The Condor 101:282–287

A PREDICTIVE MODEL OF WETLAND HABITAT USE ON GUAM BY ENDANGERED MARIANA COMMON MOORHENS[1]

MICHAEL W. RITTER[2]
Division of Aquatic and Wildlife Resources, P.O. Box 2950, Agana, Guam 96910

JULIE A. SAVIDGE
University of Nebraska, School of Natural Resource Sciences, 202 Natural Resources Hall, Lincoln, NE 68583

Abstract. Mariana Common Moorhens (*Gallinula chloropus guami*) were present in 21 of 33 wetlands examined on Guam. Stepwise logistic regression identified two variables (wetland area, percent cover of emergent vegetation) that distinguished between moorhen presence or absence at a wetland. The predictive equation correctly classified 86% of the wetlands with moorhens, but only 50% of the wetlands without moorhens. The average number of moorhens at wetlands was not influenced by the amount of emergent vegetation cover. Moorhen presence at smaller wetlands with less cover of emergent vegetation may not be an indication of preference for this type of habitat on Guam. Instead, moorhen presence was likely based on wetland availability. Enhancement and management of larger natural wetlands would increase the amount of seasonal and permanent habitat available to moorhens and provide resources for more than one breeding pair of moorhens per wetland.

Key words: Gallinula chloropus guami, *Guam, habitat use, Mariana Common Moorhen, wetland.*

INTRODUCTION

The Mariana Common Moorhen (*Gallinula chloropus guami*) is the only native freshwater bird species still found on Guam in the Mariana Islands. Extirpation of the Mariana Mallard (*Anas platyrhynchos oustaleti*), White-browed Crake (*Porzana cinerea*), and Nightingale Reed-warbler (*Acrocephalus luscinia*) occurred between 1945 and 1970 (Reichel et al. 1992, Reichel and Lemke 1994). The moorhen was listed as endangered in 1984 due to loss of wetland habitat (USFWS 1992). In 1991, the moorhen population on Guam was estimated at 100–125 birds (Stinson et al. 1991).

Common Moorhens use a wide variety of natural and human-made wetlands that may be ephemeral or permanent, as well as rivers, streams, canals, agricultural wetlands, and occasionally brackish waters (Taylor 1984, Helm et al. 1987, Ritter and Sweet 1993). In general, moorhens prefer small to medium-sized wetlands that provide more cover of emergent or woody vegetation over larger, more open systems (Ripley 1977, Cramp and Simmons 1980). On Saipan, an island approximately 200 km north of Guam, moorhen use was highest on wetlands with open water, low salinity. and without *Tilapia* sp., an introduced fish (Stinson 1993). Moorhens also made use of flooded pastures and taro fields. Moorhens on Guam have been reported from fresh and brackish water wetlands, fallow rice paddies, and cultivated taro patches (Hartert 1898, Seale 1901, Beaty 1967). Baker (1951) reported large numbers of moorhens in wetlands adjacent to the Ylig River and in the Agana Swamp. More recent research on Guam has identified an increased and consistent use of seasonal, human-made wetlands. Of 18 wetlands where moorhens were recorded, most ($n = 11$) were less than 0.6 ha in size, averaged 55% open water (range 0–95%), and were vegetated primarily with non-persistent emergent macrophytes such as Cyperaceae and Gramineae (Ritter 1989, Stinson et al. 1991).

Due to limited information on habitat characteristics and requirements and to an increasing interest in enhancing or creating wetlands, a study of wetland use by moorhens was undertaken from October 1992 through November 1993. The objectives of this study were to improve the conservation of endangered Mariana Common Moorhens through the: (1) identification of wetland features related to moorhen presence or absence and (2) development of a logis-

[1] Received 29 June 1998. Accepted 28 December 1998.
[2] Present address: U.S. Fish and Wildlife Service, Guam National Wildlife Refuge, P.O. Box 8134, MOU-3, Dededo, GU 96912. E-mail: islaguam@netpci.com

TABLE 1. Variables used to describe features of study wetlands on Guam.

Variable	Code	Description
Wetland area	WA	Total area (ha) of wetland
Shoreline development	SLD	Index of shoreline irregularity calculated as the ratio of the wetland perimeter to the circumference of a circle with an area equal to that of the wetland area (Wetzel 1975)
Emergent	EMG	Percent area (ha) in emergent vegetation (e.g., *Pharagmites, Panicum*)
Open	OPN	Percent area (ha) without vegetation
Floating	FLT	Percent area (ha) in floating vegetation (e.g., *Lemna*)
Aquatic bed	AQB	Percent area (ha) in aquatic bed vegetation (e.g., *Potamogeton, Hydrilla*)
Distance to road	DIR	Linear distance to nearest actively traveled road (m)
Distance to building	DIB	Linear distance to nearest actively used building (m)
Distance to wetland	DIW	Linear distance from center of study wetland to nearest wetland used by moorhen (m)
Development	DVT	Percent surrounding (r = 0.25 km) habitat that is urbanized (roads, buildings, etc.)
Grassland	GRS	Percent surrounding (r = 0.25 km) habitat occupied by upland grasses excluding those associated with development
Forest	FRT	Percent surrounding (r = 0.25 km) habitat occupied by primary or secondary forest
Disturbances in wetland	DIN	Combined ranking of disturbances from ungulates, fish, and machinery
Disturbances adjacent to wetland	DAJ	Combined rankings of disturbances from traffic, mowing, and recreation

tic regression model to predict the probability of moorhen use at a given wetland.

METHODS

STUDY AREA

Guam (13°28′N, 144°45′E) is an unincorporated territory of the United States in the western Pacific Ocean. It is the southernmost and largest (540 km^2) of the Mariana Islands and is located approximately 6,600 km west of Hawaii and 2,500 km south of Japan. Northern Guam is an uplifted and porous limestone plateau, whereas southern Guam is composed of volcanic soils (Stone 1970). Nearly all wetlands occur in the southern and central portion of the island, where soils prevent percolation.

The climate is warm and humid throughout the year. Temperatures range from 31–33°C during the day to 24–26°C at night and mean annual rainfall is approximately 2.5 m. About 55% of the rainfall occurs in the wet (July to November) season and 15% during the dry season (January to April) with the remainder falling in the transitional months.

We viewed black and white aerial photographs (scale 1:26,000) and orthophoto maps (scale 1:400) from 1975, along with recent (1987–1991) aerial photographs of some wetlands to prepare base maps. Field surveys using a hip chain and/or range finder updated current wetland features. Aerial photographs of large wetlands and orthophoto maps of small wetlands were scanned, enlarged, and cropped using an Apple OneScanner employing Ofoto software (Light Source, Inc., San Rafael, California). Scans were transferred to IMAGE, an image processing program for the Macintosh (National Institutes of Health, Research Services Branch, Bethesda, Maryland), where present wetland conditions were delineated and measurements computed for each wetland.

Wetlands were characterized by 14 habitat variables (Table 1). Distance to nearest road and building were determined during field surveys and from aerial photos. Land uses (percent development, percent grassland, and percent forest) within a 0.25-km radius of each wetland were visually estimated during field surveys and computed from base maps and scanned aerial photos. Rankings of adjacent traffic, mowing, and recreation, and rankings of ungulate presence including deer (*Cervus mariannus*), feral pigs (*Sus scrofa*), and water buffalo (*Bubalus bubalis*), fish abundance, and machinery use in wetlands were used to assess the level of disturbance to wetlands. Disturbance factors were ranked according to occurrence (rare, infrequent, frequent, common) and degree (light, moderate, severe). Disturbances ranked from 1 (rare, light) to 12 (common, severe). If no disturbance was identified, then a score of zero was given. Calculation of percent open water for seasonal wetlands was based on field surveys during the 1992 wet season. For all 33 wetlands in this study, comparisons between wetlands of different origin (human-made or natural) and water regime (permanent or seasonal) are reported in Ritter (1997), and many of these wetlands are described in greater detail in Wiles and Ritter (1993).

Presence or absence of moorhens at wetlands was determined while circumnavigating or traversing wetlands during collection of wetland habitat variables. Moorhens seen or heard confirmed presence. Maximum number of moorhens using a wetland was obtained during additional surveys. For these, wetlands were visited randomly between 06:00–15:00 and at least twice in both the dry and wet seasons. Cumulative time spent at each wetland was at least 1 hr. Wetlands were designated as used regardless of the season in which moorhens were recorded.

STATISTICAL ANALYSES

Where appropriate, data were normalized using log and logit transformations (1/2 log[p/1 − p]) and all other data were log transformed. Homogeneity of variances were tested (*F*-test) before the appropriate two-tailed *t*-tests were used to compare characteristics of wetlands with and without moorhens. We compared moorhen occurrence between human-made and natural wetlands, seasonal and permanent wetlands, and among three cover classes (low, <33%; medium, 33–66%; high, >66%) of emergent vegetation. The significance value for comparisons was set at $P < 0.05$.

Stepwise logistic regression was used to identify the optimal set of variables for predicting moorhen presence or absence. Fourteen variables were initially used to characterize each wetland. Two variables (percent cover of floating vegetation, percent cover of aquatic bed vegetation) each contained a large number of zero data points and were omitted. Spearman correlation coefficients were calculated for the remaining 12 numeric plus two categorical variables (origin, water regime). Correlation analyses were conducted separately for wetlands with and without moorhens. Only one variable of a highly correlated ($r_s > 0.6$) pair was retained. Six variables consisting of two categorical and four numeric (distance to nearest wetland used by moorhens, percent surrounding grassland, wetland area, percent cover of emergent vegetation) were retained for stepwise logistic regression analysis. The significance level for entry of variables into the logistic regression model was user defined at $P = 0.15$.

RESULTS

Thirty-three wetlands at 25 locations on Guam were sampled (Fig. 1). Twenty-five were human-made and 8 were natural, and 22 were seasonal and 11 were permanent. All but one of the sites were located in central and southern Guam. Moorhens were recorded at 64% (21 of 33) of the wetlands examined. A total of 51 birds were observed, and wetlands with moorhens averaged (± SD) 2.4 ± 1.8 birds (range 1–10). Moorhens used 68% (17 of 25) of the human-made wetlands and 50% (4 of 8) of the natural wetlands. This difference in utilization rates was not significant ($\chi^2_1 = 0.7$, $P > 0.1$). There was no difference in use of seasonal (59%, 13 of 22) and permanent (73%, 8 of 11) wetlands ($\chi^2_1 = 0.6$, $P > 0.1$), and no difference in the average number of moorhens among wetlands with high ($\bar{x} = 1.8$), medium ($\bar{x} = 2.3$), or low emergent cover ($\bar{x} = 2.3$) ($\chi^2_2 = 3.6$, $P > 0.1$).

Based on the results of the univariate analysis and logistic regression, two variables (percent cover of emergent vegetation and wetland area) were most useful in discriminating between wetlands with and without moorhens. However, in the original correlation analysis, percent cover of emergent vegetation was negatively correlated with percent cover of open water ($P < 0.01$), and wetland area was positively correlated with the percent of surrounding forest and shoreline development ($P < 0.01$). Wetlands with moorhens were smaller than wetlands without moorhens ($P < 0.05$, Table 2); 62% (13 of 21) of these were less than 0.65 ha. A 0.1-ha human-

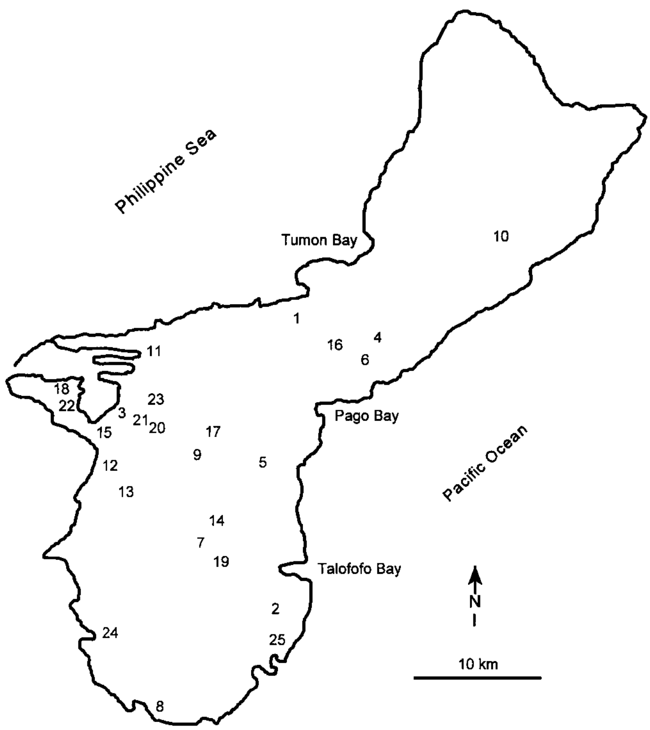

FIGURE 1. Location of 25 of the 33 wetlands examined on Guam. The wetland number, name, origin (H = human-made, N = natural) and water regime (P = permanent, S = seasonal), wetland size (ha), and number of moorhens for each wetland is: (1) Agana Wetland, NS, 70.0, 0; (2) Assupian, HS, 1.1, 0; (3) Atantano Wetland, NS, 17.5, 0; (4) Barrigada Ponding Basin, HS, 0.3, 2; (5) Country Club of the Pacific, HP, 0.4, 4; (6) Department of Agriculture, NS, 8.3, 2; (7) Fena Reservoir, HP, 75.0, 10; (8) Liyog, HS, 0.2, 1; (9) Manengon Hills Country Club, HP, 0.1, 2; (10) Marianas Terrace Ponding Basin, HS, 0.7, 0; (11) Masso Reservoir, HP, 1.7, 4; (12) Namo Wetland, NS, 11.4, 0; (13) Naval Magazine Pond, HP, 0.3, 2; (14) Naval Magazine North, NS, 0.9, 2, Naval Magazine South, NS, 1.4, 2; (15) Naval Station, NS, 36.0, 0; (16) Prison Ponding Basin, HS, 0.2, 2; (17) Pulantat East, HS, 0.5, 2, Pulantat West, HP, 1.8, 2; (18) San Luis East, HP, 6.5, 0, San Luis West, HP, 0.6, 0; (19) Sarasa, HP, 2.6, 0; (20) Shell Guam Upper, HP, 0.2, 2, Shell Guam Lower, HP, 0.4, 2; (21) Shell Guam Settling Pond East, HS, 0.8, 2, Shell Guam Inc. Settling Pond West, HS, 1.1, 2; (22) Sumay North, HS, 4.6, 0, Sumay South, HS, 4.6, 1; (23) Tenjo Vista Bioremediation #25, HS, 0.3, 1, Tenjo Vista Bioremediation #26, HS, 0.3, 0, Tenjo Vista Bioremediation #27, HS, 0.2, 0; (24) Toguan Bay Treatment Pond, HP, 0.2, 2; (25) Yabai, NS, 1.4, 2.

made permanent wetland at the Manengon Hills Country Club was the smallest wetland occupied by a pair of moorhens. Wetlands with moorhens also had on average 33% less cover of emergent vegetation (Table 2). Percent cover of emergent vegetation, the first variable in the logistic regression, provided an equation that correctly classified 76% of the wetlands where moorhens were recorded and 67% of the wetlands where they were not recorded ($P < 0.05$). When the second variable (wetland area) was entered into the equation, the correct classification of wetlands with moorhens increased to 86%, but the correct classification of wetlands without moorhens decreased to 50% ($P < 0.10$). These two variables provided a final logistic equation of:

$$\text{probability of use} = \frac{e^{[2.76-1.02(\mathrm{LWA})-2.82(\mathrm{EMG})]}}{1 + e^{[2.76-1.02(\mathrm{LWA})-2.82(\mathrm{EMG})]}}$$

where LWA is the log of the total area (ha) of wetland, and EMG is percent area (ha) in emergent vegetation.

DISCUSSION

Both univariate and logistic regression analyses indicated that moorhens were more likely to oc-

TABLE 2. Comparisons of characteristics of Guam wetlands with and without moorhens.

Variable	With Moorhens (n = 21) $\bar{x} \pm$ SD[a]	Without Moorhens (n = 12) $\bar{x} \pm$ SD[a]
Wetland Features		
Wetland area (ha)	4.8 ± 16.2	12.6 ± 20.9*
Shoreline development	1.6 ± 0.6	2.1 ± 1.0
Emergent (%)	55.6 ± 33.7	83.0 ± 25.7*
Open (%)	34.7 ± 34.7	17.0 ± 25.7
Floating (%)	7.0 ± 20.6	0.00
Aquatic bed (%)	2.8 ± 7.7	0.00
Spatial Relations		
Distance to road (m)	587 ± 979	660 ± 1,226
Distance to building (m)	601 ± 879	686 ± 1,167
Distance to wetland (m)	1,904 ± 1,953	2,349 ± 3,574
Surrounding Habitat		
Development (%)	28.3 ± 32.7	37.1 ± 32.3
Grassland (%)	22.0 ± 30.2	16.7 ± 29.5
Forest (%)	44.9 ± 42.5	46.3 ± 29.5
Disturbances[b]		
In wetland	4.0 ± 5.3	8.0 ± 7.1
Adjacent to wetland	8.0 ± 7.1	6.2 ± 3.8

[a] Means and standard deviations are from untransformed data. Comparisons significantly different, $*P < 0.05$.
[b] In wetland = combined rankings of disturbances from ungulates, fish, and machinery. Adjacent to wetland = combined rankings from traffic, mowing, and recreation.

cur at smaller wetlands with lower percent cover of emergent vegetation. In general, *G. chloropus* shows an affinity for small to medium-sized wetlands that provide emergent cover as compared to larger more open systems (Ripley 1977, Cramp and Simmons 1980). On Guam, the majority of available wetlands are small, and larger wetlands are either mostly open water or overgrown with vegetation. During the dry season, the high numbers of moorhens using Fena Valley Reservoir, the largest permanent open system on Guam, is probably an indication that permanent wetland habitat with an appropriate cover-to-water ratio is limited. Although other large systems such as the Atantano and Namo wetlands could have provided moorhens with emergent cover, these wetlands predominately support dense vegetation monocultures (mostly *Phragmites karka*) over most of their area and lack any appreciable areas of open water. Most of these larger systems are natural wetlands; moorhens have been recorded at some of them, but only in areas where thick vegetation had been removed and was naturally replaced with non-persistent vegetation.

Seasonal wetlands were important resources for Mariana Common Moorhens during the wet season, but permanent sites provided habitats during the dry season. Moorhens are opportunistic and readily occupy seasonally available habitat (Reichel and Glass 1988) and newly created wetlands (Ritter and Sweet 1993, Worthington 1998).

Although percent emergent cover influences the presence of moorhens, it probably does not affect the number of birds per site because the small size of many of the wetlands likely precludes use by more than one breeding pair. Small wetlands are usually inhabited by only one pair (Dement'ev et al. 1969), and moorhens may use wetlands as small as 0.03 ha (Brown 1944). In slightly larger wetlands studied in Great Britain, moorhens defended territories that averaged 0.11 ha (Gibbons 1986). Because many of the wetlands used by moorhens on Guam are usually occupied by only one breeding pair, territorial defense may occur infrequently. This may allow breeding pairs to allocate more energy to rearing young and multiple broods (Ritter 1994).

Vegetation in wetlands used by moorhens was comprised predominantly of non-persistent emergent macrophytes such as *Fimbristylis* spp., *Eleocharis* spp., *Cyperus* spp., and *Echinochloa* spp. The composition of non-persistent vegetation and open water provided readily available escape cover, food sources, and potential nest sites. Some wetlands also supported floating

(*Lemna* sp.) and submerged aquatic vegetation such as *Hydrilla verticillata, Hygrophila difformis, Chara* spp., and *Potamogeton marianensis.* These vegetation components likely increased habitat diversity and food resources available to moorhens.

In conclusion, moorhens frequented small wetlands that supported emergent cover of nonpersistent vegetation. Wetlands, regardless of their regime (seasonal or permanent) or origin (natural or human-made), were used in proportion to their availability. Most wetlands not used by moorhens were overgrown with vegetation. Permanent wetlands were important habitats for moorhens during the dry season. Enhancement of natural wetlands on Guam through vegetation removal or disking during the dry season would supplement the amount of suitable seasonal and permanent wetland habitat for this species. Larger wetlands, if managed, could likely provide habitat for more than one breeding pair of moorhens.

ACKNOWLEDGMENTS

This study would not have been possible without the support of the Guam Division of Aquatic and Wildlife Resources. In particular, comments and support from Bob Anderson, Bob Beck, and Gary Wiles were beneficial during the early phases of this project. The research was conducted as part of a graduate program in the School of Natural Resource Sciences at the University of Nebraska-Lincoln. Comments from John Morton, Gad Perry, and three reviewers improved the manuscript. This is Journal Series 12279 of the Agricultural Research Division, University of Nebraska–Lincoln.

LITERATURE CITED

BAKER, R. H. 1951. The avifauna of Micronesia, its origin, evolution, and distribution. Univ. Kans. Publ. Mus. Nat. Hist. 3:1–159.

BEATY, J. J. 1967. Guam's remarkable birds. South Pacific Bull. 4:37–40.

BROWN, R. H. 1944. Notes on a pair of moorhens. British Birds 37:202204.

CRAMP, S., AND K. E. L. SIMMONS. (EDS.). 1980. The birds of the western Palearctic. Univ. Oxford Press, Oxford.

DEMENT'EV, G. P., N. A. GLADKOV, AND E. P. SPANGENBERG. 1969. Birds of the Soviet Union. Vol. 3. Israel Program for Scientific Translations, Jerusalem.

GIBBONS, D. W. 1986. Brood parasitism and cooperative breeding in the moorhen *Gallinula chloropus.* Behav. Ecol. Sociobiol. 19:221–232

HARTERT, E. 1898. On the birds of the Marianne Islands. Novit. Zool. 5:51–69.

HELM, R. N., D. N. PASHLEY, AND P. J. ZWANK. 1987. Notes on the nesting of the Common and Purple Gallinules in southwestern Louisiana. J. Field Ornithol. 58:55–61.

REICHEL, J. D., AND P. O. GLASS. 1988. Land and freshwater bird investigations, p. 106–130. *In* Commonwealth of the Northern Marianas Islands Division of Fish and Wildlife Progress Report. Oct. 1982–Sept. 1987. Saipan.

REICHEL, J. D., AND T. O. LEMKE. 1994. Ecology and extinction of the Mariana Mallard. J. Wildl. Manage. 58:199–205.

REICHEL, J. D., G. J. WILES, AND P. O. GLASS. 1992. Island extinctions: the case of the endangered Nightingale Reed-Warbler. Wilson Bull. 104:44–54.

RIPLEY, D. S. 1977. Rails of the world. M. F. Fehelel Publ., Toronto.

RITTER, M. W. 1989. Moorhen recovery and management, p. 207–213. *In* C. F. Aguon, G. J. Wiles, and L. L. Mariano [eds.], Guam Division of Aquatic and Wildlife Resources Annual Report. Mangilao, Guam.

RITTER, M. W. 1994. Notes on the nesting and growth of Mariana Common Moorhen on Guam. Micronesica 27:127–132.

RITTER, M. W. 1997. Wetland habitat characteristics and wetland use by Mariana Common Moorhen on Guam. M.Sc. thesis, Univ. Nebraska, Lincoln, NE.

RITTER, M. W., AND T. M. SWEET. 1993. Rapid colonization of a human-made wetland by Mariana Common Moorhen on Guam. Wilson Bull. 105: 685–687.

SEALE, A. 1901. Report of a mission to Guam. Occas. Papers Bernice P. Bishop Mus. 1:17–60.

STINSON, D. W. 1993. Mariana Common Moorhen, p. 283–297. *In* Commonwealth of the Northern Marianas Islands Division of Fish and Wildlife Progress Report. Oct. 1987–Sept. 1992. Saipan.

STINSON, D. W., M. W. RITTER, AND J. D. REICHEL. 1991. The Mariana Common Moorhen: decline of an island endemic. Condor 93:38–43.

STONE, B. C. 1970. The flora of Guam. Micronesica 6: 1–659.

TAYLOR, K. 1984. The influence of watercourse management on moorhen breeding biology. British Birds 77:141–148.

US FISH AND WILDLIFE SERVICE. 1992. Recovery plan for the Mariana Common Moorhen (= Gallinule), *Gallinula chloropus guami.* US Fish Wildl. Serv., Portland, OR.

WETZEL, R. G. 1975. Limnology. W. B. Saunders, Philadelphia, PA.

WILES, G. J., AND M. W. RITTER. 1993. Guam, p. 129–178. *In* D. A. Scott [ed.], A directory of wetlands in Oceania. Int. Waterfowl and Wetlands Res. Bureau, Slimbridge, United Kingdom.

WORTHINGTON, D. J. 1998. Intra-island dispersal of the Mariana Common Moorhen: a recolonization by an endangered species. Wilson Bull. 110:414–417.