur NWR. Although some locally produced birds are harvested in the Harney Basin, most of the hunting mortality of mallards and Canada geese appears to occur after they have left the area (Jarvis and Furniss 1978, Furniss et al. 1979). The highest hunting pressure was in the Central Valley of California. In addition, significant numbers of Canada geese produced at Malheur NWR were harvested in southern Alberta, Canada. The geese were probably harvested in Canada during molt migration (Krohn and Bizeau 1979).

Conditions in other nesting areas may influence the number of breeding pairs at Malheur NWR. In 1980 and 1981, when some of the Canadian prairie breeding areas experienced drought conditions, increased numbers of blue-winged teal were noted at Malheur NWR. A similar occurence was noted at Tule Lake NWR (Jim Hainline, pers. comm.). It is possible that some of these teal returned southward after finding conditions at their traditional nesting areas unfavorable.

Uncontrolled Local Factors

Local weather influences waterfowl production at Malheur NWR. A prerequisite for successful nesting and brooding is an adequate water supply. In the semi-arid climate of southeastern Oregon, water availability depends, to a large degree, on runoff from the surrounding mountains. Mountain snow pack varies considerably from year to year causing marked fluctuations in water availability. The amount of runoff influences the amount of suitable nesting habitat.

For the period 1955 to 1980, there is a significant correlation between diving duck production and the size of Malheur Lake (Figure 4). The highest correlation is with minimum annual lake acreage ($r = 0.6134, P < 0.01$), followed by mean annual lake acreage ($r = 0.6069$, $P < 0.01$), and maximum annual lake acreage ($r = 0.4937$, $P < 0.05$). There is not a significant correlation between lake acreage and dabbling duck or goose production. A low, but significant, correlation is evident between trumpeter swan production and minimum lake acreage ($r = 0.4530$, $P < 0.05$) and mean lake acreage ($r = 0.4382$, $P < 0.05$), but not maximum lake acreage ($P > 0.05$).

Hail, snow, or freezing temperatures can occur during the nesting season and may stress or kill incubating females and young birds. Uncontrolled runoff has destroyed numerous waterfowl nests in recent years by flooding. Hot, dry summer weather may dry up important brooding areas before the young birds fledge.

Local Factors That May Be Controlled

Sago pondweed provides food for breeding waterfowl and their young. The pondweed beds also provide excellent habitat for numerous aquatic invertebrates that provide important food resources. There is a low, but significant correlation

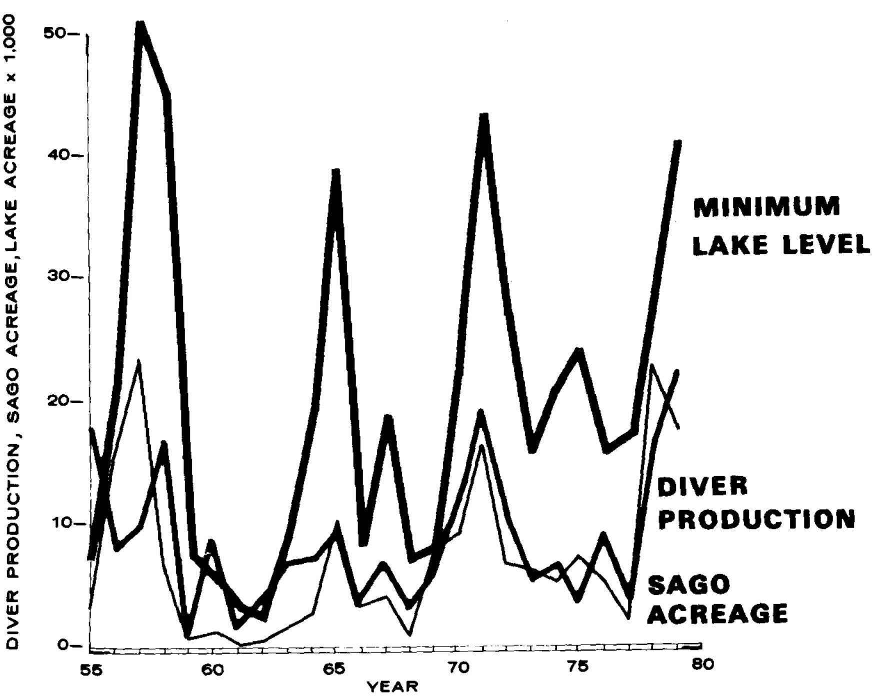

Figure 4. Minimum annual acreage of Malheur Lake (broad line), diving duck production (medium line), and acreage of sago pondweed in Malheur (narrow line), 1955–1980.

between sago pondweed and diving duck production from 1955 to 1980 ($r = 0.4020$, $P<0.05$). Sago pondweed production fluctuates greatly, especially in Malheur Lake. There appears to be an inverse relationship between carp *(Cyprinus carpio)* numbers and sago pondweed production. Carp were accidentally introduced in the early 1920s. In the 1950s, greatly reduced submergent vegetation was thought to have been the result of the activities of carp. This led to a major carp control program in 1955 with subsequent efforts in 1960–1961, 1968–1969, and 1977. Following each control program, production of sago pondweed increased dramatically (Figure 4). Because carp control was conducted only during drought years, some of the increased pondweed productivity may have been due to drying out of large areas of the lake bed. The highest redhead production since 1948 occurred in 1979, a year that combined excellent water availability and excellent sago pondweed production.

Numerous authors have suggested that annual grazing and/or mowing reduced waterfowl production (Keith 1961, Gates 1962, Martz 1967, Duebbert 1969a, Krapu et al. 1970, Page and Cassel 1971, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1976, Kirsch et al. 1978). A study conducted at Malheur NWR in 1964 provided indirect evidence that annual mowing and grazing reduced vegetation density and waterfowl production (Jarvis and Harris 1971). More recent studies (Clark 1977, Jarvis 1980) have substantiated this relationship.

Refuge records indicate an increase in grazing from less than 40,000 AUMs in 1942 to over 100,000 in 1951 (Figure 4). Grazing remained high through the 1950s and 1960s. After peaking at about 126,600 AUMs in 1973, grazing has decreased steadily, reaching 42,056 AUMs in 1980. Annual mallard production exhibits a significant negative correlation ($r = 0.7507$, $P<0.01$) to AUMs of grazing and haying (Figure 5). Other waterfowl with significant ($P<0.01$) negative correlations between production and AUMs are green-winged teal ($r = -0.5373$), gadwall ($r = -0.4728$), and Canada geese ($r = -0.4255$). Before grazing reductions were initiated, virtually every grazable acre of Malheur NWR was grazed annually. Since the early 1970s nesting cover for upland nesting waterfowl has improved in both quantity and quality.

Numerous nests of waterfowl are destroyed by predators each year. Sooter (1946) reported that common ravens *(Corvus corax)* and coyotes *(Canis latrans)* were major predators of waterfowl nests at Malheur NWR. Jarvis and Harris (1967) reported that 34.6 percent of the 78 Canada goose nests he studied in 1964 were destroyed by predators. Raccoons *(Procyon lotor)*, coyotes, and ravens were the major nest predators. In 1974 and 1975, 72 percent of the duck nests in study plots in the upper Blitzen River Valley were depredated. Avian predators accounted for 57 percent of that total, and mammals caused 36 percent (Clark 1977). Nest predation remained high during a follow-up study from 1976 through 1979 (Jarvis 1980). A nesting study in the Double-O Ranch area disclosed high nest predation rates in 1981. Predators destroyed 88 percent of the waterfowl nests in the study plots.

In addition to destroying nests, predators kill both immature and adult waterfowl. The extent of this predation is difficult to assess and, therefore, it is not known to what degree this affects production.

From the mid-1930s until 1976 some type of predator control was practiced at Malheur NWR. A variety of methods were used, including poisons traps, and

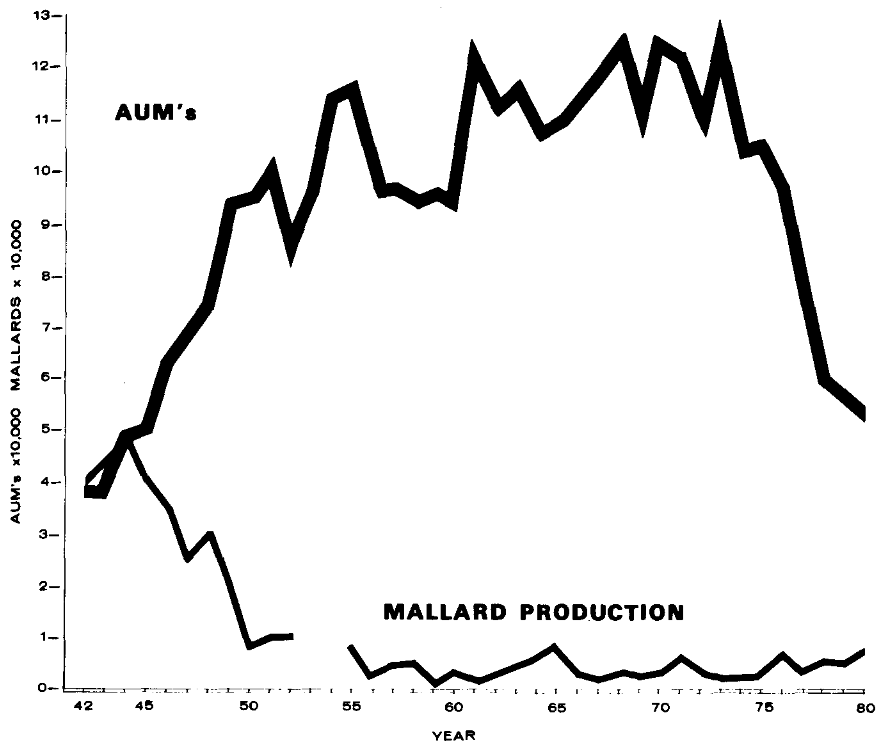

Figure 5. Grazing in animal unit months (AUMs) and mallard production at Malheur National Wildlife Refuge, 1942–1980.

guns. Poisoning was halted during the winter of 1970–1971. A very limited amount of shooting occurred from 1976 to 1980 in peripheral areas of the refuge. Predation of nests appears to have increased following the halting of intensive predator control.

In general, water availability is dictated by snow pack, but some measure of water control is possible with man-made water control structures. If sufficient water is available, the timing and depth of the flooding of meadows and ponds can be regulated. General observations suggest that early spring flooding of meadows attracts more pairs of early nesting species than later flooding. Similar results were reported by Schroeder et al. (1976) in Colorado. Water control can also influence the quantity of nesting habitat and the amount and distribution of brood water. Results from nesting studies at Malheur NWR suggest that water timing, distribution, and depth are important to nesting waterfowl (Clark 1977, Jarvis 1980). These factors need to be examined in more detail so that water management planning can be refined.

Interactions

The factors discussed above interact in complex ways. The number and condition of breeding waterfowl determines the potential for production in a given year. The complex interactions of the breeding birds with each other, with the habitat, with the weather, and with predators determines how much of that potential will be realized. If all of these factors are favorable, a large number of waterfowl can be produced at Malheur NWR. If one or more of the factors are unfavorable, production will be reduced. For example, if adequate water is available, but production of submergent vegetation is poor, diver production may be relatively low. Although cover for upland nesting waterfowl improved after grazing was reduced at Malheur NWR, the increase in waterfowl production was not as pronounced as some observers expected. This may be due, in part, to the simultaneous decrease in predator control.

Two or more unfavorable conditions may combine to compound the problems of breeding waterfowl. Poor cover or poor water conditions may increase the susceptibility of nests and young birds to predation. High water can limit the amount of upland nesting habitat, causing waterfowl to concentrate their nesting in relatively small areas. This may also leave them more vulnerable to predation. These are just a few examples of the almost endless list of interactions that can influence waterfowl production.

Conclusions

The production of waterfowl at Malheur NWR is influenced by a number of interacting factors. Some of these, such as the number of breeding pairs of waterfowl that arrive in the spring, the availability of water, and local weather conditions, are largely uncontrolled. Others, like upland nesting habitat, submergent vegetation, and predation, may be managed to some extent. Increases in grazing between the early 1940s and the early 1970s reduced the quality and quantity of upland nesting cover, but this trend has been reversed. Submergent vegetation production problems in Malheur Lake remain an important influence on diving duck production. The destruction of numerous waterfowl nests by predators continues. Despite these problems, it appears that the long decline in waterfowl production at Malheur NWR has been reversed. With additional research and refined resource management this positive trend should continue. As more waterfowl breeding habitat is lost to urban and agricultural development, production areas, such as Malheur NWR, will be increasingly important.

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