AN ABSTRACT OF THE THESIS OF

Leilani L. Takano for the degree of Master of Science in Wildlife Science presented on March 18, 2003.

Title: Seasonal Movement, Home Range, and Abundance of the Mariana Common Moorhen (*Gallinula chloropus guami*) on Guam and the Northern Mariana Islands

Abstract Approved:

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Susan M. Haig

The endemic avifauna of Guam and the Mariana Islands represent a unique assemblage of bird species found nowhere else in the world and thus, are of considerable biological and conservation importance. Unfortunately, most of these species are understudied and exist in precariously low populations. The endangered Mariana Common Moorhen (*Gallinula chloropus guami*), one of the last remaining native waterbirds, is a prime example of this since information is lacking for development of an effective recovery plan. Thus, this thesis attempts to provide much needed information regarding moorhen space use, seasonal movement, distribution, and abundance.

In Chapter 2, the dynamic use of space and movement among moorhens within and across landscapes on multiple islands is explored throughout the annual cycle. Adult Mariana Common Moorhens were radio-marked on Guam (N = 25) and Saipan (N = 18) to determine home range and inter- and intra-seasonal movement patterns in 2000 and 2001. Birds were tracked throughout the dry and wet season. During the dry season, 48 and 11.1% of radio-marked adults on Guam and Saipan, respectively, dispersed from their capture site to another wetland site. During the wet season, 71.4 and 70% of radio-marked birds on Guam and Saipan, respectively, dispersed from their capture site to another wetland site. In 2001, Saipan moorhen surveys indicated juveniles dispersed during the onset of the rainy season. Thus, intra-island movement increased during the wet season. Similarly, inter-island movement occurred from Saipan to Tinian during the onset of the wet season.

On Guam, moorhens were more likely to move greater average distances in the wet season than the dry season. Among Guam moorhens captured on Fena Reservoir (N = 9), Guam and that dispersed during the 2000 wet season, 66.6% returned to Fena Reservoir during the 2001 dry season. During the wet season, the frequency of movement among sites was inversely proportional to the average distance between each site. Home-range estimates on Guam averaged 3.1 ha $\pm$ 4.8 SD and did not differ significantly between sexes or seasons. However, during the dry season, females exhibited significantly smaller mean core areas than males. To our knowledge, this is the first radio telemetry study that has taken a multi-island approach to understanding a mobile islands species throughout its annual cycle.

In Chapter 3, population estimates for the Mariana Common Moorhen were determined on Guam, Saipan, Tinian, and Rota from island-wide surveys conducted from May through September 2001. We estimate the total adult moorhen population to be 287, including 90, 154, 41, and 2 adult moorhens on Guam, Saipan, Tinian, and Rota, respectively. Surveys also revealed changing moorhen distribution throughout the annual cycle and suggested inter-island movement from Saipan to Tinian occurred during the onset of the wet season. Surveys conducted on Fena Reservoir from March through August 2000 indicated adult moorhen numbers were significantly less than those from a similar survey in 1988. In addition, nest surveys of six territories revealed 58.8 % egg loss and 71.4% chick loss. Conservation efforts for this subspecies have mainly focused on protection of remaining wetlands. Efforts need to be expanded to include more active monitoring of populations, vegetation management, and predator control on wetlands throughout the Marianas and Guam.

SEASONAL MOVEMENT, HOME RANGE, AND ABUNDANCE OF THE MARIANA COMMON MOORHEN (GALLINULA CHLOROPUS GUAMI) ON GUAM AND THE NORTHERN MARIANA ISLANDS

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1. INTRODUCTION

1.1. INTRODUCTION

Islands are of considerable biological and conservation importance because of their species richness, having unique ecosystems that support many indigenous flora and fauna found nowhere else in the world. Also, greater numbers and higher proportions of recent species extinctions have been on islands rather than on continents (Manne et al. 1999). In particular, fewer than one-fifth of the world's avifauna are restricted to islands and island bird species have suffered the majority of bird extinctions that have occurred during historic times (Johnson and Stattersfield 1990).

In the Mariana Islands, an archipelago of 15 islands in the west Pacific, many of the native avifauna have been extirpated from one or more islands and are in danger of extinction within the foreseeable future. Sadly, less is known about these birds than any other avifauna on United States territory (Jenkins 1983). On Guam, the largest island in the Mariana Islands, only 4 of its 12 native forest birds remain in the wild and exist in precariously small numbers (Savidge 1984, 1987; Engbring and Fritts 1988; Reichel et al. 1992). Native waterbirds are in a similar situation in the Marianas as the result of the extirpation between 1945 and 1970 of the White-browed Crake

(*Porzana cinerea*), Guam's Nightingale Reed-warbler (*Acrocephalus luscnia*), and Marianas Mallard (*Anas oustaleti*) (Reichel et al. 1992). Habitat loss, overhunting, pesticides, marsh fires, and predation by the Brown Tree Snake (*Boiga irregularis*) may have all contributed to their demise (Reichel et al. 1992). The remaining native wetland species are the endangered Nightingale Reed-warbler, which persists as three subspecies (*Acrocephalus luscinia luscinia, A. l. niijoi, A. l. yamashinae*) on other Mariana Islands, and the endangered Mariana Common Moorhen (*Gallinula chloropus guami*) (USFWS 1984).

My study focused on the Mariana Common Moorhen, which is locally known as "Pulattat". The Mariana Common Moorhen uses multiple wetland areas on Guam, Saipan, Tinian, and Rota. Only these islands contain freshwater wetlands capable of supporting moorhens in the Mariana archipelago. Mariana Common Moorhens once existed on Pagan; however, they were extirpated due to the 1981 eruption of Mt. Pagan (Stinson et al. 1991, USFWS 1992). Population surveys conducted in the late 1980s estimated moorhen populations on Guam, Tinian, Saipan to be 100-125, 75, and 100, respectively (Stinson et al. 1991). Based on habitat loss and an estimate of 75 moorhens on Pagan, these estimates are believed to represent approximately 36-52% of the population that existed in the Marianas at the beginning of the century (Stinson et al. 1991). A more recent survey suggests a revised estimate of 50 moorhens on Tinian (USFWS 1996), and Worthington (1998) reported at least one breeding pair on Rota.

Habitat loss is the major cause of moorhen population decline (USFWS 1992). Wetland habitat is lost due to vegetation encroachment (particularly by *Phragmites* *karka),* development, siltation, and pollution. Other potential limiting factors of the Mariana Common Moorhen include competition with Tilapia (*Oreochromis mossambicus*), a freshwater fish (Stinson et al. 1991), nest loss due to flooding (Ritter 1994, USFWS 1996), destruction of nesting habitat by feral ungulates, as well as predation by Brown Tree Snakes, cats (*Felis catus*), rats (*Rattus* spp.), and Monitor Lizards (*Varanus indicus*).

1.2. LIFE HISTORY

Mariana Common Moorhen adults have slate-black plumage with white undertail coverts and white bands on their flanks, red bills and frontal shields, and olive-green legs (Baker 1951, Ritter 1994). Females resemble males, but are smaller in size and have smaller frontal shields (Baker 1951). Adult male and female moorhens range from 12-15 inches in length (USFWS 1992). Males and females weigh approximately 340 and 265g, respectively (Dunning 1993). Moorhens go through three developmental stages (chick, juvenile, subadult) over a 21-week period (Ritter 1994). Chicks have black natal down, black legs, and a red upper mandible with a yellow-green tip. Juveniles can have various shades of light and dark brown plumage, brownish-green developing into dirty yellow-green legs, and a red upper mandible with a brownish-orange with yellow-green tip. Subadults are similar to adults, but have a duller plumage and smaller frontal shield (Ritter 1994).

The Mariana Common Moorhen is one of 12 subspecies of Common Moorhens (*Gallinula chloropus*), which are globally distributed (Clements 2000).

Studies of various Common Moorhen subspecies indicate that the Mariana Common Moorhen colonized the Marianas from Asia probably by way of Japan and the Bonin and Volcano islands (Baker 1951). The Mariana Common Moorhen was first recorded in the Mariana Islands on Guam by Quoy and Gaimard (1824 – 1826), on Saipan and Tinian by Oustalet (1896), and on Pagan by Takatsukasa and Yamashina (1932). However, archaeological excavations revealed the presence of moorhens on Rota between 1,500 – 2,000 years ago (Butler 1988). Currently, birds are extinct on Pagan due to large quantities of ash and cinder deposited from the volcano eruption of May 1981 and possibly by the destruction of vegetation by feral ungulates (Stinson et al. 1991, USFWS 1992).

The best habitat information for Mariana Common Moorhens comes from Guam, where populations were considered numerous and widely distributed. Moorhens were reported to inhabit cultivated taro patches, fallow rice paddies, and fresh and brackish water wetlands. They were also found in large numbers along the Ylig River and in the Agana Swamp (Baker 1951). Previous surveys have recorded moorhens at 18 wetlands, including 15 man-made sites (Ritter 1989, Stinson et al. 1991). Recent data shows no difference in moorhen use of man-made versus natural wetlands or seasonal versus permanent wetlands (Ritter 1997).

Little is known of the reproductive characteristics of the Mariana Common Moorhen, although moorhens are considered socially monogamous. Communal nesting among adult moorhens occurs (McRae 1996) and juveniles from earlier broods are known to stay on their natal territory and help rear siblings from later broods

(Wood 1974; Siegfried and Frost 1975; Gibbons 1987; Ritter 1994; McRae 1996; Takano and Haig, pers. obs.).

Mariana Common Moorhens breed year-round (USFWS 1992) and a peak breeding period has not been reported. A similar subspecies, the Hawaiian Moorhen, (*G. c. sandvicensis*), also a year-round breeder, exhibits annual peak breeding periods. Annual differences in nesting peaks suggest the height of nest cover, which is controlled by temperature and water levels, may determine when nesting occurs (Byrd and Zeillemaker 1981).

Mariana Common Moorhens produce multiple broods throughout the breeding season. Broods range from two to eight chicks with an average of three birds successfully fledged. Up to three broods per year have been observed (Guam Division of Aquatic and Wildlife Resources, unpubl. data). Average clutch size is unknown; however, Ritter (1994) observed two nests, each containing six eggs. In Hawaiian Moorhens, Byrd and Zeillemaker (1981) found an average clutch size of 5.6 eggs, with a range of 4 to 8 eggs per clutch.

Like other moorhen species (Craig 1980, Petrie 1984), Mariana Common Moorhens are territorial (Takano and Haig, pers. obs.). In other moorhen species, males do not compete for females, but for territories, which they defend against other males. Females initiate courtship and compete with other females for mates (Eastman 1999). Whether Mariana Common Moorhens exhibit this same behavior is not known. Another unknown life history trait is the moorhen's lifespan. Moorhens have been observed to survive in the wild to age six (Eastman 1999). However, longevity of the closely related American coots (*Fulica americana*) sometimes surpasses 20 years, so moorhens probably survive much longer than age six (Eastman 1999).

1.3. STUDY OBJECTIVES

Although moorhens inhabiting temperate regions are migratory (Cramp and Simmons 1980), moorhen populations on Guam and the Northern Mariana Islands are considered non-migratory and treated as separate demographic units (USFWS 1992). Because information is lacking on inter- and intra-island dispersal, space use, and wetland site fidelity, developing an effective recovery plan for this endangered bird is difficult. For example, the unexpected arrival of moorhens on Rota in 1995, in response to the creation of wastewater treatment ponds, provided the first evidence that this subspecies is capable of inter-island dispersal. Rota was probably colonized by moorhens migrating from either Guam (77 km SSW of Rota), Tinian (120 km NNE of Rota), or Saipan (127 km NNE of Rota) (Worthington 1998).

Based on monthly counts between 1963-68 and 1987-88 on Guam, moorhens are known to increase in numbers at permanent wetlands during the dry season when seasonal habitats dry out, and decrease when seasonal wetlands are reflooded (Guam Division of Aquatic and Wildlife Resources, unpubl. data). Thus, intra-island movements between ephemeral and persistent wetlands occur (Stinson et al. 1991, Ritter 1997). Identifying movement patterns among waterbirds (i.e., moorhens) is not only key to defining metapopulation structure and explaining metapopulation dynamics, but is also important in maintaining habitat and landscape connectivity (Haig et al. 1998, Webster et al. 2002).

Movement patterns or gap-crossing between habitat patches by animals is one of the least understood factors that control metapopulation dynamics (Grubb and Doherty 1999) and ignoring movement patterns can lead to incorrect and potentially devastating consequences for conservation (Taylor et al. 1993). Thus, this study consisted of monitoring moorhen inter- and intra-island movement patterns within and between seasons, and defining home range. This research also included the estimation of moorhen populations and distribution, as well as determining breeding success on Fena Reservoir, Guam.

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2. INTER- AND INTRA-ISLAND MOVEMENT PATTERNS, HOME RANGE, AND CORE AREA OF THE MARIANA COMMON MOORHEN

2.1. ABSTRACT

Adult Mariana Common Moorhens (*Gallinula chloropus guami*) were radio-marked on Guam (N = 25) and Saipan (N = 18) to determine home range, inter- and intra-seasonal space use, and movement patterns in 2000 and 2001. Birds were tracked throughout the dry and wet season. During the dry season, 48 and 11.1% of radio-marked adults on Guam and Saipan, respectively, dispersed from their capture site to another wetland site. During the wet season, 71.4 and 70% of radio-marked adults on Guam and Saipan, respectively, dispersed from their capture site to another wetland site. In 2001, Saipan moorhen surveys indicated juveniles dispersed during the onset of the rainy season. Thus, intra-island movement increased during the wet season. Similarly, inter-island movement occurred from Saipan to Tinian during the onset of the wet season. Among moorhens captured on Fena Reservoir (N = 9), Guam and that dispersed during the 2000 wet season, 66.6% returned to Fena Reservoir during the 2001 dry season. Guam moorhens were more likely to move greater average distances in the wet season than the dry season. During the wet season, the frequency of movement among sites was inversely proportional to the average distance between each site. Home-range estimates on Guam averaged 3.1 ha $\pm$ 4.8 SD and did not differ significantly between sexes or seasons; however, during the dry season, females exhibited significantly smaller mean core areas than males. This

study demonstrates the dynamic use of space and movement among moorhens within and across landscapes on multiple islands.

2.2. INTRODUCTION

Natural landscapes have discrete spatial patterns that can occur in a mosaic of patches and over a broad range (Kotlier and Wiens 1990, Hansson et al. 1995, Wu and Loucks 1995, Collins and Glen 1997). Physical and biotic processes vary within landscapes and habitat functionality varies depending on the needs of a particular species. Thus, understanding how species perceive and use similar landscapes is important in determining connectivity among heterogeneous habitats and explaining metapopulation dynamics (Kotlier and Wiens 1990). In particular, waterbirds (e.g., Gruiformes, Anseriformes, Charadriiformes) use wetland complexes that are spatially heterogeneous, exhibiting considerable variability in time and space. They have population dynamics that can include frequent among-site movements throughout different phases of their annual cycle. Thus, they make excellent indicators of wetland connectivity (Haig et al. 1998).

Most investigations into avian movement patterns are based on investigation of a single local population during limited periods in the annual cycle. However, recent studies emphasize the importance of studying movement of individuals at multiple sites during multiple phases of the annual cycle (Lima and Zollner 1996; Haig et al. 1998, 2002; Webster et al. 2002). Failing to examine the appropriate spatial and temporal scales at which movement occurs can produce potentially devastating consequences for conservation (Haig et al. 1998, Walters 2000).

While waterbird movement studies are beginning to be carried out at more appropriate scales on continents (e.g., Plissner et al. 2000a,b; Haig et al. 2002; Sanzenbacher and Haig 2002), as far as I know, no studies have been carried out across an island chain for waterbirds capable of inter-island movement. A prime example of the need to adequately understand movement and connectivity between habitat patches occurs in the Northern Mariana Islands and Guam. The Mariana Common Moorhen (*Gallinula chloropus guami*), locally known as "Pullatat", is one of the last remaining wetland-dependent birds endemic to the Mariana archipelago. Other wetland species that are known from the Mariana Islands include: the White-browed Crake (*Porzana cinerea*) (Jenkins 1983, Steadman 1992) and Mariana Mallard (*Anas platyrhynchos oustaleti*) (Reichel and Lemke 1994), which are both recently extinct; and the Nightingale Reed-warbler (*Acrocephalus luscinia*), which is endangered (USFWS 1984).

The Mariana Common Moorhen was listed as endangered primarily due to habitat loss (USFWS 1984). This subspecies has been known to inhabit five islands; however, it has been extirpated from one island in the Mariana archipelago. On Pagan, two 16-hectare lakes supported moorhens until the 1981 eruption of Mt. Pagan. Thus, moorhens were extirpated from Pagan as a result of ash and cinder fall out and the grazing and rooting of emergent vegetation by feral cattle and pigs (Stinson et al. 1991, USFWS 1992). Currently, moorhens persist in small numbers on Guam, Rota, Saipan, and Tinian. Moorhen population surveys conducted in the late 1980s estimated populations on Guam, Tinian, and Saipan to be 100-125, 75, and 100, respectively (Stinson et al. 1991). Overall, it is estimated that the moorhen population has been reduced by at least 36-52% in the last century (Stinson et al. 1991). On Rota, the most recent survey suggests at least one breeding pair (Worthington 1998, Chapter 3).

Mariana Common Moorhens are year-round breeders (Marshall 1949) and can produce multiple broods throughout the year (Ritter 1994). Average clutch size is unknown; however, Ritter (1994) observed two nests, each containing six eggs. Broods range from two to eight chicks with an average of three birds successfully fledged. Up to three broods per year have been observed (Guam Division of Aquatic and Wildlife Resources, unpubl. data). Among Mariana Common Moorhens and other moorhen species, juveniles from earlier broods are known to stay on their natal territory and help rear siblings from later broods (Wood 1974, Siegfried and Frost 1975, Gibbons 1987, Ritter 1994, McRae 1996, Takano and Haig, pers. obs.).

Mariana Common Moorhens use multiple wetlands on Guam, Rota, Saipan, and Tinian. Only these islands contain freshwater wetlands capable of supporting the moorhen in the Mariana archipelago. Historically, major losses of wetlands have occurred in the Marianas due to changing agricultural practices, encroachment by undesirable vegetation, and clearing and filling of wetlands for development. Estimates of loss are difficult to quantify because information is lacking on size, location, and type of wetlands that existed before European contact. On Guam, many of the existing natural wetlands (e.g., Agana Swamp, Atantano and Namo wetlands) have been heavily encroached by *Phragmites karka* (Ritter and Savidge 1999). However, Fena Reservoir, the largest permanent body of water on Guam, provides important habitat, especially in the dry season when habitat is limited elsewhere (Guam Division of Aquatic and Wildlife Resources, unpubl. data). On Saipan, estimates of wetland loss have been suggested to range from 30 (Stinson 1992) to 64% (CNMI 1989). There is no information on wetland loss for Tinian and Rota. Rota has no natural permanently flooded freshwater wetlands (USFWS 1989); however wetlands habitat may have existed 1,500-2,000 years ago since moorhen remains have been found on the island dating to that time period (Butler 1988).

Moorhen wetland use varies during dry and wet phases of the annual cycle. On Guam, adult moorhens are known to increase in numbers at permanent wetlands during the dry season when seasonal habitats dry out and decrease when seasonal wetlands are reflooded (Guam Division of Aquatic and Wildlife Resources, unpubl. data). Intra-island movements between ephemeral and persistent wetlands occur, as moorhens have appeared at newly-flooded ephemeral wetlands, but movement and home range have not been quantified (Stinson et al. 1991, Ritter 1997). Understanding space use of moorhens and their role in inter- and intra-island wetland connectivity will help prioritize wetland conservation efforts for this endangered species.

2.3. METHODS

2.3.1. *Study Area*

The Mariana Island archipelago is comprised of the 14-island chain of the U.S. Commonwealth of the Northern Mariana Islands (CNMI) and the U.S. Territory of Guam (Figure 2.1). These 15 islands extend 750 km between 13° 14' N, 144° 45' W and 20° 3' N, 144° 54' W (Figure 2.1). Though volcanic in origin, the islands where moorhens occur (Guam, Rota, Saipan, and Tinian) are mainly forested limestone plateaus. The climate is tropical, with average annual temperatures on Guam of

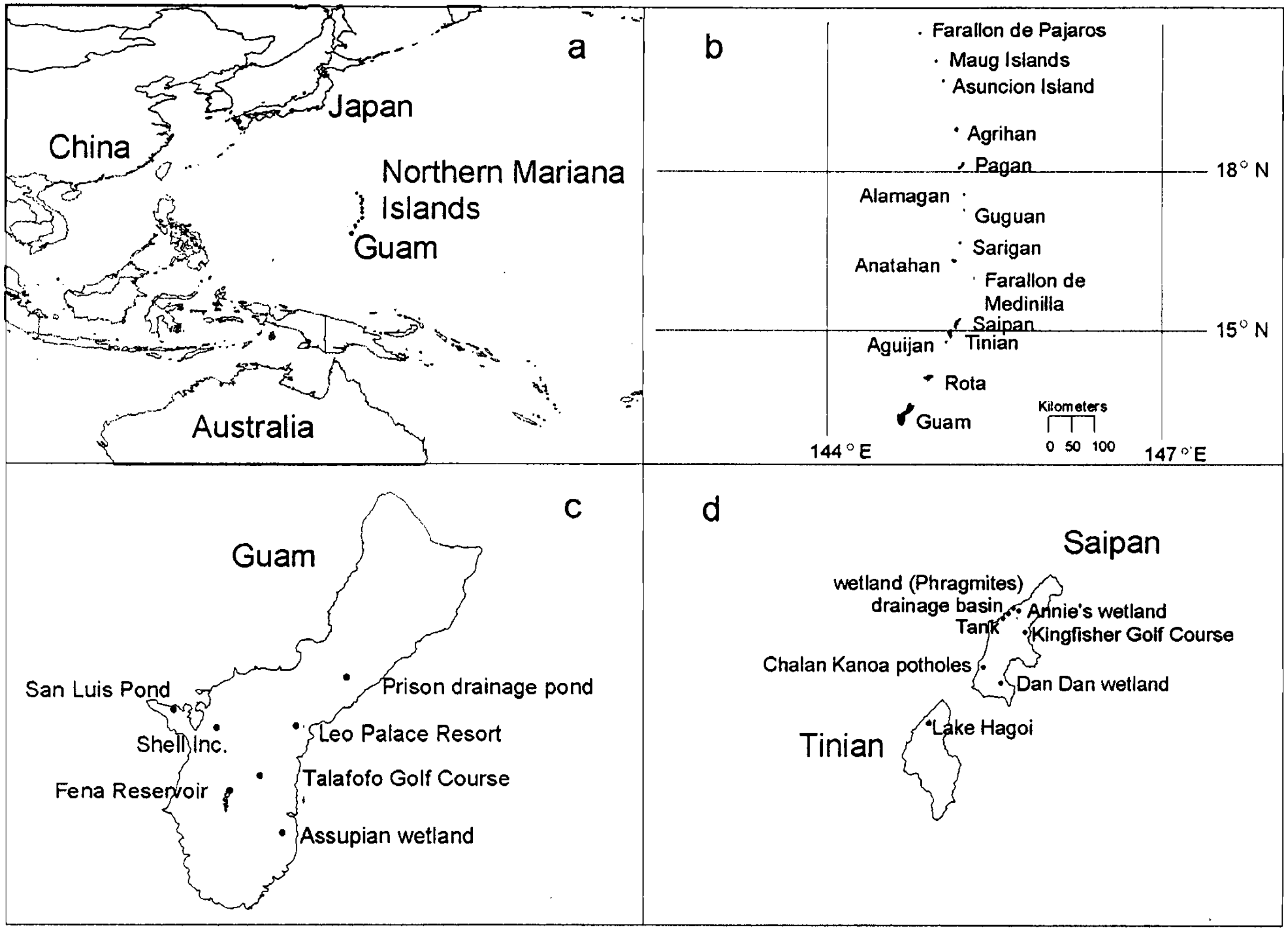

Figure 2.1. a) Location of Guam and the Northern Mariana Islands in the Pacific. b) Location of study sites: Guam, Rota, Tinian, Saipan. c) Guam capture sites and wetlands utilized by moorhens in study. d) Saipan capture sites and Saipan and Tinian wetlands utilized by moorhens in study.

26.3°C and on Saipan of 25.8°C (Kendrick 1997). Daily temperatures range from 31 – 33°C during the day and 24 - 26°C at night. Average annual precipitation for Guam and Saipan is 251 and 218 cm, respectively, and ranges from 200-260 cm (Kendrick 1997). The year is divided into the dry and wet season. Generally, the dry season occurs between the months of January – April and wet season from July – November. The other months are transitional periods that may be dry or wet depending on the particular year. On average, about 15% of annual rainfall occurs during the dry season and 55% during the wet season.

On Guam, with the exception of Fena Reservoir (81 ha), most wetlands inhabited by moorhens are less than 0.6 ha in size (Ritter 1989, Stinson et al. 1991). Among 33 wetlands.on Guam examined by Ritter (1997), 21 were occupied by moorhens. In his study, wetlands inhabited by moorhens consisted of 13 seasonal and 8 permanent wetlands. On Saipan, moorhens were recorded at 14 of the 30 wetlands surveyed (USFWS 1996). Among the wetlands used by moorhens, Lake Susupe (17 ha) and the Chalan Kanoa marsh/potholes (185 ha) account for 77% of the remaining freshwater and estuarine wetlands (Stinson et al. 1991). In our study, Saipan moorhens were also found breeding in an abandoned World War II concrete oil tank (approximately 0.5 ha), which is inundated by rainwater. Concrete platforms, aquatic vegetation (when water levels are low), and fallen branches from overhanging vegetation provided roosting and nesting sites within the tank. On Tinian, Lake Hagoi (18 ha), a semi-permanent wetland with approximately 1 ha of open water, has been identified as a wetland that may potentially support a significant moorhen population (Engbring et al. 1986). In addition to Lake Hagoi, two seasonal wetlands on Tinian exist: the Mahalang (13.4 ha) and Bateha (6 ha) wetlands; however, both are overgrown with vegetation (USFWS 1996). On Rota, the only wetlands inhabited by moorhens are located on an 18-hole golf course resort. The wastewater treatment plant for the resort includes two 0.6 ha primary stabilization ponds and two 1.5 ha secondary polishing ponds, which are used by moorhens. For a more complete description of wetlands in Guam and the Marianas see USFWS (1992, 1996) and Wiles and Ritter (1993).

2.3.2. *Capture and Marking*

I studied the Mariana Common Moorhen on Guam (541 km^2), Rota (85 km^2), Tinian (101 km^2), and Saipan (122 km^2). I captured moorhens on two sites: Fena Reservoir and the Department of Corrections prison drainage pond on Guam (Figure 1c). On Saipan, moorhens were captured in an abandoned oil storage tank. Moorhens were captured at night by boat and on foot using a spotlight and a 1.5-meter pole net.

All trapped birds were fitted with an aluminum U.S. Fish and Wildlife Service band and given a unique combination of ultra-violet resistant-color rings (A.C. Hughes, England) placed on the tarsus. Birds were fitted with 8.64-gram radio-transmitters (model RI-2C, Holohil Systems Ltd., Canada) with a life span of approximately 90 weeks. Radios were attached by a backpack method using a Dacron braided line as harness material. Adult males and females weighed approximately 340 and 265g, respectively (Dunning 1993), thus, radio-transmitters weighed approximately 3.27 % of the female moorhen's body weight. Birds were aged using plumage characteristics (Ritter 1994) and sexed via blood samples (0.2 mL) that were collected from the brachial vein and stored in a cryogenic tube containing a buffer solution (100mM Tris HCl pH 8.0, 100mM EDTA pH 8.0, 10 nM NaCl, 0.5% SDS) until shipment to Avian Biotech International (Tallahassee, Florida).

2.3.3. *Radio-tracking*

I tracked Guam moorhens daily from March to August 2000 and March to June 2001 and once every two weeks from September 2000 to February 2001. Saipan-captured moorhens were tracked bi-weekly from June to September 2000 and weekly from June to September 2001. Most tracking was conducted during daylight hours (approx. 0600 – 1800 hrs); however, I also sampled after dark to identify nocturnal roost sites.

Multi-island tracking consisted of routine searches on Guam and Saipan (as described above) and periodic surveys on Rota and Tinian when individuals were not found on Guam or Saipan. On Rota, surveys consisted of visual observations for banded moorhens and radio telemetry on golf course wetlands and water treatment ponds. On Tinian, ground telemetry surveys were used to detect missing radio-tagged moorhens on Lake Hagoi. Aerial telemetry was conducted when ground surveys failed to locate missing individuals. Missing individuals that were not detected by ground or aerial surveys were assumed to have lost their radios or had their radios fail prematurely.

Exact positions of radio-marked birds were determined on the ground via triangulation of at least three bearings. A 2-element 'H' hand-held antenna and receiver (Model R2100, Advanced Telemetry Systems, Inc.) was used to detect transmitter signals. Each bearing was recorded with a global positioning system unit (GPS II+; Garmin Ltd. Olathe, KS). Individual locations were recorded once daily. During aerial telemetry, locations of individuals were marked on a map and sites were revisited by foot to determine exact locations. Location data was analyzed by LOAS (Ecological Software Solutions 2001), which produced estimates of individual locations.

2.3.4. *Population Surveys*

Moorhen adults, juveniles, and chicks were surveyed to establish distribution, abundance, patterns of phenology, and to identify marked individuals. . Survey efforts covered both permanent and seasonal wetlands on Saipan, Tinian, and Guam. Surveys consisted of visual observations by two people using binoculars during crepuscular hours when moorhens were most active. Birds in the Saipan tank were observed using a spotting scope during daylight hours since a complete view of the inhabitants in the tank could be seen from one vantage point. Multiple island-wide moorhen surveys on Saipan and Tinian took place from May to September 2001. On Saipan and Tinian, each survey was conducted over a two-week period. The total count of moorhen juveniles and chicks for each two-week period was summed across all wetlands visited. These counts represent an index of relative juvenile and chick numbers within a vast majority of available wetlands during the dry and wet seasons. In addition, nesting activity was recorded in the Saipan tank from May to September 2001.

On Guam, monthly surveys were conducted on Fena Reservoir from March to August 2000. Surveys started at dawn and included two persons with binoculars in a boat powered by an electric motor. Observers traveled close to and along the periphery of the reservoir at approximately 3.2 km/hour. In addition, observations of nesting activity were recorded during daily wetland visits from March to August 2000 and March to June 2001, and bi-weekly from September 2000 to February 2001.

2.3.5. *Data Analyses*

All data were partitioned into dry and wet season. Since timing of seasons varies annually, rainfall patterns were examined in order to determine dry and wet seasons. I established the cutoff point between the dry and wet season to occur when there was a difference of 25.4 cm [10 in] between monthly precipitation of transitional months (Figure 2.2). However, when the change from dry to wet season was more subtle (e.g., on Saipan in 2000), the wet season was identified as the later months of the year consisting of approximately 55% of the annual rainfall.

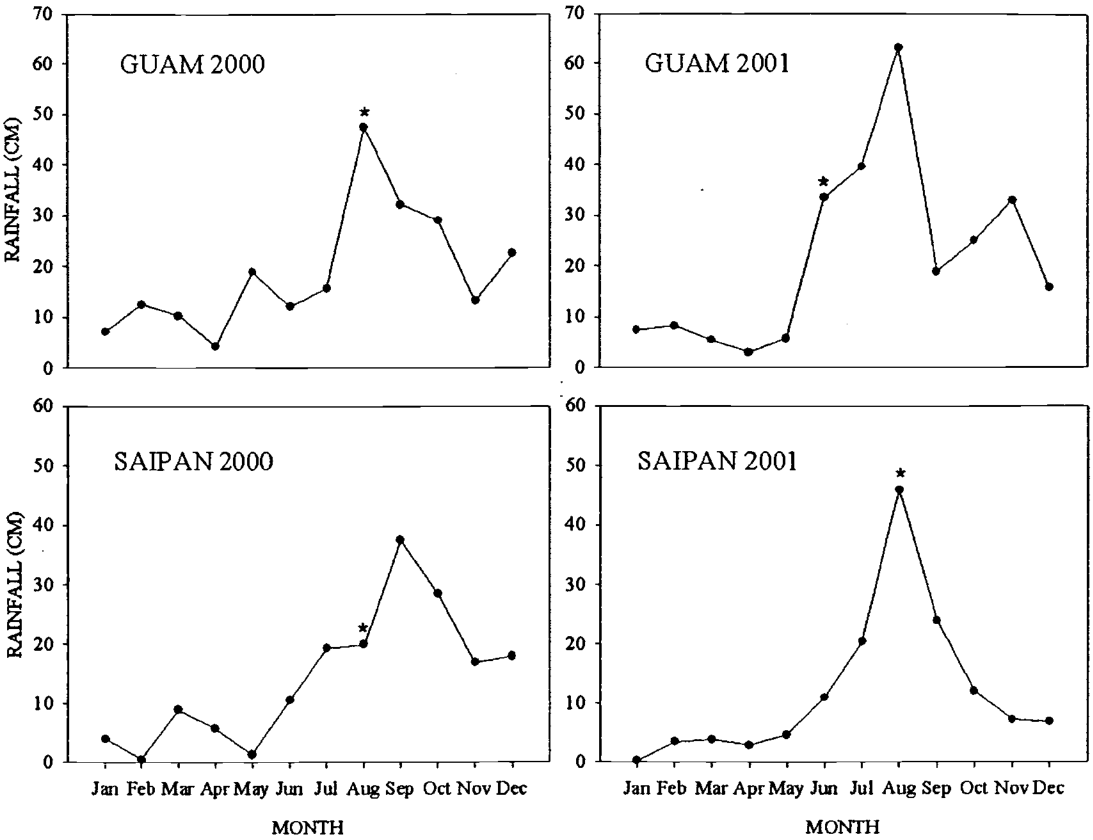

Figure 2.2. Total monthly rainfall on Guam and Saipan in 2000 and 2001 (NOAA, National Climate Data Center). First month of wet season denoted by *.

For this study, movement was defined as an individual traveling from one discrete wetland site to another. Bird locations were plotted on topographic maps using a geographical information system (GIS; ArcView 3.2, ESRI Inc.). As one measure of wetland connectivity, mean and mean maximum distances moved among wetland sites were calculated. I examined potential bias due to sample size differences among all birds by plotting and regressing both mean and mean maximum distances on the number of locations per individual. Mean and mean maximum distance data were log transformed prior to analysis to meet assumptions of normality. In regression analysis, slopes were not significant ($P > 0.5$); therefore, results were calculated for all birds (≥ 10 locations for each season, i.e. dry and wet).

A univariate analysis of variance (ANOVA) with a split-plot design was used to compare home-range size and movement parameters across seasons and sexes (S-Plus 2000, MathSoft Inc). In the split-plot design, birds were grouped by sex, then split by season (i.e., wet or dry). I performed separate tests for each response variable (i.e., mean home range size, mean and mean maximum distance moved, frequency of movement between sites, and average number of sites visited). In addition, the interaction term (sex x season) was included in each analysis. The analysis involved only birds whose radios were active throughout dry and wet seasons.

For birds that moved off capture sites to other wetlands, first departure dates and monthly rainfall totals were qualitatively compared among individuals. In addition, I wanted to determine whether moorhens preferentially dispersed to closer sites during the dry and wet season. Therefore, linear regression was used to examine the relation between the number of movements, the explanatory variable, and average distance between sites for each season, the response variable. In order to assess site fidelity, I quantified the number of sites at which birds were detected throughout a season, proportion of relocations within each site category, and after dispersing from its dry season site, whether the bird returned to that particular site during the next dry season.

Daily movements were examined through observations of radio-tagged Guam individuals. In addition, during the dry season, four radio-tagged moorhens on Guam were tracked for a 16-hour period (from 0500-2100) per day on four different days in May and June 2000. Each bird was located hourly and mean distance an individual traveled per day and roost sites was determined.

Home ranges were calculated using the fixed kernel method in the program KERNLHR (version 4.27, Seaman et al. 1998) using a least square cross-validation method to determine smoothing parameters and automatic selection of grid cell size. Home-range estimates consisted of 95% use areas for each individual. Comparisons of home range methodologies indicate that kernel density estimates are among the most accurate measures of habitat utilization and home range (Worton 1995, Seaman and Powell 1996). Kernel based estimators are non-parametric and not influenced by the size or placement of an overlying grid (Silverman 1996). However, with highly clumped data, such as occurs with incubating birds, kernel density estimates can sometimes produce erroneous results. Therefore, the home-range volume parameter was used to assess the validity of individual home-range estimates. Volume parameter values that differed from 1 by more than 0.02 indicated an erroneous estimate. Based on evaluation of the volume parameter, one individual was excluded from the seasonal analysis.

Prior to analysis, I investigated potential bias due to sample size differences by examining scatterplots and conducting regression analysis with home-range size as the dependent variable and sample size as the independent variable. There was no significant relationship between home-range estimates and sample size ($r^2 = 0.05$, d.f. = 21, P = 0.28). Similarly, there was no significant relationship between seasonal home-range estimates and sample size (dry season: $r^2 = 0.03$, d.f. = 17, P = 0.53; wet season: $r^2 = 0.04$, d.f. = 19, P = 0.43). All birds had $\geq$ 10 locations. Therefore, since slopes were not significant, results were calculated for all birds. In addition, home-range estimates were checked for outliers by examining scatterplots and using Cook's Distance (S-Plus 2000, MathSoft Inc.). Home range data were log transformed prior to analysis to meet assumptions of normality.

In order to measure the changing patterns of use within moorhen home ranges, core areas were determined by examining kernel density isopleths 10-90. Core areas are defined as areas receiving concentrated use by resident animals (Samuel et al. 1985). Using the program Plot Contour (PLOTCON4 for use with KERNLHR version 4.27), isopleths were calculated from the same data used to calculate the 95% kernel home-range estimates. The area enclosed by each isopleth was then determined (GIS; ArcView 3.0, ESRI Inc.). Plotting the isopleths in increments of 10 against the area enclosed within each isopleth, I identified the point at which the gradient of slope changes. This point of inflection was used to define the core area. When the point of inflection occurred between two values, the lower one was used to define the core area (Harris et al. 1990).

For moorhens captured at Fena Reservoir on Guam, I compared mean core area between birds that moved off their territories and those that remained on the reservoir throughout the study using a two-sample t-test. I also compared mean core area between sexes during the dry season (two-sample t-test, S-Plus 2000, MathSoft Inc). Core area data were log transformed prior to analysis to meet assumptions of normality. Inadequate sample size prevented comparison of wet season mean core area between sexes.

2.4. RESULTS

2.4.1. *Annual Phenology*

Monthly surveys conducted on Fena Reservoir during 2000 indicated chicks hatched throughout the dry season (Figure 2.3d), but ceased with the onset of the wet season when an approximate 30-cm increase in rainfall occurred between July and August (Figure 2.2). On Fena Reservoir, no nesting activity was observed from September to November 2000. However, one pair of moorhens was observed nesting on Fena Reservoir in December 2000. From Fena Reservoir and other wetland visits throughout the year, we observed year-round nesting activity on Guam at permanent and seasonal wetlands. We also observed moorhens to be socially monogamous and some pairs (N = 4) had juvenile helpers from an earlier brood.

Saipan moorhen surveys in 2001 suggested synchronous breeding within wetlands during the dry season. Chick production reached an asymptote during the dry season and juveniles from earlier broods began to fledge at the beginning of the wet season (Figure 2.3a). This same pattern was indicated in censuses of moorhens in the tank. Juveniles in the tank also began to fledge at the onset of the rainy season (Figure 2.3b). Between August and September, chick numbers in the tank increased by a few individuals, whereas they began to decline on the other Saipan wetlands. This decline may be caused from rain inundating nesting habitat (i.e., shoreline), whereas in the tank, nesting habitat (i.e., concrete platforms) is relatively stable. However, there was no increase in nesting activity within the tank at the start of the wet season in August (Figure 2.3c).

2.4.2. *Radio Telemetry*

We radio-tagged 43 adult moorhens: 25 were captured on Guam and 18 on Saipan. On Guam, 23 moorhens were marked in the 2000 dry season, and 2 in the 2001 dry season. The sex ratio of moorhens captured on Guam was 9:13 (males: females), with 3 birds of unknown sex. A total of 1,291 locations were recorded for Guam moorhens. The mean number of locations recorded per individual was 56.13 (38.55 SD). Among the 1,291 locations, 683 and 579 were recorded in the dry and wet season, respectively. During the dry season, the mean number of locations per individual was 35.95 (21.77 SD). During the wet season, the mean number of locations per individual was 30.47 (20.82 SD).

Moorhens radio-tagged on Saipan were captured in the 2000 dry season (N = 13), 2001 dry season (N = 1), and 2001 wet season (N = 4). The sex ratio of Saipan birds was 10:8 (males:females). Tracking efforts resulted in a total of 280 locations and the mean number of locations per individual used in movement analysis was 15.56

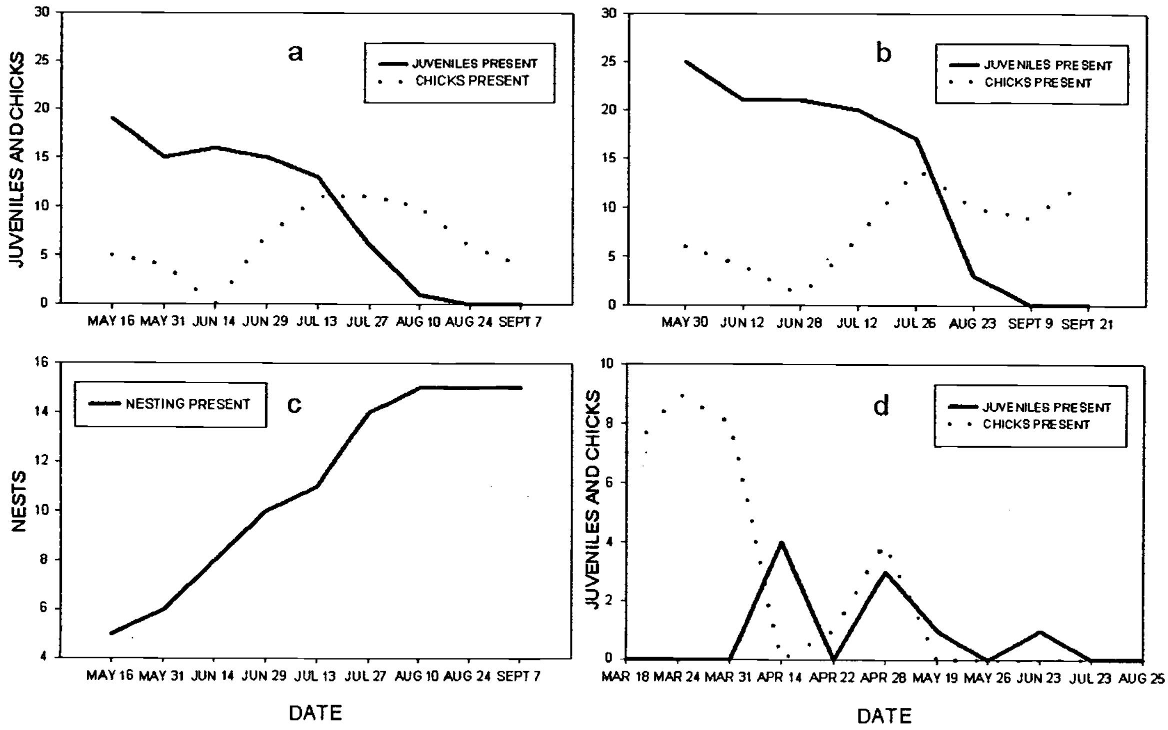

Figure 2.3. Reproduction effort on Saipan and Guam: a) Juveniles and chicks at the Saipan tank in 2001. b) Juveniles and chicks at Saipan wetlands (excluding the tank) in 2001. c) Nests at the Saipan Tank in 2001. d) Juveniles and chicks at Fena Reservoir, Guam in 2000.

(8.18 SD). Among the 280 locations, 108 and 172 were recorded in the dry and wet season, respectively. During the dry season, mean number of locations per individual was 9 (3.62 SD). During the wet season, mean number of locations per individual was 7.82 (2.52 SD).

2.4.3. *Inter-island Movement*

No inter-island movement was detected among Guam radio-tagged moorhens; however, two adult moorhens moved from Saipan to Tinian. Movement from Saipan to Tinian was detected in the 2000 wet season in mid-September and in the 2001 wet season in mid-August. In 2000, an adult moorhen tagged in the tank moved to the Chalan Kanoa potholes in August and stayed there for 3 weeks before flying approximately 5 km to Lake Hagoi, Tinian. In 2001, an adult moorhen tagged at a Kingfisher Golf Resort wetland on Saipan flew directly to Lake Hagoi, Tinian.

2.4.4. *Site Fidelity*

During the dry season, most Guam moorhens (N = 25; 52%) stayed on capture sites; however, during the wet season, only 28.6% stayed at capture sites. For Guam moorhens that moved away from capture sites, permanent sites were used 92.5 and 83% of the time during the dry and wet season, respectively. Moorhen use of river and seasonal wetlands at least doubled during the wet season (Table 2.1). Among nine birds that were captured in the 2000 dry season and moved off Fena Reservoir in the 2000 wet season, at least 66.6% of them returned to Fena Reservoir during the 2001 dry season. The six birds that returned included four females and two males. Among birds that were not detected on Fena Reservoir during the 2001 dry season, one female was found at a Leo Palace Resort wetland, and the other two, a male and female, were not found on any of the wetlands, indicating their radios had fallen or failed prematurely.

Among 2000 and 2001 radio-tagged Saipan moorhens (N = 18), 88.9% stayed on their capture site during the dry season, while 38.9 % remained in the wet season. During both dry seasons, only 1 of 10 marked males moved off its capture site. Similarly in both dry seasons, only one of eight females moved off its capture site. Among all birds radio-tagged during the 2000 and 2001 wet seasons, 4 of 10 males and 3 of 8 females moved off their capture site.

2.4.5. *Local Movement*

Guam radio-marked birds were detected at a total of 27 distinct sites on the island. Sites included 7 permanent wetlands, 10 seasonal wetlands, and 10 rivers (Table 2.2). While no birds moved off the island, the mean number of sites visited per individual (N = 24) across both seasons for year 2000 was 2.71 (2.24 SD). For 2001, mean number of sites visited per individual (N = 11) was 2.18 (0.98 SD). Moorhens moved as individuals when movement between discrete wetland sites occurred. One pair (male and female) was observed to move from Fena Reservoir to the Shell Wetlands, departing within a few days of each other. Flight between wetland sites was not observed during daylight hours, suggesting that moorhens flew between wetlands during crepuscular hours or at night. However, observation of flight during daylight occurred when a bird leaving Fena Reservoir visited the nearby Maulap River and returned to Fena Reservoir the same day. On a separate occasion, this same bird was observed flying during daylight to Almagosa River and back to Fena Reservoir the same day. Saipan radio-marked birds were detected at four permanent, two semi-permanent, and two seasonal wetlands (Table 2.3). Mean number of sites visited per individual calculated for both years was 1.23 (0.39 SD) and 1.25 (0.42 SD) for 2000 and 2001, respectively.

Table 2.1. Location and proportion (%) of resightings for Mariana Common Moorhens (N = 13) on Guam that moved off capture sites during the dry and wet seasons (2000-2001).

	Dry season sites				Wet season sites			
	Permanent	Seasonal	River	Upland veg.	Permanent	Seasonal	River	Upland veg.
Proportion (%)	92.54	2.69	3.11	1.66	82.96	8.94	6.98	1.12
No. of obs.	447	13	15	8	297	32	25	4

2.4.6. *Seasonal Movement*

On Guam, average distance moved among sites differed significantly by season ($F_{3,10}$ = 7.42, P = 0.02, Table 2.4). Moorhens were more likely to move greater average distances among sites in the wet season than the dry season. However, there were no differences among sexes in average distance moved among sites ($F_{3,10}$ = 1.94, P = 0.19) and no interaction between season and sex ($F_{3,10}$ = 0.003, P = 0.95).

Seasonal period was a significant factor affecting average maximum distance birds traveled ($F_{3,10}$ = 17.69, P = 0.002). Moorhens were more likely to move greater average maximum distances among sites in the wet season than the dry season. Sex was not a significant factor affecting average maximum distance ($F_{3,10}$ = 1.94, P = 0.19) and no interaction between sex and season was found ($F_{3,10}$ = 0.51, P = 0.49). For Guam birds, there was no sex, season, or sex and season interaction affect on the average number of sites visited or frequency of movement among sites (P > 0.5) (Table 2.4). Most movement was from Fena Reservoir to local wetlands sites and occurred more often (66.67%) during the wet season as rainfall levels increased (Figure 2.4). During the wet season, the number of times moved was inversely proportional to the average distance between each site (r^2 = 0.56, d.f.= 12, P = 0.003). In other words, the frequency of movement among sites increased if the average distance between wetland sites was relatively small (Figure 2.5). During the dry season, there was no relationship between the average distance moved per individual and the frequency of movement (r^2 = 0.002, d.f.= 9, P = 0.90).

Table 2.2. Sites visited by Mariana Common Moorhens on Guam and number of individuals detected at each site in 2000 and 2001. (See Figure 2.1 for map.)

Site	Individuals detected at site	Location UTM[a]
Permanent		
Fena Reservoir	23	N1478500 E250181
Leo Palace Tank	1	N1483941 E256301
Leo Palace Wetland	1	N1484381 E254433
San Luis Ponds	1	N1487011 E245516
Shell Oil Basin	1	N1484575 E249196
Shell Wetland	2	N1484299 E249670
Talofofo Golf Course Wetland	1	N1478216 E255110
Seasonal		
Assupian	1	N1471715 E255782
Prison Pond	2	N1487810 E260062
Shell Tank 1901[b]	1	N1484370 E249157
Shell Tank 1902[b]	1	N1484362 E249341
Shell Tank 1904[b]	2	N1484302 E249540
Shell Tank 1907[b]	2	N1484504 E249727
Shell Tank 1932[b]	1	N1485009 E249301
Shell Tank 1933[b]	1	N1484847 E249367
Shell West	1	N1484484 E249037
Puddle[c]	1	N1478043 E250375
Rivers		
Amagosa River	1	N1476392 E249249
Bonya River	5	N1478794 E251456
Mahlac River	4	N1479389 E253029
Maulap River	2	N1477357 E250423
Maemong River	3	N1479815 E251927
Muagas River	1	N1477630 E252083
Talisay River	4	N1479779 E251304
Tinango River, Dandan	1	N1471847 E254748
Tinechong River	2	N1476697 E252700
Ylig River	1	N1481024 E256157

[a] Universal Transverse Mercator

[b] Water ponding adjacent to tanks, Shell Inc.

[c] West of Fena Reservoir

Table 2.3. Sites visited by Mariana Common Moorhens on Saipan and Tinian and number of individuals detected at each site in 2000 and 2001. (See Figure 2.1 for map.)

Site	Individuals detected at site	Location UTM[a]
Permanent		
Dan Dan Wetland	1	N1674033 E363350
Drainage Pond	1	N1683950 E365408
Kingfisher Golf Course Hole 9/10	1	N1682931 E368944
Tank (abandoned oil tank)	17	N1683190 E364362
Semi-permanent		
Chalan Kanoa Potholes	2	N1674472 E360747
Lake Hagoi, Tinian[b]	2	N1666006 E351966
Seasonal		
Annie's Pond	2	N1684025 E365476
Wetland (near Annie's Pond)	1	N1683977 E365411

[a] Universal Transverse Mercator coordinates

[b] Unless indicated, sites are located on Saipan.

Table 2.4. Movement of Mariana Common Moorhens at multiple temporal and spatial scales on Guam, USA.

	All radio-tagged birds				Radio-tagged birds that moved from capture site to other wetlands or rivers				
	Indiv.	Obs.	Mean (SD) sites visited	% of birds that moved off capture site at least once	Indiv.	Obs.	Mean (SD) number of movement events among sites	Mean (SD) distance traveled (km) among sites	Mean (SD) maximum distance traveled from capture site (km)
Year									
2000	24	673	2.71 (2.24)	58.33	14	303	3.81 (2.45)	2.64 (1.78)	4.36 (2.66)
2001	11	717	2.18 (0.98)	81.81	9	522	3.75 (2.76)	2.90 (3.35)	3.65 (3.58)
Sex									
Male	9	409	2.22 (1.18)	55.56	5	264	1.88 (1.18)	2.81 (3.21)	4.40 (2.89)
Female	13	894	2.54 (1.48)	61.54	8	551	4.38 (2.2)	3.93 (2.43)	4.39 (3.27)
Unknown	3	87	1.00 (0.00)	0					
Season									
Dry	25	753	1.40 (0.56)	48	10	376	4.8 (4.02)	2.00 (1.98)[a]	2.46 (2.28)[b]
Male	9	219	1.44 (0.53)	44.44	4	121	2.75 (1.71)	2.80 (3.52)	1.21 (0.71)
Female	13	487	1.46 (0.63)	53.85	7	265	6.17 (4.67)	1.47 (0.75)	3.45 (2.58)
Wet	21	629	2.50 (1.87)	71.43	13	429	5.23 (3.68)	4.60 (2.47)[a]	5.03 (2.89)[b]
Male	8	190	2.00 (0.96)	75	4	143	4.4 (4.67)	4.75 (2.78)	6.24 (2.19)
Female	13	407	2.85 (2.29)	69.23	9	286	5.75 (3.15)	2.87 (3.19)	4.28 (3.15)
Total	25	1390			13	815			

[a, b] Indicates means that are significantly different from one another.

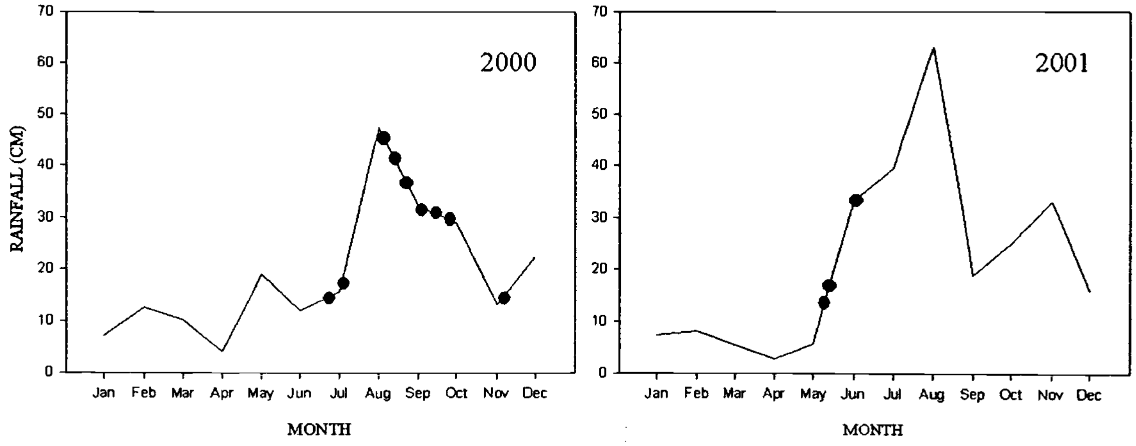

Figure 2.4. Monthly rainfall estimates for Guam and first detection of moorhen movement (•) away from Fena Reservoir to another wetland. Movement data includes data from March 2000 – June 2001 and excludes daily movement to adjacent rivers.

On Saipan, there was no sex, season, or sex x season interaction affects on the average number of sites visited or frequency of movement among sites ($P > 0.5$). In the dry and wet seasons, the mean number of sites visited was 1.14 (0.36 SD) and 1.33 (0.49 SD), respectively (Table 2.5). Similarly, there was no sex, season, or sex x season interaction affecting mean and mean maximum distance moved ($P > 0.5$, Table 2.5). Birds mostly remained in the tank.

2.4.7. *Daily Activity*

On Fena Reservoir, moorhens foraged primarily during dawn and dusk hours along the shoreline. However, adult moorhens with chicks foraged throughout the day as well (L. Takano, pers. obs.). During the dry season, moorhens foraged along algal mats, which appeared primarily during this season. Telemetry of four moorhens on Fena Reservoir over a 16-hour period per day indicated daily mean total distance moved to be 408.38 m ($\pm$ 137.75 SD) (Table 2.6). During sampling periods, these moorhens did not have chicks or juveniles present on their territories.

At night, all four moorhens roosted within their territories. Fluctuation of transmitter signals at nocturnal sites suggested foraging may be a common activity during this time period. Moorhens roosted on floating vegetation (*Hydrilla* spp.), branches of hibiscus trees (*Hibiscus tiliaceus*) extending towards the water, top of a coconut tree leaf (*Cocos nucifera*), and in emergent vegetation (i.e., paragrass or *Panicum maximum*).

Observations of adult moorhens indicated they roosted in close proximity to one another. Some paired adults roosted on the same branch or within a few meters of each other in emergent vegetation. When paired adults were incubating eggs, one adult stayed on the nest during the night, while the other remained in close proximity within emergent vegetation. I do not know whether adults took turns incubating at night or which sex predominantly incubated eggs at night; however, I observed a radio-tagged adult female incubating eggs at night. Moorhen juveniles would almost always roost in close proximity to one of it parents and chicks would roost in the nest with one of their parents.

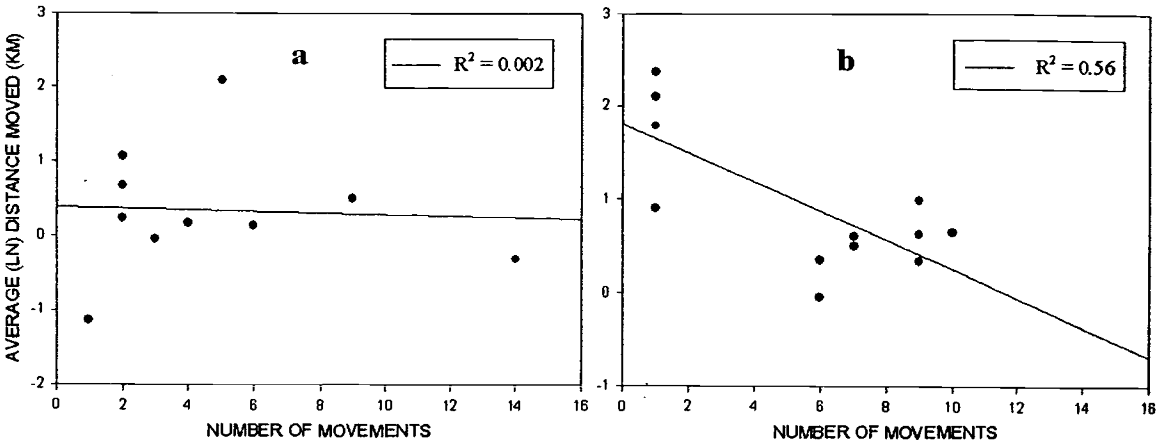

Figure 2.5. The average distance moved and number of times moved among sites from Guam moorhens in the 2000 and 2001 dry (a) and wet (b) seasons.

Table 2.5. Movement of Mariana Common Moorhens at multiple temporal and spatial scales on Saipan and Tinian, USA.

	All radio-tagged birds				Radio-tagged birds that moved from capture site to other wetlands				
	Indiv.	Obs.	Mean (SD) sites visited	% of birds that moved off capture site	Indiv.	Obs.	Mean (SD) number of movement events among sites	Mean (SD) distance traveled (km) among sites	Mean (SD) maximum distance traveled from capture site (km)
Year									
2000	13	216	1.23 (0.39)	38.46	5	67	1 (0)	5.83 (3.70)	5.83 (3.70)
2001	6	64	1.25 (0.42)	33.33	2	15	1 (0)	12.74 (16.19)	12.74 (16.19)
Sex									
Male	11	173	1.18 (0.34)	36.36	4	47	1 (0)	9.47 (9.92)	9.47 (9.92)
Female	7	107	1.36 (0.48)	42.87	3	36	1 (0)	5.59 (5.67)	5.59 (5.67)
Season									
Dry	18	108	1.14 (0.36)	11.11	2	22	1 (0)	10.46 (0.22)	10.46 (0.22)
Male	7	64	1.11 (0.33)	14.30	1	11	1 (0)	10.6 (8.46)	10.6 (8.46)
Female	4	44	1.20 (0.45)	25.00	1	11	1 (0)	10.32 (0)	10.32 (0)
Wet	10	172	1.33 (1.49)	70.00	7	59	1 (0)	7.47 (8.44)	7.47 (8.44)
Male	11	109	1.27 (0.47)	36.36	4	36	1 (0)	8.46 (10.49)	8.46 (10.49)
Female	6	63	1.43 (0.53)	50.00	3	25	1 (0)	6.15 (6.64)	6.15 (6.64)
Total	18	280			7	83			

Table 2.6. Daily mean total distance traveled of four Mariana Common Moorhens over a 16-hour period (0500 - 2100) per day on Guam during the 2001 dry season.

		Total distance traveled (m)				Mean distance (SD) traveled (m)
Sex	Obs.	16-May	7-Jun	13-Jun	28-Jun	Mean
Female	48	112.42	47.64	68.14	no data	76.07 (33.11)
Female	64	129.24	98.93	74.56	149.99	113.18 (33.20)
Female	64	219.46	136.76	95.09	282.86	183.54 (84.00)
Male	64	1237.92	1266.76	615.23	458.34	894.56 (418.23)
Total	240					316.84 (142.14)

2.4.8. *Home Range*

An average kernel estimate of home range for Guam birds (N = 23) over all sample periods was 3.1 ha (4.8 SD, Table 2.7). Average home-range estimates did not differ significantly by season ($F_{3,17} = 0.08$, $P = 0.17$) or sex ($F_{3,17} = 1.16$, $P = 0.30$) nor was there an interaction between season and sex ($F_{3,17} = 0.51$, $P = 0.49$). Two radio-marked birds (female and unknown sex) captured in the Guam Department of Corrections prison basin were not included in home range analyses since only absence or presence was recorded for them. However, 39 locations from 28 June through 5 September 2000 and 63 locations from 23 May through 7 October 2000 suggested these birds did not move from this 0.3 ha site.

Similarly, home range was not determined for Saipan moorhens. Because the tank is made of concrete, transmitter signals were difficult to accurately pinpoint within the tank. Moorhens within the tank utilized at least 80% of the 0.5 ha-tank.

Table 2.7. Mean (± SD) home range area (95% area used, kernel) of Mariana Common Moorhens on Guam in 2000 and 2001. Results were calculated for all birds ≥ 10 locations.

	Individuals	Observation	Home range (ha)
Sex			
Male	9	406	4.3 (5.7)
Female	12	856	3.0 (1.9)
Unknown	2	26	0.9 (0.3)
Season			
Dry	18	683	2.8 (3.1)
Wet	19	579	4.1 (5.3)
Total	23	1291	3.1 (4.8)

2.4.9. *Core Area*

Mean core area (ha) for the wet and dry seasons on Guam were 1.9 (0.3 SD) and 0.9 (1.7 SD), respectively (Table 2.8). Core area analyses for the dry and wet season indicated Guam moorhens utilized their home ranges differently according to season. During the dry season, individuals were more concentrated within a defined area, whereas during the wet season, movements were spread out within a bird's home range. Since Guam moorhens moved more often to rivers and other wetlands during the wet season, not finding a core area during the wet season may be a direct result of this wider distribution. Only 2 of 19 birds had core areas defined during the wet season since 17 of the birds' home ranges did not show a defined change in isopleths, whereas 17 among 18 had core areas defined during the dry season.

During the dry season, mean core area (ha) for females (N = 10) and males (N = 7) were 0.3 (0.3 SD) and 1.9 (2.4 SD), respectively (Table 2.8). Females exhibited significantly smaller mean core areas than males ($F_{2,15}$= 2.8, P = 0.04). In addition, dry season mean core area estimates among birds that moved off (N = 9) their Fena Reservoir territory compared to those that stayed (N = 8) on their territories year-round was 1.6 ha (2.1 SD) and 0.2 ha (0.2 SD), respectively. Birds that moved off Fena Reservoir had significantly larger mean core areas than birds that stayed on their territories throughout the year ($F_{2,15}$= 2.9, P = 0.01). There was no sex difference in mean core area among birds that remained on Fena Reservoir year-round ($F_{2,6}$= 1.0, P = 0.36). Similarly, there was no sex affect ($F_{2,7}$ = 3.0, P = 0.23) among birds that moved off their territories on Fena Reservoir.

Table 2.8. Mean (± SD) core area of Mariana Common Moorhens on Guam in 2000 and 2001.

	Individuals	Observation	Core area (ha)
Season			
Dry	17	626	0.9 (1.7)
Male	7	228	1.9 (2.4)
Female	10	398	0.3 (0.3)
Wet	2	79	1.9 (0.3)

2.5. DISCUSSION

A landscape perspective has been increasingly emphasized in understanding how species are distributed across a mosaic of habitat patches (Dunning et al. 1992, Plissner et al. 2000a, Haig et al. 2002). My research demonstrates the dynamic use of space and movement among moorhens within and across landscapes on multiple islands throughout the annual cycle. To my knowledge, this is the first telemetry study that has taken a multi-island approach to understanding a mobile island species throughout the annual cycle. However, inter-island movement patterns of banded Hawaiian Stilts (*Himantopus mexicanus knudseni*) have been reported (see Reed et al. 1998). Responsible management efforts need to look at multiple scales in island species capable of inter-island movement {e.g., Mariana Fruit Bat (*Pteropus mariannus mariannus*), Micronesian Megapode (*Megapodius laperouse*), Hawaiian Duck (*Anas wyvilliana*), Hawaiian Coot (*Fulica Americana alai*)} in order to understand population dynamics, identify sites of conservation importance, and devise a comprehensive regional recovery plan.

Seasonal movement of moorhen species in temperate regions is common and movement can be dependent on seasonal shifts during winter and spring (Sibley 2000). Movement among tropical moorhen residents can also be a response to dry and wet seasons. Hawaiian Moorhens exhibit movement patterns related to droughts and wet periods and readily disperse to seasonal wetlands within the island (Nagata 1983, Engilis and Pratt 1993). Similarly, we found that Mariana Common Moorhens exhibited greater intra-island movement in the wet season as seasonal wetlands become inundated. As precipitation increases, moorhens exhibit reduced breeding and natal site tenacity, presumably a response to resource shifts caused by flooding of habitat, creation of new seasonal habitat, and possibly behavioral changes (i.e., Saipan juveniles).

Inter-island movement of radio-tagged moorhens from Saipan to Tinian during the transition from the dry to the wet season and moorhen population surveys revealed increasing moorhen numbers on Lake Hagoi as the wet season progressed (Chapter 3). Thus, Lake Hagoi provides an important resource during the wet season and limited habitat during the dry season. On Tinian, Lake Hagoi represents the only suitable wetland capable of holding large numbers of moorhens (USFWS 1996). However, Lake Hagoi is subject to encroachment by a dominant wetland plant, *P. karka*, which occupies approximately 80% of the wetland area (USFWS 1996). Therefore, managing wetland vegetation to create a more diverse habitat for moorhens is important in order to restore Lake Hagoi to a more functional wetland throughout the moorhen's annual cycle.

For Guam moorhens, identifying essential wetlands and site fidelity is especially important since wetland habitat is increasingly very limited. Moorhens are faced with fewer choices because most of the large natural wetlands are overgrown with persistent vegetation and dense monocultures of *P. karka* (Ritter and Savidge 1999, L. Takano, pers. obs.). Our study demonstrates the importance of Fena Reservoir to the persistence of moorhens on Guam. Site fidelity on Fena Reservoir was high, as birds that dispersed during the wet season readily returned during the dry season as smaller ephemeral wetlands gradually dried up. In addition, the number of observations on individuals within Fena Reservoir in both the dry and wet season was greater than any other wetland site (L. Takano, unpublished data).

Mean home ranges for Guam moorhens reported in this study were larger than reported in most temperate moorhen studies. In other studies, mean home range estimates ranged from 0.06 hectare (McRae 1997) and 0.09 – 0.13 hectare (Gibbons 1987) at Peakirk in Cambridgeshire, England to 3-5 hectares in Northwest Italy (Acquarone et al. 2001). However, with the exception of Acquarone et al. (2001), these studies involved visual observations of linear distances that a moorhen would occupy over a limited time period. Only Acquarone et al. (2001) provided home-range estimates from radio-telemetry data for six moorhens, mostly throughout the winter months, which were based on serial telemetry sessions that usually lasted six hours per day. My study, based on independent observations, produced estimates for moorhens throughout its annual cycle and emphasized moorhens have varying space needs throughout the annual cycle. Thus, this study illustrates the importance of considering appropriate temporal and spatial scales.

Most observations in this study were of moorhens captured on Fena Reservoir, the largest permanent body of water on Guam. Therefore, home-range estimates of Fena Reservoir moorhens may be higher than those moorhens inhabiting smaller wetlands for most of the annual cycle. An example of this is the Saipan tank where 51 individuals (30 adults, 21 juveniles and chicks) in July 2000 and 40 individuals (21 adults, 15 juveniles, 4 chicks) in May 2001 occupied an approximate 0.5-ha area. Most radio-tagged moorhens on Saipan stayed within the tank as the wet season progressed. This particular site provided sufficient roosting and nesting sites, aquatic vegetation, and since high concrete walls surrounded it, provided predator control. Another example is the two moorhens that occupied the Department of Corrections prison basin 0.3 ha–site, where a small but presumably high quality area was apparently sufficient to meet their needs for most of the annual cycle. These smaller wetlands may have provided better habitat conditions (e.g., stable water levels, sufficient cover from predators, abundant food), and thus resulted in smaller home ranges since home range for most vertebrates is known to decrease with increased habitat productivity (i.e., resource density, Haskell et al. 2002).

Core area analysis indicated moorhens utilize their home range differently according to season. This suggests that resources are more spread out during the wet season. In addition, moorhens that stayed on their territories year-round on Fena Reservoir occupied territories with relatively small core areas, but were consistently "good". These "good" territories had abundant emergent vegetation, located on shoreline areas that were not flooded during the wet season, and during the dry season, produced algal mats on floating vegetation (*Hydrilla)*, which moorhens were observed to utilize as nesting substrate and provided a ready supply of aquatic invertebrates for chicks. In addition, these territories were observed to produce the most chicks. Breeding resources may be limited on Guam, especially during the wet season. Thus, this lack of suitable habitat could favor year-round residency (Kokko and Lundberg 2001) on "good" territories throughout the annual cycle.

The role of the sexes may shed some light into why females exhibited significantly smaller mean core. Few behavioral studies of socially monogamous moorhens exist. However, in other moorhen species, females tend to do most of the incubation during the day, hence freeing males for territorial defense (Craig 1976, 1979). Mariana Common Moorhen females may occupy their time more with nesting activities during the day, resulting in a smaller core area.

Developing conservation strategies for the Mariana Common Moorhen is challenging because of the need to focus on maintaining the functionality and connectivity within and among island wetlands throughout the year. Responsible management efforts need to look at this broad scale, especially when dealing with a small population and limited habitat. In addition, efforts need to focus on key wetlands (i.e., Fena Reservoir and Lake Hagoi) to insure habitat quality throughout the year. Management of natural wetlands should be focused on controlling encroachment of *P. karka*, as well as protection and monitoring of the Saipan tank. This study suggests rivers are important resources for moorhens and use of rivers increases during the wet season. Previous literature recorded moorhens along the Ylig River on Guam (Baker 1951), but the extent of moorhen use of rivers was not known until this study. Thus, protection of Guam river systems, especially the lower reaches of rivers or tributaries where moorhens have been observed, will be key. Future moorhen research should examine seasonal habitat quality as it relates to site tenacity and chick production, as well as predator control and eradication.

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3. DISTRIBUTION AND ABUNDANCE OF THE MARIANA COMMON MOORHEN

3.1. ABSTRACT

Population estimates of the endangered Mariana Common Moorhen (*Gallinula chloropus guami*) were determined on Guam, Saipan, Tinian, and Rota from island-wide surveys conducted from May through September 2001. We estimate the total adult moorhen population to be 287, including 90, 154, 41, and 2 adult moorhens on Guam, Saipan, Tinian, and Rota, respectively. On Guam's largest permanent wetland, Fena Reservoir, surveys conducted from March through August 2000 indicated adult moorhen numbers were significantly less ($F_{4,11} = 16.86$, $P = 0.01$) than those from a similar survey in 1988. In addition, nest surveys of six territories revealed 58.8 % egg loss and 71.4% chick loss. Conservation efforts for this subspecies have mainly focused on protection of remaining wetlands. Efforts need to be expanded to include monitoring of populations, wetland restoration, and predator control on wetlands.

3.2. INTRODUCTION

Complete surveys of an entire species or subspecies are rarely undertaken, but they are extremely important for conservation planning (Haig et al. in review). This is particularly true for species that occur in fragmented populations where understanding distribution and abundance within their entire range is not only important in determining population dynamics, but is essential in assessing current population status. For most species this type of assessment is difficult because of vast distributions and lack of logistic support. The endangered Mariana Common Moorhen (*Gallinula chloropus guami*) is a bird that uses easily identifiable, discrete habitats (i.e., wetlands) and whose distribution is limited. They are secretive in nature, so obtaining population estimates can be challenging. However, given their precarious state, obtaining a current population estimate is important in assessing their status.

The Mariana Common Moorhen, locally known as "Pullatat", is one of the last remaining wetland-dependent birds endemic to the Mariana archipelago. The Mariana Common Moorhen is extinct on the island of Pagan (USFWS 1992), but currently uses freshwater wetland areas of Guam, Saipan, Tinian, and Rota. Only these islands contain wetlands capable of supporting moorhens in the Mariana archipelago. U.S. Fish and Wildlife Service has listed this subspecies as endangered (USFWS 1984) and a past study estimated populations to include 300 to 400 individuals (Stinson et al. 1991).

Historically, Mariana Common Moorhens were considered numerous and widely distributed across cultivated taro patches, fallow rice paddies, and fresh and brackish wetlands (Stott 1947, Marshall 1949, Baker 1951). On Guam, they were also found in large numbers along the Ylig River and in the Agana Swamp (Baker 1951). However, major wetland loss has occurred in the Marianas due to changing agricultural practices, encroachment by undesirable vegetation, and clearing and filling of wetlands for development. On Pagan, moorhens were extirpated due to large quantities of ash and cinder deposited from a volcanic eruption in May 1981 and destruction of vegetation by feral ungulates (Stinson et al. 1991, USFWS 1992). Other potential limiting factors of Mariana Common Moorhens include competition with Tilapia (*Oreochromis mossambicus*), a freshwater fish (Stinson et al. 1991); nest loss due to flooding (Ritter 1994, USFWS 1996); destruction of nesting habitat by feral ungulates; as well as predation by Brown Tree Snakes (*Boiga irregularis*), cats (*Felis catus*), rats (*Rattus* spp.), and Monitor Lizards (*Varanus indicus*).

Although important, comprehensive surveys for the Mariana Common Moorhen can be hindered because of their secretive behavior and affinity for hiding in emergent vegetation. Moorhens often utilize impenetrable swamps and marshes (Stinson et al. 1991) and move among ephemeral, seasonal, and persistent wetlands (Chapter 2). Thus, we surveyed multiple islands at various temporal and spatial scales to determine a current population estimate. We also examined breeding success on Fena Reservoir, Guam's largest permanent wetland, and compared past and current population counts on the reservoir.

3.3. METHODS

3.3.1. *Study Area*

The Mariana archipelago includes 15 islands that extend 750 km between 13° 14' N, 144° 45' W and 20° 3' N, 144° 54' W. The largest and southern-most island is the U.S. Territory of Guam and the other 14 islands consist of the U.S. Commonwealth of the Northern Mariana Islands (CNMI). The Mariana archipelago is located approximately 1500 km east of the Philippine Islands. Though volcanic in origin, the islands where moorhens currently occur, Guam, Tinian, Saipan, and Rota, are mainly forested limestone plateaus.

The climate is tropical, with average annual temperatures on Guam of 26.3°C and on Saipan of 25.8°C (Kendrick 1997). Daily temperatures range from 31 – 33°C during the day and 24 - 26°C at night. Annual average precipitation for Guam and Saipan is 251 and 218 cm, respectively, and ranges from 200 - 260 cm (Kendrick 1997). The year is divided into the dry and wet season. Generally, the dry season falls between the months of January – April and wet season from July – November. Other months are transitional periods that may be dry or wet depending on the particular year. On average, about 15% of annual rainfall occurs during the dry season and 55% during the wet season.

3.3.2. *Multiple Island-wide Surveys*

Moorhen adults, juveniles, and chicks were surveyed on Guam, Saipan, Tinian, and Rota. We reviewed literature on past moorhen surveys and descriptions of wetlands in the Marianas to determine locations of wetlands throughout the archipelago (USFWS 1989, Stinson et al. 1991, USFWS 1992, Wiles and Ritter 1993, USFWS 1996, Ritter 1997, Worthington 1998). Survey efforts covered all permanent and seasonal wetlands on Saipan and Tinian during the dry and wet season. On Rota, wetlands were located on the golf course. On Guam, all permanent wetlands were surveyed where access was possible (approximately 90% of all wetlands on Guam) during the dry season. Depending on the size of the wetland, fifteen minutes to three hours was spent at each site.

Most surveys consisted of visual observations by two persons using binoculars during crepuscular hours when moorhens were most active. We also used audio playbacks in wetlands that were more enclosed and heavily vegetated. During these surveys, observers were stationed in different areas of the wetland and hidden from view within the vegetation. We found that staying hidden was crucial in order for moorhens to respond to audio playbacks. This audio survey method did not work on more open wetlands such as Fena Reservoir on Guam.

During audio surveys, adult moorhen calls were played three to five times at approximately 30-second bursts. Playback calls have been used successfully by Brackney and Brookout (1982) to census the Common Moorhen (*Gallinula chloropus*). They found isolated moorhen pairs responded to the tape-recorded calls as readily as pairs in high density areas. Common Moorhens also responded equally well throughout the breeding season; however, males responded (93%) to tape calls a greater percentage of the time than females (21%). Therefore, we believe our survey method of using audio playbacks to enhance visual observations are unlikely to produce overestimations, but underestimations may occur. Moorhen calls and visual observations were recorded on a map and compared by each observer at the end of 15 minutes.

A complete census of all individuals was possible in many man-made wetlands, although it was difficult in natural wetlands. For example, on Saipan, a World War II abandoned concrete oil tank (approximately 0.5 ha), inundated by rainwater, was used by moorhens. In this tank, a complete view of all inhabitants could be seen from one vantage point through a spotting scope during daylight hours. Similarly, complete censuses were possible on small man-made drainage basins, golf-course ponds, and fish ponds, when the perimeter of the wetland was walked and moorhens flushed out of narrow bands of vegetation.

Multiple island-wide surveys on Saipan (N = 8) and Tinian (N = 7) took place from 16 May through 6 September 2001. On Guam, two island-wide surveys were conducted in May and June 2001. With the exception of Rota, each island-wide survey was carried out over a two-week period. On Rota, a survey was conducted on 13 August 2001 at a wastewater treatment system and wetlands on an 18-hole golf resort. Since creation of the golf course in 1994, its water treatment polishing ponds have attracted a variety of migratory birds, including one breeding pair of Mariana Common Moorhens (Worthington 1998).

When possible, moorhens were classified by age: adult, juvenile, and chick. Mariana Common Moorhen adults have slate-black plumage with white undertail coverts and white bands on their flanks, red bills and frontal shields, and olive-green legs (Baker 1951, Ritter 1994). Females resemble the males, but are smaller and have a smaller frontal shield (Baker 1951). Males and females weigh approximately 340 and 265g, respectively (Dunning 1993); however, we were not able to distinguish among sexes during surveys. Chicks have black natal down, black legs, and a red upper mandible with a yellow-green tip. Juveniles have mostly brown plumage and a brownish-orange bill with a yellow-green tip. A subadult stage also occurs during the moorhen's first 14 - 21 weeks and is characterized by a duller plumage and smaller frontal shield than adults (Ritter 1994). Since subadults and adults were difficult to distinguish during surveys, we included subadults with the adult counts. The total count of moorhen adults, juveniles, and chicks for each two-week period was summed by age class across all wetlands visited to determine population estimates for each island and the subspecies.

Saipan and Tinian surveys encompassed both the dry and wet seasons. Therefore, I further examined whether there were any patterns to moorhen distribution and abundance among permanent, semipermanent, and seasonal wetlands on Saipan and at Lake Hagoi on Tinian. In addition, I compared 2000 rainfall levels (NOAA, National Climate Data Center) to these data since I know from radio-telemetry data that more movement occurs during the wet season (Chapter 2).

3.3.3. *Fena Reservoir Surveys*

On Guam, monthly adult moorhen and nest surveys were conducted on Fena Reservoir from March through August 2000. Surveys started at dawn and included two persons with binoculars in a boat powered by an electric motor. Observers traveled close to and along the periphery of the reservoir at approximately 3.2

km/hour. Monthly adult moorhen counts were used to compare with past surveys conducted on Fena Reservoir by Guam Division of Aquatic and Wildlife Resources (GDAWR) from March through August 1988 (GDAWR 1988). Analysis of Variance (ANOVA) was used to test whether water levels (data from USGS, Guam), year, and month had an affect on the number of adult moorhens present on Fena Reservoir (Data Desk 4.2, 1994). In addition, moorhen nest counts were conducted on six territories in order to determine breeding success at the north end of the reservoir where breeding was observed to be more successful than other areas of the reservoir. Bi-weekly nest checks were conducted from March through August 2000. Nest checks included the number of juveniles, chicks, and eggs on each territory.

3.4. RESULTS

3.4.1. *Island-wide Surveys*

Island-wide moorhen surveys included 28, 56, and 2 wetlands on Guam, Saipan, and Tinian, respectively, and resulted in a total population estimate of 287 adults. Using the maximum number of adults counted on Saipan and Tinian wetlands during any one survey, we estimate the total number of adult moorhens on Saipan and Tinian to be 154 and 41, respectively. Surveys did not detect moorhens on Rota; however, three months after our surveys, two adult moorhens were observed on Rota during the Christmas Bird Count (CBC). Based on the CBC, we can estimate there are at least two adult moorhens on Rota. The total number of adult moorhens on Guam is estimated to be 90. This estimate represents the greatest number of adults counted during any one survey period on Guam.

On Guam, moorhens were present in 78.6% (22/28) of wetlands surveyed, which comprised 1 seasonal and 27 permanent wetlands (Table 3.1). Guam surveys were conducted primarily over the dry season. Therefore, most permanent wetlands were surveyed. Some sites were inaccessible because surrounding vegetation was overgrown and the area of open water was minimal. However, we suspect limited use of these areas by moorhens during the dry season {i.e., Naval Station Marsh (Camp Covington) wetland, Sasa Bay wetland, NavMag Ponds}. From two island-wide surveys, moorhen numbers averaged 88.5 (SD = 2.12), 2.25 (SD = 1.5), and 5.8 (SD = 3.72) for adults, juveniles, and chicks, respectively.

On Saipan and Tinian, moorhens were present in 73.2% (41/56) of wetlands surveyed (1 tidal, 11 seasonal, and 44 permanent wetlands) (Table 3.2). Moorhens were present on 7 seasonal and 34 permanent wetlands. On Tinian, adult moorhens were present (numbers ranged from 7 to 42) on Lake Hagoi, but not on Makpo wetland, which was overgrown and retained little water during the dry and wet seasons. No juveniles were observed during surveys on Tinian; however, we observed seven active nests and a brood of four chicks during July and August 2001. The average number of adult moorhens on Saipan and Tinian was 122 (SD = 23.7), and 36.33 (SD = 7.26), respectively. On Saipan, the average number of juveniles and chicks on the island was 12.86 (SD = 9.01) and 8.29 (SD = 4.68), respectively. On Rota, no moorhens were detected on the three golf course ponds or four water

Table 3.1. Location, type, and number of adult moorhens present on seasonal and permanent Guam wetlands in May 2001. These data were used to estimate the total number of moorhens on Guam to be 90 adults.

Site	Adults Present	Type	Location UTM[a]
Atantano Wetland	0	permanent	N1484391 E249141
Agana Swamp	4	permanent	N1489884 E256743
Barrigada Ponding Basin	0	permanent	N1490830 E262021
Country Club of the Pacific - No. 3 Pond	0	permanent	N1479100 E257615
Fena Dam (behind spillway)	2	permanent	N1478046 E251779
Fena Valley Reservoir	33	permanent	N1478500 E250181
Harmon/Dededo Ponding Basin	0	permanent	N1495036 E265580
Leo Palace Golf Course– D3 Pond	2	permanent	N1482882 E254870
Leo Palace Golf Course – D5 Pond	2	permanent	N1482706 E255220
Leo Palace Golf Course – E3 Pond	2	permanent	N1483781 E254210
Leo Palace Golf Course Water Tank	2	permanent	N1482480 E256347
Leo Palace Wetland	2	permanent	N1484473 E254437
Masso Reservoir	2	permanent	N1488837 E250454
Namo River Marsh	0	permanent	N1482920 E247455
Naval Magazine Pond	3	permanent	N1481106 E248883
Prison Ponding Basin[b]	2	seasonal	N1487810 E260062
San Luis Ponds	3	permanent	N1487284 E245563
Shell Wetland (across office)	2	permanent	N1484542 E249914
Shell Inc. drainage basin	4	permanent	N1484833 E249369
Toguan Bay Treatment Pond (upper)	6	permanent	N1469751 E246997
Toguan Bay Treatment Pond (lower)	3	permanent	N1469951 E246889
Talafofo Fish Ponds	6	permanent	N1475628 E257244
Talafofo Golf Course - Hole 1 Pond	2	permanent	N1478353 E255722
Talafofo Golf Course – wetland by clubhouse	2	permanent	N1478500 E255200
Talafofo Golf Course – Tee 3 (drainage basin)	2	permanent	N1475628 E257244
Talofofo Golf Course – Hole 12 Pond	2	permanent	N1478183 E254370
Talafofo Golf Course – Hole 15 Pond	2	permanent	N1477981 E254830
Talafofo Golf Course - Hole 17 Pond	0	permanent	N1477964 E254503

[a] Universal Transverse Mercator coordinates

[b] Contains open water during the majority of the dry season (depending on rainfall levels during this period)

Table 3.2. Location, type, and number of adult moorhens present on Saipan wetlands during August 2001. These data were used to estimate the total number of moorhens on Saipan to be 154 adults.

Site	Adults Present	Type	Location UTM[a]
Agriculture Station Pond	2	permanent	N1673321 E360847
Airport Catchment	0	permanent	*
Annie's Pond	6	permanent	N1684025 E365476
Bird Island Pond	0	seasonal	N1686699 E371878
Black Microl Ponds	2	semipermanent	N1684158 E365284
Chalan Kanoa Pothole # 1	6	semipermanent	N1674472 E360747
Chalan Kanoa Pothole # 2	4	semipermanent	N1674433 E360745
Chalan Kanoa Pothole # 3	5	semipermanent	N1674405 E360710
Chalan Kanoa Pothole # 4	4	semipermanent	N1674339 E360758
Chalan Kanoa Pothole # 5	4	semipermanent	N1674439 E360794
Chalan Kanoa Pothole # 6	4	semipermanent	N1674453 E360838
Chalan Kanoa Pothole # 7	4	semipermanent	N1674385 E360845
Chalan Kanoa Pothole # 8	8	semipermanent	N1674427 E360901
Chalan Kanoa Pothole # 9	8	semipermanent	N1674446 E360960
Chalan Kanoa Pothole # 10	2	semipermanent	N1674522 E360951
Coral Ocean Point Golf Course – Hole 6/8 Pond	0	permanent	N1671697 E359493
Coral Ocean Point Golf Course – Hole 15/16 Pond	0	permanent	N1670635 E360940
Dan Dan Range	3	permanent	N1674033 E363350
Department of Land and Natural Resources Ditch	1	permanent	N1683881 E364856
Education Drainage	1	seasonal	N1678123 E367701
Education Ponds	0	seasonal	N1678386 E367670
Falig Pond	8	permanent	N1684164 E365296
Flores Pond	8	seasonal	N1673997 E362870
Frosty Boy Pond	0	seasonal	N1676946 E361657
Handsome Pond – Western Equip. Co.	4	seasonal	N1684069 E365538
Joshua's Pond	0	seasonal	N1676951 E367051
Kagman North	2	permanent	N1678188 E367776
Kagman South	0	seasonal	N1677196 E367229

-continued-

Table 3.2. Continued. Location, type, and number of adult moorhens present on Saipan wetlands during August 2001. These data were used to estimate the total number of moorhens on Saipan to be 154 adults.

Site	Adults Present	Type	Location UTM[a]
Kingfisher Golf Course – Hole 9/10 Pond	5	permanent	N1682931 E368944
Kingfisher Golf Course – Hole 14/15 Pond	0	permanent	N1682555 E369145
Kingfisher Golf Course – Hole 17/18 Pond	2	permanent	*
Lake Susupe	1	permanent	N1675374 E361335
Lao Lao Bay Golf Course – Hole 13 Pond	4	permanent	N1676648 E368234
Lao Lao Bay Golf Course – Hole 12 Pond	0	permanent	N1676880 E368205
Lao Lao Bay Golf Course – Hole 11 Pond	0	permanent	N1676756 E367878
Lao Lao Bay Golf Course – Hole 18 Pond (large)	0	permanent	N1676012 E367833
Lao Lao Bay Golf Course – Hole 18 Pond (small)	0	permanent	N1676070 E367770
Lao Lao Bay Golf Course – Hole 8 Pond	0	permanent	N1676012 E368382
Lao Lao Bay Golf Course – Hole 6 Pond	2	permanent	N1676299 E368451
Lao Lao Bay Golf Course – Hole 5 Pond	0	permanent	N1676229 E368795
Mariana Country Club – Hole 17 Pond	4	permanent	N1687337 E370401
Mariana Country Club – Hole 15 Pond	0	permanent	N1687461 E370349
Mariana Country Club – Hole 18 Pit	0	seasonal	N1687251 E370409
Mariana Country Club – Hole 5 Pond	0	permanent	N1687173 E370403
Mariana Country Club – Hole 6,7,8 Pond	0	permanent	N1687155 E370322
Memorial Park Canal	0	permanent	N1682435 E362091
MIHA Pond	0	seasonal	N1681871 E362578
Oleai Pothole #1	2	permanent	N1675830 E361517
Oleai Pothole #3	2	permanent	N1675810 E361580
Oleai Pothole #4	0	permanent	N1675794 E361624
Oleai Pothole #5	4	permanent	N1675754 E361621
PDI Wetland/ Transfer Station Pond	0	seasonal	N1683627 E364828
Price Costco Wetland	32	permanent	N1677316 E361631
Puerto Rico Mudflats	0	tidal	N1682805 E363450
Sablan Mitigation Pond	0	permanent	N1683646 E364881
Tank	10	permanent	N1683190 E364362

[a] Universal Transverse Mercator coordinates

* Missing data

treatment ponds, although two adult moorhens were present during non-survey moorhen numbers periods.

As the wet season progressed, Saipan and Tinian surveys revealed the number of adults decreasing at Saipan permanent wetlands, while increasing at Saipan seasonal wetlands and at Tinian's semipermanent wetland, Lake Hagoi (Figure 3.1). Chalan Kanoa (CK) potholes on Saipan played an important role in the wet season as areas of open water increased, augmenting moorhen habitat. Thus, the number of adult moorhens increased on this semipermanent wetland complex as the wet season progressed.

3.4.2. *Fena Reservoir Surveys*

Analysis of adult moorhen surveys on Guam's Fena Reservoir revealed water level ($F_{4,11} = 18.2$, $P = 0.01$) and year ($F_{4,11} = 16.86$, $P = 0.01$) had a significant affect on the number of adult moorhens present. During the same month for both years, there were significantly fewer adult birds present on Fena Reservoir in 2000 than in 1988. The average number of adults on Fena Reservoir was 17.67 (ranged from 10 to 28) in 2000 and 33.33 (ranged from 7 to 57) in 1988. Date (month) also had a significant affect on the number of adults on Fena Reservoir ($F_{4,11} = 8.13$, $P = 0.03$), with the greatest number of adults present on the reservoir during the months of March and April. Nest counts (N = 6 nests) on six territories indicated egg and chick loss to be 58.8 % (20/34) and 71.4 % (7/9), respectively.

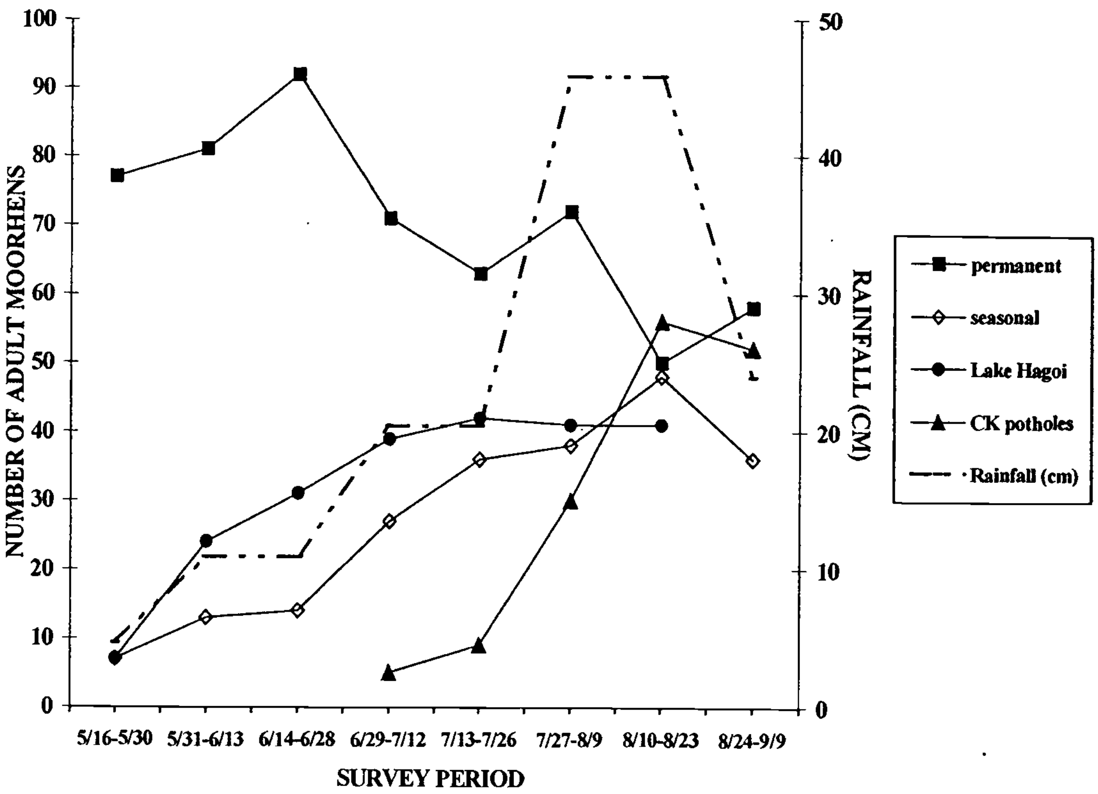

Figure 3.1. Saipan and Tinian adult moorhen surveys conducted from 16 May through 6 September 2001 and Saipan 2001 rainfall levels. Surveys included Saipan permanent, semipermanent {i.e., Chalan Kanoa (CK) potholes}, and seasonal wetlands and Tinian's Lake Hagoi.

3.5. DISCUSSION

This study estimated a current population for the Mariana Common Moorhen to be 287 adults, a precarious population level for this or any subspecies. It represents the most complete survey effort for this subspecies and is a rare example of a complete survey that spanned multiple islands. Because of the secretive nature of moorhens, our population estimate may be conservative. Mariana Common Moorhens exist in such low numbers with much of their permanent natural wetland habitat subject to encroachment by persistent vegetation; thus, we strongly recommend more active monitoring and management of this endangered bird.

SAIPAN AND TINIAN

Compared to past surveys, this study's population estimate for Saipan and Tinian resulted in a higher population estimate for moorhens on Saipan, but fewer birds counted on Tinian. Past moorhen surveys estimated populations on Saipan and Tinian to be 100 and 75, respectively (Stinson et al. 1991). A more recent survey suggests a revised estimate of 50 moorhens on Tinian (USFWS 1996). On Tinian, past survey efforts have primarily relied on audio detection, without audio playbacks, of adult moorhens on Lake Hagoi. Thus, past and current population estimates on Tinian are difficult to compare. However, past Tinian surveys may be more conservative than ours due to the lack of enhanced detection from audio playbacks.

Evaluating changes in the moorhen population on Saipan is challenging because our surveys covered more wetland sites than past survey efforts. Further, previous results included juveniles in estimates and some guesses regarding the number of moorhens present on wetlands that could not be surveyed (D. Stinson, pers. comm.). While juveniles are challenging to survey because of their small size, plumage characteristic, and their reluctancy to vocalize (L. Takano, pers. obs.), they are only present during a brief period of any year; thus, including juveniles in past surveys probably represented a small fraction of individuals (D. Stinson, pers. comm.).

Since this study has shown movement (Chapter 2) and numbers fluctuating between Saipan and Tinian in response to seasonal changes, it is important to treat moorhens on both islands as one population when considering population trends and management of this subspecies. On Lake Hagoi, Tinian, the greatest number of adult moorhens occurred during the wet season. Only emigration from a source population (i.e., Saipan) can explain the increase in numbers since other wetlands on Tinian are not capable of supporting large number of moorhens (Stinson et al. 1991, USFWS 1992). Radio-telemetry further suggested this direction of inter-island movement during the wet season (Chapter 2). Intra-island movement on Saipan also increased during the wet season. As the wet season progressed, surveys revealed increasing numbers of adult moorhen at seasonal and semipermanent wetlands and decreasing numbers at permanent wetlands. Based on low counts of moorhens on Lake Hagoi during the dry season and other survey data (e.g., USFWS 1996), we suggest movement from Tinian to Saipan probably occurs during the onset of the dry season.

ROTA

Surveys did not detect moorhens on Rota. However, three months after our surveys, two adult moorhens were observed on Rota during the Christmas Bird Count

(CBC). One month after the CBC, one moorhen was observed on a farm, where it lived with chickens, bathed in the chickens' water pans, and roosted in a Tangantangan tree (*Leucaena* spp.) (P. Wenninger, pers. comm.). In 1998, Worthington reported at least one breeding pair on Rota. Our efforts failed to detect moorhens probably because our search area was restricted to the golf course wetlands and moorhens may have been utilizing other areas during the wet season such as the farm or seasonal streams.

GUAM

Our population estimate of 90 adult moorhens on Guam is lower than past estimates of 100-125 (GDAWR unpublished data cited in Stinson et al. 1991). While past surveys did exclude juveniles from counts (M. Ritter, pers. comm.), they were conducted during the wet season and may not have covered all available habitat. Our surveys were conducted during the dry season when moorhens were more concentrated on permanent wetlands. Past surveys covered 5 seasonal and 14 permanent wetlands and our surveys covered 1 seasonal and 27 permanent wetlands. Ten permanent wetlands were created on golf courses after 1991. Thus, it is difficult to compare past and present moorhen estimates on Guam. However, we believe Mariana Common Moorhens on Guam may be experiencing a decline. Comparison of the 2000 and 1988 adult moorhen surveys, which included Fena Reservoir counts from March through August for both years, revealed significantly less adults in 2000 than 1988. This period is generally characterized as the dry season and includes transitional months into the wet season. It is a time when a major proportion of the

Guam moorhen population resides on Fena Reservoir. The number of adult moorhens found on newly created golf course wetlands does not make up for the difference in adult numbers between both years because most of the golf course wetlands are small and have only one breeding pair inhabiting each wetland. In addition, other permanent natural wetland areas, which provided much needed habitat during the dry season, have been increasingly reduced throughout the years due to encroachment of *Phragmites karka* (Ritter and Savidge 1999, L. Takano, pers. obs.). In the future, a comparison of adult moorhen counts from surveys covering this period, primarily during the dry season, would be a good approach to determine a change in moorhen numbers on Guam.

Moorhens also appear to be subject to heavy egg and chick loss on Fena Reservoir. Nest counts on six territories revealed 58.8 and 71.4% egg and chick loss, respectively. For the Hawaiian Moorhen (*Gallinula chloropus sandvicensis*), egg and chick loss is considerably lower. Byrd and Zeillemaker (1981) reported a 21% egg loss due to predation or human disturbance. Bell (1976) observed a 40% reduction from mean clutch size to mean brood size in 1-10 day old Common Moorhen (*Gallinula chloropus*) chicks in Louisiana. Our nest counts were conducted at the north end of the reservoir, where breeding was observed to be more successful than other areas of the reservoir; thus, our estimates of egg and chick loss on Fena Reservoir may be conservative. Nest flooding combined with the lack of suitable emergent vegetation for nesting habitat has contributed to the rarity of chicks recorded during monthly counts at Fena Reservoir since 1988 (GDAWR, unpublished data). However, we strongly suspect the Brown Tree Snake to be a major predator of moorhen eggs and chicks. We observed eggs disappearing at night without any shell fragments left behind and two Brown Tree Snakes were observed swimming on Fena Reservoir at night. Thus, even moorhen nests built on floating vegetation are not safe from snakes.

CONSERVATION IMPLICATIONS AND FUTURE RESEARCH

This study demonstrates the importance of simultaneous and complete surveys of the Mariana Common Moorhen. By conducting simultaneous counts on all islands during the dry and wet season, we can better understand how distribution and abundance changes throughout the annual cycle, as well as population connectivity (Haig et al. 1998). Seasonal differences in moorhen use of wetlands are important to address when designing conservation efforts. We suggest future studies determine detection probability of moorhens in different habitat types in the Marianas in order to develop more accurate estimates. We recommend continuing annual, simultaneous, Mariana-wide surveys during the dry season to better assess population structure and status of the Mariana Common Moorhen. We also suggest future research should explore breeding success as well as predator control methods for wetlands on Guam. In addition to low chick recruitment, ungulates such as feral pigs (*Sus scrofa*) and water buffalo (*Bubalus bubalis*) were observed to uproot vegetation (i.e., emergent vegetation critical for moorhen nesting habitat) on Fena Reservoir. These are problems resource managers need to immediately address.

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4. CONCLUSIONS

This study explores the dynamic use of space, seasonal movement, distribution, and abundance among Mariana Common Moorhens (*Gallinula chloropus guami*). In chapter two, inter-island movement from Saipan to Tinian at the onset of the wet season was documented for the first time. Similarly, during the wet season, intra-island movement increased among moorhens as seasonal wetlands become inundated. Moorhen home range and core area were quantified and compared between sex and season. In addition, my research identified essential wetlands and rivers throughout the moorhen's annual cycle. Thus, it is important to recognize seasonal movements within and between islands so that multiple wetland options will be secured for the future.

In chapter three, we attempted to determine a current population estimate and distribution of the Mariana Common Moorhen. Since Mariana Common Moorhens persist in precariously small numbers, there is a need to continue to actively monitor populations and manage wetlands throughout the Marianas.

4.1. MOVEMENT AND HOME RANGE OF THE MARIANA COMMON MOORHEN

Inter- and intra-island movement patterns, home range, and site fidelity of the Mariana Common Moorhen was examined. Mariana Common Moorhens exhibited greater intra-island movement in the wet season as seasonal wetlands become inundated. Similarly, our research revealed moorhen movement from Saipan to Tinian during the onset of the wet season in 2000 and 2001. On Guam, this study emphasized the importance of Fena Reservoir to the persistence of moorhens on this island. Since most of the large permanent natural wetlands are overgrown with persistent vegetation and dense monocultures of *P. karka*, moorhens on Guam are faced with fewer choices, especially during the dry season when habitat is limited. Thus, site fidelity on Fena Reservoir is high, as dispersed birds readily returned to the reservoir after seasonal wetlands dried up. Mean home range for Guam moorhens did not differ significantly among sex or season. However, location of core areas indicated moorhens utilized their home range differently according to season, which suggested resources were more spread out during the wet season. In addition, female moorhens used significantly smaller mean core areas and males traveled further distances during the wet season.

My research demonstrates the dynamic use of space and movement among moorhens within and across landscapes on multiple islands. Responsible management efforts need to look at multiple scales in island species capable of inter-island movement in order to understand population dynamics, identify sites of conservation importance, and devise a comprehensive regional recovery plan. Immediate factors that limit the Mariana Common Moorhen include loss of habitat due to vegetation encroachment, predation, and habitat degradation by feral ungulates.

4.2. DISTRIBUTION AND ABUNDANCE OF THE MARIANA COMMON MOORHEN

My study estimated a current population for the Mariana Common Moorhen to be 287, including 90, 154, 41, and 2 adult moorhens on Guam, Saipan, Tinian, and Rota, respectively. This represents the most complete survey effort for this subspecies and documents current wetland use by moorhens. Mariana Common Moorhens exist in precariously low numbers and utilize much of the available wetland habitat. Permanent natural wetland habitat is subject to encroachment by persistent vegetation. Thus, I recommend active management of wetlands and continuing annual, simultaneous, Mariana-wide surveys during the dry season to better assess moorhen population structure and status. I suggest future studies determine detection probability of moorhens in different habitat types in the Marianas in order to develop more accurate estimates. In addition to moorhen population surveys, efforts should focus on monitoring reproductive success of moorhens in various wetlands. Low chick recruitment and high egg loss occurs on Fena Reservoir. Further, ungulates such as feral pigs (*Sus scrofa*) and water buffalo (*Bubalus bubalis*) uproot vegetation along the shoreline of Fena Reservoir, reducing the quality and quantity of viable breeding habitat. Resource managers need to address these issues in order for Mariana Common Moorhens to recover and maintain healthy populations into the foreseeable future.

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