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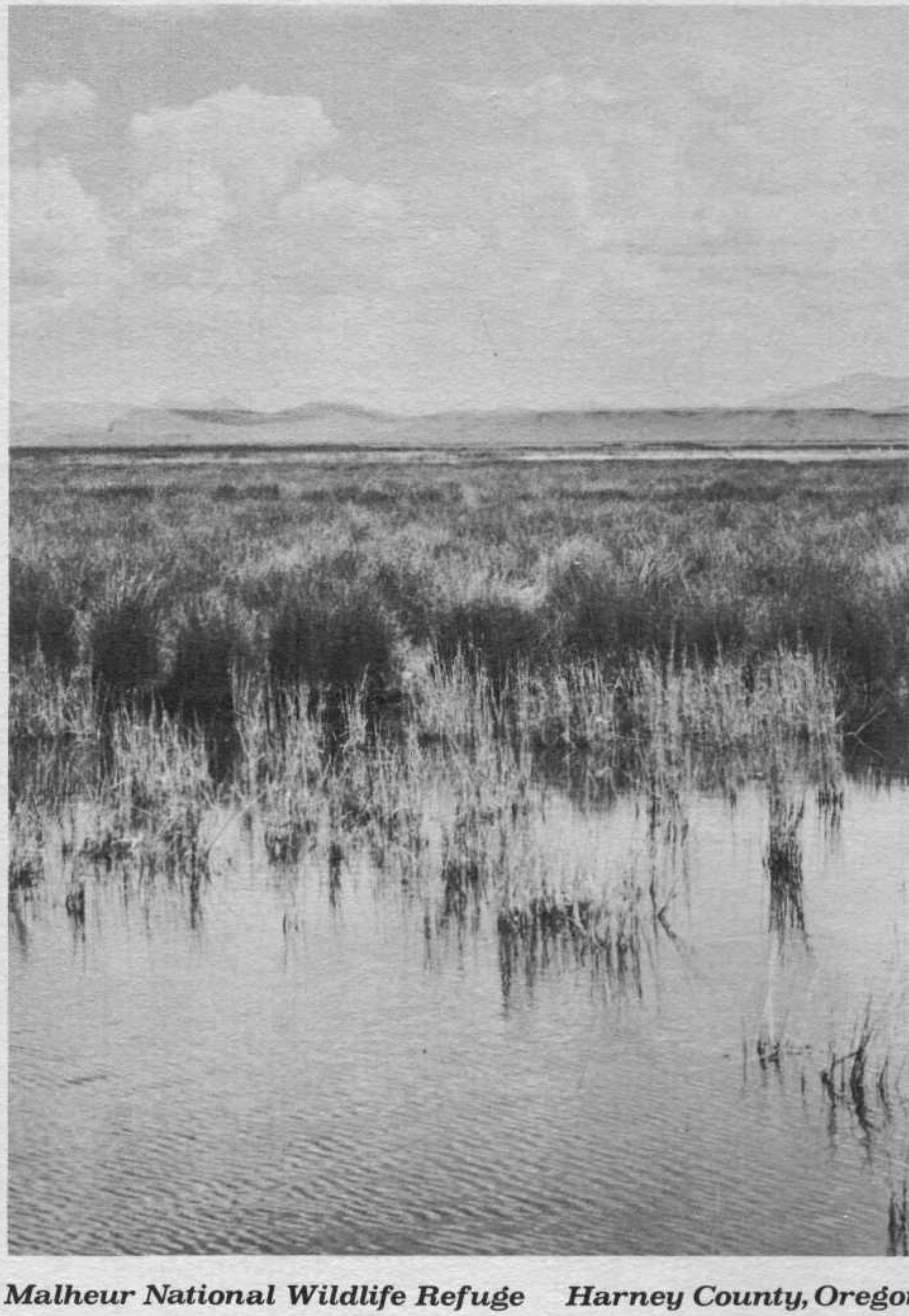
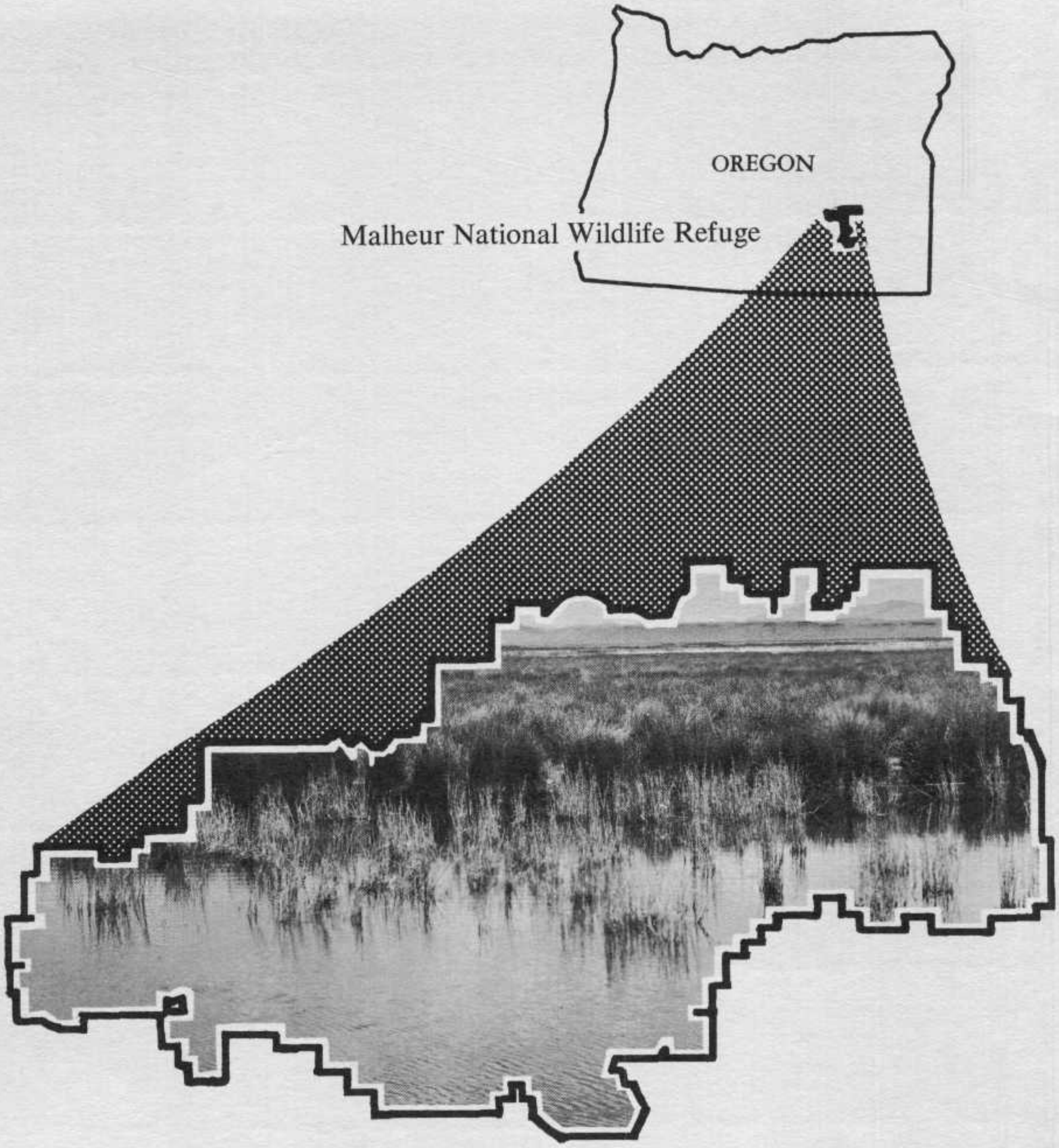
the ecology of malheur lake

And Management Implications



Malheur National Wildlife Refuge   Harney County, Oregon



MALHEUR LAKE

THE ECOLOGY OF MALHEUR LAKE
and management implications

By

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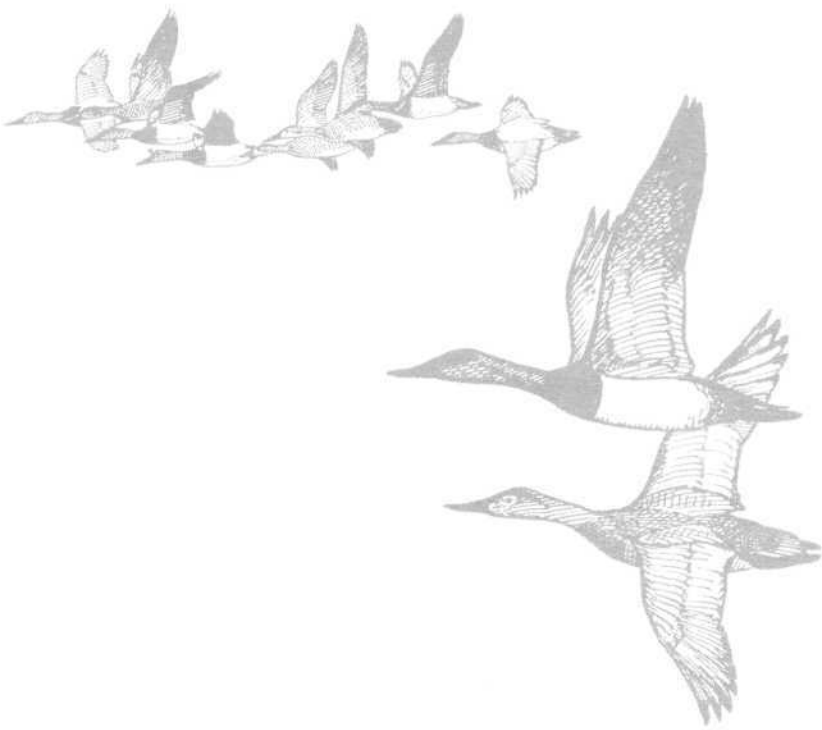

The high biological productivity of the Malheur Lake marshes led to the establishment of Malheur and Harney Lakes as one of the first National Wildlife Refuges in 1908. The primary management objective for the lake when it was established as a refuge was preservation and propagation of migratory waterfowl, and the same is true today.

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INTRODUCTION

Malheur Lake is one of the largest inland marshes in the United States and has the added distinction of being essentially in a natural condition. It is one of the most important sections of the Malheur National Wildlife Refuge and comprises about one-third of the total refuge acreage of 181,000 acres.

Malheur Lake is really a marsh. When water levels are at a maximum, it covers approximately 50,000 acres and is about 20 miles long by 12 miles wide. The great biological productivity of the lake region, especially the size and diversity of its bird fauna, has impressed amateur and professional naturalists from the late 1800's to the present. Although *Malheur Lake* is one of the outstanding aquatic habitats in the western United States, details of its ecology are known to only a few. Therefore, it is appropriate to focus attention on the area.

GEOLOGY

Many important aquatic habitats in North America were created by the action of one or more geologic processes, and Malheur Lake is no exception. Volcanism, glaciation, and wind and water erosion were all important in developing the land surface. Surface strata of Harney Basin, wherein Malheur and nearby Harney Lakes lie, date back in geologic time to the Quarternary Period which began about one million years ago. The valley fill consists of alluvium and lake deposits, as well as aeolian sediments derived largely from volcanic rocks of adjacent uplands. Geologists infer that alluviation of Harney Basin followed after an extrusion of basalt dammed Malheur Gap (near Princeton), a former drainage outlet for the basin.

During the Pleistocene epoch, increased precipitation and decreased evaporation formed a "pluvial" lake in Harney Basin. When at its highest level, this expanded and deepened lake drained eastward into the Malheur River. Drainage was first through a channel near Princeton, and later through one near Crane when lava flows blocked the former outlet near Malheur Caves (Baldwin 1964). At the end of the Pleistocene glacial stages (about 10,000 years ago), warmer and drier conditions caused the pluvial lake to lower and its water no longer had an outlet to the sea. Much of this former lake bottom is now brush-covered desert or seasonally flooded grass-sedge meadowland, with Malheur and Harney Lakes remnants of the Pleistocene lake.

Shore lines indicating the maximum depth of the Pleistocene lake are not well defined, as they are at other pluvial lakes in the Great Basin. It is doubtful, however, that its depth ever exceeded 50 feet.

We can infer that a marsh similar to the present one has occupied Malheur Lake basin since the end of the Pleistocene, or for nearly 10,000 years. Its basic ecology has apparently changed little, although there have been frequent fluctuations between wet and dry conditions. Its biota is well adapted to these ecological extremes, however. As will be discussed later, the biological productivity for which the marsh is known may be dependent upon periodic fluctuations in water levels.

GEOGRAPHY AND TOPOGRAPHY

Malheur Lake occupies a generally flat basin. Its principal water supply is from melting snow on nearby mountain ranges. Steens Mountain on the south (Blitzen River watershed) and the Blue Mountains on the north (Silvies River watershed) provide most of the water. About 45 percent originates from the former source, and 55 percent from the latter. As most of this water originates as snow, the amount reaching the lake varies greatly from year to year. Appendix 1 summarizes lake sizes from 1735 to 1965. During the earliest years (1735-1865) size can be inferred only from tree-ring studies indicating climatic trends (Piper *et al.,* 1939), but between 1865 and 1937 records of various observers can be used. After 1938, surface elevations and acreage estimates are based on staff gauge readings. The information suggests severe and protracted droughts at intervals of 70 to 90 years, with lesser droughts at various other times. Very high water levels appear to follow a similar cycle. Between extreme drought years and extremely high water years, almost every possible variation in water condition may be expected.

The lake lies at about 4,100 feet above sea level. Lowest point in its basin is 4,089 feet and highest surface elevation of water recorded in historic time was about 4,095 feet (1952 and 1958). The lake has been completely dry only once since the 1850's (1934), but in 1961 it was reduced to 500 acres.

Upland vegetation surrounding Malheur Lake falls generally within the sagebrush-greasewood association, within the province of the Great Basin sagebrush association. Tertiary and Quarternary lava flows are prominent. Nearer the lake, Quarternary gravel, sand, and silt occur. Alkaline salts are generally abundant in the watersheds and are reflected in lake water chemistry.

Numerous silt ridges six to ten feet higher than the lake floor occur at various places. These were probably formed by wind action during drought of past geologic time. Many are high enough to support terrestrial plants. These ridges form peninsulas and islands, important elements in creation of a desirable interspersion for wildlife of upland and aquatic habitat types. This wind-formed habitat is most prevalent along the north portion of the basin, between Graves Point and the Narrows. Cole Island and Pelican Island are examples of larger formations of this kind.

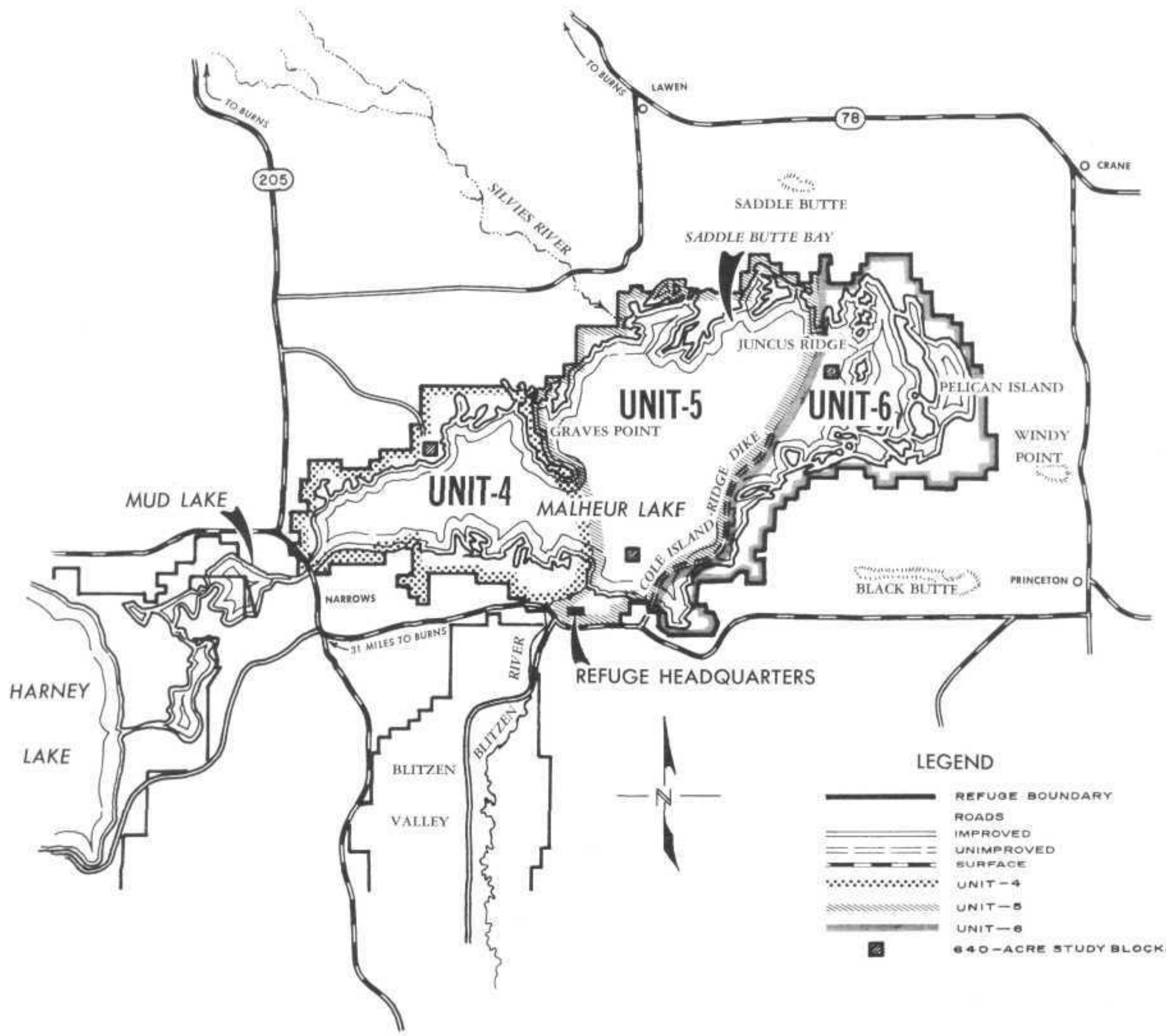
Big sagebrush *(Artemisia tridentata),* rabbitbrush *(Chrysothamnus nauseosus)* and greasewood *(Sarcobatus vermiculatus)* are dominant shrubs on adjacent uplands. Several species of grass are interspersed with the brush, giant wild rye *(Elymus cinereus)* and desert saltgrass *(Distichlis stricta)* being especially prominent.

Chemical composition of marsh water ranges from moderately alkaline (pH 7.9) in the west and center sections to highly alkaline (pH 8.6) in the east section (July, 1965). Alkalinity varies from year to year, depending on the amount of water present. During high water periods water flows from Malheur Lake to Harney Lake, carrying mineral salts with it. This flushing action is of great importance in maintaining a water chemistry in Malheur Lake favorable for developing desirable aquatic plants and invertebrates. These lower food-chain elements provide the basic attraction for the large number and variety of water birds that have historically frequented the lake.

ECOLOGICAL UNITS

Malheur Lake contains three distinct ecological units separated by two low north-south ridges, Graves Point and Cole Island. From west to east these areas are designated Units 4, 5, and 6 (part of a management unit numbering system applied to the entire refuge, hence numbers other than 1, 2, and 3). Figure 1 shows details of the lake.

Figure 1. Location of ecological units in Malheur Lake.



Unit 4 is a series of ponds 10 to 500 acres in size, separated by a complex network of upland islands and peninsulas (Figure 2). Water is generally shallower than in Unit 5 and less alkaline. Emergent vegetation is mainly hardstem bulrush *(Scirpus acutus)*, burreed *(Sparganium eurycarpum)*, cattail *(Typha latifolia)*, and Baltic rush *(Juncus balticus)*. Pondweeds, mainly *Potamogeton pectinatus* and *P. pusillus*, are dominant submergent plants. Uplands are vegetated by saltgrass and greasewood.

This unit is flooded when the surface elevation of the lake reaches 4092.00 feet. It is one of the refuge's best waterfowl production areas.

Figure 2. View of Unit 4, Malheur Lake, October 8, 1965, looking westward from Graves Point. Surface elevation of lake 4039.0 feet above sea level.

The center section of the lake (Unit 5) is predominantly a hardstem bulrush marsh with interspersed open zones (Figure 3). It is the lowest part of the basin and receives inflow from both the Silvies and Blitzen Rivers. Thus, water is deeper and more permanent than in the other units. Although bulrush dominates, shallower zones support good growths of burreed, cattail, Baltic rush, and sedges. Water milfoil *(Myriophyllum exalbescens)* is the most widespread and abundant submergent, although sago pondweed occurs abundantly in the northeast portion.

Figure 3. View of Saddle Butte Bay, in the northeast portion of Unit 5, August 3, 1966. Surface elevation 4091.7 feet.

Duck production on this unit is restricted mainly to its outer fringes. Herons, egrets, eared and western grebes, and black and Forster's terns are major nesting birds. Large numbers of pintails molt here (populations ranging from 20,000 to 25,000) along with fewer numbers of mallards, widgeons and other ducks.

Unit 6 is the most alkaline portion of the lake and also has the most open water. When surface elevations reach 4091 feet, water flows eastward into this area through gaps in Cole Island ridge.

This area contains the best stands of sago pondweed and traditionally has the greatest seed production. Low ridges are vegetated with nearly pure associations of Baltic rush and foxtail barley *(Hordeum jubatum);* higher areas are covered with saltgrass and greasewood. Figure 4 shows a portion of this unit.

Figure 4. View west over "Juncus Ridge" toward Cole Island Dike, Unit 6. Surface elevation 4092.9 feet, April 28, 1966.

PLANT ECOLOGY

Although Malheur is commonly called "lake," the term "marsh" is more descriptive, for it contains vast quantities of submerged and emergent aquatic vegetation and the water does not exceed 6 feet in depth. On the basis of water depth, water chemistry, and vegetation, it is classified as an Inland Deep Fresh Marsh (Shaw and Fredine, 1956), although some portions of Unit 6 have characteristics typical of an Inland Saline Marsh.

In zones of emergent vegetation with the deepest water, hardstem bulrush is strongly predominant, and in shallower areas broad-fruited burreed, broad-leaved cattail, and Baltic rush are locally abundant. The clumped distribution of these emergent plant zones adds greatly to the overall value of the marshes as habitat for waterfowl and other water birds.

In zones of shallowest water, including those areas which may only be flooded for short periods, foxtail barley, Baltic rush, various species of sedge *(Carex spp.,* especially *C. atherodes)* and spike rush *(Eleocharis palustris)* cover large areas. Other conspicuous moist soil plants include water plantain *(Alisma plantagoaquatica),* broadleaved arrowhead *(Sagittaria latifolia),* and silver weed *(Potentilla anserina).* Common grasses associated with moist soil zones which may also be temporarily flooded are desert saltgrass, alkali ryegrass *(Elymus triticoides),* meadow barley *(Hordeum brachyantherum)* and squirrel-tail barley. Coarse weeds such as flixweed *(Descurainia sophia),* Canada thistle *(Cirsium arvense),* hoary nettle *(Urtica holosericea),* and others occupy various-sized areas of disturbed soil. Many basically terrestrial plants rapidly invade bare soil zones of lake bottom when water levels recede. Flixweed and foxtail barley cover large areas of exposed lake bottom in relatively monotypic stands during low water years.

On black silt soils in Units 4 and 5, which contain less alkaline salts than those in Unit 6, a great variety of plants invade recessional mudflats. Succession proceeds rapidly from bare mud to solid vegetation. Common invaders are: golden dock *(Rumex persicarioides)*, dock-leaved persicaria *(Polygonum lapathifolium)*, American speedwell *(Veronica americana)*, marsh speedwell *(Veronica scutellata)*, red goosefoot *(Chenopodium rubrum)*, curly-leaved dock *(Rumex crispus)*, western dock *(Rumex occidentails)*, great swamp senecio *(Senecio hydrophilus)*, elegant downingia *(Downingia elegans)*, Cusick's allocarya *(Plagiobothrys cusickii)*, field mint *(Mentha arvensis)*, silver weed, diffuse cinquefoil *(Potentilla millegrana)*, and others. On the more highly alkaline soils in Unit 6, there are fewer species growing on recessional mudflats. In this area common invading plants are: curly-leaved dock, red goosefoot, Pahute weed *(Suaeda depressa)*, and other alkali-tolerant plants.

While emergent vegetation is most obvious to a casual observer, it is the vast quantities of submerged plants—primarily sago pondweed—that make Malheur Lake such good waterfowl habitat. The species composition of submerged aquatic vegetation is variable from year to year, depending upon environmental factors. Table 1 presents various species of submerged vegetation and their relative rank in abundance during the period 1958-65, which encompassed a variety of habitat conditions and may be considered fairly representative.

Table 1. Species composition of submerged aquatic vegetation, Malheur Lake, Oregon 1956-58, 1964-65 (5-year average).

Species	*Percent occurrence in samples*	*Relative Rank*
Sago pondweed *(Potamogeton pectinatus)*	80	1
Horned pondweed *(Zannichellia palustris)*	36	2
Water milfoil *(Myriophyllum exalbescens)*	34	3
Muskgrasses *(Chara sp., Nitella sp.)*	32	4
Coontail *(Ceratophyllum demersum)*	18	5
Small pondweed *(Potamogeton pusillus)*	10	6
Leafy pondweed *(Potamogeton foliosus)*	4	7
White water buttercup *(Ranunculus aquatilis)*	4	7
Rocky mountain waterweed *(Elodea canadensis)*	1	8
Bladderwort *(Utricularia vulgaris)*	Tr.	9
Widgeon grass *(Ruppia maritima)*	Tr.	9

In the above table percentages are based on the number of times respective species occurred in samples taken along line transects.

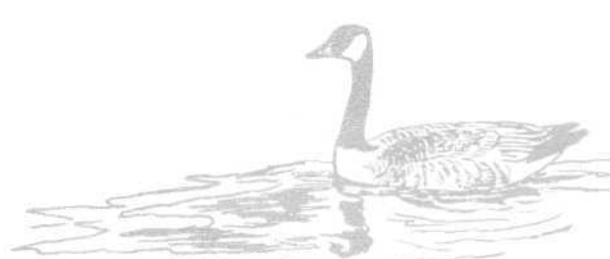
Sago pondwood is the most valuable waterfowl food plant in the lake. The importance of sago to waterfowl is so great that use of the lake by migrating birds, especially whistling swans and canvasbacks, depends on its abundance. The extent of sago pondweed in any one year hinges on environmental factors and ranges from about 20,000 acres in a favorable year to none in a poor year. In experimental studies, single plants of sago, grown from a tuber and a seed, in six months developed over 36,000 tubers and 63,000 seeds respectively (Yeo, 1965). This demonstrates the tremendous productivity of sago and makes the following figures (Table 2) more significant.

After carp *(Cyprinus carpio)* were introduced into the Silvies River watershed in the early 1920's, these fish often became sufficiently numerous in the lake to be detrimental to submerged aquatic vegetation. By 1955 carp activity had created such turbidity that desirable submerged aquatics were nearly eliminated. In 1955 the carp population was controlled with rotenone, a fish toxicant. It was estimated that 1.5 million carp averaging 20 to 25 inches in length were killed. The beneficial effect was demonstrated the next year, when sago showed immediate response to improved growing conditions and covered 15,000 acres.

Other wetland plants occur in and adjacent to Malheur Lake, but the above account serves to portray its basic plant ecology.

Table 2. Acreage of sago pondweed in Malheur Lake, 1956-65.

	Acreage			*Acreage*	
Year	*Sago*	*Lake Size*	*Year*	*Sago*	*Lake Size*
1956	15,000	56,000	1961	0	8,000
1957	23,000	66,000	1962	100	7,000
1958	6,500	66,000	1963	1,500	20,000
1959	500	51,000	1964	2,500	25,000
1960	1,000	22,000	1965	10,000	58,000



BIRDS AND MAMMALS

During spring and fall migration, 22 species of ducks and three species of geese occur. (See the refuge bird list for status and abundance of waterfowl and marsh birds occurring at Malheur Lake.) Migrant waterfowl populations in recent years averaged about 400,000 ducks, 75,000 geese, and 3,500 swans. At least three races of the Canada goose occur: The Western Canada goose *(Branta canadensis moffitti)*—year-round resident and nesting race; and cackling and lesser Canada geese *(B. c. minima* and *B. c. parvipes)*—migrant races.

As a producer of waterfowl, Malheur Lake ranks among the best habitat in North America. Twelve species of ducks, the western Canada goose, and the rare trumpeter swan regularly nest. In years of favorable nesting and brood-rearing conditions, Malheur Lake may produce 15,000 ducks and 1,000 Canada geese. In some of the best habitat, primarily the west zone of small ponds and interspersed uplands, duck production can be as high as 500 birds per square mile. On June 2, 1965 the following number and kinds of breeding pairs were estimated in a square mile sample of this habitat: mallard, 10; gadwall, 44; pintail, 4; blue-winged teal, 4; cinnamon teal, 28; shoveler, 10; redhead, 34; canvasback, 6; lesser scaup, 1; ruddy duck, 28; total pairs, 170.

Representing another type of breeding habitat, in this case a mile-long sample of marsh edge along the south shore, the following pairs were observed on May 26, 1965: mallard, 15; gadwall, 22; pintail, 1; blue-winged teal, 2; cinnamon teal, 28; American widgeon, 3; shoveler, 4; redhead, 16; canvasback, 5; lesser scaup, 4; ruddy duck, 9; total, 109.

While the above examples represent only two small units of breeding habitat in Malheur Lake in one year, they serve to illustrate the marshes' high potential for waterfowl production.

Table 3 portrays an example of duck production in three sample areas in 1966. That year may be considered fairly typical of breeding population densities and species composition, but the productivity rates are probably below normal. This was because receding water levels throughout the nesting season stranded many diving duck nests and may have contributed to heavier than normal predation on dabbling duck nests. Also, some pairs recorded as "breeding pairs" may have been non-breeders, because of over-crowding. These data were obtained by intensively searching a square mile block in each of the three habitat units. Observations were made by walking in Units 4 and 6 and by canoe in Unit 5.

Table 3. Duck breeding pairs and broods observed on three 640-acre blocks within different ecological types in Malheur Lake, 1966.

	Unit 4		*Unit 5*		*Unit 6*	
Species	*Pairs*	*Broods*	*Pairs*	*Broods*	*Pairs*	*Broods*
Mallard	10	7	5	2	7	0
Gadwall	35	17	5	1	52	11
Pintail	3	2	0	0	5	0
Green-winged teal	0	0	0	0	1	0
Blue-winged teal	3	?	0	0	2	?
Cinnamon teal	38	4	2	0	88	3
American widgeon	0	0	1	0	3	0
Shoveler	4	0	0	0	2	0
Redhead	48	9	16	2	8	7
Ring-necked duck	1	0	0	0	0	0
Canvasback	20	6	1	0	3	1
Lesser scaup	5	0	1	0	0	0
Ruddy duck	28	1	16	0	1	0
Total	195	46	47	5	172	22
Percentage successful		24%		11%		12%

In addition to being excellent for waterfowl production, Malheur Lake is vital migration habitat for birds in the Pacific Flyway. Table 4 shows the amount of use by waterfowl during 1957-65. These years encompassed periods in which the amount and quality of habitat varied from poor to excellent. In addition to habitat availability during migrations, the size of Pacific Flyway populations also influences the amount of use at Malheur Lake. About 75 percent of waterfowl use of the lake occurs during spring and fall migrations, with most use in the fall.

Amount and diversity of bird life varies from year to year, in response to the extent and quality of marsh habitat. This variation is well-known in other marshes that fluctuate between extremes in water conditions; and, as mentioned earlier, the biota of such marshes is well adapted to such changes. To give some idea of species composition and density of the bird life occurring in Malheur Lake, Table 5 summarizes censuses of three 640-acre blocks in June, 1966. Surface elevation of the lake at the time was 4092.5 feet above sea level. Blocks in Units 4 and 6 were censused by walking and in Unit 5 by canoe. Table 5 lists only birds actually observed; thus, data may be considered minimal. However, the square mile blocks were covered thoroughly, and it was felt nearly all birds were probably seen. A concept of the habitat patterns on the three census blocks may be gained from Table 6.

Table 4. Amount of use made of Malheur Lake by waterfowl during the period 1957-65 (includes ducks, coots, geese and swans)

	Number of Days' Use			
Year	*Unit 4 (West)*	*Unit 5 (Center)*	*Unit 6 (East)*	*Total*
1957	8,900,000	38,300,000	19,500,000	66,700,000
1958	6,100,000	14,800,000	18,500,000	39,400,000
1959	2,800,000	11,600,000	6,200,000	20,600,000
1960	300,000	26,800,000	1,400,000	28,500,000
1961	0	5,100,000	65,000	5,165,000
1962	120,000	4,100,000	2,000	4,222,000
1963	200,000	23,500,000	27,000	23,727,000
1964	680,000	15,300,000	100,000	16,080,000
1965	5,100,000	15,800,000	8,100,000	29,000,000

The lake serves many kinds of water birds other than waterfowl. Some of the more common nesting species are common and snowy egret; great blue and black-crowned night herons; pied-billed, eared, and western grebes; Franklin's gull; black and Forster's terns; avocet; killdeer; and Wilson's phalarope. A few white-faced ibises breed there, as well as white pelicans and black-necked stilts in some years. In spring and fall, large flocks of least and western sandpipers and long-billed dowitchers are prominent.

Table 5. Birds observed on three 640-acre blocks within different ecological types at Malheur Lake, Oregon, June 1966.

	Number Observed		
Species	*Unit 4 (June 1)*	*Unit 5 (June 2)*	*Unit 6 (June 7)*
Horned grebe	0	2	0
Eared grebe	58	1140	8
Pied-billed grebe	4	12	0
Western grebe	16	20	0
White pelican	0	8	300
Double-crested cormorant	1	2	0
Great blue heron	1	1	2
Common egret	20	2	0
Snowy egret	6	0	2
Black-crowned night heron	12	0	3
White-faced ibis	0	0	7
Trumpeter swan	2	0	0
Canada goose	0	0	1
Mallard	20	10	14
Gadwall	70	10	104
Pintail	6	0	10
Green-winged teal	0	0	2
Blue-winged teal	6	0	4
Cinnamon teal	76	4	176
American widgeon	0	2	6
Shoveler	8	0	4
Redhead	96	32	16
Ring-necked duck	2	0	0
Canvasback	40	2	6
Lesser scaup	10	2	0
Common goldeneye	2	0	0
Ruddy duck	56	32	2
American coot	275	85	62
Killdeer	4	0	40
Long-billed curlew	4	0	4
Willet	1	0	6
American avocet	12	0	125
Black-necked stilt	0	0	20
Wilson's phalarope	10	0	40
California gull	0	1	2
Ring-billed gull	4	6	10
Franklin's gull	0	10	0
Forster's tern	20	25	14
Black tern	10	185	0
Short-eared owl	0	0	1
Violet-green swallow	0	20	0
Tree swallow	0	8	0

	Number Observed		
Species	*Unit 4 (June 1)*	*Unit 5 (June 2)*	*Unit 6 (June 7)*
Barn swallow	0	2	0
Cliff swallow	4	55	0
Common raven	2	0	0
Long-billed marsh wren	1	20	8
Yellow-headed blackbird	100	53	110
Red-winged blackbird	25	0	24
Brewer's blackbird	25	0	25
Savanah sparrow	65	0	22
Total Species	35	28	34
Total Individuals	1,074	1,751	1,180

Table 6. Habitat types in three 640-acre census blocks at Malheur Lake, Oregon, August 1, 1966.

	Unit 4		*Unit 5*		*Unit 6*	
	Acres	*%*	*Acres*	*%*	*Acres*	*%*
Upland	100[1]	15.6	0	00.0	230	35.9[6]
Emergent aquatic vegetation	230[2]	40.0	345[4]	53.9	60	9.4[7]
Open water	310[3]	48.4	295[5]	46.1	350	54.7[8]
	640	100.0	640	100.0	640	100.0
Maximum water depth, Surface elevation 4091.6	18 inches		36 inches		16 inches	

[1]Desert saltgrass, 75%; greasewood, 15%; mixed grasses and forbs, 10%.

[2]Baltic rush, 60%; hardstem bulrush, 25%; *Carex atherodes, Elymus triticoides, Hordeum jubatum,* mixed forbs, 15%.

[3]*Potamogeton pectinatus,* 50%; *Potamogeton pusillus,* 40%; *Zannichellia palustris,* 10%.

[4]Hardstem bulrush, 98%; cattail, 2%.

[5]*Myriophyllum exalbescens,* 65%; *Potamogeton pusillus,* 20%; *Potamogeton pectinatus,* 5%; *Zannichellia palustris,* 5%; *Chara vulgaris,* 5%.

[6]*Hordeum jubatum-Distichlis stricta,* 35%; mudflat, 65%.

[7]*Juncus balticus,* 90%; *Scirpus acutus,* 10%.

[8]*Potamogeton pectinatus,* 60%; *Potamogeton pusillus,* 20%; *Zannichellia palustris,* 10%; *Chara vulgaris,* 10%.

(Estimates of submerged aquatic vegetation in open water zones based on percentage of occurrence in samples.)

The muskrat *(Ondatra zibethicus)* is the most conspicuous mammal in Malheur Lake and has an important influence on the marsh ecology. Like water bird populations, numbers of muskrats fluctuate primarily in response to habitat conditions, and, to a lesser extent, disease. The benefit of muskrats to a marsh, from man's viewpoint, results from their feeding and lodge-building activities. By cutting emergent vegetation for food, muskrats create an interspersed habitat more desirable for waterfowl than pure stands. Muskrat lodges provide attractive and productive nest sites for Canada geese and trumpeter swans.

Malheur Lake is a fine muskrat marsh, as well as a prime waterfowl marsh. In good years, the muskrat population exceeds 50,000. A cooperative trapping program is operated as a management technique in years when a surplus exists. When muskrat populations reach a peak, as in the early 1950's, over 20,000 may be trapped in one season. During years of low water levels—e.g., from 1959 to 1963—the muskrat population is reduced naturally to practically none. Population lows are typically followed by rapid recovery when good habitat conditions return, as they did in 1965.

In years when a high muskrat population already exists and the lake is reduced in size by lack of inflowing water, a mass exodus of muskrats occurs. At such times, they leave their aquatic environment and travel into the dry desert surrounding the lake. This is an example of population pressure—too many muskrats for the home ranges available, so some must leave. These migrations are a one-way trip, for muskrats cannot survive in the desert.

Other mammals occurring in or adjacent to the lake are beaver, raccoon, coyote, bobcat, mink, long-tailed weasel, and black-tailed jackrabbit. Small numbers of pronghorns and mule deer use habitat provided by dry marsh and meadow vegetation. Smaller animals seldom seen but often abundant in meadows surrounding the lake are meadow mice, or voles—of which the long-tailed vole *(Microtus longicaudus)* is most numerous. White-footed mice and shrews also occur.

MALHEUR LAKE AS AN AQUATIC HABITAT

Malheur Lake is strategically located between Alaskan and Canadian waterfowl breeding grounds and traditional wintering areas of these same populations, primarily in California and Mexico. The role of the lake as a production and migration habitat for waterfowl in the Pacific Flyway has been an important one in the past. When one recalls that the biological productivity of marshes is among the highest of any ecosystem, the attractiveness of Malheur Lake to such an abundance and diversity of bird life is more understandable. The vast acreages of littoral zone where plants and animals in lower levels of food chains can flourish are undoubtedly of much importance in maintaining this high productivity.

As man observes the tremendous abundance of life forms which marshes such as Malheur Lake can support, it may be thought that manipulation in such a way as to perpetually maintain a peak level of productivity should be attempted. However, it should be considered that perhaps one of the main factors in keeping shallow marshes productive is their seasonal and yearly fluctuation in water levels. It may be well to regard dry years as "fallow" years which pave the way for biological abundance when water returns. Only when marsh bottoms are dry can necessary exchanges occur to maintain a proper balance between oxygen and other elements in the soil so essential to the growth of marsh plants and animals. (Weller and Spatcher, 1965). It is no accident that the most productive marshes are those with a history of fluctuating water supply, while the least productive have stable water levels.

When all refuges within the National Wildlife Refuge Systems are considered, few have any large aquatic habitat areas in a natural condition. Almost universally, water is regulated by water control structures and dikes. Such a water control system was proposed for Malheur Lake (USBSFW 1965).

The wisdom of disturbing the natural ecology of Malheur Lake with an intricate system of water control structures—when it is so biologically productive without these—is open to serious question. In its present condition, Malheur Lake adequately serves its role in the Pacific Flyway and the National Wildlife Refuge System. Quite aside from economic and esthetic considerations involved in making a decision as to whether or not dikes should be constructed in the lake bottom, the question remains: How would artificial manipulation of water levels affect the long-term ecology of the marsh? At the present time, one can only speculate; but it is likely detrimental effects would occur—for example, ever-increasing alkalinity.

A visit to Malheur Lake by anyone interested in natural phenomena is an emotional experience not soon forgotten. The visitor is soon aware that he is seeing evidence of Nature's complex relationships that have been operating essentially unchanged since the Pleistocene, or for nearly 10,000 years. Vegetation, water, and bird and animal inhabitants certainly have repeated many thousands of life cycles. But always the cycles were in a pattern produced by the intricate interrelationships of a highly productive marsh ecosystem.

The value of having such a large natural marsh as Malheur Lake in the National Wildlife Refuge System will increase with each year that passes. A philosophy expressed by the late marsh ecologist, Paul Errington, is appropriate in this regard:

> "Apart from any esthetic appreciation that ecologists may feel toward unspoiled wilderness preserves, including marshes, one of their chief motivations in preservation of wilderness is to safeguard areas where ancient interrelationships of plants, animals, soils and climates may be studied." (1957)

Malheur Lake is an outstanding example of such a natural marsh.

APPENDIX 1. Fluctuations in size of Malheur Lake, 1735-1965.

Year	*Size of Lake*	*Authority*
1735-1755	Lake levels probably high. (Tree ring studies indicate abundant moisture.)	Piper *et al* (1939)
1755-1775	Lake levels generally low, probably dry some years. (Tree ring studies indicate severe drought.)	Piper *et al* (1939)
1175-1825	Lake levels probably high. (Tree ring studies indicate abundant moisture.)	Piper *et al* (1939)
1825-1850	Lake levels generally low, probably dry some years. (Tree ring studies indicate severe drought.)	Piper *et al* (1939)
	Note: It is interesting that tree ring data agrees with observations of early travelers. In 1826, Peter Skene Ogden reported an extensive saline lake (Harney Lake) but described only a small freshwater lake to the east (Malheur Lake).	Piper *et al* (1939)
1864	Malheur Lake sufficiently large to be named separately by Captain George Currey. (Maps published as early as 1864 showed a chain of three lakes which might be Harney, Mud, and Malheur, but they were not named.)	Piper *et al* (1939)
1865-1882	High levels reported by travelers.	Piper *et al* (1939)
1881	Unusually high water said to have caused cutting of channel through "Sand Ridge" to Harney Lake and consequent lowering of level of Malheur?	Piper *et al* (1939)
1889	Nearly dry after 3 years of low run-off.	Piper *et al* (1939)
1895-1905	Lake was "extensive."	Piper *et al* (1939)
1911	"Average 18 inches deep" (October—15,000 acres?)	Alva Lewis
1912	"Flooded to Narrows" (34,000-40,000 acres?)	Alva Lewis
1915	"No connection between Narrows and Main Lake" (25,000 acres?)	George Cantwell
1916	"Water at extremely low level. No connection between Mud Lake and Harney Lake."	George Cantwell
1917	Very small.	Piper *et al* (1939)
1918	"Driest year in history of region; greater part of lake dry, water not over one foot in depth." (10,000 acres?)	George Willett
1921	Extensive.	Piper *et al* (1939)

Year	*Size of Lake*		*Authority*
1922	"Greatest supply of water since 1917; large overflow from Narrows to Mud Lake; both Silvies and Blitzen flowing strong in June." (50,000 acres?)		Stanley Jewett
1930	Lake small; beginning of drought. (2,000 acres)		Piper *et al* (1939)
1931	Smallest size in historic times (500 acres). No run-off from Silvies River and little from Blitzen.		Piper *et al* (1939)
1932	"Small."		Piper *et al* (1939)
1933	"Very small."		Refuge files
1934	Entire bed of lake dry (Sept. 20); even the lower elevations farmed (small grains).		Refuge files
1935	"Very little water; none reached Cole Island." (10,000 acres?)		Refuge files
1936	"Very little water; none reached Cole Island, but a slight increase over 1935." (15,000 acres?)		Refuge files
1937	Increased acreage. (25,000 acres?)		Refuge files
1938*	43,000 acres	4092.70 feet a.s.l.	
1939	47,000 acres	4093.00 feet a.s.l.	
1940	25,000 acres	4091.92 feet a.s.l.	
1941	48,000 acres	4093.02 feet a.s.l.	
1942	60,000 acres	4094.81 feet a.s.l.	
1943	64,000 acres	4095.24 feet a.s.l.	
1944	52,000 acres	4093.50 feet a.s.l.	
1945	59,000 acres	4094.48 feet a.s.l.	
1946	53,000 acres	4093.60 feet a.s.l.	
1947	44,000 acres	4092.80 feet a.s.l.	
1948	56,000 acres	4093.77 feet a.s.l.	
1949	51,000 acres	4093.30 feet a.s.l.	
1950	40,000 acres	4092.56 feet a.s.l.	
1951	51,000 acres	4093.42 feet a.s.l.	
1952**	67,000 acres	4095.39 feet a.s.l.	
1953	60,000 acres	4094.44 feet a.s.l.	
1954	53,000 acres	4093.57 feet a.s.l.	
1955	36,000 acres	4092.20 feet a.s.l.	
1956	56,000 acres	4093.84 feet a.s.l.	
1957	66,000 acres	4095.12 feet a.s.l.	
1958	66,000 acres	4095.16 feet a.s.l.	
1959	51,000 acres	4093.30 feet a.s.l.	

Year	*Size of Lake*		*Authority*
1960	22,000 acres	4091.82 feet a.s.l.	Refuge files
1961	8,000 acres	4090.88 feet a.s.l.	
1962	7,000 acres	4090.78 feet a.s.l.	
1963	20,000 acres	4091.50 feet a.s.l.	
1964	25,000 acres	4091.92 feet a.s.l.	
1965	58,000 acres	4094.34 feet a.s.l.	

*Figures for 1938-65 based on staff gauge in Malheur Lake near mouth of Blitzen River; acreage computed from table in Piper *et al.* (1939). (The peak reading for the year was used in this table.)

**Highest level on record.

Lewis, Cantwell, Willett and Jewett were employees of the Bureau of Biological Survey.

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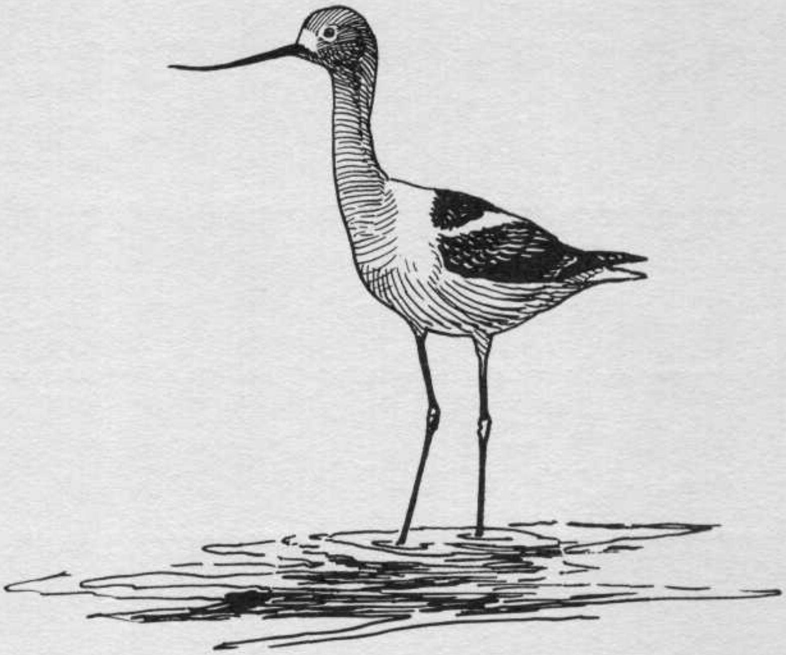

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NOVEMBER 1969

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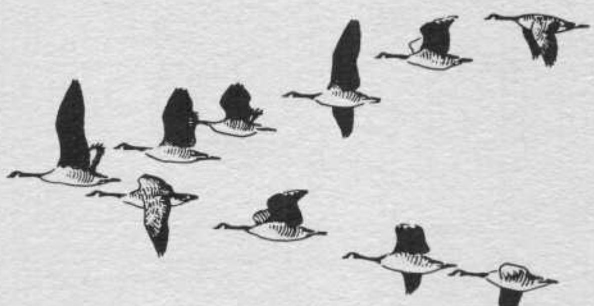

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