

First reproductive records and nest sites of the endemic Juan Fernández Tit-tyrant *Anairetes fernandezianus* (PHILIPPI, 1857) (Aves: Passeriformes: Tyrannidae) from Robinson Crusoe Island, Chile

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Abstract. The first nests of *Anairetes fernandezianus* are found on Robinson Crusoe Island, Chile, all located in native laurel forests *Myrceugenia fernandeziana*. The nesting distribution range covers all habitats of dense vegetation of an area of 2000 ha. Nests were either placed relatively high in the central canopy or low in the side-branchage of trees (1.55–8.8 m), in most cases near edge structures. The nest itself is an open cup-shaped construction attached to exterior twigs, well camouflaged by its greenish-brown colour inside the dense foliage. Small white spider cocoons and webs are integrated in the nest material. Two to three eggs are laid per clutch, each a typical white tyrannid egg (17.4 × 13.1 mm). Incubating was solely observed for the female, but the male later participates feeding the nestlings, and both lead fledglings. Nest success may be reduced by weather and predator impact. Low reproductive success and predation by rats/owls may have played a role in the population decline from 1994 to 2001, when the total population was estimated at c. 2500 individuals. Comparisons with mainland *A. parulus* are carried out to test hypotheses of island landbird ecology. Future studies should focus on reproductive success and nest predation.

Resumen. Primeros registros reproductivos y sitios de nidos del endémico Cachudito de Juan Fernández *Anairetes fernandezianus* (PHILIPPI, 1857) (Aves: Passeriformes: Tyrannidae) de la Isla Robinsón Crusoe, Chile. – Los primeros nidos de *Anairetes fernandezianus* están encontrados en la Isla Robinsón Crusoe, Chile, todos localizados en bosques nativos laureles de *Myrceugenia fernandeziana*. La distribución de nidificación cubre todos hábitats de vegetación densa de un área de 2000 hectáreas. Nidos estaban colocando relativamente alto en la copa central o bajo en el ramaje lateral de árboles (1.55–8.8 m), en la mayoría de los casos cerca de estructuras bordes. El nido mismo es una construcción abierta de la forma de una taza, fijada a ramas exteriores, bien camuflada por su color verde-café. Pequeños capullos y telarañas blancas de arañas están integradas en el material del nido, no conocido de cachuditos continentales. Dos o tres huevos formas una nidada, cada uno un huevo blanco típico de Tyrannidae (17.4 × 13.1 mm). Incubación fue observada solamente de la hembra, pero el macho mas tarde participa a alimentar los polluelos, y los dos guían los volantines. Éxito del nido sea reducido por impacto del tiempo o por predadores. Éxito reproductivo bajo y predación por ratas/nucos posiblemente tenían importancia para la declinación desde el año 1994 hasta 2001, cuando la población total fue estimada a 2500 individuos. Comparaciones provisionales con cachuditos continentales *A. parulus* han sido para probar hipótesis de ecología de aves terrestres isleñas. Estudios futuros serian concentrar al éxito reproductivo y a la predación del nido.

Key words: breeding ecology, brood care, island birds, Juan Fernandez, threatened endemics.

Introduction

The Juan Fernandez Tit-Tyrant *Anairetes fernandezianus* (PHILIPPI, 1857) is one of 15 endemic bird species of Chile (comp. ARAYA *et al.*, 1995; JARAMILLO, 2003). Among these it is the only tyrannid (Aves: Tyrannidae). Its biogeographic distribution is limited to one oceanic island, Robinson Crusoe of the Juan Fernandez group, where birds represent the only native terrestrial vertebrates. On base of genetic analysis (molecular clock: ROY *et al.*, 1999) it was postulated that *A. fernandezianus* had been separated from its ancestral form some 600,000 years ago. Since some 400 years, when the island was first reached by Man, severe human impact started to threaten the insular ecosystem. Amongst the principal problems for the native avifauna there were habitat destruction by introduced herbivores, competition of introduced

and independently immigrated birds (the latter as they now found suitable habitat), and predation by introduced predators (BOURNE *et al.*, 1992; HAHN & RÖMER, 2002; SCHLATTER, 1987; WESTER, 1991). Amongst the most important are mainly mammal species like rats, cats, dogs, and coatis. But also a raptor like the Short-eared Owl *Asio flammeus suinda* was able to maintain a population on the island after the change of environment (and prey spectrum: FUENTES *et al.*, 1993).

The influence of this predator assemblage on the population and reproduction of *A. fernandezianus* remained entirely unknown until now. Even observations according to its population size were general and rare, although it may have been drastically reduced in historical times as result of the destruction of its original habitat distribution to about 50 % (comp. SKOTTSBERG, 1953). In the 1980s BOURNE (1983) guessed the population size in the “thousands”. At BROOKE’s (1987) time still no reliable data on island and habitat area was available, and the island was thought to have a surface of 93 km² instead of 47 km² presently. By estimating about one individual per hectare forest, in an assumed 5000 ha distribution range, BROOKE (1987) calculated a population size of 5000. Although the area was overestimated, his estimate of around one individual per hectare is in an appropriate dimension and is confirmed by censuses carried out on base of 91 line transect counts on Robinson Crusoe (HAHN *et al.*, in press). Pooling these data from different habitat types, a total population size of about 3000 individuals in 1994 and of 2500 in 2001 was estimated, which makes a population decline of about 17 %. Such a decline may reflect periodical fluctuations (DIAMOND, 1985). But it may also turn out to be a true trend, eventually caused by an increase of adult mortality or decrease of reproduction success through predator impact (TOMKINS, 1985).

Nearly 150 years after the bird’s scientific description still nothing is known about reproductive activity, not even basic data of nest sightings or food carrying adults are available. This is noteworthy, as at least some early ornithologists presented information on Juan Fernandez landbirds (JOHOW, 1896; REED, 1874; SALVIN, 1875; SALVIN & SCLATER, 1872; SCHALOW, 1897, 1898, 1899; SCLATER, 1871; SCLATER & SALVIN, 1878). The zoologist Bäckström explicitly mentioned that he could not find an *Anairetes* nest in 1916/17 during the visit of the Swedish Pacific expedition (LÖNNBERG, 1921). Even BROOKE (1987), providing detailed information on the island’s birds and carrying out field work on the Juan Fernandez Firecrown *Sephanoides fernandensis* in the same habitat, did not note any reproductive behaviour of *A. fernandezianus*.

Such data on reproduction would not only provide basic knowledge of its aut-ecology but also enable a first comparison with the next ally on the mainland, the Tufted Tit-tyrant *Anairetes parulus*. Thereby it would become possible to test some general hypotheses of island bird ecology (ABBOTT, 1980; CARLQUIST, 1974; GRANT, 1965; LACK, 1971; MAYR, 1963; WHITTAKER, 1998) for validity in the tit-tyrants and in the biogeographic region of Southern temperate Chile. Since inter-specific competition and predation are originally lower on islands than on the mainland, it was postulated that (1) egg size is increased and (2) clutch size reduced in island birds. Such a tendency towards higher energetic investment per egg may also be expressed in (3) a reduced reproduction rate (shorter breeding season / reduced number of broods), and (4) reduced antagonistic behaviour in general. Especially the last two points would be critical in case of high threat by introduced predators. Answering them would have the applied value to estimate the impact of predators and help to identify the reasons for possible population decline of Robinson Crusoe’s only endemic passerine bird and Chile’s rarest tyrannid (BIRDLIFE INTERNATIONAL 2004: classified as “near threatened”; comp. also GLADE, 1993; STATTERSFIELD & CAPPER, 2000). Thus apart from providing information of applied conservation relevance, the study is aimed to provide first basic reproduction data, and to enable a preliminary comparison with the mainland sister species to test these hypotheses.

As this is the first attempt to focus particularly on *Anairetes fernandezianus* and to deal with any aspect of its ecology, another general aim is addressed: to present a complete as possible review of literature sources according to observations and other investigations of this species.

Study area and methods

Robinson Crusoe (former name: Masatierra) is the Easterly island of the Juan Fernández Archipelago, situated in the south-east Pacific Ocean 587 km off the coast of Chile. It stretches from 33° 28' 48" to 33° 33' 38" south and 78° 47' 12" to 78° 56' 44" west of Greenwich. The island area is 47.11 km² (CIPMA, 2003), reaching an altitude of 915 m above sea-level (a.s.l.) at the summit of the Yunque Mountain. The entire island, with exception of the San Juan Bautista settlement (c. 600 inhabitants), is a Chilean National Park since 1935 and UNESCO Biosphere Reserve since 1977. More detailed geographical descriptions may be taken from CASTILLA (1987) and SKOTTSBERG (1920–1956).

The island was visited for field work at 24 Nov 1992, 2 Feb 1993, 24 Mar–4 Apr 1994, 8–13 Apr 1994, 22 Oct–14 Dec 1994, 10–13 Feb 1995, 9 Nov 2001–22 Jan 2002, and 8–11 Feb 2002 (149 days) but most observations and data collections were made in 2001/02. Visual identification of birds was straight forward, using ARAYA *et al.* (1992, see also JARAMILLO, 2003) and the original species description. Acoustic identification was possible after learning the bird vocalisations from observation and taping with a DAT-Recorder (Sony, HD-S100) (similar to HAHN & MATTES, 2000). However, systematic studies of the island dialects (comp. e.g. PÄCKERT & MARTENS, 2004) of this endemic taxon are still in wait. Nests were searched by climbing potential host trees and by visually controlling trees in previously detected territory centres from a camouflaged observation point (MÜHLENBERG, 1993). To not influence birds more than necessary all nest measures were taken during their absence. No birds were mist-netted or collected. Research permits by the Chilean Government and National Forestry Service (CONAF) covered all field campaigns (numbers: V. Reg. 03/04 and V. Reg. 11/01).

Results

Nesting habitat

Anairetes fernandezianus have been documented already by BÄCKSTRÖM (LÖNNBERG, 1921) and BROOKE (1987) in different forested habitats during the reproductive season. This can be reconstructed on base of their field campaign dates and my determined breeding dates (comp. Reproductive season). Indeed, I recorded *A. fernandezianus* in all forested habitat types, both of introduced and native vegetation. But nests were solely found in (a) native laurel forest patches of the lower montane level (650 ha, 170–450 m a.s.l.), which also showed the highest population density of all inhabited habitat types. Other occupied habitats were: (b) native forests of the upper montane level (340 ha, 450–915 m), (c) introduced shrub vegetation of the basal level (290 ha, 100–250 m), as well as the less dense inhabited and smaller (d) cultivated forest of the basal level (70 ha, 50–170 m) and (e) cultivated lands and gardens of the settlement area (39 ha, 0–100 m). Introduced shrub vegetation is often present in the vicinity to native forests but shows a highly different structure. In some habitat types (b, c, e) the structure seems to be suitable for nesting too but records yet exist for foraging behaviour only. Thus, although a rather wide spectrum of habitats is inhabited during the breeding season, reproductive records are presently lacking (b–e).

Nest sites

Nine nests of *A. fernandezianus* were detected in November/December 2001, the first one found on 28 November at 14h15. All nests were discovered in the upper Eastern region of Quebrada Vaquería, across the ridge North-west of Puerto Ingles at the Western foot of Cerro Alto (660 m). This is Robinson Crusoe's northernmost valley, being exposed to strong oceanic winds and therefore showing laurel forests of less than 10 m height. These forests mostly grow in steep terrain of the mountain sides, being mixed up in a mosaic with secondary pastures and thickets. Thus these forests are often broken up in patches including external tree isles and small internal clearings. All nine nests were placed in the dominant (> 90 %) tree



Fig. 1: Placement and structure of first *Anairetes fernandezianus* (PHILIPPI, 1857) nest sites and nests on Robinson Crusoe Island, Chile. Nest 1 (left above) laterally shows numerous of the small white spider cocoons. The incubating female of nest 5 (left below) is visible by its tail only. The third egg of nest 6 (right) is partly covered by a feather. Photographs were taken on the first observation date in Quebrada Vaquería (Table 1).

species *Myrceugenia fernandeziana* (Figure 1), although some scattered *Boehmeria excelsa*, *Drimys confertifolia*, *Fagara mayu*, *Rhaphithamnus venustus*, and *Aristotelia chilensis* were also present in these forest stands. The Chonta palm *Juania australis* also persisted in some individuals but showed a highly unsuitable structure to host *A. fernandensis* nests.

Although the laurel forests still cover about 50 % of the valley superficies, and still large patches are found, only one nest (no. 1) was placed inside a closed stand. All eight others were located near forest edges or small clearings, and represented more open sites of stands. One nest (no. 6) was even located in a solitary tree, surrounded by a pasture and 30 m away from the next forest patch. Although the habitat patchiness was clearly increased, compared to other island forests and of course to pre-human times, a high affinity to such edge structures is recognized for nest sites. This preference of open space in the nest vicinity is additionally supported by measuring the vegetation cover around each nest (10 × 10 m = 100 m² plot). An average of 73 % (range: 60–95 %) of this direct nest vicinity was covered by high vegetation (trees, shrubs) but the remaining 27 % by low vegetation (grasses, herbs) and therefore by open space (Table 1).

Six out of nine nests were located laterally in the side-branchage of trees, mostly not far away from the densely leaved tips of exterior twigs. These were typically nests of low height above ground (1.55–2.5 m). Only three nests were placed more or less centrally within their hosting trees, representing also the three highest nests (3.1, 4.8 and 8.8 m). Thus nests have been placed whether in the high central canopy or the low lateral branchage. Pooling the two nest site types, an average height of 3.3 m is calculated.

Tab. 1.

| Nest site (no.) | 1 | 2 | 3 | 4 | 5 | 6 | 7 ^L | 8 ^T | 9 ^L | Average (± s. e.) |
|---|-------------|-------------|-------------|-------------|------------|-------------|----------------|----------------|----------------|-------------------|
| Date of first observation | 28 Nov 01 | 28 Nov 01 | 4 Dec 01 | 4 Dec 01 | 5 Dec 01 | 5 Dec 01 | 6 Dec 01 | 6 Dec 01 | 7 Dec 01 | - |
| Latitude (South of Greenwich) | 33°37'7.5" | 33°36'59.1" | 33°37'3.7" | 33°37'1.2" | 33°37'1.0" | 33°37'1.7" | 33°36'58.8" | 33°37'0.9" | 33°37'3.0" | - |
| Longitude (West of Greenwich) | 78°51'53.0" | 78°51'58.4" | 78°51'54.6" | 78°51'57.0" | 78°52'9.8" | 78°52'13.9" | 78°52'14.3" | 78°52'11.9" | 78°52'11.3" | - |
| Altitude above sea-level (a.s.l) | 400 | 300 | 305 | 300 | 214 | 215 | 185 | 210 | 260 | 265.4 ± 22.61 |
| Exposition (degrees and direction) | 326° NW | 152° ESE | 342° NNW | 240° WSW | 326° NW | 10° N | 12° NNE | 356° N | 8° N | North dominance |
| Incline of surface (degrees) | 37° | 34° | 21° | 28° | 27° | 15° | 15° | 20° | 31° | 25.3° ± 2.67 |
| Cover of tree storey (% of 100 m ²) | 95 | 80 | 60 | 75 | 75 | 50 | 80 | 80 | 65 | 73.3 ± 4.41 |
| Height of tree storey around (m) | 8-10 | 3-4 | 3-6 | 3-5 | 4-5 | 5-6 | 3-4 | 4-5 | 4-5 | 4.9 ± 0.61* |
| Height of host tree (m) | 9.5 | 3.6 | 3.8 | 4.4 | 4.2 | 5.9 | 3.2 | 4.2 | 2.2 | 4.56 ± 0.70 |
| Height of nest above ground (m) | 8.8 | 1.7 | 3.1 | 2.5 | 1.55 | 4.8 | 2.3 | 2.6 | 1.7 | 3.23 ± 0.771 |
| Number of twigs holding nest | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 5 | 3.8 ± 0.22 |
| Number of incubated eggs | - | 2 | 3 | 3 | 3 | 2 (3) | - | - | - | 2.6 ± 0.22 |

Study area was Q. Vaqueria, the island's northernmost valley. This is characterized by a mosaic of laurel forest patches, shrub- and grassland, and shows comparatively low forest heights caused by strong wind exposure. All nests were attached to thin exterior twigs of Luma, *Myrcugenia fernandeziana*. ^L = Last year's nest (and brood); ^T = This year's nest (and brood); earlier in the season; Dash (-) = no data; Egg value in parentheses = three laid in first instance but later only two were present and incubated; ± = standard error; * = calculated from the medians of individual values.

Comparing these nest heights to the heights of their host trees (of *c.* 4.5 m) shows an average distance of nests below the top of canopy of 1.3 ± 0.24 m (range = 0.6–3.0; *n* = 9). However, evaluating the two nest site types separately, clear differences are found: central canopy nests were located in higher trees (6.4 ± 0.66 m; *n* = 3) and lateral branchage nests were located in lower trees (3.6 ± 0.34 m; *n* = 6). Interestingly the three nests found in the higher trees were placed in the very upper canopy (5.6 ± 1.69 m high; nests 0.8 ± 0.15 m below top; *n* = 3) but the six nests found in the lower trees were placed relatively low little above medium tree height (2.1 ± 0.19 m high; nests 1.7 ± 0.29 m below top; *n* = 6).

The altitude of detected nest sites ranges from 185 to 400 m above sea-level (a.s.l.), but may be extended more. A one-hour search on 18 December 2001 in the tree-fern forest on top of Cerro Alto (660 m) did not result in any nest discoveries, and to the recording of only two adult specimens (on *c.* 2.5 ha). Most nest sites showed terrain exposition to Northern directions, and one each to Southern and Western direction. Eastern expositions were rare, as the valley sloped down westwards. The southerly exposed valley-side was little less forested, but the northerly expositions surely received more sun-light and higher temperatures in general. Incline was rather high throughout the entire valley, lacking any even areas or plateaus. Nest sites showed an average incline of 25° or 56 % (range: 15–37°), representing the approximate terrain incline.

Nests

All nine nests were attached to the exterior part of *M. fernandeziana* twigs, some 50 cm from the tip, always where at least two smaller twigs were growing out of the main twig. In three cases the nest was attached to three twigs, in five cases to four, and in one case to five twigs. The main twig, meaning the thickest, had an average diameter of 7 mm (± 0.23 ; range = 3–15; *n* = 9). The general orientation of this main twig was in three cases near-horizontal (–22.5° to 22.5° incline), in two cases near-diagonal (22.5° to 67.5°), and in four cases near-vertical (67.5° to 90°).

The nest itself is a typical open nest of the size and shape of a medium cup. Seen from above it is mostly entirely circle-round, being on average about as wide (7.4 ± 0.17 cm; range = 6.95–7.85) as high (7.5 ± 0.19 cm; range = 6.9–8.2). The upper interior nest diameter (3.8 ± 0.14 cm; range = 3.25–4.9) is little smaller than that some 2 cm deeper in the centre of the chamber, and that of the average chamber height (bottom to rim: 5.0 ± 0.27 cm; range = 3.8–5.6), thus making a nest volume of the form of an up-right ellipsoid cut at its top (*c.* 4.5 cm³). Measures were taken from the nests 1–6 (*n* = 6) shortly after the breeding period.

The nests were generally well camouflaged by their exterior brownish/greyish-green colouration, sometimes including covering mosses of the same kind as growing epiphytically on twigs and between leaves. The percentages of nest materials were estimated seen from outside without taking nests apart at all nine sites. I detected an average portion of 66 % grass leaves (range: 50–80 %), 22 % *Aristotelia chilensis* leaves (0–45 %), 7 % mosses (0–45 %), 4 % spider cocoons (0–5 %), and 1 % fine root-fibre (0–5 %). The integration of the small, whitish-grey balls (1–3 mm) of spider cocoon was highly constant (present in eight out of nine nests). The interior of the nest chamber is lined with several fine (brownish-grey to olive) feathers, probably mostly from *A. fernandezianus* itself. Few slightly larger feathers (2–3) were also placed in the nest, to cover the brood when the adult bird left the nest. These larger ones have been identified to originate from petrels cf. *Puffinus creatopus*, wild doves *Columba livia*, and *Asio flammeus suinda*.

Eggs and juveniles

In five nests (no. 2–6) eggs were found. These were of entirely while colouration, rather dull than glossy. The clutch of these five active nests consisted of two or three eggs. At the time of first observation two nests contained two eggs, and three nests contained three eggs. One

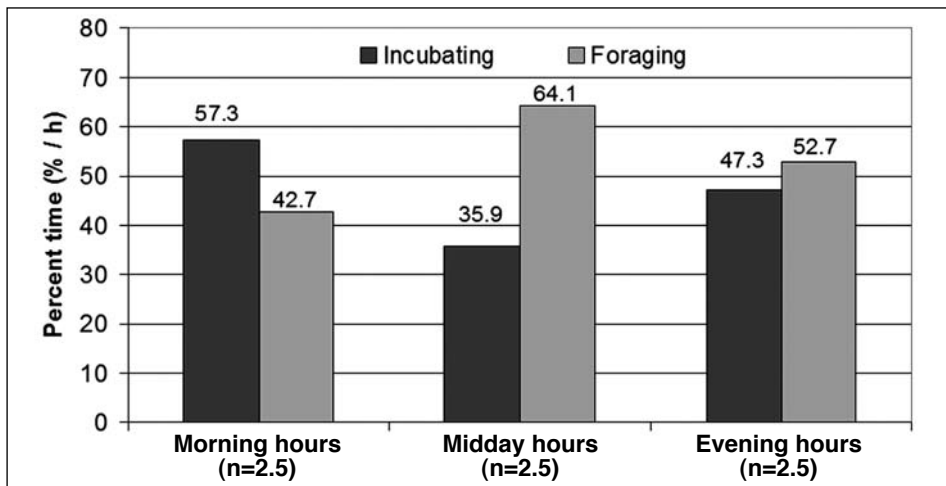


Fig. 2: Incubation activity of an *Anairetes fernandezianus* (PHILIPPI, 1857) at nest 2 during morning (06h40–09h10), midday (11h30–12h00), and evening (18h00–20h30) hours ($n = 7.5$) on 4/5 December 2001 in Quebrada Vaquería, Robinson Crusoe Island, Chile. Solely the female was incubating the two white eggs. No predator impact interrupted breeding during registration time.

of the two-egg broods (no. 5) was completed by a third egg at next control (6 Dec 2001). The other two-egg brood (no. 2) was not completed by a third egg. Contrarily, at nest 6 three eggs were laid in the first instance, but one was lacking later on (6 Dec 2001) and breeding continued with two eggs.

Five of the 14 observed eggs were measured at the time of first observation. An average length of 17.4 mm (± 0.09 ; range = 17.1–17.6) and a transversal of 13.1 mm (± 0.07 ; range = 12.8–13.2) resulted. The transversal (max. width) is located close to the middle (medium length), giving the egg a rather obtuse than pointed shape. Nestlings, seen freshly hatched at nest 4, have a typical passerine appearance, showing an entirely naked body of purple-greyish colouration and still closed eyes. Three recently fledged juveniles (of nest 1) were observed perching in the nest hosting tree at heights between 4 and 6 m above the ground. They had left the nest above (at 8.8 m) probably some hours before, being well hidden in the foliage of a mature *M. fernandeziana* tree and an adjacent *Aristotelia chilensis*. Movements were still rare, perching in a distance of 1 to 2 m to each other. Their plumage differed from that of the feeding adults not only according to the typical voluminous ruffled feathers but also to a rather uniform, unobvious grey colouration, especially at breast and belly, still lacking the characteristic adult black-and-white streaking. Family parties, all with two guiding adults, were observed nine times in Q. Vaquería. They consisted of five ($n = 4$), four ($n = 4$), and three ($n = 1$) individuals. The young of the latter was already difficult to distinguish from its parents, showing a nearly entirely developed plumage. The other juveniles were easily distinguishable by their shorter tail and crest.

Brood care

Breeding activity was observed at all five nests containing eggs. In the cases which allowed sex determination (body size, crest length), always the female was incubating the eggs, never the male. This was the matter during 7.5 observation hours at nest 2 and single incubating phases at the other nests. The female was always observed to stay in the nest for a limited time and then left the brood alone to forage until return (Figure 2).

Pooling the presence/absence data covering the different day hours ($n = 7.5$), an average of 47.3 % of the time (28 min 24 sec / h) was spent incubating the eggs and 52.7 % (31 min 36 sec / h) was used for foraging away from the nest. Differences of breeding intensity become obvious in Figure 1, showing that breeding was intense in the morning (57.3 %), lowest during midday (35.9 %), and moderate during evening hours (47.3 %). Not illustrated data additionally indicated that breeding intensity during midday may increase if rain or strong wind comes up. The average duration of incubation phases was 13 min 50 sec, being long in the morning (20 min 55 sec), short during midday (8 min 35 sec), and little above average during evening (16 min 0 sec). Three times during the 7.5 observation hours (0.4 / h) the female left the nest to protect the territory and to attack an invading tit-tyrant (individual or pair).

Although the male was not reported to breed, it was territorial and often present in the nest vicinity. The male was also stated to carry food, indeed, at the first observation of any reproductive activity of this species made in the laurel forest west of Plazoleta at 310 m a.s.l. on 16 November 1994. Probably the arthropod food was dedicated to feed nestlings, but the attempt to monitor the bird and a later nest search remained unsuccessful. The described territorial activity of the female took place in the absence of the male, or while the latter was already defending the territory and then was joint by the female. The general territoriality of the male near its nest, the intense pair bond as well as observations of inter-pair competition indicate a monogamous system of male (and female); both partners seem to be active at only one nest at a time.

The nest success of all five broods turned out to be zero: none of the juveniles of the 14 eggs fledged. Two to five at least hatched, but disappeared shortly afterwards, like all other unhatched eggs. The possible reasons for this devastating balance are matter of the discussion. Controls approximately one week after brood loss showed no further use of four nests and already clear signs of decay, but one nest (no. 5) was still maintained six to nine days after brood loss in mid-December. It showed an unusual characteristic: the whole nest chamber was densely stuffed with fine grey feathers! This was also the only of five nests where adults were still around and vocally marking the territory centre. The ball of feathers kept the nest in shape and hindered rain water to reach chamber sides and bottom. At the last control on 27 December 2001, however, no sign of nest maintenance and territoriality were recognised any more. Thus in none of the unsuccessful nest cases an immediate try of a substitutive brood was carried out, and facing the nest decay it is unlikely to have taken place later on.

Antagonistic behaviour

Anairetes fernandezianus may be very curious if met by a human observer outside of the breeding season or far way from the nest. They behave tame/fearless, often curiously approaching the quite observer to a few meters only, representing a typical island-like behaviour. Near to their active nest, however, they behave rather unobvious and cryptic. Therefore an approach directly to the nest should only follow preliminary observation from the distance and then always take place in the female's absence, checking also the surroundings for the male. Nevertheless, acoustic and motoric warning behaviour is less intense towards a human observer than towards a particular avian predator: *Asio flammeus suinda*. Two individual observations of inter-specific interaction were made.

First, on 6 December 2001 at 12h35 an *Asio* arrived and perched on a canopy branch c. 10 m distant to the *Anairetes* nest (no. 2). Although this took place during absence of the female from the nest, the intruder was immediately discovered by one of the partners. It approached the *Asio* to a distance of several meters intensively warning, being located between the predator and its nest but protected by the dense canopy branchage (max. height of 4 m). Soon the second bird arrived, probably alarmed by the partner, and jointed the loud aggressive warning behaviour (mobbing). The *Asio* waited until 12h45 and then flew some 50 m downhill to perch again. It was followed by the two *Anairetes*, which were heard to continue mobbing. They did not return to routine and to their nest for the next ten minutes or longer (when I left the

observation site). It seemed that the *Asio* had watched out for the *Anairetes* nest and probably knew the approximate position; the *Anairetes* reacted extremely sensitive and aggressive to this particular predator.

Second, on 14 December 2001 I observed an *Asio* preying on an *Anairetes* during my return to Puerto Ingles having just crossed the ridge Puerta Franca south-west of Cerro Alto at 370 m a.s.l.. The *Asio* flew hang-parallel and about 5 m above the vegetation cover (1.5 m high shrubs), then suddenly dropped down and snatched with the talons into the foliage. The prey success could not be visually controlled but immediately after this event an *Anairetes* stared to alarm from about the same position, whether the escaped individual or the partner of the victim. Thus both, broods as well as adult *A. fernandezianus* represent potential preys of *Asio flammeus* on Robinson Crusoe.

Reproductive season

The minimum breeding time was determined to last 16 days at nest 4: at the first observation on 4 December three eggs were already laid. On 19 December two nestlings had just hatched, awaiting their youngest sibling (the latter's egg-shell was found below the nest on 23 December when all three had disappeared): No information of the duration of nestling time and parental care of fledglings exists. If both are assumed to last between two and three weeks, the minimum temporal extension of the breeding season can be calculated. The earliest indication of breeding results from a single, near-independent juvenile seen with its parents on 8 December 2001 (maybe its sibling(s) had already left the family). Even calculating only two weeks for each of the three time periods (Breeding, nestling, juvenile leading), an egg laying date in late October results. Apart of this, the laying date of the three freshly fledged young seen on 28 November near their nest (no. 1) may probably have been in late October too. However, during census counts in different other island regions between 9 and 26 November no family party or juvenile was observed. Even on 21 November the overwhelming number of *A. fernandezianus* records felt upon pairs. Thus female incubation, separating male and female for most of the time, might not yet have been very frequent at that date.

Overseeing numerous territories of the upper South-eastern Q. Vaquería valley, I estimate that about 50 % of the reproductive adult birds were leading young at 8 December. The remaining 50 % may have started to breed later (like at the active nests 2–6). The latest recorded egg was laid on 6 December, completing the clutch (nest 5). This then may not have hatched before 22 December and not have fledged before 6 January. Such a late family party, with recently fledged young (few days out), was seen in a laurel forest between Puerto Frances and La Pasqua at 260 m a.s.l. on 3 January 2002. Until 22 January no further family party was recognised in various island regions, indicating the end of the reproductive season. Altogether, initial egg-laying can be reconstructed for the period from late October to early December but might be little more extended into the summer.

Discussion

Reasons for the late record of first nest sightings of *Anairetes fernandezianus* may be linked to three circumstances: (1) the scarceness of surveys on Juan Fernandez birds in general, partly caused by the islands' remoteness and steep terrain, and on *A. fernandezianus* in particular; (2) the small size, camouflage (colouration, material) and placement of nests in dense branchage making random discoveries improbable; and (3) the shyness and sensitivity of adult birds during the breeding season, which complicates to follow breeding or feeding individuals to the nest. The latter was also the case after the first observation of any reproductive activity of this species on 16 November 1994, when a food carrying adult could not be monitored.

The distribution of the potential nesting habitat of *A. fernandensis* covers all areas of scrub and forest vegetation, representing an area of about 2000 ha. This is probably about the half of its

original range before human forest destruction started some 400 years ago (comp. GREIMLER *et al.*, 2002; SKOTTSBERG, 1953), and much less than roughly estimated by BROOKE (1987) on base of older cartographic material. Thus *A. fernandezianus* has to be considered as the most isolated as well as geographically most limited species of all 429 Tyrannidae (the Galapagos Flycatcher *Myiarchus magnirostris* occurs on 12 islands) (comp. DEL HOYO *et al.*, 2004; CORY & HELLMAYR, 1927; SKUTCH, 1960).

The two different types of nest sites indicate a rather wide nesting spectrum. As the vegetation was generally low and patchy in Q. Vaquería, nests in high canopies of closed stands may take a higher portion in other island regions but only be discovered by systematically climbing trees (like done for nest 1). Comparisons to its next relative (ROY *et al.*, 1999), the Tufted Tit-tyrant *Anairetes parulus* at the Chilean mainland, indicate some similarities, like to hide the nest extremely well. HUMPHREY *et al.* (1970) state that nothing is known about the reproduction of this species on Fire land, and cites a later PHILIPPI (1954) that “saw a pair which appeared to be playing hide and seek with them only a few meters away in the dense bushes; in spite of their best efforts they were unable to find any sign of the nest. They had a similar experience...” on other occasion again.

Further similarities of nest site choice are derived from JOHNSON (1967) stating that mainland “Tit-Tyrants build a open, cup-shaped nest ... in shrubs, bamboo or other plants, preferably bordering a path or stream or, in forested areas, around the edge of small clearings”. This would mean a similar preference of both species for edge structures. However, lack of any *A. parulus* data of nesting in closed forest stands indicates a comparatively wider nest site spectrum of *A. fernandezianus*.

This is remarkable, especially as another reducing factor may be the presence of island-specific predators, which also could cause reduction of nest site choice. Island predators often show higher population densities than their mainland counterparts and specialize on one of the few prey species rather than having a species-rich spectrum to choose from. This may force a potential prey to restrict nesting to a few types of safe nest sites (HAHN *et al.*, 2004, PORNELUZI, 2003). Through the anthropogenic introduction of additional predator species to islands (mostly mammals: cf. HERNANDEZ *et al.*, 1999), the spectrum of occupied nest sites may have been reduced since, forcing a smaller and suggesting a formerly wider spectrum.

Contrarily to the variation in site choice, the nests themselves of *A. fernandezianus* were found to be highly homogenous, varying very little in shape, colour and material. *Anairetes parulus* nests seem to be similarly constructed, as they have been described by JOHNSON (1967) as “carefully and compactly built of root-fibres, grass leaves, lichens or thistle-down and warmly lined with numerous small feathers”. Indeed, JOHNSON’s description can be confirmed by a nest I found in Conguillio National Park about 1.5 m high in a young Southern beech *Nothofagus dombeyi*, which showed similar size and shape like those of *A. fernandezianus*. Solely the nest materials differed by more root-fibre inside and lichens at the top rim; another difference is the lack of spider cocoons in *A. parulus* nests. The use of this unusual material by *A. fernandezianus* seems to be a specific insular phenomenon of Robinson Crusoe. On this island the other small endemic, *Sephanoides fernandensis*, uses the same white cocoons – representing the only characteristic to distinguish its nest reliably from that of Green-backed Firecrown *S. sephaniodes*. The Spider cocoons may have a high isolation effect, useful where low temperatures often occur even during early summer-time.

The first description of *A. fernandezianus* eggs shows slight colouration differences as they are not cream-coloured like in mainland *Anairetes* (comp. JOHNSON, 1967; PÄSSLER, 1922), but white with only the very finest yellowish touch. The average size of the five measured eggs is significantly larger (15 % length, 11 % transversal, 42 % volume) than that of the *A. parulus* egg series measured by JOHNSON (1967) ($15.1 \pm 0.12 \times 11.8 \pm 0.05$ mm; n = not given), and therefore preliminarily confirms the hypothesis of increased egg size on islands (1). This difference coincides to other clear differences of both species, e.g. in body size (*A. fernandezianus*: 14 cm, *A. parulus*: 11 cm), breast and belly streaking, and distinctive sexual dimorphism of *A. fernandezianus* regarding the crest size and shape, and thus have to be added

to an observation made by ROY *et al.* (1999) who stated that “*A. parulus* having slightly more yellow on its underside being the most obvious difference.” No significant difference of clutch size can be identified yet: both species lay two to three eggs per clutch. Although this may stand in relation to small sample size, the hypothesis of smaller island clutch sizes (2) can not be confirmed for *Anairetes* at the time being.

The hypotheses concerning reduced number of broods / duration of breeding season (3) and reduced antagonistic aggression (4) of island taxa may be answered for *A. fernandezianus* on base of indications only. Indeed, hypothesis 3 seems to proof right as no reproductive activity could be recognised or re-calculated for the time before late October and after early January. Therefore two *A. fernandezianus* broods within this short time-span and per breeding season seem to be improbable. Even for substitutive broods no record was made. Contrarily, *A. parulus* is known to raise “two broods during the summer months” (JOHNSON, 1967). That author also states that: “Nesting activities start early, even in August in some parts of its range and nowhere later than November“. Thus, an indication is found for an overall reduced island reproduction rate per season, not caused by smaller clutch size but by reduced number of broods in a shorter breeding season. This supports the validity of hypothesis 3 for the genus *Anairetes*. For reduced antagonistic aggression of the island form (hypothesis 4) yet no indication is found. The individual observations lead to the suggestion that *A. fernandezianus* has not lost its potential of aggression towards raptors during insular evolution, maybe in relation to co-existence with *Falco sparverius fernandensis* on this island.

Possible reasons for the brood loss of all five active nests were: (a) weather impact and (b) predation by predators. Observer impact can not be excluded and is principally possible in most field studies (MÜHLENBERG, 1993), however, according to observation technique and antagonistic behaviour of birds it is not valued as severe. During the breeding period two heavy Pacific storms hit the island. The first one occurred during the night of 6/7 December continuing in the next morning little more moderate until early 8 December, and the second on 16 and 17 December 2001. At least nest 3 is likely to have lost its eggs through the wind: during daylight hours extreme deformation of the nest hosting canopy section of this young laurel tree was observed, down to a horizontal position of the usually vertical stem. The broods of the nests 4 and 5 may have been destroyed by the second storm, or have been the victim of rat/owl predation. One *Rattus norvegicus* was observed to climb even 7 m (!) high in a tree at my campsite (comp. also ATKINSON, 1985; HILL, 1983; RÖMER, 1995), about 100 m away from nest 5.

Asio flammeus suinda was shown to visit an *A. fernandezianus* nest site (without recognizing the observer) and is favoured to be responsible for the brood loss of nest 6. This was located in the thin canopy branchage of a solitary tree, difficult to climb for a mature *R. norvegicus*. An *Asio* repeatedly perched in nearby trees the day before. It probably preys only on hatched nestlings, not on eggs, as was the case with the brood disappearance of nest 4. Such avian prey would mean an extension of the *Asio* prey spectrum identified by FUENTES *et al.* (1993). This latter would not be a surprise related to the small sample size of 20 pellets; ABS *et al.* (1965) show that passerine birds play a major role in the prey spectrum of *Asio flammeus galapagoensis*. Another potential predator is the feral cat *Felis catus*, which lives very secretly in the wild, and has not been seen during 2001/02 fieldwork, but I saw several cats in other island regions in 1994, and GUTIERREZ *et al.* (1976, comp. MANN, 1981) reported on cat predation on one *A. fernandezianus*.

A dead *A. fernandezianus* specimen found by REED (1874) in a spider net represents an unusual observation. I never saw a net that would hold such pressure and, however, most prey situations are assumed to be the other way round. Indeed, own systematic arthropod samples of the laurel foliage by using standardized beating-stick method showed a very high abundance (and species richness) of small spiders, most of them still lacking taxonomic description (comp. SKOTTSSBERG, 1920–1956).

Competition for nest site, nest material, and arthropod prey with the two *Sephanoides* species living on Robinson Crusoe, may be very limited, if existing at all. *Sephanoides* sometimes catch

a flying insect and *A. fernandezianus* too (pers. obs. 1994, REED, 1874), but the latter mainly preys on stationary arthropods (insect larvae, spiders). Nest sites and nest materials seem to be sufficiently available, but at nest 6 it was observed three times that a *S. sephaniodes*, perching on a twig in 50 cm distance, was immediately chased away and not tolerated near the nest. Lack of knowledge and demands for further studies cover the wide spectrum of reproductive ecology of *A. fernandezianus*. Primary questions are (1) if the reproductive season is further extended, (2) if a substitutive brood or even a second brood per season may be carried out, (3) which are the exact period durations for breeding, feeding, and leading young, and (4) which influence predators may have on reproduction and population. If the population decline is related to low reproductive success and/or high predation has to be decided on base of further investigations. The population development should be continuously monitored in five-year steps and accompany the outlined reproduction studies of Robinson Crusoe's island tyrant.

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