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ECOLOGY OF NESTING HAWAIIAN COMMON GALLINULES AT HANALEI, HAWAII

G. VERNON BYRD, Aladdin Rt. Box 160 E, Colville, Washington 99114

C. FRED ZEILLEMAKER, Crescent Lake NWR, Star Rt. Box 21, Ellsworth, Nebraska 69340

The Hawaiian subspecies of the Common Gallinule (*Gallinula chloropus sandvicensis*) is endangered (U.S. Fish and Wildlife Service 1980). As recently as 1891, Munro (1960) found the species common on all the main Hawaiian Islands with wetlands, but by 1947 its status was precarious (Schwartz and Schwartz 1949). Currently the gallinule remains only on the islands of Oahu and Kauai (Shallenberger 1977). Loss of habitat, predation by introduced mammals and hunting (prior to closures in 1939) are listed as the major causes for the decline (Hawaiian Waterbirds Recovery Team 1977).

Gallinules have been counted along with other waterbirds in semi-annual statewide censuses since 1970 (Hawaii Department of Land and Natural Resources unpubl. data). A detailed summary of the distribution of Hawaiian waterbirds, including gallinules, was provided by Shallenberger (1977). Our study is the first of the nesting ecology of the Common Gallinule in Hawaii, although other subspecies have been studied (e.g., Howard 1940, Fredrickson 1971, Krauth 1972, Relton 1972, Wood 1974, Bell and Cordes 1977, Brackney 1979).

Since 1970 the U.S. Fish and Wildlife Service has acquired five refuges in Hawaii for enhancement of endangered waterbirds. This study was undertaken to provide data for gallinules as an aid in habitat development and management decisions on the new refuges.

STUDY AREA

The study was conducted at Hanalei National Wildlife Refuge, a 371-ha area located at the lower end of the Hanalei River valley (Figures 1 and 2). The valley has been used for the cultivation of irrigated taro (*Colocasia esculenta*), from which the traditional Hawaiian food "poi" is made, since at least 610 ± 95 A.D. (Schilt 1980). In 1980 approximately 50 ha of the refuge was in taro production. Taro is grown in constantly flowing water which is approximately 5 to 8 cm deep. Diked paddies ranged from 0.1 to 0.4 ha in area. The agricultural cycle is as follows:

dry fallow — field drained, lasts 1 to 6 mos (occurs every second or third cycle)
wet fallow — field flooded, lasts 1 to 3 mos (occurs after dry fallow and after harvest)
planting — leafless stems planted in wet paddies (accomplished in 1 to 3 wks)
growth — gradual growth of leaves until complete canopy forms (canopy closes at about 4 mos, plants mature at 14 mos)
harvest — entire plants removed (harvest followed by either wet or dry fallow)

Harvesting is accomplished on a sustained-yield basis, so a taro farm always contains paddies in various stages of the agricultural cycle. An interspersion of habitats occurs ranging from open water to dense stands of robust emergents (taro).

The average temperatures at Hanalei vary between 21° and 26°C. Seasonal variations are slight. The annual rainfall at the refuge is approximately 2 m, but 8 km up the valley the annual average is 10 m (U.S. Weather Service records).

METHODS

The study was initiated by Zeillemaker, the first resident manager of Hanalei National Wildlife Refuge. He made observations of gallinules incidental to other duties from 1975 to early 1977. During mid-to late 1977,

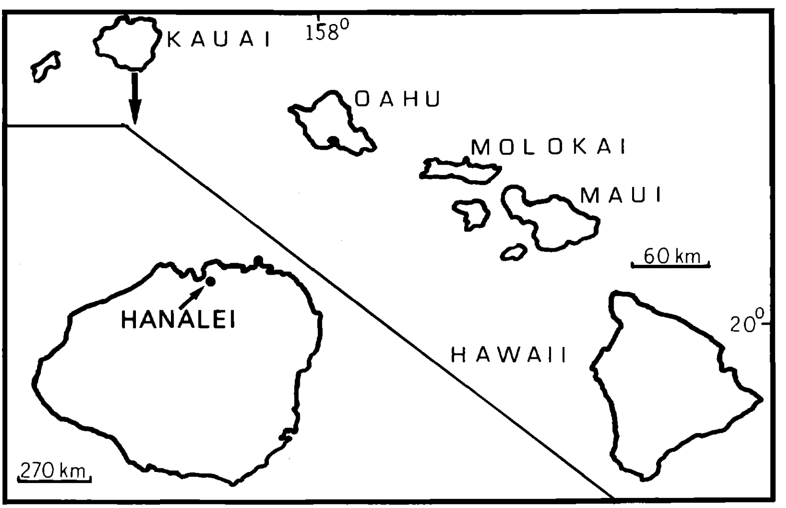

Figure 1. The main Hawaiian Islands with Hanalei NWR identified in the inset.

when Zeillemaker left and Byrd arrived, few observations were recorded, but in 1978 and 1979 more time was devoted to the study than previously. In April 1980, Byrd left, and infrequent observations were continued by D. Moriarty throughout the summer.

Systematic searches of taro paddies for gallinule nests were not possible due to the risk of taro root damage by walking among the plants. Farmers reported nests they discovered while weeding or harvesting. It is not known what percentage of the nests were discovered and reported.

At the first visit to each nest, measurements were made of eggs and nests, the stage of incubation was estimated by floatation (Westerkov 1950), and the clutch size was recorded. The date of clutch initiation was determined by using a laying rate of one egg per day (Relton 1972, Krauth 1972) and backdating. If the eggs were fresh, nests were usually rechecked within 3 days to determine if more eggs were present. At nests where incubation was well underway, checks were made every 5 to 10 days until hatching occurred.

Adult gallinules eat egg shells or carry them away from nests (Fredrickson 1971), therefore little evidence of hatching remained at successful nests. We assumed that an egg hatched if it was present in the nest late in incubation but was not found in or near the nest after hatching. A search for eggs, shell fragments or membranes was always made within a 5-m radius of nests.

Brood counts were recorded only when extended observations indicated a high probability that all chicks were seen. Chicks were assigned to age classes commonly used for waterfowl (Yocum and Harris 1965).

Figure 2. Hanalei NWR, Kauai, Hawaii, photographed from the overlook.
Photo by C.F. Zeillemaker

RESULTS AND DISCUSSION

Nest Sites

At Hanalei all nests were supported by the sturdy stems of dense taro (Figure 3). Only 4 of 80 (5%) nests occurred in taro less than 4 months old, the age at which the canopy started to close. Gallinules have been found nesting in *Scirpus, Typha, Paspalum, Brachiaria* and *Nelumbo* elsewhere in Hawaii (Shallenberger 1977, T. Burr and R. Coleman pers. comm.). Weller and Fredrickson (1973) suggested that species of plants used by gallinules for nesting was unimportant as long as it is a robust emergent. Apparently this statement is widely true (United States — Fredrickson 1971, Krauth 1972, Bell and Cordes 1977, Reagan 1977, Strohmeyer 1977; England — Relton 1972, Wood 1974; Finland — Karhu 1973).

The average water depth at 16 gallinule nests at Hanalei was 6.5 cm (s.d. = 1.2 cm), much shallower than the 30-cm to 2-m depths recorded at nests elsewhere (Fredrickson 1971, Bell and Cordes 1977, Reagan 1977, Brackney 1979). Nest sites with deeper water were not available at Hanalei, but in marshes with variable depths elsewhere, Brackney (1979) found that gallinules chose deeper areas. The birds also preferred deep marshes to shallow marshes. Deep water apparently protects nesting birds from mammalian predators: e.g., six gallinule nests were destroyed by predators within 1 week after a drastic reduction in water levels on Brackney's (1979) study area.

Nests

Nests at Hanalei were oblong with outside dimensions of over 27 cm, and they averaged approximately 5 cm deep (Table 1). The top of the rim of 10 nests averaged 13.7 cm (s.d. = 2.4 cm) above the bottom of the taro field, and 7.2 cm above the water. Wood (1974) found nests of a similar size in England — 20 to 25 cm in diameter, 2 to 5 cm deep.

Taro leaves were available at every nest, but they were used in construction of only 64.6% of the nests, and they comprised only 53.6% of the material used in the nests where they occurred (Table 2). Apparently plants other than taro were favored for nest construction if they were available nearby. Wood (1974) recorded a similar situation in which a pair of gallinules nesting in a clump of reeds brought sedge leaves from 12 m away to build their nest. Elsewhere, gallinules usually construct nests from the same plant that supports the nest (Fredrickson 1971, Reagan 1977).

Table 1. Dimensions (in cm) of Common Gallinule nests at Hanalei National Wildlife Refuge, Kauai, Hawaii.

	Outside Diameter	Inside Diameter	Depth	Height of Nest Rim Above the Water
Average	27.3 x 25.4	16.6 x 15.4	5.1	6.7
Standard Deviation	4.0 x 3.1	1.8 x 1.6	1.4	1.2
Sample Size	27	27	24	10

Figure 3. Common Gallinule nest supported by taro.

Photo by G.V. Byrd

Table 2. Plants used for nest construction by Common Gallinules at Hanalei National Wildlife Refuge, Kauai, Hawaii.

	Percent Occurrence *	*Percent Composition* **	
Species	$\bar{x}$	$\bar{x}$	S.D.
Colocasia	64.6	53.6	35.9
Brachiaria	39.6	36.4	30.3
Cyperus	33.3	47.1	37.6
Commalina	16.7	38.5	34.2
Echinochola	14.6	27.1	24.1
Azolla	14.6	13.3	14.4

* n = 48
** n = 22

Eggs

The average size of 114 gallinule eggs measured at Hanalei was 44.1 mm (s.d. = 1.9 mm) × 31.5 mm (s.d. = 1.0 mm). These measurements are almost identical with those made by Witherby et al. (1938-1941) in Great Britain and by Bent (1926) and Simmons (1915) in the United States. Unaccountably, 29 eggs measured in Iowa were shorter (40.4 mm x 31.4 mm; Fredrickson 1971).

Nesting Chronology

At Hanalei clutches were completed in all months except December and January (Figure 4), with a peak from April through June. The data for 1978 are the most complete, and while there may have been real annual differences in nesting peaks, they were probably less marked than the small sample sizes suggest. Shallenberger (1977) reported that gallinules nest year-round in Hawaii, and he recognized a peak in activity from March through August.

Two marked pairs of resident Common Gallinules in South Africa (34°S) nested continuously and were repeatedly successful for 48 months, and Siegfried and Frost (1975: 102) assumed that the species has the capacity for reproducing "whenever and for as long as conditions are favourable." In more temperate areas gallinules are usually migratory, and eggs are found April to July (Brown 1944, Fredrickson 1971, Karhu 1973, Wood 1974, Reagan 1977, Bell and Cordes 1977, Brackney 1979). The height of nesting cover, which is controlled by temperature and water levels, may determine when nesting occurs (Weller and Spatcher 1965).

Incubation Period

The period between laying of the last egg and hatching of the first egg was 22 days in the two nests for which it was known at Hanalei. We could not determine whether gallinules began incubating before the last egg was laid at Hanalei, but slightly asynchronous hatching was noted.

Reports of the timing of initiation of incubation in other areas vary widely: e.g., Krauth (1972) found that incubation began after the fifth egg (of eight or nine) was laid, but Karhu (1973) concluded that incubation began after the first egg was laid. Wood (1974) clarifies the situation somewhat. He found that in first nests incubation usually did not start until completion of the clutch, but in renests or second nests it began when about half the clutch was laid or earlier. The problem of knowing when incubation starts makes it difficult to interpret reported incubation periods, but most authors report periods of 19 to 22 days (Witherby et al. 1938-1941, Brown 1944, Krauth 1972, Relton 1972, Karhu 1973, Wood 1974).

Brood Rearing

Only one gallinule family with known-age chicks was frequently observed at Hanalei. The chicks were fed by the adults at first, but by the age of 21 to 25 days the brood began to spend part of the day feeding independently, yet within 20 m of the adults.

Captive gallinule chicks fed independently at about 21 days old (Karhu 1973), and Howard (1940) saw adults driving away 21-day old chicks. Wood (1974) found that parents occasionally fed chicks until they were 45 days old, but that a reduction in reliance of chicks on parents occurred by the age of 25 days.

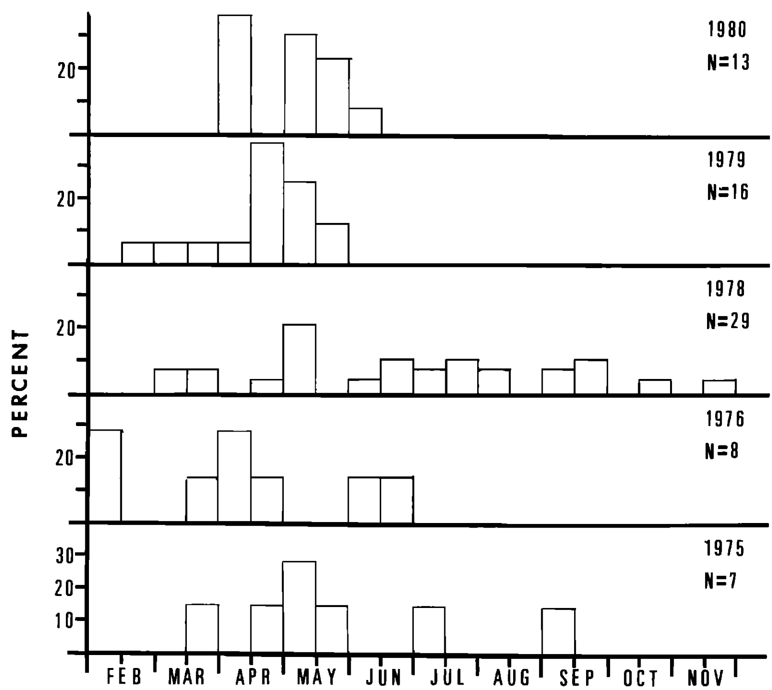

Figure 4. Distribution of clutch completion dates of Common Gallinules at Hanalei NWR, Kauai, Hawaii.

Table 3. Average clutch sizes of Common Gallinules at Hanalei National Wildlife Refuge, Kauai, Hawaii.

	1975	1976	1978	1979	1980	5-year Average
Average	5.3	5.7	5.3	5.6	6.0	5.6
Standard Deviation	0.8	1.4	1.3	1.1	1.3	1.2
Sample Size	7	7	28	13	9	64

Multiple Broods

There was circumstantial evidence of second broods at Hanalei. Periodically a nest would hatch in a particular taro paddy, and 40 to 60 days later another nest would hatch near or at the same location. Elsewhere two broods are routinely raised, three broods are fairly common (Karhu 1973 summarizes literature), and four broods have been successfully raised in one season (Benthum 1931). In an unusual situation where the food supply may have been supplemented, two pairs of gallinules produced 33 and 32 broods respectively in a 48-month period (Siegfried and Frost 1975).

Groups of gallinules containing two adults and both downy and nearly-fledged chicks were occasionally seen at Hanalei. These "multiple brood family units" (Wood 1974:150) have also been recorded elsewhere. The older chicks feed younger chicks (Brown 1944), collect food for parents which in turn feed younger chicks (Wood 1974), incubate eggs if the pair has not yet hatched the second clutch (Robertson 1964), and brood younger siblings (Bull 1972, Wood 1974).

Clutch Size

At Hanalei gallinules laid from 4 to 8 eggs per clutch, and averaged 5.6 eggs (Table 3). The true average could have been slightly higher as eggs could have been lost before nests were found. The average gallinule clutch in the continental United States is larger than at Hanalei, but those in England are a similar size (Table 4). A factor that might account for the high average clutches reported in the continental United States is the occasional clutch with up to 14 or even 17 eggs reported by most authors. These large clutches are probably the result of second females laying in nests with completed clutches (Witherby et al. 1938-1941, Relton 1972, Shallenberger 1977). Relton (1972) suggested this phenomenon was due to the second hen being without her own territory. No large clutches were recorded at Hanalei (Table 3), perhaps indicating there was no shortage of nest territories.

Nesting, Hatching, and Fledgling Success

At least one egg hatched in nearly 75% of all nests at Hanalei, and in successful nests 75% of the eggs hatched (Table 5). Although our sample of Class I broods was small, it appears high mortality occurred before chicks attained their first feathers, the stage at which they were considered to be

Class II (Table 6). Since average brood sizes do not include pairs that lost all their chicks (because we could not identify them), the estimate of 2.3 fledglings per pair (54.8% of the eggs hatched) is probably high.

Table 4. Clutch sizes of Common Gallinules at various locations.

Average Clutch*	Sample Size	Location	Source
10.0	26	Pennsylvania	Harlow (1918)
9.1	142	Texas	Cottam and Glazener (1959)
8.6	35	Louisiana	Causey et al. (1968)
8.1	11	Louisiana	Bell and Cordes (1977)
8.1	18	Wisconsin	Krauth (1972)
8.0	55	Ohio	Brackney (1979)
7.1	13	Iowa	Fredrickson (1971)
6.6	2278	Great Britain	Huxley and Wood (1976)
6.0	39	England	Relton (1972)
5.4	40	England	Wood (1974)

* First and subsequent clutches and replacement clutches combined

Table 5. Productivity* of Common Gallinules at Hanalei National Wildlife Refuge, Kauai, Hawaii.

	1975	1976	1978	1979	1980	5-year Average
Nesting Success	71(7)**	86(7)	75(24)	80(10)	62(13)	75(61)
Hatching Success	68(5)	82(6)	71(24)	70(10)	84(8)	75(53)
Fledging Success***	69(6)	81(22)	61(21)	46(6)		64(55)

* Expressed in percentages
** Sample size in parenthesis
*** Percentage of chicks that fledged based on brood counts

Table 6. Brood sizes of Common Gallinules at Hanalei National Wildlife Refuge, Kauai, Hawaii.

Age Class	1975	1976	1978	1979	4-year Average
I		3.8(5)*	4.0(4)	5.0(4)	4.3(13)
II and III	3.0(19)	2.8(12)	3.0(5)	2.3(4)	2.8(40)
Fledgling	2.5(6)	2.4(22)	2.3(21)	1.8(6)	2.3(55)

* Sample size in parenthesis

Table 7. Nesting, hatching and fledging success* of Common Gallinules at various locations.

Location	Nesting Success	Hatching Success	Fledging Success	Source
Texas	79	60		Cottam and Glazener (1959)
Louisiana		97	32	Bell and Cordes (1977)
Louisiana		85		Causey et al. (1968)
Louisiana		86	71	Fowler et al. (1971)
Wisconsin	61	50		Krauth (1972)
Ohio	77	83	89	Brackney (1979)
England	66	94	91	Relton (1972)
England	21	18	96	Wood (1974)
Great Britain	65			Huxley and Wood (1976)

*Expressed in percentages

In other gallinule studies, nesting success was 60 to 79% in all areas except one, but hatching and fledgling success varied greatly (Table 7).

Flooding was the major cause of nest failure at Hanalei (Table 8), but of the nests where entire clutches were lost, 21% was taken by dogs, cats or human vandals. The cause of egg loss in successful nests was generally not known, but the discovery of pecked egg shells near 10 nests suggests that predation by birds may have been a major contributor. The Common Myna (*Acridotheres tristis*) is a known egg predator in Hawaii (Schwartz and Schwartz 1949, Byrd 1979), and the species is common at Hanalei. Another possible predator found at the refuge is the Black-crowned Night Heron (*Nycticorax nycticorax*). This species is known to be an opportunistic feeder in Hawaii (Shallenberger 1977) and elsewhere (Wolford and Boag 1971). Only four eggs that may have been infertile were discovered at Hanalei.

Others have observed low infertility rates in gallinules (Krauth 1972, Relton 1972, Wood 1974, Brackney 1979). Predation is widely listed as the most important cause of egg and chick loss in gallinules (Miller 1946, Krauth 1972, Relton 1972, Wood 1974, Huxley and Wood 1976, Bell and Cordes 1977, Brackney 1979). Flooding has been reported as a major cause of egg loss in some studies (Wood 1974, Huxley and Wood 1976, Brackney 1979).

Table 8. Causes of Common Gallinule nest failure* at Hanalei National Wildlife Refuge, Kauai, Hawaii.

	Percent of total nest failure					
Event	1975	1976	1978	1979	1980	Five-year Average
Flooding	50(1)**	100(1)	67(4)	100(2)	80(4)	79(12)
Predation	50(1)		33(2)		20(1)	21(4)

* For nests in which the cause was known

** Sample size in parenthesis

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LITERATURE CITED

Bell, G.R. & C.L. Cordes. 1977. Ecological investigation of Common and Purple gallinules on Lacassine National Wildlife Refuge, Louisiana. Proc. Annual Conf. Southeast. Assoc. Fish & Wildl. Agencies 31:295-299.

Bent, A.C. 1926. Life histories of North American marsh birds. U.S. Natl. Mus. Bull. No. 135.

Benthum, H. 1931. Moorhens rearing four broods. Brit. Birds 25:106.

Brackney, A.W. 1979. Population ecology of Common Gallinules in southwestern Lake Erie marshes. M.S. thesis. Ohio State Univ., Columbus.

Brown, R.H. 1944. Notes on a pair of Moorhens. Brit. Birds 37:202-204.

Bull, A.L. 1972. Breeding behaviour in Moorhens. Bird Study 9:250.

Byrd, G.V. 1979. Common Myna predation on Wedge-tailed Shearwater eggs. Élepaio 39:69-70.

Causey, M.K., F.L. Bonner & J.B. Graves. 1968. Dieldrin residues in the gallinules *Porphyrula martinica* L. and *Gallinula chloropus* L. and its effect on clutch size and hatchability. Bull. Environ. Contam. and Toxicol. 3:274-283.

Cottam, C. & W.C. Glazener. 1959. Late nesting of waterbirds in southern Texas. Trans. N. Am. Wildl. Conf. 24:382-395.

Fowler, J.F., L.D. Newsom, J.B. Graves, F.L. Bonner & P.E. Schilling. 1971. Effect of dieldrin on egg hatchability, chick survival and eggshell thickness in Purple and Common gallinules. Bull. Environ. Contam. & Toxicol. 6:495-501.

Fredrickson, L.H. 1971. Common Gallinule breeding biology and development. Auk 88:914-919.

Harlow, R.C. 1918. Notes on the breeding birds of Pennsylvania and New Jersey. Auk 35:18-29.

Hawaiian Waterbird Recovery Team. 1977. Hawaiian waterbirds recovery plan. U.S. Fish & Wildl. Serv., Washington, D.C.

Howard, E. 1940. A waterhen's world. Cambridge Univ. Press, London.

Huxley, C.R. & N.A. Wood. 1976. Aspects of the breeding of the Moorhen in Britain. Bird Study 23:1-10

Karhu, S. 1973. On the development stages of chicks and adult Moorhens *Gallinula chloropus* at the end of a breeding season. Ornis Fennica 50:1-17.

Krauth, S. 1972. The breeding biology of the Common Gallinule. M.S. thesis. Univ. Wisconsin, Oskosh.

Miller, R.F. 1946. The Florida Gallinule. Breeding birds of the Philadelphia region (part III). Cassinia 36:1-16.

Munro, G.C. 1960. Birds of Hawaii. Charles E. Tuttle Co., Rutland, Vermont & Tokyo.

Reagan, W.W. 1977. Resource partitioning in the North American gallinules in southern Texas. M.S. thesis. Utah State Univ., Logan.

Relton, J. 1972. Breeding biology of Moorhens on Huntingdonshire farm ponds. Brit. Birds 65:248-256.

Robertson, K.W. 1964. Juvenile Moorhen brooding eggs. Brit. Birds 57:123-124.

Schilt, A.R. 1980. Archeological investigations in specified areas of the Hanalei Wildlife Refuge, Hanalei Valley, Kaua'i. Bishop Museum, Honolulu.

Schwartz, C.W. & E.R. Schwartz. 1949. The game birds in Hawaii. Div. Fish & Game and Board Comm. Agric. & For., Honolulu.

Shallenberger, R.J. 1977. An ornithological survey of Hawaiian wetlands. Contract DACW 84-77-C-0036, U.S. Army Eng. Dist., Honolulu. Ahuimanu Productions.

Siegfried, W.R. & P.G.H. Frost. 1975. Continuous breeding and associated behaviour in the Moorhen *Gallinula chloropus*. Ibis 117:102-109.

Simmons, G.F. 1915. On the nesting of certain birds in Texas. Auk 32:317-331.

Strohmeyer, D.L. 1977. Common Gallinule (*Gallinula chloropus*). Pp. 110-117 *in* G.C. Sanderson, ed. Management of migratory shore and upland game birds in North America. Inter. Assoc. Fish & Wildl. Agencies. Washington, D.C.

U.S. Fish & Wildlife Service. 1980. Republication of lists of endangered and threatened species and correction of technical errors in final rules. Fed. Reg. 45:33767-33781.

Weller, M.W. & L.H. Fredrickson. 1973. Avian ecology of a managed glacial marsh. Living Bird 12:269-291.

Weller, M.W. & C.S. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa State Univ. Agr. Home Econ. Exp. Sta. Spec. Rep. No. 43.

Westerkov, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14:56-67.

Witherby, H.F., F.C.R. Jourdain, N.F. Ticehurst & B. W. Tucker. 1938-1941. The handbook of British birds, vol. 5., London.

Wolford, J.W. & D.A. Boag. 1971. Food habits of Black-crowned Night Herons in southern Alberta. Auk 88:435-437.

Wood, N.A. 1974. The breeding behaviour and biology of the Moorhen. Brit. Birds 67:104-115, 137-158.

Yocom, C.F. & S.W. Harris. 1965. Plumage descriptions and age data for Canada Goose goslings. J. Wildl. Manage. 29:874-877.

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