The seasonal home range and movements of Mandarin Ducks *Aix galericulata* on tributaries of the Tachia River, central Taiwan

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The home range and movements of wild birds are closely associated with their habitat selection and use, knowledge of which is critical for management and conservation programmes. From 1999 to 2002 we used radio-tracking technology to document the location and movement of 29 adult and six first-year male and 41 adult and five first-year female Mandarin Ducks *Aix galericulata* on the Tachia River and some of its tributaries in central Taiwan. The home ranges of both males and females were smaller during the breeding season than the non-breeding season. The home ranges of males were larger than those of females only during the breeding season. Female yearling Mandarin Ducks appeared to show stronger philopatry than males.This information may be useful in helping design a plan for the sustainable management of the Mandarin Duck population on the Tachia River.

INTRODUCTION

For the purpose of bird population management, knowledge of individuals' home ranges and movements is essential to understand their habitat requirements and use, data necessary when designing a reserve (Gilmer *et al.* 1973, Parr *et al.* 1979, Chubbs *et al.* 2008). Waterfowl are mostly migratory; annual migrations may be short- or long-distance, with some species even crossing the equator (Mauser *et al.* 1984, Carboneras 1992). Consequently, most studies of waterfowl only document behaviour in the breeding season (Dwyer *et al.* 1979, Kirby *et al.* 1985, Dwyer & Baldassarre 1994, Staus 1998, Mack & Clark 2006) or on their wintering grounds (Morton *et al.* 1989, Iverson *et al.* 2004, Legagneux *et al.* 2009). To our knowledge, no study has yet documented the year-round variation in the home ranges and movements of a population of non-migratory ducks.

The Mandarin Duck *Aix galericulata* is the Asian ecological equivalent of the migratory North American Wood Duck *A. sponsa*; both are cavity-nesting birds inhabiting forest ponds or lakes (Bellrose & Holm 1994). Each year, Mandarin Duck populations that breed in Russia and northern China migrate to Japan, Korea and southern China (Carboneras 1992). However, the most southerly breeding populations, in Taiwan and the Yunnan–Guizhou plateau in south-eastern China (Lever 2013), are non-migratory; in Taiwan, where the species is considered threatened (Council of Agriculture 1997), an estimated 300–500 resident birds live along mountain streams and lakes at 600–2,300 m (Zhang 1983, Fang 2005). In this study we document the year-round variation in the home ranges and movements of Mandarin Duck with respect to sex and age on the Tachia River, which has the largest population on Taiwan (Sun 2004).

METHODS

Study area

The 142 km long Tachia River (24.350–24.467°N 120.550–121.433°E) is the fourth longest river in Taiwan and rises in the Syue (3,886 m) and Nanhu (3,742 m) mountains in central Taiwan. Kukuan Reservoir (950 m) and Techi Reservoir (1,400 m) form artificial lakes on the river and are used by both resident and migratory waterfowl. Taiwan Red Pine *Pinus taiwanensis* plantations, orchards and vegetable farms fragment the adjacent primary forest. Annual rainfall averages almost 2.3 m in the upstream watershed, which includes the Chichiawan (1,780–2,000 m) and Yousheng (1,780–1,948 m) streams. Rainfall occurs primarily in summer and early autumn while there are numerous wildfires during the winter dry season (Lin 1992).

Trapping

Walk-in traps baited with corn kernels (replaced if dampened by rain) were placed at ponds near the Chichiawan and Yousheng streams (three traps on each) and Techi Reservoir. Although those at the reservoir captured three birds, the traps there were closed because of vandalism. Over the study period, traps were set on ten days each month and checked 2–3 times each day. Birds were fitted with a numbered aluminum ring, and weighed, sexed, aged and radio-tagged. We identified sex by the bill colour (grey in females, dark red in males) and the presence of white bars on the secondary flight feathers of females (Sun *et al.* 2001). Birds trapped in May–September were classified as first-year or adult based on the breast plumage pattern. Birds trapped at other times, when age is difficult to determine (Sun *et al.* 2001), were classified as adults. Radio-transmitters (5.1 × 1.5 cm diameter; model CHP-4P; Telonics Inc., Mesa, AZ) were attached dorsally with a backpack harness made from 2 mm multi-strand nylon string passed around the wings and joined over the sternum. Each transmitter and harness weighed 19.8 g, or 2.83–3.81% (mean = 3.63%) of a bird's 520–700 g body mass (Sun 2001), with batteries expected to last 24 months.

Radio-tracking

We attempted to locate each bird once a month, during the day, from January 1999 to December 2002. We tracked them from roads parallel to the streams and the two reservoirs using a directional hand-held H-antenna and receiver (model TR-4; Telonics Inc., Mesa, AZ). Locations of radio-tagged birds were determined by triangulation (White & Garrott 1990) from at least two bearings taken within five minutes of each other.

Data analysis

The home range of each Mandarin Duck is the maximum distance (km) on the river between locations at which a given individual was identified by radio-tracking. A 'linear 2-dimensional' home range is a reasonable assumption because, except for the 4-week incubation period, ducks spent all their time foraging, resting and roosting along the river. We divided the year into breeding (March–June) and non-breeding (July–February) seasons (Sun *et al.* 2003). Only those ducks tracked for more than four months during the breeding or non-breeding season of a given year were used in the home range analysis. Birds excluded from the analysis either died from predation or illness, or could not be located for unknown

reasons. We used the paired t-test (Zar 1999) to test for seasonal differences in the home range size of adult females and males tracked for two or more consecutive seasons. However, home range sizes were averaged for those individuals that had been tracked for more than one breeding or non-breeding season over the study period. For the comparison of home range size between sexes, those birds with only one season of tracking data (n = 37) were added to the sample, and the t-test was used rather than the paired t-test. We used the binomial test to examine the return rate of first-year birds by sex. The significance level was set at α = 0.05. All statistical calculations were performed with SPSS 10.0 for Windows.

RESULTS

Over the study period we caught 81 Mandarin Ducks: 78 on the Chichiawan and Yousheng tributaries of the Tachia, and three (one male and two females) at Techi Reservoir. They consisted of 41 adult females, 29 adult males, five first-year females and six first-year males. Ducks were radio-tracked for periods from less than one month up to 27 months, with a mean of 9.2 ± 6.5 months (n = 81). We excluded five adult females, three adult males, three first-year females and one first-year male from the home range analysis because they were not tracked for more than four months during the breeding or non-breeding season of a given year.

Table 1. Differences in the mean home range size of adult female and male Mandarin Ducks during the breeding and non-breeding seasons on the Tachia River, Taiwan.

	Breeding (March–June)			Non-breeding (July–February)		
Sex	***n***	**Mean**	**s.d.**	***n***	**Mean**	**s.d.**
Female	27	4.28	3.21	21	16.81	7.27
Male	22	8.81	5.93	23	15.23	7.92

Breeding: t = -3.40, df = 47, p = 0.001; Non-breeding: t = -0.687, df = 42, p = 0.49

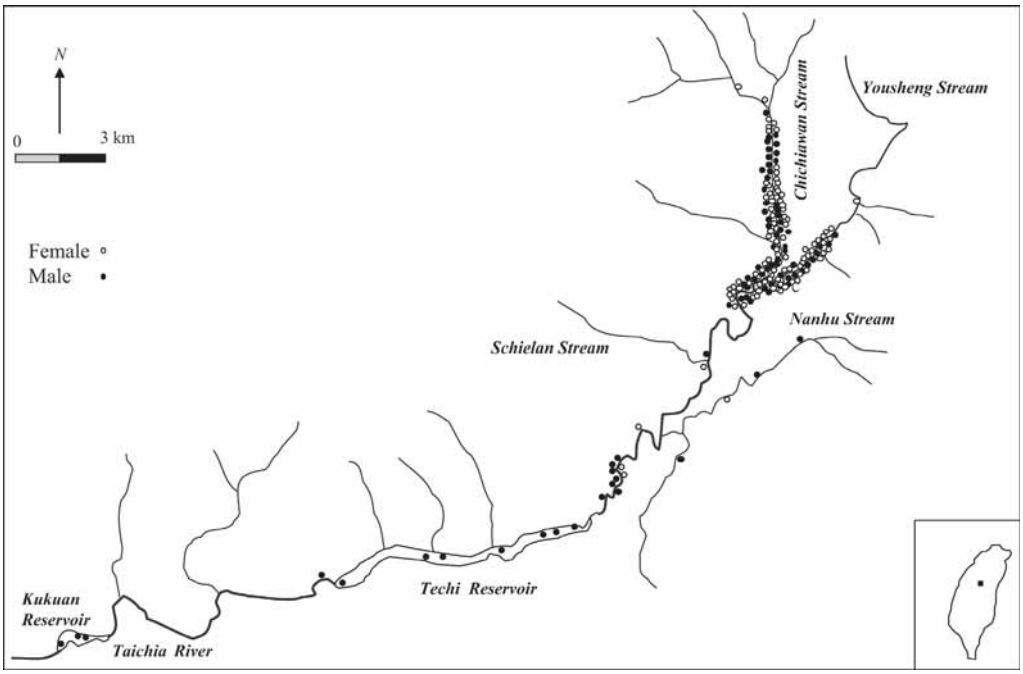

Figure 1. Radio-tracked locations of female and male Mandarin Ducks along the Tachia River, Taiwan, during the breeding seasons (March–June), 1999–2002.

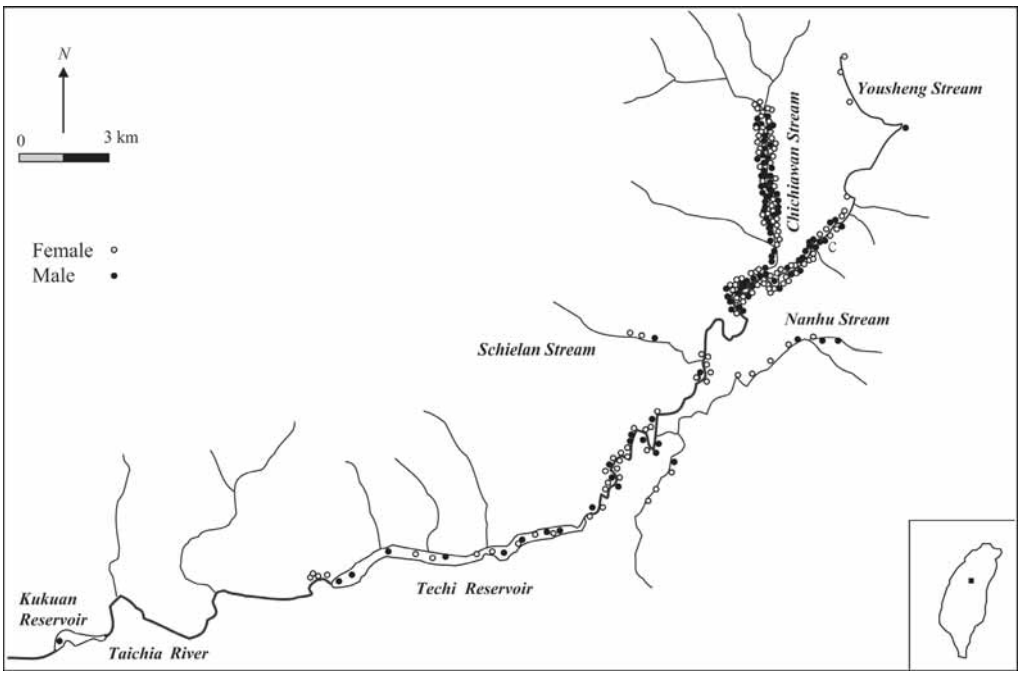

Figure 2. Radio-tracked locations of female and male Mandarin Ducks along the Tachia River, Taiwan, during the non-breeding seasons (July–February), 1999–2002.

A total of 420 radio-locations were collected during the study; results are summarised in Table 1. During the breeding season, the average home range size of males, 8.8 ± 5.9 km (n = 22), was about twice as large as that of females, 4.3 ± 3.2 km (n = 27) (t_{47} = 3.40, p = 0.001); 14 of 22 males moved outside the Chichiawan and Yousheng streams, compared with only two of 27 females. However, there was no difference in the home ranges of males (15.2 ± 7.9 km, n = 23) and females (16.8 ± 7.3 km, n = 21) in the non-breeding season (t_{42} = 0.687, p = 0.496) and during this period only one female stayed on these two streams. At this time, nearly all ducks expanded their home range by moving downstream to the Nanhu and Herhwan streams and Techi Reservoir, with one male going at least as far as Kukuan Reservoir, 35 km from Chichiawan stream. Only one bird, a male, moved upstream and over the ridge to the Lanyang River in Ilan county, north-east Taiwan.

For 23 adult Mandarin Ducks that were tracked continuously for at least two seasons, the linear home range size was significantly larger during the non-breeding season than the breeding season for both males (paired t-test, t_9 = 3.122, p = 0.012) and females (paired t-test, t_{12} = 4.020, p = 0.002) (Figures 1 & 2). For yearling Mandarin Ducks, all ten males and eight out of ten females left their natal sites along the Chichiawan and Yousheng streams. Although not a statistically significant difference, young females tended to exhibit stronger philopatry than males, as only one male returned and bred in its second year, while four (three of them siblings) out of eight females returned to the two streams, and two of them bred in the second year (binomial test, p = 0.375).

DISCUSSION

Mandarin Ducks, particularly females, suffered high mortality during our study (Sun *et al.* 2011). This contributed to the small sample sizes in location data for some of our birds. At least 30 relocations per animal are considered necessary in order to estimate its home range size (Kenward 1987). However, our study is still meaningful in estimating the birds' linear home range size because the species tends to have relatively fixed feeding and roosting sites in both the breeding and non-breeding seasons.

The home ranges of both male and female Mandarin Ducks were longer during the non-breeding season than in the breeding season. We found that breeding birds did not forage more than 4 km from their nest trees during the incubation and post-hatching periods. Thus, their home range at that time was much shorter than it was after breeding was completed. The furthest site to which our radio-tagged Mandarin Ducks were known to have moved was 35 km downstream at Kukuan Reservoir to the west and upstream of Nanyang stream to the east. Large expanses of open water are deemed to be ideal moulting sites for waterfowl during the flightless period (Bailey 1983). Finding a safer moulting place at the downstream reservoir may be another reason for longer ranges during the non-breeding period.

Many factors can directly affect the movement and home range size of birds, including age, sex, breeding status, habitat structure and weather conditions. These factors act as constraints on birds whose home range size is driven by the availability of food resources (Legagneux *et al.* 2009). Young birds, whose competitive ability is more limited, may be excluded by experienced adults (Clark *et al.* 2003). In our study, most Mandarin Ducks moved downstream from the breeding area during the non-breeding season. This suggests that suitable nesting habitat is limited to the upstream areas but suitable foraging habitat extends well downstream. In other cases, unsuitable conditions (e.g. drought in wetland areas) may cause ducks to stay in the breeding area (Gilmer *et al.* 1975). In central Taiwan, high stream discharge during the summer monsoons decreases the availability of suitable habitats such as pools and shallow riffles, and corresponds with the departure of Mandarin Ducks to downstream reservoirs.

The strongly male-biased sex ratio (2.2:1) in this study population of Mandarin Ducks (Sun *et al*. 2001) may account, in part, for the larger home ranges of males during the breeding season. This is probably caused by the much higher mortality rate (50%) of females than males (26.3%) (Sun 2002). The chance for males to mate was therefore undoubtedly much lower than for females (Sun *et al.* 2003). Consequently, bachelor males might be forced to wander further in pursuit of a better chance of mating. In fact, in 1999 a single male left the Chichiawan and Yousheng stream area and found a mate downstream at Kukuan Reservoir. Paired males tended to stay around the breeding site whilst females rarely left the upstream areas during the breeding season. Those that did were single or separated females. Bruggers (1974) found that only about one third of first-year female Mandarin Ducks bred.

Waterfowl exhibit female-biased natal philopatry (Rohwer & Anderson 1988). Our results support this finding: yearling Mandarin Duck females appeared to show stronger philopatry than males. This is also true of young Wood Duck females in North America (Grice & Rogers 1965, Brown 1972). Female-biased philopatry arises because pairs generally form in the wintering areas or during migration and the pair then returns together to the natal breeding area or the previous nesting location of the female (Hepp *et al.* 1989).

Movement and home range information is important for wildlife management and conservation decision-making, because the availability of suitable habitat is essential for the maintenance of wild animal populations (Gilmer *et al.* 1973, Parr *et al.* 1979, Chubbs *et al.* 2008). Our radio-tracking study on the tributaries of the Tachia from 1999 to 2002 provides rarely reported, year-round information about changes in the size and location of Mandarin Duck home ranges during the breeding and non-breeding seasons. Although the resident population of Mandarin Ducks is non-migratory, it is clear that small-scale movements within the Tachia watershed are important for breeding and survival. A few Mandarin Ducks roamed to the Kukuan Reservoir, beyond the boundary of Sheipa National Park, where birds are less protected, and we suggest that the park boundary be extended to include the reservoir.

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