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Habitat Use and Population Dynamics of the Azure-Winged Magpie, *Cyanopica cyanus*, and their Response to Fire in Northern Mongolia

A thesis

submitted in partial fulfilment

of the requirements for the Degree of

Master of International Nature Conservation (M.I.N.C)

at

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by

Haojin Tan

Lincoln University, New Zealand/

Georg-August University, Germany

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The Azure-winged Magpie *Cyanopica cyanus* in Khonin Nuga, Northern Mongolia. Photo by Kerry-Jayne Wilson (2010)

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Habitat Use and Population Dynamics of the Azure-winged Magpie,
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Fires are natural distubances in many ecosystems, but humans have altered fire regimes throughout the world. The effect of fire on organisms, particularly birds, depend on the extent and regime of the fire and the species' ecology.

The Azure-winged Magpie, *Cyanopica cyanus* is a cooperative breeder, and occurs in a disjunct distribution across much of Asia and in Iberia (Portugal and Spain). I conducted my study on the Northern Mongolian subspecies of *Cyanopica cyanus* in West Khentii, Northern Mongolia in 2009 and 2010. An anthropogenic fire that broke out in 2009 in the study area provided an opportunity to document the habitat use of the *C. cyanus* during the breeding seasons of 2009 and 2010, and to investigate the impacts of fire on the population dynamics of *C. cyanus*.

The home range of this colony of *C. cyanus* is ca. 1.233 km^2 and the colony utilises six main areas (ca. 0.532 km^2) in their home range. *C. cyanus* utilises an area which has the densest *Padus asiatica* shrub stands within their home range, and which is also the richest in species utilised by the *C. cyanus*. This area was also the least affected by the fire amongst all six areas in 2009. *C. cyanus* seemed to have expanded their home range compared to pre-fire years, and a change in social structure was observed.

To address questions on population dynamics, four years worth of data was obtained from a previous study of the breeding biology of the same colony of *C. cyanus*. I found that over the four years: (1) colony size at the beginning of the breeding season did not change; (2) the number of hatched and fledged chicks declined significantly; (3) juvenile survival was constant, but adult survival declined slightly after the year of the major fire and following severe winter; (4) variable

proportions of banded adults and juvenile were re-sighted from year to year, suggesting an open population; (5) between 26-67% of adults breed each year; (6) divorce rates in this colony of *C. cyanus* can be as high as 25%, and females still obtained new mates even though they had bred successfully the previous years; and (7) there was no association between breeding success and likelihood of returning in subsequent years.

At this stage, no conclusions can be made about the long-term impacts of fire on this colony. A longer-term study must be conducted in order to understand the population dynamics and ecology of the Northern Mongolian population of *Cyanopica cyanus*. The presence of cooperative breeding behaviour is expected to affect population structure and how this species reacts to environmental stochasticity and catastrophies.

Keywords: Azure-winged Magpie, *Cyanopica cyanus*, Northern Mongolia, habitat utilisation, forest fire, population dynamics, survival, pair-bonds, site-fidelity.

Acknowledgements

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Acronyms & Abbreviations

CI   Confidence Interval

ESRI   Environmental Systems Research Institute

Est.   Estimated

FAO   Food and Agricultural Organisation of the United Nations

Fig.   Figure

GIS   Geographic Information System

GPS   Geographic Positioning System

IUCN   The International Union for Conservation of Nature

Pers. comm.   Personal communication

Pers. obs.   Personal observation

UNICEF   The United Nations Children's Fund

Chapter 1

Introduction

1.1 Impact and effects of fire

Fires are part of natural disturbances in many terrestrial ecosystems, usually in grasslands (savannah), woodlands and chaparral (Kozlowski & Ahlgren, 1974) but also in temperate and boreal forests (Weber & Stocks, 1998). Fire frequencies, intensities and patterns depend on meteorological conditions, fuel loads and topography (Viegas, 1998). In regions where natural fires are common, e.g. Australia, Africa, the Mediterranean and North America, species have adapted to fire regimes (Gillon, 1983; van Wilgen *et al.*, 2003; Reiner, 2007) and some even rely on fire as agents for proliferation (Weber & Stocks, 1998). However, humans have significantly (directly or indirectly) altered the frequencies, intensities and patterns of fire in the last two centuries by changing fuel loads, active suppression or accidental burns (Pausas & Keeley, 2009).

Fires are beneficial where they promote germination, growth or fruiting in plants which provide food, cover, or optimal habitat for some specialist species. For example, the Florida population of Scrub Jays (*Aphelocoma coerulescens coerulescens*) only inhabit open scrub lands dominated by oak shrubs *Quercus spp.* which are endemic to the peninsula of Florida (Woolfenden & Fitzpatrick, 1990). Around the region, humans have suppressed frequent natural fires which are necessary to maintain the scrub habitat crucial for survival of the Florida Scrub Jays. As a result they are confined to small, isolated populations as scrub habitat is becoming rare. Thus periodic burning is important to maintain a healthy population of Florida Scrub Jays (Woolfenden & Fitzpatrick, 1991; Breininger *et al.*, 2006).

Fires can provide an immediate but temporary direct benefit to some species by increasing the short term abundance of food via dead or injured animals, or seed-fall promoted by burning. Fires can also increase the accessibility to food by flushing out prey such as invertebrates, small birds and mammals, removing understory of tall grass, or removing dense foliage that provides cover for some prey-species (Lawrence, 1966; Gillon, 1983; Woinarski, 1990).

Some resident bird species may be flexible enough to alter their diet, foraging or nesting behaviour following alteration of vegetation and resources after a fire (Brooker & Rowley, 1991) without moving to a new site and setting up new territories. Finding a new suitable habitat and

territory is perhaps costly for breeding pairs, especially if the breeding season has already started, as they would have to familiarise themselves with the new territory and other territory-holders. Furthermore, good quality territories may already be taken, leaving areas that are inferior.

Fire can be detrimental to populations and species if it is unmanaged or unprecedented in the history of the region. Especially so if the species concerned has limited dispersal ability, shows site fidelity, has a narrow range of diet, or is a habitat specialist. The occurrence of fires, depending on severity, extent, frequency and timing, can individually or collectively affect breeding success and hence the population structure and dynamics.

For example, eggs and young can perish if fires occur during the nesting season, although adults are rarely killed in fires because of their advantage in being able to fly (Lawrence, 1966; Murphy *et al.*, 2010). Fires can shorten or disrupt breeding seasons (Murphy *et al.*, 2010) and can be especially detrimental for species living in extreme environments where the breeding season is short, such as in the Taiga or the Arctic.

Fires can affect the territory quality of birds, for example by reducing food and water availability, nesting substrates or sites, shelter from the elements and reducing or destroying hiding places from predators (Bendell, 1974; Brooker & Rowley, 1991; Artman *et al.*, 2001; Humple & Holmes, 2006; Murphy *et al.*, 2010). As a considerable amount of energy and nutrients are put into egg production and laying (Perrins, 1996; Nager, 2006), a reduction in available resources may induce birds to reduce output or not breed at all in the same or following season (Brooker & Rowley, 1991). On the other hand, female birds that reduce their output (clutch size) could be adapting to the limited resources and nutrients they can provide to their young when they hatch (Lack, 1954).

Fires may also induce physiological changes in birds that affect their reproductive output in that season or in subsequent seasons. Fires may lower the immunity ability of individuals thus rendering them more vulnerable to parasites and diseases. A study of the effects of a late dry-season fire on the physiology of Red-backed Fairy-wrens *Malurus melanocephalus* showed that the mass of affected birds decreased after the fire, but haemoglobin level and parasite load did not change. The authors did however note that the fairy-wrens reduced their reproductive output in subsequent breeding seasons (Murphy *et al.*, 2010).

In contrast to the arguments above, fires can increase invasion of non-native plant species, which indirectly alter fire regimes by increasing or altering fuel loads (Davis, 1998); this subsequently affects native species by altering the habitat and resources (Brooks & Pyke, 2000; Humple & Holmes, 2006). Furthermore, high fire frequencies can alter landscapes and reduce species composition, thereby also reducing the native species community (Gill & Williams, 1996).

1.1.1 Effects of Fire on Home Range and Habitat Utilisation

Home range is defined as "the extent of area with a defined probability of occurrence of an animal during a specified time period" (Kernohan *et al.*, 2001). Individuals will however most likely not use all of their home range, so that the area of habitat actually used is smaller than the home range. This is because individuals prefer some habitats in the home range over others. The utilisation of habitat is characterised by how resources are distributed (spatially and temporally), and by competition or interference of individuals within or between species (Partridge, 1978).

The extent to which individuals remain and survive in their habitat post-fire could be influenced by the nature of burns and nature of the species affected. Nature of burns includes the intensity and extent of the burnt area (bare patch with no food resources left compared to a remnant patch suitable enough for recolonisation; amount of shelter from elements and predation) and subsequent burns (the length of time for vegetation, resources or other organisms and the species to recover). The nature of species includes species requirements (diet, nesting substrates, cover from predators), their responses to fire (specialist or generalist/ flexible/ adaptive) and ecology (tenacity to site, longevity, dispersal abilities).

1.1.2 Effect of Fire on Population Dynamics—Short and Long-term effects

Population dynamics, simply termed, is the variation in time and space in the sizes and densities of populations and the factors influencing these changes (Solomon, 1976; Begon *et al.*, 1996, p. 965). This subject deals on the one hand with environmental influences upon populations, e.g. the effects of temperature and climate, resources and competition or predation from other species. On the other hand it deals with the interactions of population members, i.e. internal population regulation (Solomon, 1976). Studies on population dynamics normally include determining immigration and emigration, births and deaths, breeding success, age structure, proportion of breeders, sex ratio and survival rates of a population.

Some effects of fire may be long term and may not be apparent immediately post-fire. Continued presence of a species does not indicate that fire does not have any effect on the breeding success and hence the population dynamics of resident populations. In one study, apart from a delay in the onset of egg-laying 1-2 years post-fire which shortened the breeding season, birds suffered from a high rate of nest failures even though nesting attempts were increased 1.5-2 fold, and reproductive success was less than in pre-fire years (Brooker & Rowley, 1991). Similarly, in a Mediterranean shrubland, population decrease post-fire was suggested to be a result of an increase in non-breeding individuals and a decrease in recruitment of new individuals (Pons *et al.*, 2003). However, most published literature appears focussed on post-fire species composition and density, but neglects the survival, breeding success and demography of species. This is perhaps partly due to constraints that limit study duration to the short-term (less than five years).

Long-term effects of frequent, unmanaged and uncontrolled fire regimes can result in the fragmentation or loss of suitable habitat, thus affecting re-colonisation or recruitment of species and consequently leading towards genetic bottlenecking in the population. An already small population could suffer from demographic or environmental stochasticity, resulting in even smaller populations or meta-populations (extinction vortex), and could ultimately lead to local, then larger scale extinctions (Gilpin & Soulé, 1986). In Australia, inappropriate fire regimes have caused, or contributed to the loss of two species and three subspecies of birds (Woinarski, 1999). On the other hand, the suppression of fire has resulted in the decline of Florida Scrub-jays, as a result of loss of suitable habitat usually maintained by fires (Woolfenden & Fitzpatrick, 1990; Breininger *et al.*, 2006).

1.2 Cooperative breeding

Cooperative breeding is one potential advantage of group living. Cooperative breeding involves breeding and non-breeding individuals (usually offspring from the previous year(s), or relatives of either male or female) assisting the breeding pair, or showing parent-like behaviour towards young that are not their own offspring (Skutch, 1961). Recent reviews report the presence of cooperative breeding in about 3-4% of the extant bird species (Arnold & Owens, 1998; Ligon & Burt, 2004). Cooperative breeding may be either facultative or obligative (Ford, 1989).

Two main theories have been proposed to explain cooperative breeding: one theory proposes that, in stable and predictable environmental conditions, a high population density near the carrying

capacity will result in increased intraspecific competition and decreased chances of new breeders establishing territories (Woolfenden and Fitzpatrick 1984, in Komeda et al. 1987). Therefore, fledglings will stay with parents and help them with nesting activities until opportunities to breed arise, such as when a breeding individual dies and the young takes over its place. A second theory proposes that if environmental conditions are harsh or poor (because of fluctuating food resources, for example), this may inhibit the young from dispersing and breeding (Grimes 1976, Rowley 1976, Orians et al. 1977 in Komeda *et al.*, 1987). Therefore it may be a good strategy to stay and help the parents until the environmental conditions improve.

There are several potential benefits of helping. Helpers may benefit through (i) enhanced production of non-descendant but related kin (indirect fitness); (ii) direct access to parentage (direct fitness); (iii) 'payment of rent', which allows access to other benefits of living on the territory of the group; (iv) enhancement of the territory or group size in a way that improves later opportunity for direct reproduction; (v) enhancement of social circumstances via formation of alliances that improve the prospect of reproduction; or (vi) acquisition of skills and experience or prolonged maturation that facilitates later reproduction (Cockburn, 1998).

Cooperative breeding is relatively common in the Corvids (Corvidae *sensu* Sibley & Monroe, 1990), along with other families such as the Fairy-wrens (Maluridae) and Bee-eaters (Meropidae), suggesting a strongly conserved evolutionary trait in these families (Arnold & Owens, 1998; Ekman & Ericson, 2006). Cooperative breeding has been found to correlate positively with reproductive success in the Iberian population of *C. cyanus* (de la Cruz *et al.*, 2003; Canário *et al.*, 2004), as well as in close relatives the Florida Scrub Jay (*Aphelocoma coerulescens*) (Woolfenden, 1975), Brown Jay (*Cyanocorax morio*) (Williams & Hale, 2006) and Carrion Crow (*Corvus corone corone*) (Canestrari *et al.*, 2008).

There have been reported differences in helper numbers between populations in different regions of Iberia for *Cyanopica cyanus* (Canário *et al.*, 2004). Thus environmental constraints might be a factor that determines if cooperative-breeding is present in *C. cyanus* as suggested by Canário *et al.* (2004) and Valencia *et al.* (2003). Within a single population, cooperative breeding might be present only in adverse environmental conditions, such as in seasons where food is scarce or when the environment is harsh. In this case, helpers may only be present in that specific year because they themselves fail to breed, so they make the best out of a 'bad job' by helping

relatives. It is further supported by observations that some breeders that failed earlier in the season give up breeding and help care for other breeders and the chicks (Valencia *et al.*, 2003).

1.2.1 Population structures/ dynamics of cooperative breeders

Cooperative breeders have a unique population structure —there is a high proportion of non-breeding helpers in the population. Furthermore, there is a certain sex bias in the helpers, because one sex usually disperses. Some cooperative breeding species form basic units, consisting of the true monogamous breeding pair, aided by non-reproductive, usually related helpers (e.g. Florida Scrub-jay, *Aphelocoma coerulescens*). Some other species of cooperative breeders have complex social structures. For example, Splendid Fairy-wrens *Malurus splendens* form family units consisting of breeding pairs where they maintain socially monogamous pair-bonds but seek extra-pair copulations, while Pukeko *Porphyrio porphyrio* has a polygynandrous mating system (Cockburn, 2004).

1.2.2 Cooperative breeding species in fire regimes

Cooperative breeders found in fire regimes (with positive or negative effects) include (limited to the family Corvidae and other closely-related families): Fairy-wrens, *Malurus spp.* (Maluridae; Australia); Apostlebird *Struthidea cinerea*, White-winged Chough *Corcorax melanorhamphos*, Australian Magpie *Gymnorhina tibicen* (Corvidae; Australia); and Florida Scrub-jay *Aphelocoma coerulescens* (Corvidae; USA). Cooperative breeders constitute a larger proportion of the avifauna in Australia than other continent, particularly in the *Eucalyptus* woodlands (Brown, 1987). This is also a region where fire is a regular natural disturbance.

Unfortunately, published long-term studies of both fire and/ or cooperative breeders in fire regimes are scarce and restricted to North America or Australia. In the limited literature that is available, fire is termed beneficial for the Florida Scrub-jay because the current suppression of fire reduces habitat quality for this species (see above). In Australia, most species which have low reproductive output and relatively limited dispersal abilities are affected due to the current managed regime of frequent control burning. It has been suggested that a fire regime of longer intervals between fires, e.g. once in eight to ten years, would be beneficial from a conservation viewpoint, while still considering the protection of human life and properties (Brooker, 1998; Woinarski, 1999).

The subject of this study, *Cyanopica cyanus*, is a cooperatively breeding corvid that has a disjunct distribution across the northern latitudes of the Eurasian continent (Madge & Burn, 1994; Snow *et al.*, 1998). Those living in fire regimes include populations in Spain, Portugal, and to a certain extent, Northern Mongolia. Only a few studies have focussed on *C. cyanus* in their unmodified habitat; all other populations studied have been in modified landscapes such as cities and agricultural land (Komeda *et al.*, 1987; Canário *et al.*, 2004; Valencia, de la Cruz *et al.*, 2006). The Northern Mongolian *C. cyanus* population occupies the least modified habitat of all the putative subspecies, but it is also the least studied. A fire in 2009 provided an opportunity for me to study how fast the population rebounds after a major disturbance, and whether the disturbance affected habitat utilisation. Such a study is of conservation value, particularly because the birds occur in such restricted and localised areas, and also because of their cooperative breeding behaviour.

The aims of this study are two-fold: the first one is to document the post-fire (up to one year and six months) utilisation of habitat mosaic in the home range of the *Cyanopica cyanus* colony inhabiting a valley in West Khentii, Northern Mongolia. The second aim is to investigate the colony structure and population dynamics of this colony of *C. cyanus* over a four-year period, using data from this study and other studies.

1.3 General Aims

To investigate *Cyanopica cyanus*'s utilisation of habitat mosaic at Khonin Nuga, Northern Mongolia after the 2009 fire, and to investigate the population dynamics of the colony using four years' of data, and how these have been affected by the 2009 forest fire.

1.3.1 Objectives

The aim will be achieved by fulfilling the following objectives:

1) **Habitat use**

- Determine *C. cyanus*'s home range and describe the habitat mosaic utilised inside their home range
- Describe the utilisation of habitats, plant species utilised, group composition, activities and food items of *C. cyanus* colony following a major forest fire in 2009 and one year post-fire in 2010

2) **Populations Dynamics**

- Determine frequency of nest predation and the species responsible
- Determine changes in group size from year to year
- Determine changes in group membership
- Determine adult and juvenile survival and re-sighting rates from 2006 to 2010
- Determine proportion of adults remaining in the population from year to year
- Determine proportion of fledglings remaining in the population from year to year
- Determine proportion of adults that breed each year
- Determine proportion of successful and unsuccessful breeders that remain in the colony one year to the next
- Determine pair-bond retention in breeders
- Determine how rapidly colony size recovers following the May 2009 fire

Chapter 2

Methods

2.1 General Information about *Cyanopica cyanus*

2.1.1 Species Description & Classification

The azure-winged magpie (*Cyanopica cyanus*) (after Dickinson, 2003) is the only species in the genus '*Cyanopica*' in the Corvidae family (Madge & Burn, 1994), which includes crows, jays and allies. Genetic, morphological and behavioural studies suggest that *C. cyanus* is more closely related to the Old and New World jays than to the magpies of the genus *Pica* (Madge & Burn, 1994; Fok *et al.*, 2002). It is the only Corvid in which the juvenile replaces its flight feathers at the first moult. It weighs 60-120g (Madge & Burn, 1994; pers. obs.) and is about 34 cm in length (including tail), with a combination of black hood, pale blue wings, and long graduated pale blue tail (Fig. 2.1). The underside is white, pale creamy in colour. This species is sexually monomorphic in plumage (Madge & Burn, 1994; Snow *et al.*, 1998). In the field, the sex of birds can be determined by sex-specific behaviour or presence of a brood patch (only females incubate and brood; Komeda *et al.*, 1987). Males are generally slightly larger than females, with longer tails, wings and head plus bill length (Kryukov *et al.*, 2004; Alarcos *et al.*, 2007).

Juveniles and adults can be differentiated by plumage characteristics—juveniles have whitish tips or strips on all feathers of alulae, greater secondary coverts, greater primary coverts and rectrices, whereas adults have distinctive broad white tips only on their central rectrices[1] (Fig. 2.1). Additionally, the central rectrices are shorter than the second innermost rectrices in juveniles, as opposed to the adults whose central rectrices are the longest (Harada, 1997; Gantulga, 2010). Juveniles can also be distinguished from older birds by white mottling on the former's black caps (Goodwin, 1986 in Harada, 1997).

There are ten proposed subspecies of *Cyanopica cyanus* (Fig. 2.2 a & b), characterised by morphological differences and geographical distribution (Goodwin, 1986 in Fok *et al.*, 2002). In general, the Asiatic races differ from the European birds by having slightly bigger bodies, white tips on the tail, and slightly lighter-blue wings (Madge & Burn, 1994).

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[1] This applies only to Asiatic subspecies as the Iberian subspecies do not have white tips on the tail.

2.1.2 Species Distribution

The species has a disjunct distribution (Fig. 2.2a): they are present on the Iberian Peninsula (central & southern Spain and Portugal) and widely distributed throughout eastern Palearctic Asia (Fig. 2.2b). Their northern range runs from the extreme northwest of Mongolia (Uliasutay) east to the south of Lake Baikal, across northern Mongolia and Transbaikalia to the Khabarovsk region, with a northern boundary following the Amur River Valley. The far-eastern range extends south over Ussuriland, Korea and much of eastern China, then west to extreme east Qinghai and south Sichuan, with a southern boundary following the valley of the Yangtze to Shanghai. In Japan they are only present in Honshu (main island of Japan) although up to the 1950s, the species was common in Kyushu but is now locally extinct, probably as a result of competition with the introduced black-billed magpie, *Pica pica* (Madge & Burn, 1994).
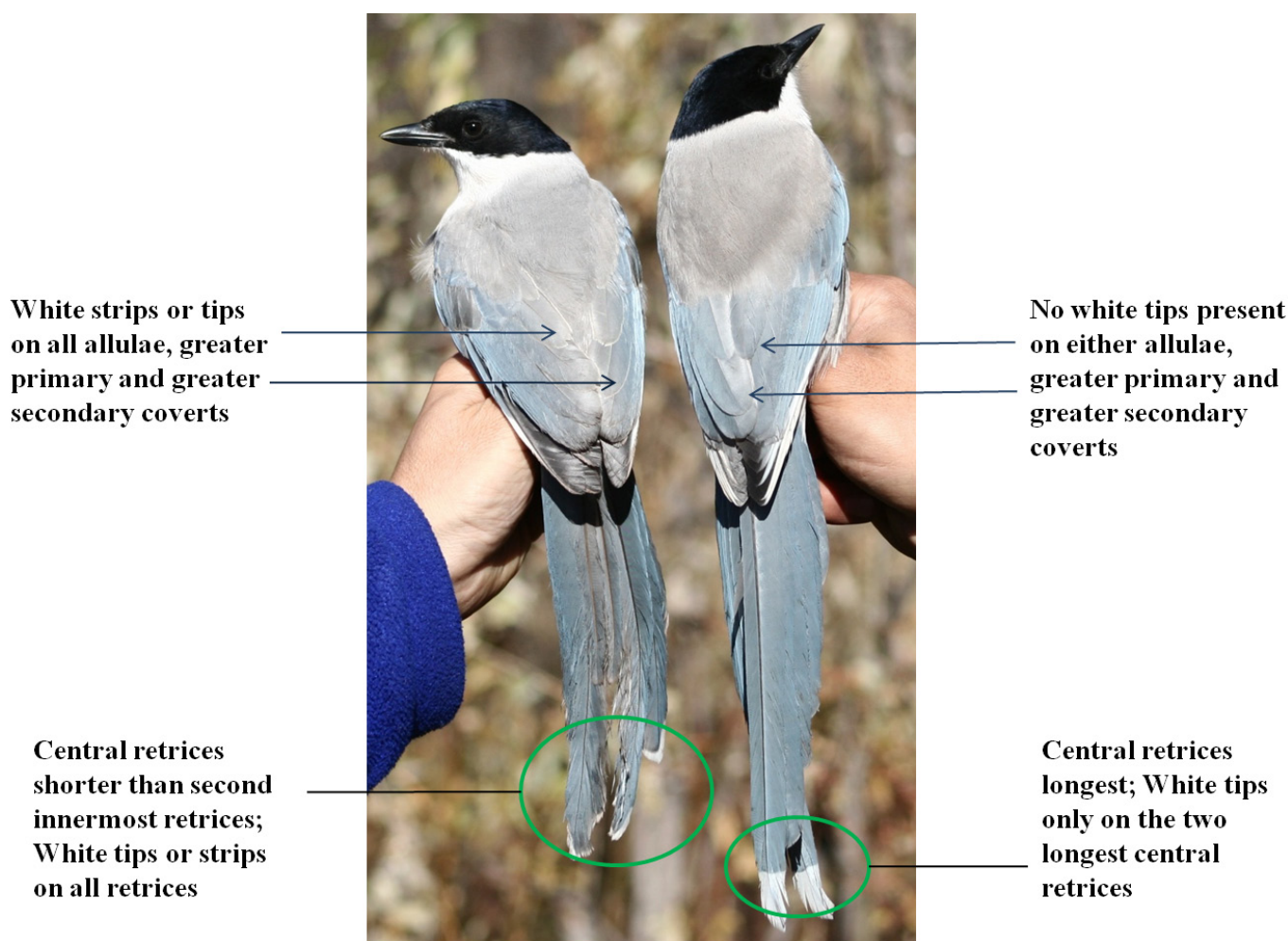
Figure 2.1 Morphological differences between juvenile (left) and adult (right) *Cyanopica cyanus cyanus* in Khonin Nuga, Northern Mongolia. Photo courtesy of Gantulga Bayandonoi.

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The extreme disjunct distribution of *C. cyanus* has attracted interest since the mid-19th century (Wallace, 1881 in Fok *et al.*, 2002) and two alternative theories have been put forward to explain this disjunct distribution. The first, the 'introduction theory' proposes that the Iberian population was established in the 16th century by Portuguese sailors who brought them back from the far east (Dos Santos, 1968, Tyrberg, 1998 in Fok *et al.*, 2002). Alternatively, the 'refugium theory' proposes that the species had a more continuous range prior to the Pleistocene glaciations. The advance of the ice (Goodwin 1986, in Fok et al. 2002) caused isolation and divergence between the birds in these two regions (but see Klicka & Zink, 1997; Avise & Walker, 1998). The fairly marked racial difference of the Iberian race from the Asian races suggests that they have been isolated in Europe for a long time, and not introduced recently (Madge & Burn, 1994). However, there was no conclusive evidence to support either theory, until the discovery of *C. cyanus* bones from late Pleistocene sites in Gibraltar that were at least 44,100 years old, which is not consistent with the 'introduction theory' (Cooper, 2000). Even if there was a chance of mistaken identity of the bones, recent studies show that the European race diverged from the Asian races 1.2 million years ago, which also disproves the 'introduction theory', and this renders them distinct enough to be classified as different species (Fok *et al.*, 2002). However, within the Asian clades, both genetic and morphological differences between putative subspecies were not distinct enough for them to be regarded as such (Fok *et al.*, 2002; Kryukov *et al.*, 2004). As a result of their studies, Fok *et al.* (2002) have suggested that the Iberian subspecies be recognised as a separate species, *Cyanopica cooki* (Bonaparte, 1850) and the Asian birds continue to be named *Cyanopica cyana*[2] (Pallas, 1776). For the sake of simplicity, I will retain the use of *Cyanopica cyanus* as a general name for this species. When needed, I will refer to regions when mentioning different populations.

(a)

417. AZURE-WINGED MAGPIE

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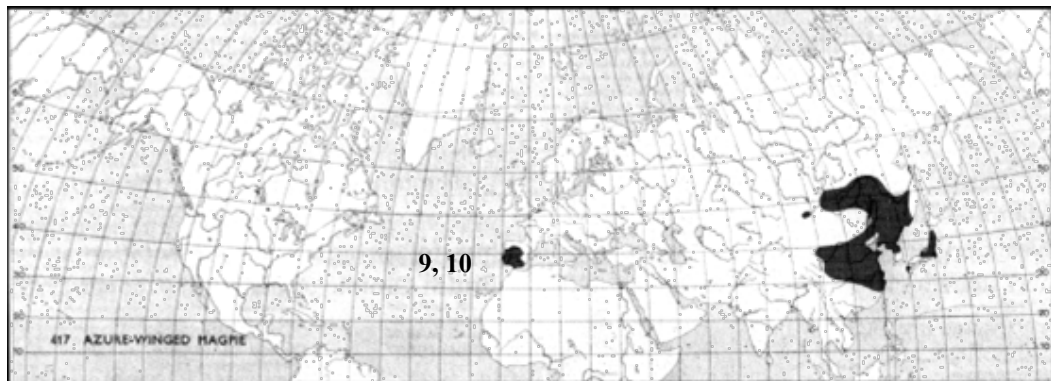
[2] See Dickinson Dickinson, E.C., (Editor) (2003) *The Howard & Moore Complete Checklist of the Birds of the World*, 3rd edn. Christopher Helm, London. for changes to species name.
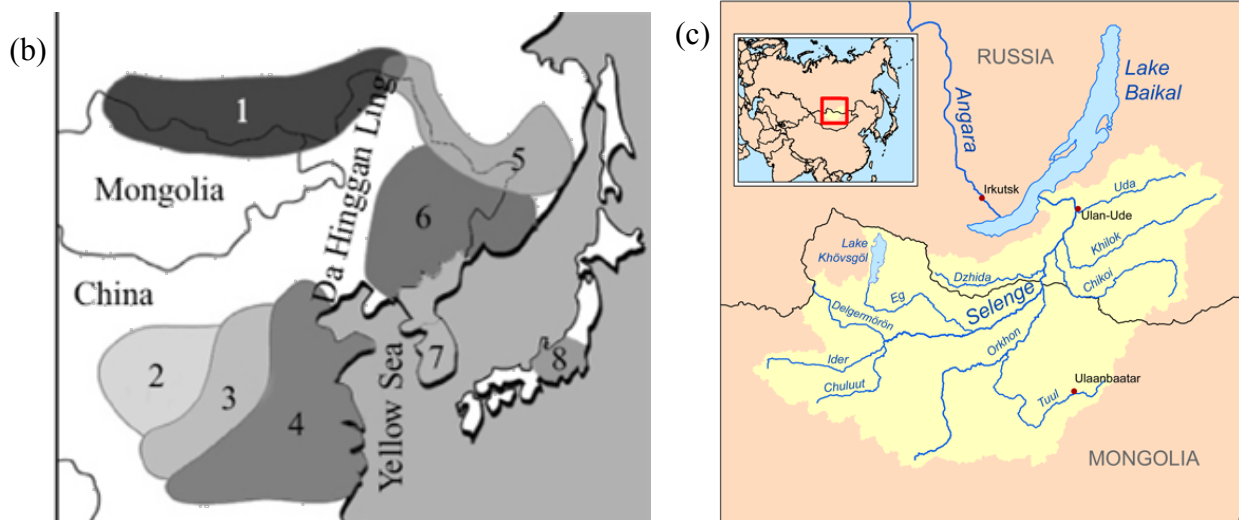
Figure 2.2 **(a) Distribution of _Cyanopica cyanus_ worldwide (b) East Asian region and (c) in Northern Mongolia. Asian subspecies: (1) _C. c. cyanus_, (2) _C. c. kansuensis_, (3) _C. c. interposita_, (4) _C. c. swinhoei_, (5) _C. c. pallescens_, (6) _C. c. stegmanni_, (7) _C. c. koreensis_, (8) _C. c. japonica_; European subspecies: (9) _C. c. cooki and_ (10) _C. c. gili_. Figure 2.2 (a) and (b) from Fok et al. (2002). Figure 2.2 (c) from Wikipedia (2011).**

C. cyanus is locally common and increasing in Spain (240,000-260,000 pairs) and Portugal (10,000-100,000 pairs) although their range is still rather restricted and fragmented (Snow _et al._, 1998). This is perhaps because it was considered an agricultural pest and farmers destroyed their nests (Dos Santos, 1968, in Kryukov _et al._, 2004). Persecutions nowadays are rare in Spain, as the species is protected; the situation in Portugal is unknown (de la Cruz, pers. comm.). However, Fok _et al._ (2002) attributed the fragmented distribution to possible existence of physical barriers because similar patterns of postglacial dispersal have been observed in other species in the Iberian region (Bilton _et al._, 1998; Hewitt, 1999). Numbers are also increasing over the main part of their range in Asia, but populations are still very localised in the Baikal region (Madge & Burn, 1994) although Kryukov _et al._ (2004) noted that between 1974 and 2004 it was observed that their range has expanded towards the west of Lake Baikal. Again, potential barriers exist such as the Da Hinggan Ling (Big Hinggan Mountains), the desert over Southern Mongolia and Western China, and the Yellow Sea (Fig. 2.2b).

In Mongolia, the subspecies _C. c. cyanus_ occurs in the Yuruu (Eroo), Orkhon, Selenge river basins and their branch river basins of Northern Mongolia (Fig. 2.2c; Tugarinov, 1929, Kozlova, 1930, Bold 1973, 1977, Boldbaatar 1999, 2006 in Gantulga, 2010).

C. cyanus has been well-studied on the Iberian Peninsula and in Japan, but there has been little research into the northern and central range of the birds, especially in northern Mongolia.

The IUCN lists *Cyanopica cyanus* as 'least concern' (BirdLife International, 2009). They estimate about 260,000-460,000 breeding pairs present in Europe (Iberian Peninsula) and 3,250,000-27,600,000 individuals globally.

2.1.3 Climate and Habitat

The climate in Iberia is typically Mediterranean, with dry-hot summers and mild-wet winters (Valencia *et al.*, 2003; Canário *et al.*, 2004). Precipitation is extremely variable year to year (Valencia *et al.*, 2002; Canário *et al.*, 2004).

The Japanese population occurs in colder climates, with snow covering the ground from December to early April. Temperatures in winter can reach -8°C (Komeda *et al.*, 1987). In Northern Mongolia, winter conditions can be more severe, with temperatures reaching -30°C in January and snow covering the ground from early October to mid-April (Dulamsuren *et al.*, 2005). However, conditions are relatively stable within seasons compared to climate in the Iberian Peninsula.

This species uses a wide range of habitats—from woodlands and forest edges to open cultivated fields and orchards; they may even be found in city parks and gardens (e.g. Beijing Heavenly Temple, China, pers. obs.). They are mainly found in lowlands and valleys, but can ascend to 1600 m in Japan (Madge & Burn, 1994; Snow *et al.*, 1998). The Iberian population, in contrast to those in Asia, shows no marked preference for broad-leaved trees, or for river banks and islands (Snow *et al.*, 1998).

2.1.4 Diet

C. cyanus feed on invertebrates especially beetles, seeds, fruits, and, more rarely, small vertebrates, carrion, scraps and refuse (Madge & Burn, 1994; Snow *et al.*, 1998). Hosono (1966) reported bird nestlings in the diet (<10%) of *C. cyanus* chicks in Nagano, Japan, while Canário, *et al.* (2002) found bird nestlings were rare (1%) from their diet study of *C. cyanus* in South-eastern Portugal. *C. cyanus* usually forage in flocks, very often on the ground. They have been reported to store food (acorns, olives, pine seeds) in caches on the ground, presumably for later consumption (Snow *et al.*, 1998).

Gantulga *et al.* (in review) reported that azure-winged magpies at Khonin Nuga, Mongolia, feed on *Plecoptera* (stoneflies), moth pupae and their larvae (usually gypsy moths, *Lymantria dispar*)

during the breeding season. After breeding, the adult birds switch to fruit and adult moths. The magpies have also been seen to take food scraps from the field station kitchen (Gantulga B, pers. comm.).

2.1.5 Social behaviour

C. cyanus is a sociable and gregarious bird. The flocks vary in size; they are generally in family groups during breeding season, but will form winter flocks, sometimes exceeding well over 100 birds in China and Japan. The flocks also congregate to form large communal roosts in winter (Hosono, 1968; Madge & Burn, 1994). Territoriality is reported in the European (Snow *et al.*, 1998) and Japanese populations (Komeda *et al.*, 1987), where flocks defend extensive territories against other flocks throughout the year; however, the Spanish colony studied by Valencia *et al.* (2003) was not territorial. Birds are non-migratory but can flock and disperse up to 15kms in winter (Hosono, 1968; Gantulga, 2010).

2.1.6 Breeding biology

Eggs are laid between early April and late July, depending on the altitude (Snow *et al.*, 1998; Valencia *et al.*, 2002). In central Spain, eggs are laid from early April to late May at lower altitudes (300 m) while at higher altitudes (1250 m), eggs are laid early June to late July. In southern Spain and east Portugal, eggs are laid end of April to early or mid-May. In the Far East, egg-laying is usually around late May and June (Madge & Burn, 1994). Pairs typically produce one brood per season, although second broods have been reported occasionally in Spain (Valencia *et al.*, 2000) and Asia (Madge & Burn, 1994). Replacement clutches are laid as a result of earlier brood loss if conditions allow (Valencia *et al.*, 2000; Gantulga *et al.*, in review).

The birds nest socially, with nests in loose colonies, normally not more than one nest per tree (Madge & Burn, 1994; Snow *et al.*, 1998); however, colonies can be quite large, with as many as 70 nests. Nests are usually located at the fork of a branch towards the edge of tree crown, up to 12m above ground (Snow *et al.*, 1998). In Khonin Nuga, Northern Mongolia, nests were always close to tree trunks or at the fork of several criss-crossing branches, and never exceeded 2m in height (pers. obs.). Nests are usually built from a rough, loose foundation of twigs, layered inside with earth, mud or dung, shaped to form a bowl about 2-5cm thick. The nest is then lined with soft material such as moss, lichen, animal hair, feathers etc (Snow *et al.*, 1998).

Clutches range from four to eleven eggs, but usually five to nine eggs are laid. Incubation is 14-17 days, and only females incubate. Males feed females while they are incubating (Komeda *et al.*, 1987), and even after eggs are hatched (Gantulga, 2010). Nestlings are fed equally by both parents. Chicks usually fledge within 14-16 days (about 20 days in Khonin Nuga, Northern Mongolia colony; Gantulga *et al.*, in review), but the parents still continue feeding them for another 30 days (pers. obs.). Chicks stay with their parents and 'extended family' for the rest of the season, moving around in tight groups.

Cyanopica cyanus seems to be socially monogamous (Valencia *et al.*, 2003), but pairs may receive help from other flock members. Co-operative breeding has been reported in the Iberian (Snow *et al.*, 1998; Valencia *et al.*, 2003) and Japanese populations, (Hosono, 1983; Komeda *et al.*, 1987). For the Khonin Nuga population helping has only been observed following a major forest fire (Gantulga, 2010). During the season prior to this major forest fire only the parents attended the nest (K-J Wilson pers. comm.). Valencia *et al.* (2003) described cooperative breeding in the Spanish population as flexible, which means that not only juveniles help the breeding pair, but also adults (whose own nests failed or after they have finished breeding for the season). Furthermore, role reversals were common, i.e. helpers switched to breeders and vice versa within one breeding season or between years. Helping can take the form of nest building, feeding the incubating female, and feeding the nestlings after hatching. Surprisingly, Valencia *et al.* (2003) found that most of the time, helpers and the helped were not closely related (i.e. neither parent-offspring nor siblings).

2.1.7 Predators

Sparrowhawks (*Accipiter nisus*) are potential predators of adult birds on the Iberian Peninsula (Avilés & Parejo, 2006). Eggs and chicks are often predated by the Common Raven, *Corvus corax* (Canário *et al.*, 2004) in Iberia, and Jungle Crow, *C. macrorhyncos* in Japan (Ueta, 1994).

Nest parasitism by the common cuckoo (*Cuculus canorus*) is quite frequent in the eastern Palearctic (Nakamura et al. 1998, in Avilés & Parejo, 2006). The great spotted cuckoo (*Clamator glandarius*) is a potential brood parasite of the Iberian population of *Cyanopica cyanus*, but so far no brood parasitism by the great spotted cuckoos has been observed (Valencia *et al.*, 2005).

No predations on adult birds have been reported at Khonin Nuga, Mongolia. However, chicks and eggs are preyed on by the Carrion Crow (*Corvus corone corone*) (Gantulga, 2010) and possibly

small arboreal mammals (K-J Wilson, pers. comm.). When crows fly close to nests, the magpies respond either by ducking down low in the nest, or mobbing the crow (K-J Wilson, pers. comm.). The Halys Pit Viper (*Gloydius halys*) and Steppe's Rat Snake (*Elaphe dione*) are present, which are potential predators of the birds (Gantulga B, pers. comm.). Goshawk (*Accipiter gentilis*) and the Hobby (*Falco subbuteo*) have been observed attempting to take juveniles or attacking the group in Khonin Nuga (pers. obs.). Nest parasitism has not been recorded at Khonin Nuga, although both the Common (*Cuculus canorus*) and Oriental (*Cuculus saturatus*) cuckoos occur in the region (Gantulga, 2010).

C. cyanus will mob, dive-bomb, and attack (with beaks and claws) to deter their predators. Some individuals of *C. cyanus* in Japan have been reported to nest near Japanese Lesser Sparrowhawk (*Accipiter gularis*) nests and synchronise their breeding to the hawks' to reduce nest predation (Ueta, 1994,2001).

2.2 Study sites and subject

2.2.1 Study site

My research was carried out around the Khonin Nuga Research Station in Northern Mongolia. This research station lies in a valley in the West-Khentii (Khentey) Mountains, 250 km north of the capital, Ulaanbaatar. The rivers Sharlan and Khong join in the valley and become the Eroo (Yuroo) River, which forms the upper drainage of Lake Baikal. The field station is located at 49˚05'17'' N and 107˚17'36'' E, 930 m above sea level. It was founded in 1997 and is run by both the Centre of Nature Conservation of Georg-August University, Germany, and the National University of Mongolia. Khonin Nuga Research Station is also situated in the buffer zone of the Strictly Protected Area of Khan Khentii, where about 15,000 km^2 of primeval forest and grassland are completely protected by law (Mühlenberg, 2006).

This region is relatively untouched by humans as herders traditionally avoided this region because of the high density of wolves and bears (Dulamsuren *et al.*, 2005). However, in recent years (2003-2006), as the availability of transport has increased, there is an observed increase in holidays-makers (M Muehlenberg, pers. comm.), both foreign and local, who utilise the area around the field station for camping and fishing. This region was logged in the 1980s to supply wood for building railways (Oyunsanaa B., pers. comm.). However, the extent of area logged and amount of wood taken is unknown. In 2009 and 2010, loggers who were conducting salvage

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logging set up a makeshift camp ca. 3km upstream (pers. obs.). The resident ranger and family have a herd of horses and cows (about 20 individuals), which roam and graze freely within ca. 10 km radius around the station in the Khonin Nuga valley.

Climate in the West Khentii region is continental, with temperatures between -23°C and -30°C in January, and 12 - 18°C in July (Dulamsuren *et al.*, 2005), although it does exceed 30°C on some days (pers. obs.). Annual precipitation is around 250-260 mm (Dulamsuren *et al.*, 2008), with most falling in summer, during July and August. Frost occurs around 300 days per year and permafrost is a characteristic feature of the soils in the region (Tsedendash 1995, in Dulamsuren *et al.*, 2005).

This region is where the Siberian dark and light taiga borders the Mongolian-Daurian mountain forest steppe. In higher altitudes, the landscape is a mosaic of dark and light taiga species such as *Picea obovata*, *Abies sibirica*, *Pinus sibirica*, *Betula platyphylla*, *Larix siberica*, and montane meadow steppe which consists of *Festuca lenensis*, *Pulsatilla ambigua*, and *Artemisia frigida* species in the water-limited southern slopes. In the river valley and floodplains, common species include shrubs such as *Betula fusca*, *Rosa acicularis*, *Padus asiatica*, *Crataegus sanguine*, *Salix spp.* and floodplain meadow vegetation such as *Carex spp.* (Dulamsuren *et al.*, 2005).

My study sites were in the immediate vicinity of the field station (ca. 2 km radius), covering the river valley, floodplains and only occasionally the southern slopes of the hills northwest of the field station (Fig. 2.3). The sites were not more than 2 km from the Eroo River. The habitats of my study area are mainly open riparian woodland with dense understory shrub layers and grasslands with mixed flowers, herbs and shrub species (classifications according to Dulamsuren *et al.*, 2005). My search area was on both sides of the Eroo River, delineated downriver at Kassel field station[3] and the meadows up to 1km south and southeast of it, and upriver at the delta where the Sharlan and Khong Rivers meet (Fig. 2.4).

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[3] Kassel field station belongs to the Kassel University, Germany. The field station has not been used regularly since 2006 (M Muehlenberg pers. comm., 2011)

Figure 2.3   On top of a hill facing south-east direction, looking down into Khonin Nuga valley, the Eroo River and Khonin Nuga Field Station. The Sharlan and Khong Rivers join at the upper left of the picture to form the Eroo

Figure 2.4   On a hill facing north-west direction, looking down on Sharlan Meadows (before the river, foreground of photo) and Padus patch (after the river, centre of photo) (2009). The Khong and Sharlan Rivers meet on the left side of the photo to become Eroo River.

2.2.2 *Cyanopica cyanus* in Khonin Nuga, Northern Mongolia

This study involved a colony of *C. cyanus* inhabiting the valley around the Khonin Nuga field station. This population appears to have established only recently in 2005 after an outbreak of Gypsy Moths (*Lymantria dispar*). At the Khonin Nuga Research Station and in northern Mongolia generally, the *C. cyanus* population is very localised, living in small colonies isolated from any other colonies. At the research station they appear to inhabit only one single area making only short excursions to forage within 1 km of their breeding range (K-J Wilson, pers. comm.). As with populations of *C. cyanus* from other regions, the Khonin Nuga population does not migrate in winter, but will travel up to 15 km along the river for one to three days (Gantulga, 2010).

Previous work on *C. cyanus* at Khonin Nuga involved: colour banding by Kerry-Jayne Wilson in 2006; banding and breeding dates recorded by Jenny Beyer, Georg-August University, Germany in 2007; breeding biology and banding studies by Gantulga Bayandonoi (National University of Mongolia) and Kerry-Jayne Wilson in 2008 and 2009. In 2007 and 2008, the birds started laying eggs in May and usually finished around June (Gantulga *et al.*, in review). Preliminary data showed that very few of the chicks that were banded in 2007 were subsequently re-sighted in Khonin Nuga in 2008, whereas a large proportion of chicks banded in 2008 were sighted in 2009 (Gantulga *et al*., unpublished data).

In May 2009, a huge anthropogenic fire broke out and devastated 70,000 ha of the area in and around the Khonin Nuga valley (Oyunsanaa B., pers. comm.). In the immediate vicinity of the field station (3km radius), all vegetation was affected save for some small pockets along the river (pers. obs.). The fire reduced the initial breeding population to just one nest, although pairs were observed building nests and breeding within weeks of the fire (Gantulga, 2010).

I will use the term 'colony' when referring to this group of *Cyanopica cyanus* at Khonin Nuga. 'Colony' was preferred over 'group' because the latter implies that there is more than one group breeding or resident in the vicinity. Although 'colony' generally is used for birds that nest closely to each other e.g. gull colonies, I used the term in this context to reflect the social behaviour (e.g. flocking while foraging, roosting together, non-territoriality) of the *C. cyanus* at Khonin Nuga.

Figure 2.5 **On a hill north-west of the Khonin Nuga Research Station, looking down onto the Main Breeding Area. Prior to the 2009 fire, the *Cyanopica cyanus* colony spend most of their time at the Main Breeding Area (large red circle), making occasional foraging forays in groups to three areas across the Eroo River (small red circles). Photo by Nina Tiralla (2008).**

2.3 Methods

2.3.1 Data collection

Habitat utilisation

Activity and plant species utilisation

I conducted behavioural observations from 21 July 2009 to 6 September 2009, and again from 20 July 2010 to 30 August 2010. Observations were made after the chicks had fledged and could move around with their parents. I conducted daily observations in areas where the birds frequently occurred in years prior to 2009 (Fig. 2.5). I searched for birds systematically, beginning at places where they were last observed, unless sighted prior to the search. If the birds were not found at the sites where I had begun, I moved to the next site, either upstream or downstream, depending on where I started first, and if I started my search on the true left bank of the Eroo River (same side as the field station), I would cross the river on horseback and resume my search on the other side of the river, as long as conditions allowed (e.g. level of water was safe enough to allow crossing). I noted the duration and route of the search, regardless of whether birds were seen or not. My observations were done at 0700-0900, 1030-1330 and 1630-1900 daily unless there was adverse weather or unforeseen circumstances.

Whenever birds were encountered, I recorded their location and group size. Location was described using landmarks and later given a short name to facilitate note-taking. Group size was recorded using either: 1) the largest number of birds seen flying over an open area/ across the river, or 2) the maximum number of birds seen at any one time. If both methods were available in an observation event, I used the first method. All observations were conducted at a distance where the birds did not appear to perceive me as a threat (5-10m; initial experience was that if I moved closer than 5m, the birds dispersed).

When the birds settled in an area, I recorded the activity, height above ground, and the species of tree or shrub (or substrate) used for the activity performed by the focal bird (Table 2.1; Appendix 1). The activities performed by each focal bird were recorded instantaneously (instantaneous sampling, i.e. observations not lasting more than three seconds). I then moved on to another bird until I had finished observing all members that I could locate by sight. This method was repeated again every five minutes until the group dispersed to a different habitat within the same area, or a new area. A potential bias with this method is that observations on the same individual could be made more than once. If possible, group composition was determined by recording the colour

band combinations of focal birds if they were banded. This was usually done at the same time as activity observations.

I also recorded food items taken by *C. cyanus*. If a food item could not be identified immediately, I brought a sample back to the field station and sought help from other scientists who were familiar with plants and animal species from this region.

I opportunistically recorded any interactions occurring within the *C. cyanus* group (e.g. aggressive behaviour, allofeeding), including who was the aggressor/ victim, or feeder/ recipient. I also recorded interactions between *C. cyanus* and other bird species with similar ecology, such as the Eurasian Jay, *Garrulus glandarius*, Wagtails *Motacilla spp.* and woodpeckers *Dendrocopus spp.*.

Table 2.1   Definitions of activities performed by focal bird

Activity	Definition of activity
Bathe	Immersing part or whole body inside water-body
Call	Opening beak and vocalising
Drink	Actively swallowing at or close to a water-body
Feed	The act of swallowing, or has food in its beak, regardless of how food was obtained
Probe	Inserting beak into substrate (e.g. tree bark or soil)
Search	Actively looking and moving, apparently searching for food but has no food in mouth nor feeding
Snatch	Obtaining food item without leaving its original position (e.g. taking prey from mid-air while sitting on a branch)
Glean	Using beak and running it along a substrate, e.g. along a tree branch
Hawk	Catching food item in mid-air, either using beak or claws
Perch	Remaining still on a tree-branch
Perch and pounce	Perching/ standing on a substrate, then leaping or jumping onto another substrate on food item
Preen	Using beak like a comb while grooming feathers
Pursue	Actively moving after prey, either in air or ground
Rest	Perching on a tree branch, not moving and eyes shut
Transit	Pauses in a location (e.g. tree or shrub) for less than 30 seconds[4]
Interactions	Performing a behaviour directed toward one or more other birds, or acting in a behaviour that induces a change in the behaviour of other individual(s) (conspecifics or interspecifics) such as attacking, allofeeding, chasing etc

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[4] This behaviour was usually seen when the whole group was transiting in an area before going somewhere, and was not included in my instantaneous sampling.

If the group moved on to another area or habitat, I followed at a safe distance to minimise influencing their behaviour. Observations were recorded again once they paused in a new area. I recorded separately every move into a different habitat (classified visually by estimating what species was dominant i.e. ≥ 50% abundance, see below). Birds were followed until it was impractical to continue, i.e. they had dispersed and could not be found anywhere in the valley where they were known to frequent; or crossed the river and conditions were that they could not be followed (e.g. high water level). The duration of observations were noted.

I noted the daily temperatures and weather conditions at 0800, 1300 and 1900.

Habitat utilisation

Habitat description was done on a later, separate occasion when I located all areas used by *C. cyanus* during behavioural observations. I recorded the locations of each area where I had observed the *C. cyanus* colony using a handheld GPS (Garmin *e*Trex, Kansas, USA). I delineated my study sites into six areas and named them to ease note-taking in the field. I then described the habitat types present in each area.

Radio Tracking

As a huge amount of time was spent searching for the birds in 2009, in 2010 I put transmitters onto some birds to help locate the group if they couldn't be located visually or aurally. If the birds were within 1.5km radius of the camp, I could quickly and easily locate them by radio-tracking. Only one transmitter was deployed at any one time because the birds flocked together and moved as a single group in 2009.

The transmitter used was a VHF Single Stage glue-on transmitter with a whip-antenna (Sirtrack Ltd, Havelock North, New Zealand). It was about 2.4g (*C. cyanus* adults in this study colony weighs about 80g during breeding season), and 19.5cm (including antenna) in length (Fig. 2.6). The battery life was about 54 days. I deployed four transmitters (numbered 1, 3, 5, and 7, according to the channel set on the radio receiver) over the 2010 summer field season.

A handheld Yagi antenna (Titley Electronics, Australia) and a radio receiver (TR-4; Telonics, Arizona, USA) were used to detect the transmitted signals. I tracked the birds by homing (Mech & Barber, 2002). After I was able to determine the general location of the birds using the radio and antennae, and therefore move closer, I then located the exact group position by sight and sound.

After the transmitters had been deployed, I opportunistically observed the birds fitted with transmitters for the rest of the season. All were present throughout the season and didn't show any signs of stress or difficulty in flying. One individual that was fitted with a transmitter was a breeding male, and he continued to forage and feed his chicks frequently (pers. obs.). I did not attempt to re-capture the birds to retrieve the transmitters because the birds moult at least once before winter sets in, and the transmitters will fall off with the tail feathers. However, I was careful to put transmitters on only the birds that had undergone their first moult in the season, or didn't seem likely to moult for the next few weeks. This was done by looking for any feathers that looked dull and tattered.
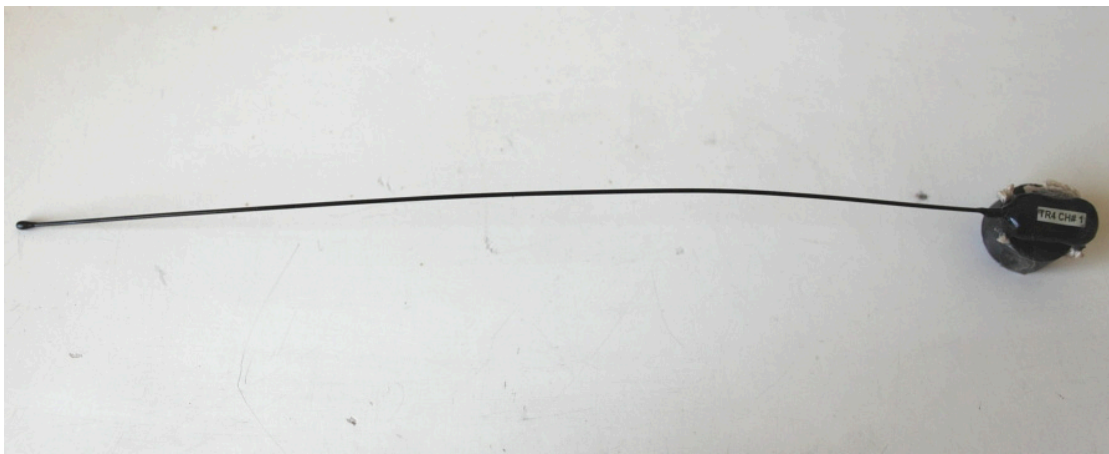
Figure 2.6   A VHF Single Stage glue-on transmitter with a whip-antenna

Population Dynamics

Nest predation

I tried to determine the frequency of nest predation and the species responsible. Tracking pads were tied to tree trunks or branches leading up to nests. This was done only in June 2010 when the chicks or eggs were still in the nests as I arrived too late in 2009 for the breeding season. Two tracking pads were placed in four *Padus asiatica* bushes with active nests, two at the main breeding area, and two at the '*Padus* Patch' area (see Results for nest locations). Tracking pads consisted of a piece of rectangular cardboard (with one smooth side and a rough side) about 25 x 10cm, spread with tracking ink (Black Track, Pest Control Research Ltd) in the middle. My use of tracking pads was to mimic the function of tracking tunnels used regularly by the Department of Conservation and pest control operators in New Zealand. Potential predators approaching *Cyanopica cyanus* nests have to walk over the ink, thus leaving footprints, and I could then determine which species were possible predators of *Cyanopica* chicks and eggs. Tracking pads are, however, vulnerable to extreme weather conditions—when it is hot the ink will dry quickly and during wet weather, the ink washes off with rain. Tracking pads were checked once every 2-3 days and the ink reapplied at the same frequency or when deemed necessary due to weather conditions.

Population dynamics

Data was obtained from Gantulga Bayandonoi, a Masters student from National University of Mongolia who worked on the breeding biology of *Cyanopica cyanus* over the breeding seasons (May-July) of 2007-2009. In 2006, Jenny Beyer from Georg-August University, Germany, banded birds as work for her diploma thesis. A total of 126 individuals were banded in the period of 2006-2010. All field work for these projects was done between May and September. Each bird was banded with a metal band with a numbering system determined by Institute for Bird Research (Vogelwarte), Wilhemshaven, Germany, and a unique colour band combination. The colours used were Red, Yellow, Green, Blue and White. The colour bands were always read from the left leg to the right leg of the bird, and always from top to bottom.

Gantulga Bayandonoi obtained nesting and population data while doing nest monitoring between 2007 and 2009 (Gantulga, 2010). Nests were located in the beginning of the breeding season and monitored subsequently until all chicks had fledged. Adult birds and fledglings were captured using mist nets of either 6 or 12m length with 4-6 pockets. Nestlings were banded when they were 13-15 days old. The sex of banded adult birds that were caught near the nest was

determined based on sex-specific behaviour such as the presence of a brood patch on females. Information recorded included sex, age (juvenile, yearling or adult), if the bird was a breeder, non-breeder or helper, number of eggs laid and the number of chicks that fledged.

2.3.2 Data analysis

Habitat Use

The vegetation and the area used by this colony of *C. cyanus* was mapped using ARCMap v. 9.3 (ESRI, 2011). In ARCMap, I first georeferenced the topographic map M48-107 (West Khentii region, Northern Mongolia) by visually matching landscape features, such as river bends, to their correct coordinates using Google Earth. I then imported the GPS points I obtained from my field sites onto the topographic map. Vegetation types of all areas used by *C. cyanus* within their home range were then sketched on top of the georeferenced map. Unfortunately I could only use a 1: 100,000 scaled map as maps of the smaller scale could not be obtained. Habitats were sketched and described to an accuracy of ± 50m. Home range (defined roughly as "an area repeatedly traversed by an animal"; Kenward, 2001) of the *C. cyanus* colony was estimated using 95% Minimum Convex Polygon method (Mohr, 1947) in ARCMap.

I investigated the association between the number of successful and unsuccessful search attempts I made and the years 2009 and 2010 by using Chi-Square Test for Association. Search attempts were defined as times when a search for the colony was made, regardless of whether or not the birds were located. The amount of time for each search attempt varied, and was classified as successful if I found the colony, or unsuccessful if otherwise. Each successful attempt was further divided into one or a few "observation events", depending on whether the colony stayed in one habitat in one area, moved into a different habitat in that same area, or moved between habitats in different areas. Durations of "observation events" were calculated in minutes.

A two sample *t*-test (Microsoft Excel 2007) was conducted to investigate the difference between average duration per observation in 2009 and 2010. A mean duration per observation was obtained for 2009 and 2010 separately before I compared the means between the two years. Using Genstat (VSN International Ltd), I also investigated the difference in the proportion of time (duration) spent by the *C. cyanus* colony at all areas between the years 2009 and 2010 with a two sample binomial test.

I investigated the similarities of areas used by the *Cyanopica cyanus* colony according to the plant species utilised by *C. cyanus* (Table 2.2). Due to time constraints, I only measured the presence or absence of the listed plant species in each area.

Table 2.2   List of plant species which were observed being utilised by *C. cyanus* in Khonin Nuga, Northern Mongolia.

Betula fusca
Betula platyphulla
Carex spp.
Crataegus sanguinea
Larix sibirica
Malus spp.
Padus asiatica
Pinus sibirica
Poa spp.
Populus laurifolia
Rosa acicularis
Ribes rubrus
Salix spp.
Ulmus pumila

Population Dynamics

I estimated the survival and re-sighting rates of juvenile and adult *Cyanopica cyanus* by analysing the available population data using MARK software (White & Burnham, 1999). I carefully arranged and analysed the data to meet all assumptions of the mark-recapture analysis.

I used the case studies of Lettink & Armstrong (2003) and Pryde (2003) as guidelines for my data analysis using MARK as I wanted to find out the survival rates (φ) of banded individuals between 2006 and 2010. As this was most likely an open population, I used the Cormack-Jolly-Seber (CJS) model (Cormack, 1964; Jolly, 1965; Seber, 1965). I also tested to determine if adults and juveniles had different survival (φ)and recapture rates (p; hereafter referred to re-sightings because most birds were re-sighted, instead of recaptured), so I further divided the data into two groups- 'banded as adults' (i.e. birds one year and above) and 'banded as juveniles' (i.e. birds that have fledged and up to one year of age).

I first ran the most complicated (global/ saturated) model that calculated both survival (φ) and re-sighting (p) probability by taking into account group (g) and time (t) interactions (Cooch &

White, 2011). I also added age as factor to the 'banded as juveniles' group, taking into account that the banded juveniles grow up into adults, ran the saturated model, then did a Bootstrap Goodness-of-Fit Test (built-in function in MARK) to test if the model fitted the data well. In addition to this, I adjusted for overdispersion ($\hat{c}$) and continued fitting all other possible models, with different combinations of group and time parameters over the survival and recapture rates.

The programme output showed that survival of *adults* from the two groups 'banded as adults' and 'banded as juveniles' were similar. Therefore I combined all *adults* from the two groups and analysed them as a single group. I retained juveniles as a separate group.

I also did model averaging between the two best models as they were of similar weightings (ΔQAICc < 2; see Results). The estimated weighted average and standard error were then used to graph survival and re-sighting probability of adult and juvenile *Cyanopica cyanus*.

For estimates of colony size for each year, I used the following formula by Davidson & Armstrong (2002) to calculate colony size for each of the years 2007-2010:

$$\widehat{N}_i = n_i / p_i$$
where n_i = number of banded individuals re-sighted in year i
and p_i = estimated recapture (re-sighting) probability for year i (obtained from MARK analysis)
with the approximate 95% confidence interval for each population estimate given by:

$$\widehat{N} \pm 2\ se$$
where $se(\widehat{N}) = n_i(se[p_i])/p_i^2$

I found that population estimates using the above formula gave a high value and wide confidence intervals in certain years compared to visual estimation (see Table 3.7; Results), therefore I used the more conservative visual estimation for my analysis. This was justified by consistency of search attempts in the field (more than one search event every day) between 2007 and 2010, plus the high-resighting rates of birds (see Results).

Once I had determined survival and re-sighting rates using MARK, I then used the regression analysis (Microsoft Excel 2007) to find out if there was any significant trend over the years for number of chicks hatched and fledged, survival rates of adult and juveniles, number of attempting breeders, successful breeders and unsuccessful breeders over the years.

I performed a Chi-Square Test of Association to determine if there was any relationship between individual's (female and male) breeding success and being present the subsequent year.

All statistical tests were considered significant if the P value was < 0.05.

Table 2.3   Summary of models used for analysis. For full details see text above.

Analysis	Model/ Statistical formulas used
Adult and juvenile survival rate and re-sighting rate	Cormack- Jolly- Seber (CJS)
Estimation of population size	Formula $\widehat{N}_i = n_i/p_i$
Association between years and search effort	Chi-Square Test
Difference between average duration per observation in 2009 and 2010	Two-sample t-test
Difference in the proportion of time spent by *C. cyanus* at *Padus* Patch areas between the years 2009 and 2010	Two-sample Binomial Test
Trend over four years in number of chicks hatched and fledged, survival rate of adults and juveniles, and number of attempting, successful and unsuccessful breeders	Regression analysis
Association between breeding success and present the subsequent year	Chi-Square Test

Chapter 3

Results

3.1 Habitat utilisation

3.1.1 Habitat description

The home range of this colony of *Cyanopica cyanus* is 1.862 km^2 (Fig. 3.1). However, the colony only utilises ca. 0.532 km^2 (28.6%) of their total home range area. Out of my 151 observation events (hereafter termed observations), this colony of *C. cyanus* was observed utilising six main areas in their home range. Only vegetation in these six areas was described and sketched. The following names were given to identify the areas easily.
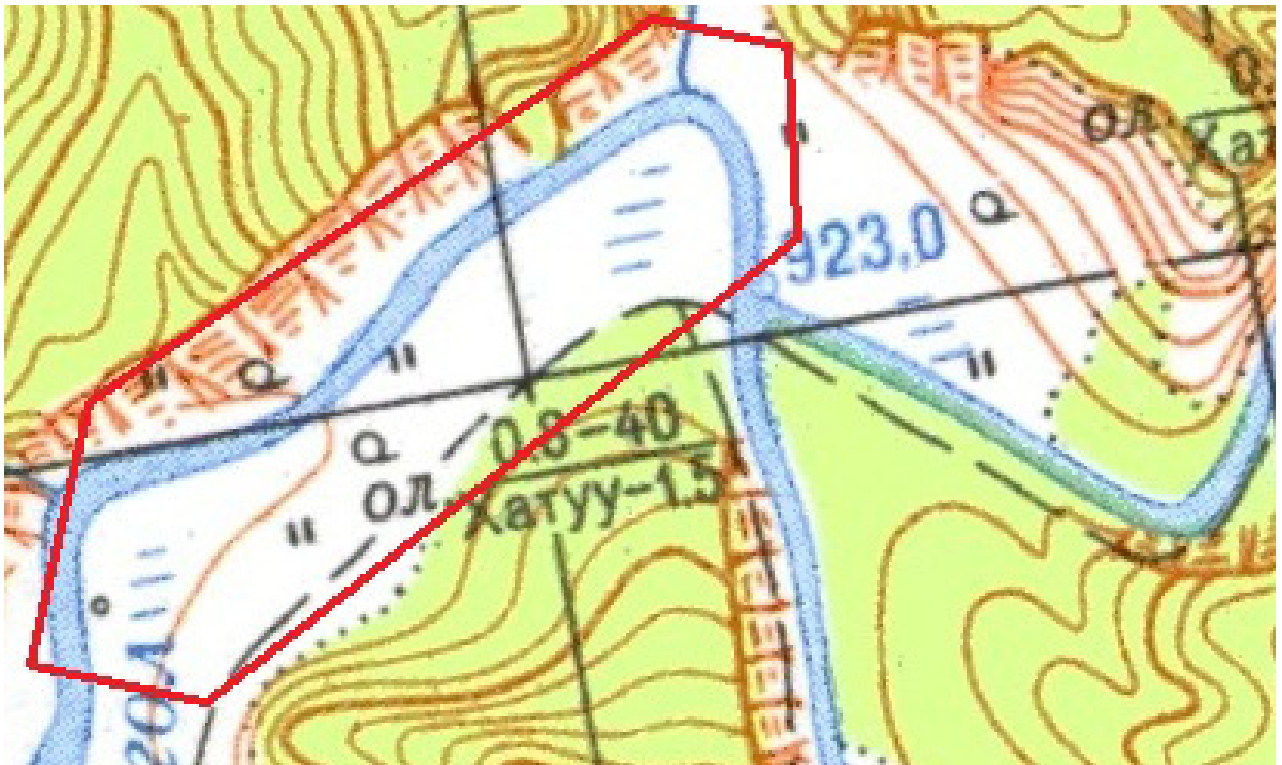
Figure 3.1   Home range of *Cyanopica cyanus* colony outlined in red polygon.
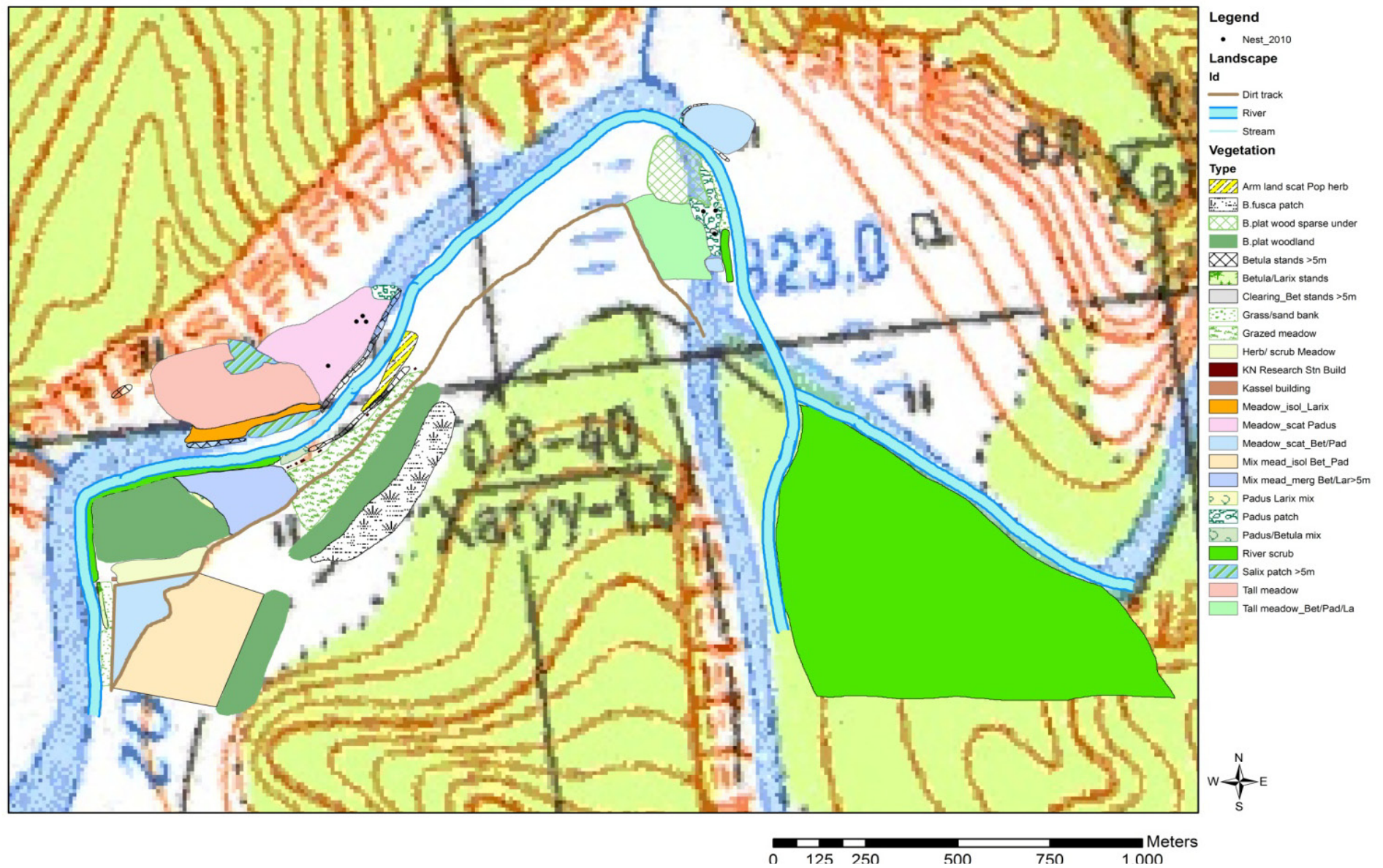
Figure 3.2   Home range of *Cyanopica cyanus* **in Khonin Nuga, West Khentii, Northern Mongolia. The two rivers Sharlan and Khong join to form Eroo River.**

Legend

- Nest_2010

Landscape
Id

- Dirt track
- River
- Stream

Vegetation
Type

- Arm land scat Pop herb
- B.fusca patch
- B.plat wood sparse under
- B.plat woodland
- Betula stands >5m
- Betula/Larix stands
- Clearing_Bet stands >5m
- Grass/sand bank
- Grazed meadow
- Herb/ scrub Meadow
- KN Research Stn Build
- Kassel building
- Meadow_isol_Larix
- Meadow_scat Padus
- Meadow_scat_Bet/Pad
- Mix mead_isol Bet_Pad
- Mix mead_merg Bet/Lar>5m
- Padus Larix mix
- Padus patch
- Padus/Betula mix
- River scrub
- Salix patch >5m
- Tall meadow
- Tall meadow_Bet/Pad/La

Meters
0   125   250   500   750   1,000

Figure 3.3   Home range of *Cyanopica cyanus* without the topographic map. Dotted lines encompass the six main areas that this colony utilised.

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<u>Kassel</u>

The area used by the birds is delineated by the Eroo river and riverine scrub to the west, a herb/scrub meadow with *Rosa spp.* bordering the *Betula platypylla* woodland to the north, junction of two dirt tracks to the south, and mixed meadows in the east (Fig. 3.4a). The area is further divided into two smaller areas by a dirt track that runs in between the two meadows. To the east of the road is a herb meadow consisting of grass (*Poa spp.*), herbs (*Lilium dauricum* and *Iris sanguinea*) and *Rosa spp*, with isolated clumps of *Padus asiatica* shrubs, and *Betula platyphylla* trees above 5m in height. Continuing further towards the east of the meadows is a *B. platyphylla* woodland. I limited my vegetation description to the area right of the junction of two dirt tracks because the birds were never observed to utilise the area beyond this. This area is ca. 0.082 km^2.

There is a small, wooden hut here that is used by Kassel University, Germany as a field station, but it has not been regularly used since 2006 (M Mühlenberg, pers. comm.). However, local and foreign holiday makers utilise the area next to the building and in front of the *B. platyphylla* stands as camp ground. When there is human presence the birds will avoid the immediate area of the Kassel building. When there are no people around, birds have been observed to forage in the ashes of the campfire.

Birds were located in the Kassel area for 11.2% (17 out of 152 observations) of my observations. When the birds were in this area, they spent a lot of time in the *P. asiatica* shrubs (14 out of the 17 observations), or moving in between them, while venturing out to the grass to forage. The birds will forage on the dirt track for insects, but use *P. asiatica* shrubs by the side of the dirt track for cover. Vehicles such as four-wheel drives and motorcycles make them flee, but they settle down very soon after the vehicles have left.

Betula Woodland (between Kassel and Khonin Nuga research station)

This area is a continuation of the Kassel area, and is delineated to the north and west by the Eroo river, and to the north-east by a dirt track running north-east to south-west (Fig. 3.4b). This area is ca. 0.128 km^2. The colony was located in this area for 14.5% (22 out of 152) of my observations.

A strip of riverine scrub, dominated by *Padus asiatica* and *Salix spp.*, grows densely along the river edge (Fig. 3.4b). The *Cyanopica cyanus* colony utilised this scrub area in seven out of the 22 observations made in this area, sometimes transiting here to move up or downriver.
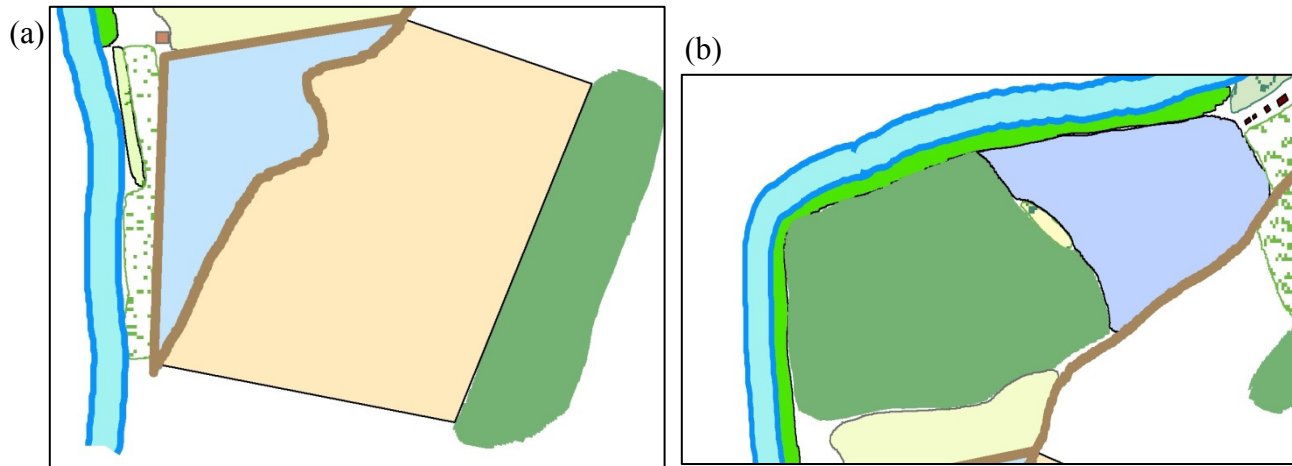
Figure 3.4 Detailed map of (a) Kassel and (b) *Betula* Woodland areas. For description of coloured areas see Fig. 3.2 & 3.3 Legend.

Cyanopica cyanus utilised the *B.platyphylla* woodland in 18.2% of my observations in this area. The trees grow sparsely (~4-5m apart), and the crowns covers about 60-70%. The ground is sparsely covered with herbs *Rosa acicularis* and grass *Poa spp.*. The birds foraged amongst the *B. platyphylla* and *Larix sibirica* trees and rarely came to the ground.

In both years, the colony was observed in the mixed meadow just south-west of the Khonin Nuga Field Station, for 50% of the observations conducted in this area. A few shrubs of *Malus spp.*, which the birds foraged and rested in, grow at the edge of the *B. platyphylla* woodland and mixed meadow. There is a *Padus asiatica* shrub (about 2 x 2 m), which *C. cyanus* liked to utilise that grows about 50m away from the first Khonin Nuga Research Station buildings. The colony often moved in between the riverine scrub and the meadow, perching on branches of tall trees (*Larix sibirica* or *Betula platyphylla*) or the *Padus* shrubs and pouncing on prey on the meadow.

Main breeding area

I delineated this area by using the foothills that run from the north to west and the Eroo River that runs from the north-east to south-west. This area is ca. 0.190 km^2 and includes a steep slope that comes very close to the river at the area's north-western end. The birds sometimes used the slopes, foraging amongst the *Padus* and the stunted *Ulmus* bushes that grow at the bottom of the slope. They occasionally foraged on the ground of the slope. This area is considered to be the main breeding area for the colony because pairs have been recorded nesting in the area since

2007. It is also the primary night roosting area for the colony. The colony was observed here 21.1% (32 out of 152) of observations.

This whole area was ravaged by fire in the spring of 2009 (May). However, about two months after the fire (July), herbs and grasses were regenerating fast and some even reached 1m in height (see Appendix 2). The *Padus asiatica* shrubs in this area were burnt and dead (no leaves left), except for a clump to the northern end of the breeding area (Fig. 3.5), which had the biggest and most clumps of live *Padus asiatica* shrubs left untouched by the fire in the whole Main Breeding Area in 2009.

Most *Padus asiatica* shrubs grow on the meadow (light pink area, right half of Fig. 3.5). Using visual estimation, I estimated that about 95% of the dead *Padus* bushes in 2009 were regenerating in 2010, with young shoots growing from the base of the dead bush.
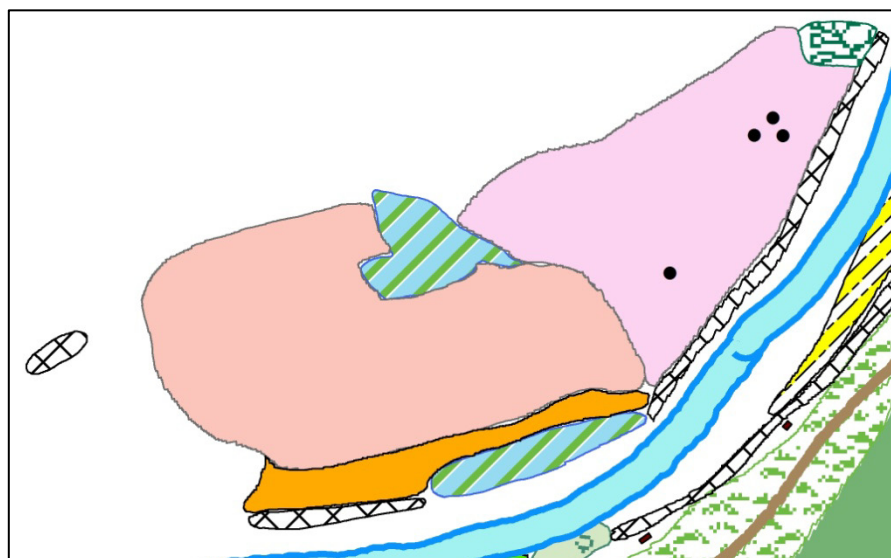
Figure 3.5   Detailed map of the Main Breeding Area habitat. Nests 1-3 were clustered together near the far right end of the Main Breeding Area, whereas Nest 4 stood alone. For description of coloured areas see Fig. 3.2 & 3.3 Legend.

Khonin Nuga (Research station)

Khonin Nuga Research Station consists of seven buildings—three living quarters, three labs/ living quarters and a kitchen (Fig. 3.6a). When observed in this area (7.2% of total observations), *C. cyanus* spent their time mainly along the riverine *Salix* and *Padus* scrub and the grassy bank next to the river. This area is ca. 0.018 km². I have never observed them utilising the habitats south-east of the dirt track, except for once when they were transiting through the *Betula platyphylla* woodland south-east of the research station.

Padus Patch

I delineated this area by using the Eroo River which runs from north-east to south-east, a dirt track to the south-west, a path leading down to the Eroo River to the north to north-west, and a dirt track leading to Eroo River to the south. This area is ca. 0.091 km^2. The birds were located here 33.6 % (51 out of 152) of my observations. In 2010, two breeding pairs established their nests here, in the dense *Padus asiatica* patch (Fig. 3.6b). They built their nests a month later than the birds that bred in the Main Breeding Area the same year.

Padus asiatica shrubs cover about 30% of this area. In certain parts of the area, the *P. asiatica* shrubs form very dense cover by growing close to each other, with low branches interlinking, forming a 'canopy' (see Appendix 2). Under the *Padus* 'canopy' there is sparse ground cover, as canopy cover is mostly 80-90% and blocks out most of the sunlight. Out of the 51 observations made in the *Padus* Patch Area, the colony spent 64.7% of observations in this dense shrub area.

Out of the 51 observations made in the *Padus* Patch Area, *C. cyanus* was observed in six observation events in the *B. platyphylla* woodland with sparse undergrowth. This is where *P. asiatica* bushes are not able to form dense covers, but herbs, grass and *Rosa spp.* is abundant and covers the ground (ca. 50cm in height), with the occasional *Betula*, *Larix* or *Pinus* trees (> 5m) (Fig. 3.6b).

Sharlan meadows

This area is delineated by the Eroo River to the south-west, and a little stream that flows into the Eroo River, north of this area. Further north-east are tall meadows, and towards the foothills running north to south-east are grassland/ meadows. However, *C. cyanus* was never observed to utilise habitats outside of the coloured area on the map (Fig. 3.6b), and therefore the vegetation outside this area was not described and sketched. This area is ca. 0.024 km^2.

Out of the 10 observations in this area, the birds always utilised the area with bush cover, alternating between foraging in the *Padus asiatica* bushes and the ground or grass/herb layer consisting of *Poa spp.*.

The Sharlan Meadows habitat area is separated from the Main Breeding Area by hills (Fig. 3.2). The *C. cyanus* colony quite often moved in between both the Main Breeding Area and Sharlan Meadows by moving up the cliffs/ slope of the hill. They would forage on the ground on the way, but the whole colony would tend to move very fast, stopping at any spot for less than 5 minutes.
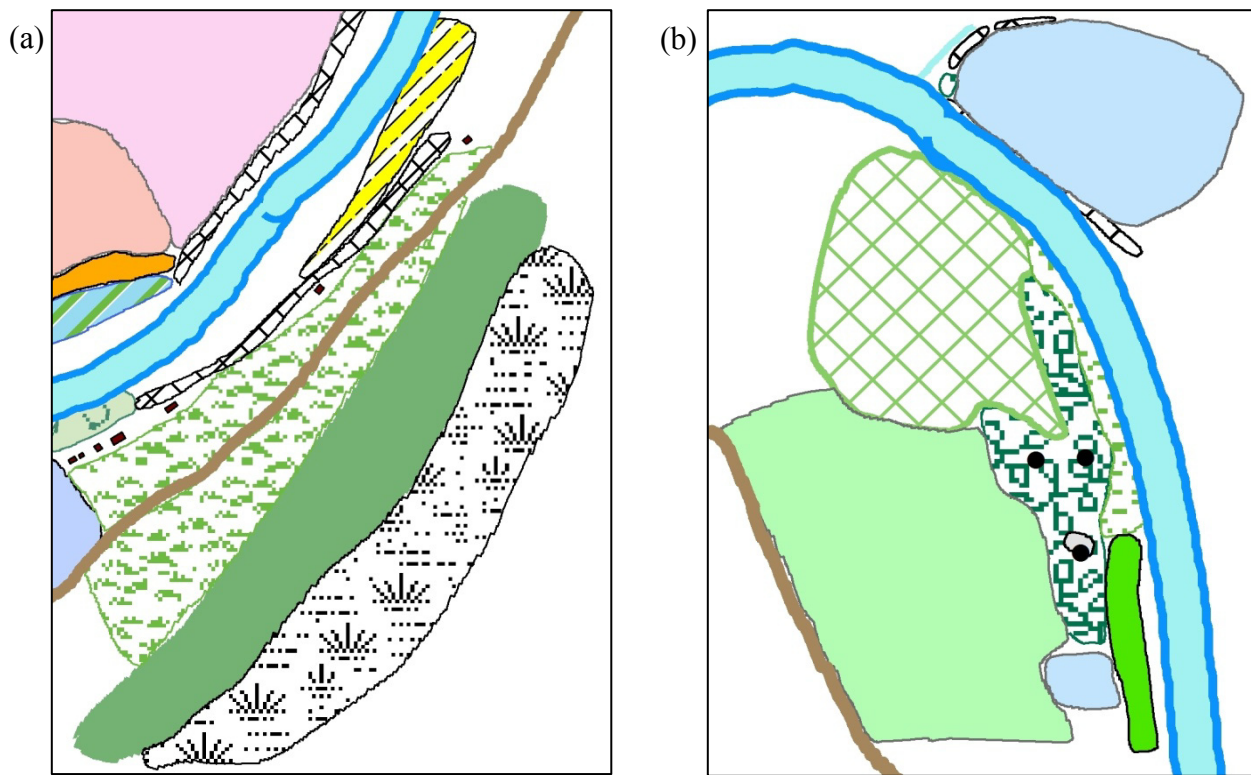
Figure 3.6   Detailed map of (a) Khonin Nuga (Research Station) and (b) *Padus* Patch and Sharlan Meadows areas. Three nests were located in the dense *Padus asiatica* bushes. Nests P1 & P2 were close together. Nest P3 was further south. For description of coloured areas see Fig. 3.2 & 3.3 Legend.

Other areas

Occasionally, this colony of *C. cyanus* utilised some habitats outside of the six described areas. On one occasion I observed the birds in the piece of land in between where the two rivers Khong and Sharlan meet (Fig. 3.2), consisting of riverine scrub with *Padus asiatica* and *Salix spp.*, and mature *Betula platyphylla* stands. However they were seen only for 10 minutes and then could not be located after that. I once followed them to the top of a hill, across the river and north of the Khonin Nuga field station. The colony did not appear to be feeding, but was actively mobbing two raptors (species undetermined).

Only on one occasion in 2009 did I observe the birds utilising areas outside their home range. This area, Sharlan Valley, is 2 km east of the Khonin Nuga valley. The birds were observed moving along both sides of a logging road and feeding in *P. asiatica* shrubs, young *B. platyphylla* trees (<5m in height) with scattered *Larix sibirica* growing on both sides of the road.

They were never seen much more than 2km from the river.

Table 3.1 **List of the six main areas utilised by *C. cyanus* and the description of main vegetation features. Utilised plant species richness here denotes the number of species utilised by *C. cyanus* that are present in each area.**

Area	Utilised Plant Species Richness	Main habitat features
Kassel	11	Meadow with scattered *Padus asiatica* shrubs; meadow consists of herbs such as *Lilium dauricum, Iris sanguinea* and *Rosa acicularis*
Betula woodland	12	*B. platyphylla* woodland with *Rosa acicularis* shrubs and grass; Riverine scrub, dominated by *Salix spp.* and *P. asiatica* with *R. acicularis* and *Ribes rubrus* growing in understorey; Mixed meadows, dominated by *Poa spp.* and *R. acicularis*
Khonin Nuga	12	Field station, surrounded mainly by grazed meadow; *B. platyphylla* trees > 5m in height lining the riverbank
Main Breeding Area	10	Tall grass meadows, with herbs and shrubs e.g. *R. acicularis;* meadow with *P. asiatica; B. platyphylla* > 5m in height lining riverbank; large patch of *Salix spp.* > 5m in height next to riverbank and near foothills
Padus Patch	12	Dense *P. asiatica* shrubs; *B. platyphylla* woodland with sparse underground cover, mostly herbs e.g. *R. acicularis*
Sharlan Meadows	5	Meadows with *Poa spp.*, other herbs and scattered *P. asiatica* shrubs near the stream; *B. platyphylla* ≤ 5m lining riverbank

3.1.2 Time spent in each area

I made 68 search attempts over 29 days in 2009 and 80 search attempts over 38 days in 2010. In 2009, 57.4% (39 out of 68) of my search attempts were futile, whereas only 11.25% (9 out of 80) attempts were futile in 2010. There was a strong association between years (2009 and 2010) and the search success (χ^2 = 35.651, df =1, P < 0.001). However, there was no difference between the average amount of time spent observing the colony in 2009 and 2010 (t = 0.034, P = 0.973, n = 47; Fig. 3.7). For both years, I spent an average of 41 minutes for each observation event. I made 152 observations in 2009 and 2010, a total duration of 102 hours and 55 minutes (Table 3.3).

This colony of *Cyanopica cyanus* spent the greatest amount of time in the *Padus* Patch area in both 2009 and 2010 (24% and 38% respectively; Fig. 3.8 & 3.9). There was a significant difference between the proportions of time spent in *Padus* Patch between the two years (two sample binomial test = 14.2%, P < 0.001). Amount of time spent in the Sharlan Meadows was 17% in 2009 but decreased significantly to 6% in 2010 (two sample binomial test = 14.3%, P < 0.001). A similar trend was found with the use of the Kassel area—the proportion of time spent was 19% in 2009 but decreased significantly to 9% in 2010 (two sample binomial test = 11.42%, P < 0.001). However, the proportion of time spent in the *Betula* Woodlands increased

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significantly from 9% in 2009 to 15% in 2010 (two sample binomial test = 6.02%, $P < 0.001$). The use of the Main Breeding Area also increased significantly, from 15% in 2009 to 22% in 2010 (two sample binomial test = 6.87%, $P < 0.001$). The use of 'other areas' in both years, such as cliffs, hill slopes, forested land between the two rivers Sharlan and Khong, and an area outside of the *C. cyanus* home range were all under 10% of total observations, so they were all combined into one category. The use of 'other areas' in both years were not significant (two sample binomial test = 0.31%, $P = 0.76$).
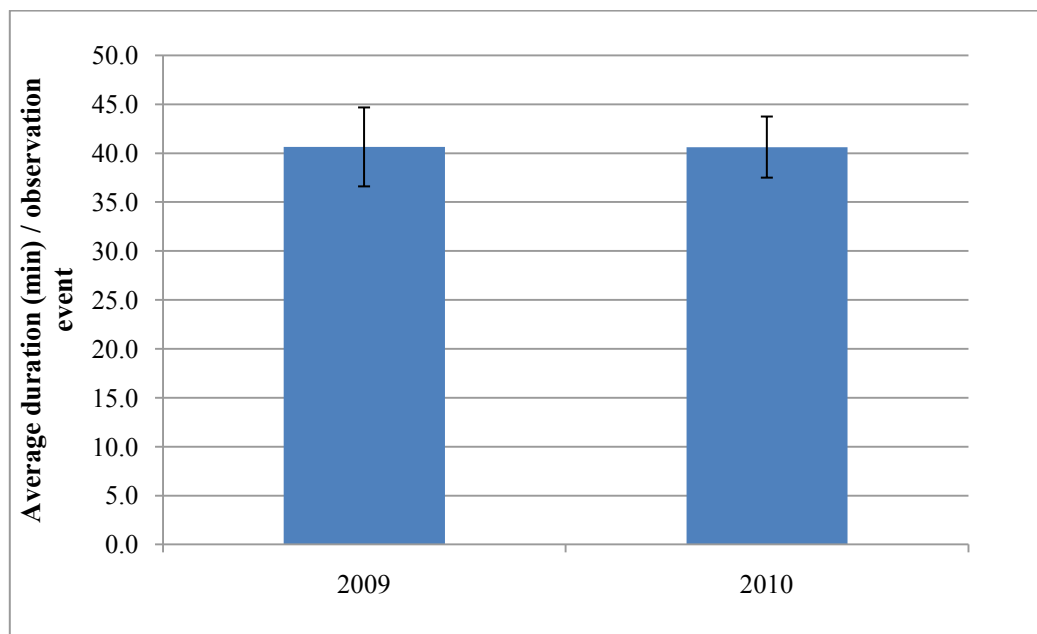
Figure 3.7   Mean duration (minutes) ± SE spent in each observation event when *Cyanopica cyanus* colony was located.

Table 3.2   Number of observations conducted and the duration for each areas in 2009 and 2010.

	2009		2010	
	No. of observations	Duration (min)	No. of observations	Duration (min)
Kassel	11	430	6	360
Betula woodland	6	210	16	580
Khonin Nuga	6	185	5	125
Main Breeding Area	8	325	24	855
Padus Patch	15	535	36	1500
Sharlan Meadows	6	375	4	220
Other areas	3	175	6	300
Total	55	2235	97	3940
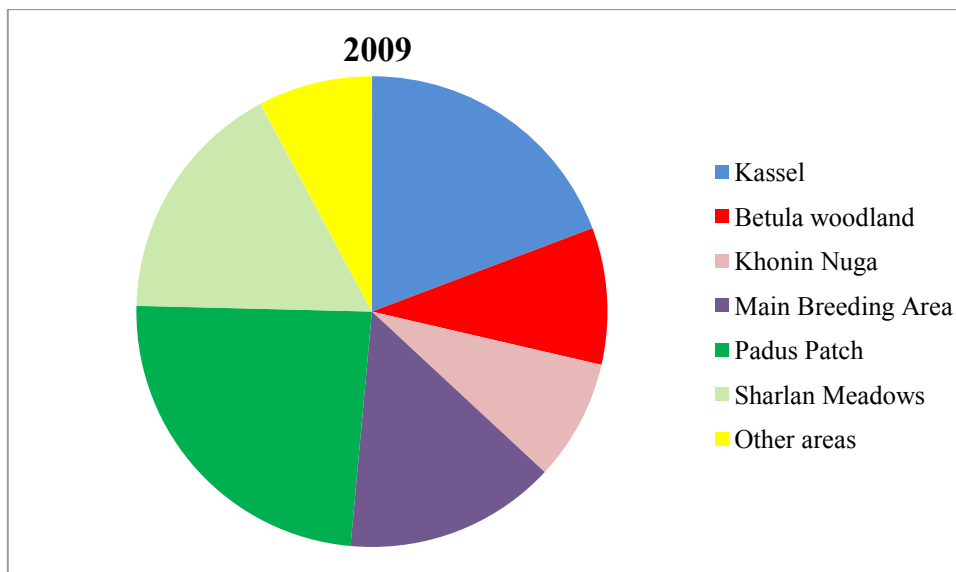
Figure 3.8   **Proportion of time spent by *Cyanopica cyanus* in six main areas, plus other areas in 2009. Other areas used this year were cliffs, an area outside of the home range of this colony of *C. cyanus* and a forested area between the two rivers, Sharlan and Khong.**
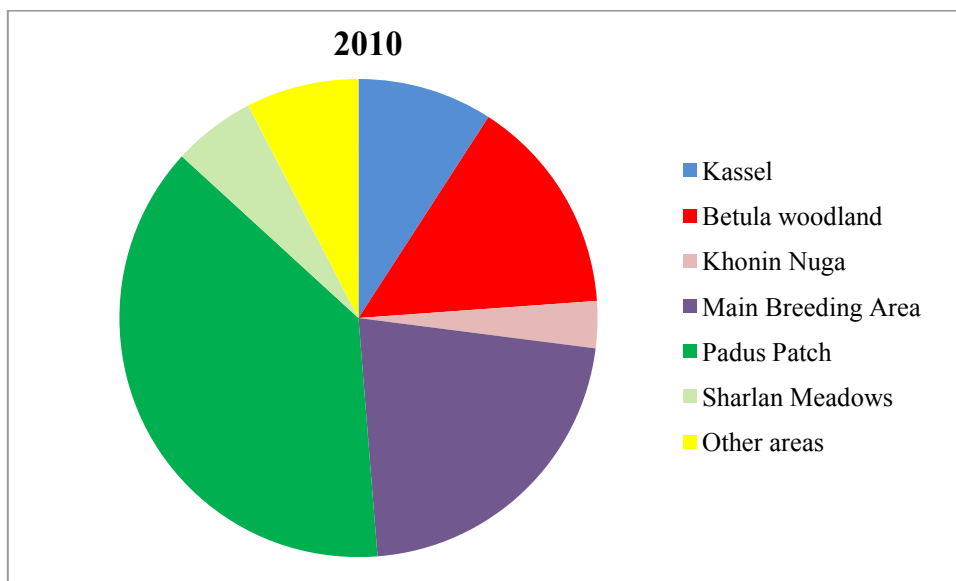
Figure 3.9   **Proportion of time spent by *Cyanopica cyanus* in six main areas plus other areas in 2010. Other areas used this year were cliffs and hill slopes.**

3.1.3   Foraging and feeding behaviour

Cyanopica cyanus exhibit a range of feeding behaviours and feed on different strata. The birds were observed foraging and feeding from ground level to ca. five metres above ground level. The most commonly utilised plant species were *Padus asiatica* shrubs (59.2% of 152 observations; Table 3.3), where I observed birds feeding on berries and insects, and resting or preening. I also

observed individuals in *Betula platyphylla* (48.7%), *Larix sibirica* (28.3%), and *Pinus sibirica* ($\leq$ 5%) trees (Table 3.3), probing in tree barks and on one occasion I observed one individual hanging upside down on a tree stump. On another occasion I saw an individual hawking an insect in mid-air. It hovered for a while before flying back to a *Padus asiatica* shrub. Individuals seldom actively pursued their prey. Only on two occasions did I observe them chasing after prey. On one occasion I observed an individual apparently flushing insects out of long grass.

The birds were observed to take a wide range of foods. I observed them consuming insects (moths, grasshoppers) and fruits of *Padus asiatica*, *Ribus rubens*, and the intestines of a dead fish. *C. cyanus* of this colony take both the larvae and adult of the Gypsy Moth (*Lymantria dispar*). When *C. cyanus* consumed the larvae, they would grasp the larvae with the beak, and rub/ beat the larvae on tree branches, as if to get rid of the thick hairs on the larvae. I have observed on one occasion, a breeding female *C. cyanus* obtaining something from a spider web. I was not sure if the bird was feeding on insects caught on the web, or the spider itself.

In 2009, there were no fruits from the *Padus asiatica* nor *Ribus rubens*, as most shrubs that escaped being burnt did not appear to produce flowers. However, in 2010 there were fruits present on both species, and *C. cyanus* were observed feeding on them.

Ten plant species that *C. cyanus* were observed utilising were found in almost all six study areas (Table 3.4). Four plant species (*Crataegus sanguinea*, *Ulmus pumila*, *Betula fusca*, *Malus spp.*) were rare and only found in one or two areas. Sharlan Meadows has the least species richness in terms of plant species utilised by *C. cyanus*.

Table 3.3 **Number of observations events that *Cyanopica cyanus* was observed utilising each listed plant species/ substrate at Khonin Nuga. Other species = *Ulmus pulmila*, *Betula fusca*, *Crataegus sanguinea*, *Rosa acicularis*, *Malus spp.*, *Ribus rubens*, *Pinus sibirica* and *Populus laurifolia*. * Dead tree includes all plants and trees that were dead, either naturally or from the fire.**

	Padus asicatica	*Betula platyphylla*	*Larix sibirica*	*Salix spp.*	Ground/ grass	Other species	Dead tree*
2009	41	34	21	3	28	10	26
2010	49	40	22	18	29	21	41

Table 3.4   List of plant species observed utilised by C. cyanus and the presence/ absence of each species in each area. 1 = present; 0 = absent. Bp = Betula platyphylla, Pa = Padus asiatica, P = Poa spp., C = Carex spp., Ls = Larix sibirica, Ps = Pinus sibirica, Pl = Populus laurifolia, S = Salix spp., Ra = Rosa acicularis, Rr = Ribus rubrus, Cs = Crataegus sanguinea, Up = Ulmus pumila, Bf = Betula fusca, M = Malus spp.

Areas	Bp	Pa	P	C	Ls	Ps	Pl	S	Ra	Rr	Cs	Up	Bf	M
Kassel	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Betula Woodland	1	1	1	1	1	1	1	1	1	1	1	0	0	1
Khonin Nuga	1	1	1	1	1	1	1	1	1	1	0	0	1	0
Main Breeding Area	1	1	1	1	1	1	1	1	1	0	0	1	0	0
Padus Patch	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Sharlan Meadows	1	1	1	1	0	0	0	0	1	0	0	0	0	0

3.2 Radio tracking

I deployed Transmitter 1 on the 16/06/2010 on an adult male 7785313 that was breeding. The transmitter fell off the bird the next day. I suspected the transmitter got snagged on a tree branch and was dropped as I found the transmitter on a branch of the *P. asiatica* bush with the tail feather still attached.

Transmitter 3 was deployed on the same adult male (7785313) on 18/06/2010. Apart from detecting a faint signal on the 30th June, no signals were detected otherwise from this transmitter. The transmitter was never recovered.

Transmitter 5 was deployed on the 18/07/2010 on a juvenile. No signals were received from the transmitter for 11 days and it was confirmed dropped from bird on 07/08/2010. It had dropped under a few dense *P. asiatica* bushes with dense undergrowth. I was unable to retrieve this transmitter.

Transmitter 7 was deployed onto a juvenile (7785366) on the 13/08/2010. This transmitter was still transmitting at the end of fieldwork on the 30th August 2010. This transmitter was not removed, as juveniles undergo another stage of moulting in autumn, and would shed the tail feather that had the transmitter on it.

Overall, radio-tracking was not successful. Out of 79 sessions, I only detected signals 31 times. Two transmitters that were deployed were known to have fallen off the bird and one was never detected.

3.3 Population Dynamics

3.3.1 Frequency of nest predation and species responsible

I monitored four active nests between 12 June 2010 and 19 July 2010. Two (N1 & 2; Fig. 3.5) already had nestlings in them, and the other two (P1 & P2; Fig. 3.6b) were in the process of being built. Overall, four out of seven (57.1%) known nesting attempts were successful (i.e. at least one chick fledged from the nest).

Nest N1 had eight young nestlings (no feathers and their eyes were still shut) on 15 June 2010. All nestlings fledged successfully on 26 June 2010.

Nest N2 had nine young nestlings on 16 June 2010. On 27 June 2010, this nest only had eight nestlings, with downy feathers. I think predation in this case is unlikely as only one nestling was missing. Furthermore, the nest was "full to the brim". It is possible that the lost nestling was actively or accidentally pushed out of the nest by its nest-mates. The remaining eight chicks fledged successfully.

Nest P1 had four eggs on the 15 June 2010 but all were predated four days later. This nest was abandoned by the parents after the nest was predated.

Nest P2 was built on the 15 June 2010. There were seven eggs in this nest on 4 July 2010. On 6 July 2010, Nest P2 had one nestling and three eggs in the nest. The other three eggs were most likely predated. Four days later there were three nestlings. It could be possible that the female bird had ejected the fourth egg or if the egg had hatched, perhaps the nestling was weak and died, therefore the parents removed it. On the 13 July 2010, there was only one nestling left, the other two possibly predated, although the species responsible was undetermined. The remaining nestling fledged successfully.

Additionally, there were two other nests—Nest 3 and 4 (Fig. 3.5), which had been predated and were abandoned by the parents before I started nest monitoring. I found nest P3 (Fig. 3.6b), containing six chicks with downy feathers, on 30 July 2010. I did not succeed in locating this nest earlier as it was well hidden in amongst the dense *Padus asiatica* bushes and I only found it by chance. I suspected that this nest was built by the breeding pair of nest P1 that failed. All nestlings from nest P3 fledged successfully.

Unfortunately the tracking pads did not yield any results at all four nest sites. No footprints, marks, or hairs were found so we could not determine the species responsible for predating the nests. When nests were predated, there were no eggshells left behind in the nests. The linings of the nests were also undisturbed, suggesting that the eggs were taken away from the nest then consumed.

3.3.2 Colony structure

A total of 125 birds in this colony were banded between 2006 and 2010 (Table 3.5 & 3.6). Out of the 125 individuals, 91 were banded as chicks and the rest were caught and banded as adults either during the breeding season or after. One banded individual was known to die of natural causes.

Table 3.5   **Details of banded adult birds in 2006-2010. Adult birds here include birds banded as adults and birds born into this colony. Yearlings were considered as adults and included in this table.**

	2006	2007	2008	2009	2010
No. banded as adults each year	11	14	5	3	1
No. banded that were sighted	11	18	20	36	6
No. banded that were not sighted	-	7	33	52	97
No. breeding individuals	-	14	18	20	12
No. of breeders fledging[5] chicks	-	14	12	10	6
No. of helpers	-	0	2	12	0
No. birds visually estimated in colony beginning of breeding season (May)	-	54	34	41	18
No. birds visually estimated in colony in autumn (September) (including juveniles born that year)	-	74	65	36	35

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[5] Fledging chicks is defined as fledging at least one chick.

Table 3.6 Life history of individuals that were born into this colony and banded as fledglings. No data for breeding was recorded in 2006. Bred here is defined as individuals that attempted breeding, but didn't necessarily fledged chicks.

	2007	2008	2009	2010
No. hatched	54	43	39	26
No. fledged	49	41	23	23
No. banded	23	34	16	18
No. sighted in autumn	40	31	17	22
No. bred as yearling	-	0	2	0
No. bred	-	0	2	1
No. helpers	-	0	7	0

Table 3.7 shows the estimated number of adults and juveniles present in the colony between 2006 and 2010. This estimation is based on the re-sighting rate (**p**) obtained from MARK analysis of adult and juvenile survival and recapture (re-sighting) rates (Fig. 3.15). The standard error for this estimation is high, resulting in a wide confidence interval (CI), especially in 2009 for adults and 2008 for juveniles. The formula estimates are higher (Table 3.7) in 2008 and 2009 compared to visual estimations (Table 3.5).Only in 2010 was the formula estimation comparable to the visual estimation. Around 20 non-breeding birds left the colony in 2009 and were then not sighted again that season (B Gantulga, pers. comm.), hence the lower number in September 2009 than in May 2009.

Table 3.7 Estimation of number of adults, and juveniles in the colony each year, from 2006 to 2010 using the methodology following Davidson & Armstrong (2002). There was no breeding data for 2006, hence only total number of adults in colony was estimated.

	2006	2007	2008	2009	2010
Estimated adults	19	31	35	63	10
95%CI (Lower, Upper)	(12.89, 25.11)	(21.01, 40.99)	(23.90, 46.10)	(43.02, 82.98)	(6.67, 13.33)
Estimated juveniles	-	35	52	24	27
95% CI (Lower, Upper)	-	(23.33, 46.67)	(34.75, 69.26)	(15.88, 32.12)	(17.87, 36.14)
Estimated total colony size	19	66	87	87	37
	(12.89, 25.11)	(44.34, 87.66)	(58.65, 115.36)	(58.90, 115.1)	(24.54, 49.47)

Based on visual estimations of total colony sizes in early autumn (September), I estimated that 55.4% of the colony was banded in 2007, 83.1% in 2008, 92.9% in 2009, and 68.6% in 2010 (Table 3.8). I took into account the ca. 20 birds that left the colony just after the breeding season in 2009.

Table 3.8 **Proportion (%) of the colony that was banded each year. No visual estimation was done for 2006. Visual estimations in early autumn (September) each year was used.**

Estimation methods	2006	2007	2008	2009	2010
Visual (%)	-	55.4	83.1	92.9	68.6

The number of birds born into this colony showed a marked decrease over four years (2006-2010) ($r^2 = 0.942$, $P = 0.020$; Fig. 3.10). The number of fledged chicks also showed a significant decline, although only marginally ($r^2 = 0.864$, $P = 0.046$).

Although group size in the beginning of the 2010 breeding season was the lowest amongst the four years for which we have data, the number of individuals present in the beginning of the season did not differ significantly across the years ($r^2 = 0.645$, $P = 0.127$; Table 3.5, Fig. 3.11).

Although the number of chicks hatched in 2009 was more than in 2010, the number of chicks that fledged in 2010 was similar to 2009 (Table 3.6; Fig. 3.10). Six breeders fledged chicks successfully in 2010 compared to 10 in 2009 (Table 3.5; Fig. 3.16). Although the number of birds visually estimated in the colony in autumn was comparable in both years (2009 & 2010), the starting population only consisted of 18 birds in June 2010 compared to 41 birds in May 2009 (Table 3.5).

Assuming the adult birds that were banded in 2006 and 2007 were yearlings, six birds in our colony were at least four years old when they were re-sighted in 2009 and 2010 (four and two respectively).
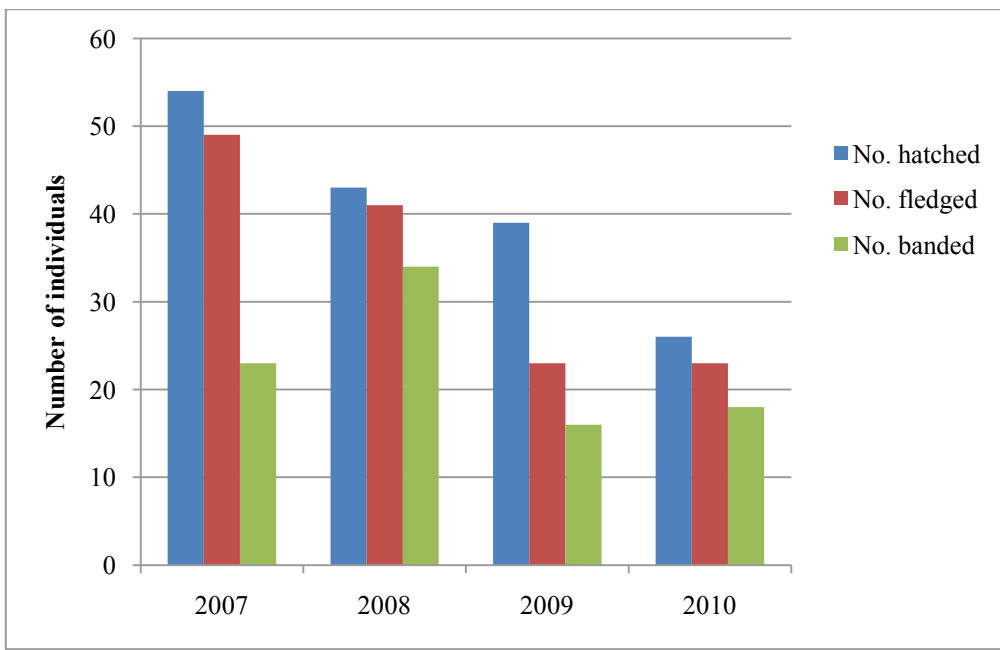
Figure 3.10 Number of chicks hatched, fledged and banded between 2007 and 2010
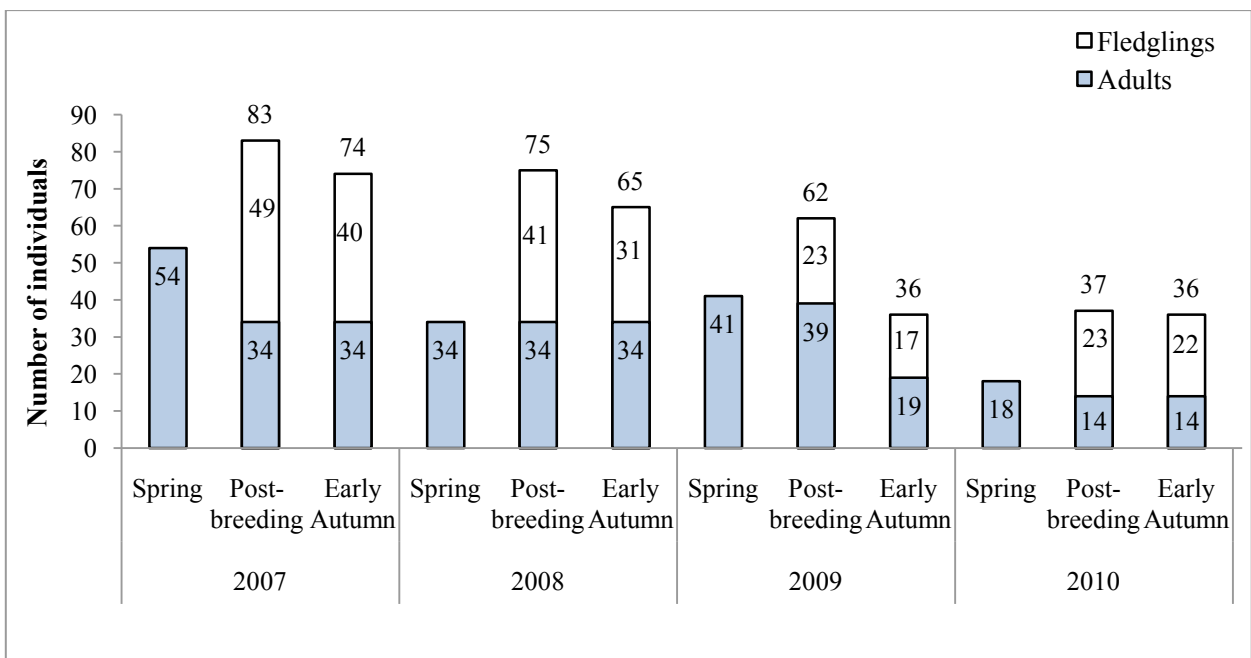
Figure 3.11 The changes in colony size throughout the season for 2007, 2008, 2009 and 2010. Numbers in columns correspond to the number of adult or fledglings. Numbers on top of the columns indicate colony size.

3.3.3 Adult and juvenile survival and re-sighting rates

Nearly half of the adults banded in 2006 were not seen in 2007 (Fig. 3.12). However, more than two-thirds of all the adult birds banded in 2007 were re-sighted in 2008 and 2009. In 2010, the re-sightings of birds banded between 2006 and 2008 were at or less than 20%. The re-sighting rate of adults banded in 2009 seemed high in 2010, but it was only because two out of three banded adults were sighted.
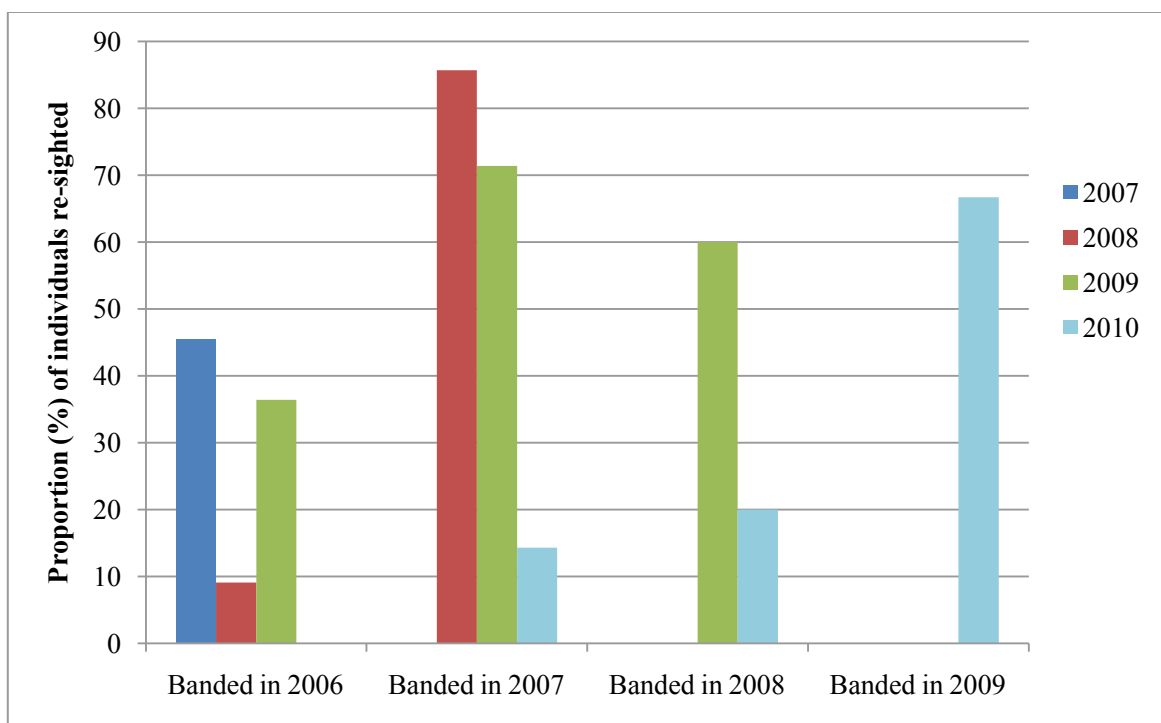
Figure 3.12 Proportion of adult birds banded each year that were-sighted in subsequent years

Only 8.7% and 13.0% of juveniles banded in 2007 were re-sighted in 2008 and 2009 as yearlings and adults respectively, whereas 38.2% of 2008 juveniles were re-sighted in 2009 as yearlings. The re-sightings of juveniles hatched between 2007 and 2009 was at or nearly zero in 2010 (Fig. 3.13).
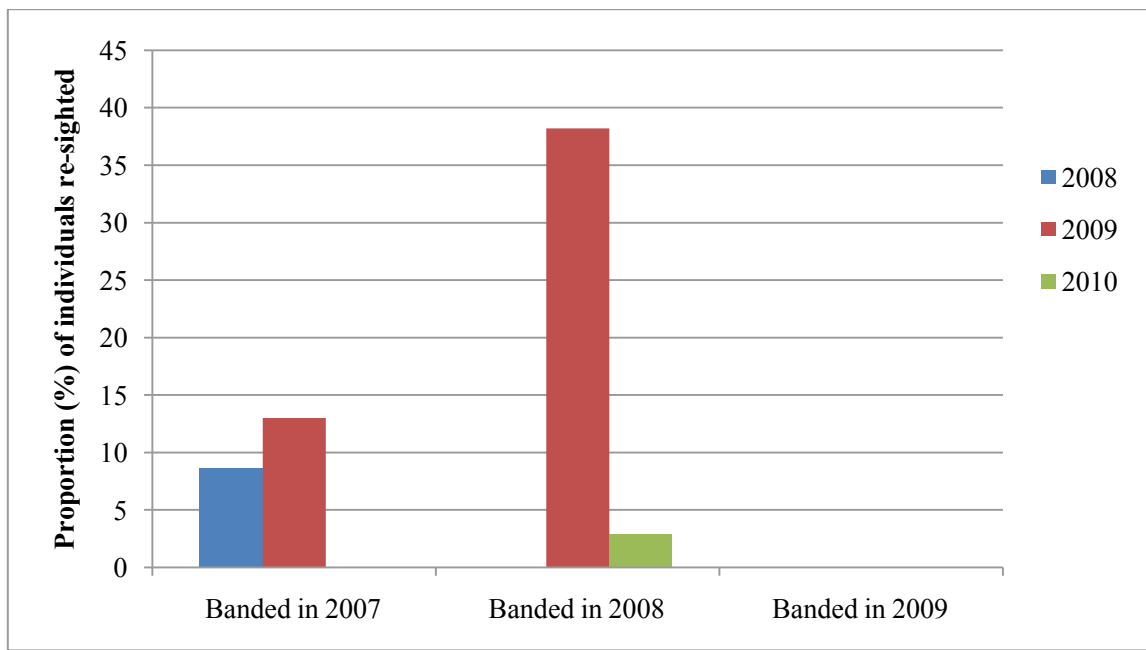
Figure 3.13 Proportion of juvenile birds banded each year that were re-sighted as yearlings and/ or adults in subsequent years.

Results from the two best-fitting averaged models (Tables 3.9 & 3.10) suggests that survival for adults varied through time but survival of juveniles stayed constant throughout the years 2006-2010 (Fig. 3.14). Adult survival almost reached 100% in 2008-2009, but then crashed to 15.14% in the years 2009-2010. Although survival rates of juveniles to their first years were slightly higher than survival rates adults, differences in survival rates between them were not significant between 2006 and 2010 as the 95% CI for both categories overlap for those years.

Re-sighting rates of adult and juvenile *C. cyanus* were constant throughout 2006-2010 (Fig. 3.15). Re-sighting rates of juveniles were only slightly higher than adults (Resightings, **p**: Juvenile = 65.72%, SE = 0.110; adult = 57.29%, SE = 0.091).

Table 3.9   Models that had a Delta QAICc of 2 or less. The models have been corrected for overdispersion.

Model	QAICc	Delta QAICc	AICc Weights	Model Likelihood	No. Par	QDeviance
Phi(a2--./t)ad(t)2gp_ad_sameP(.)	220.8861	0.0000	0.2846	1.0000	6	29.7078
Phi(a2--./t)ad(t)2gp_ad_sameP(g)	221.2512	0.3651	0.2371	0.8332	7	27.9402

Table 3.10 Description of the two models that best fit the data.

Model	Explanation
Phi(a2--./t)ad(t)2gp_ad_sameP(.)	Survival: juveniles constant through time. Adults changes through time. Recapture/ resighting: constant through time and group
Phi(a2--./t)ad(t)2gp_ad_sameP(g)	Survival: juveniles constant through time. Adults changes through time. Recapture/ resighting: changes between group but stays constant through time
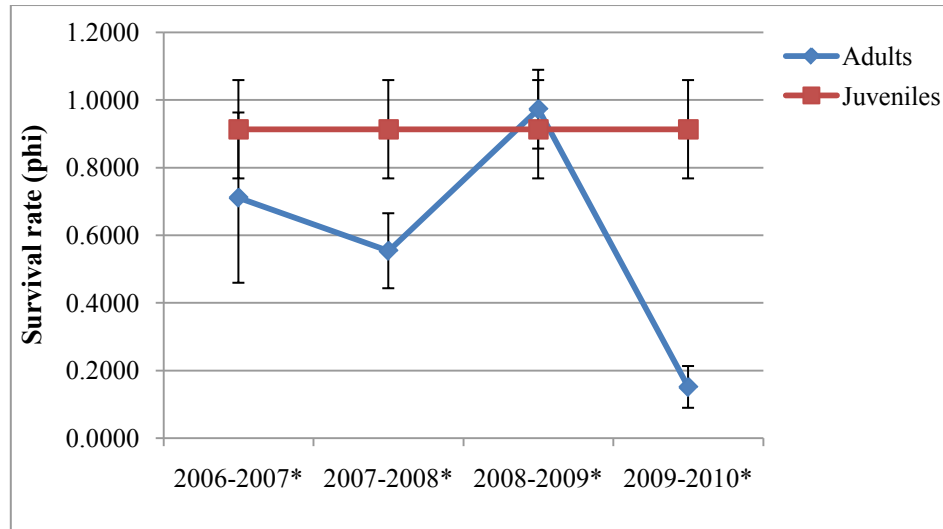
Figure 3.14 Year-to-year survival probability (φ ± SE) of adult and juvenile *Cyanopica cyanus*. *Non-significant difference between survival of adults and juveniles (i.e. the 95% Confidence Intervals of both groups overlap for that year).
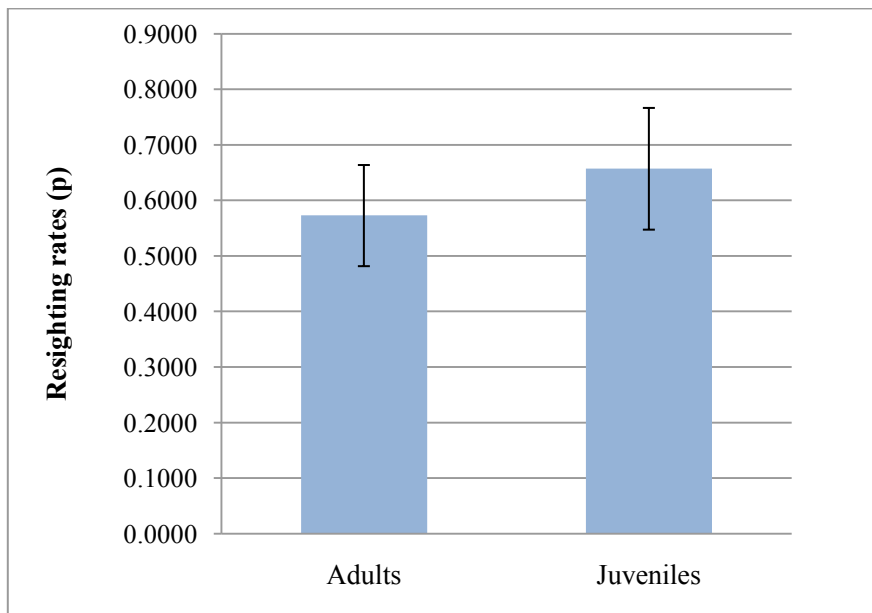
Figure 3.15 Year-to-year (2006-2010) re-sighting probability (p ± SE) of *Cyanopica cyanus* adult and juvenile.

3.3.4 Breeding individuals

Out of the 26 banded individuals that bred[6] in this colony, at least four were individuals known to be born into this colony (2008 chicks). Three females and one male banded as adults, bred for three consecutive breeding seasons (Table 3.11). Only two of the females raised chicks successfully in all three years. The third female bred and raised chicks successfully in the first two years, but in the third year she died whilst incubating. The male bred successfully in 2008 and 2009, but failed to fledge chicks in 2010. In 2009, two yearlings attempted breeding but only one succeeded in fledging chicks.

13 banded individuals (eight females and five males) bred more than once between 2007 and 2010 (Table 3.11). Based on the visual estimation of colony sizes from 2007 to 2010 (beginning of breeding season), 25.9 % of adults bred in 2007, 52.9% of adults bred in 2008, 48.8% of adults bred in 2009, and 66.7% of adults bred in 2010.

The number of individuals attempting to breed between 2007 and 2010 was similar (on average 16 birds; $r^2 = 0.47$, $P = 0.859$; Fig. 3.16). However, the number of individuals that successfully fledged chicks was lower, apart from 2007. There is a significant decrease of individuals breeding successfully ($r^2 = 0.949$, $P = 0.017$).

All individuals that attempted to breed in 2007 were successful in fledging chicks (Fig. 3.16 & 3.17). There were more successful breeders than unsuccessful breeders in 2008 and 2009. 2010 had a similar number of successful and unsuccessful breeders (six individuals each). The unsuccessful breeders did not show any significant change in numbers over the four-year period ($r^2 = 0.400$, $P = 0.225$; Fig.3.17).

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[6] Bred include birds that had laid eggs and/or hatched chicks, but didn't necessary fledge chicks.
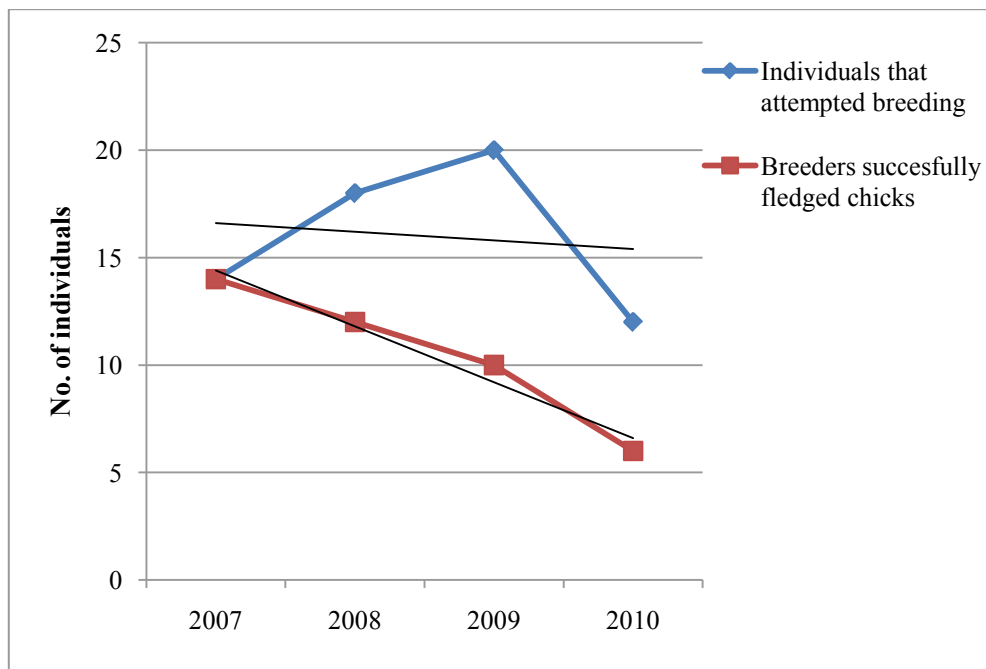
Figure 3.16 Number of individuals that attempted breeding (including unbanded birds) between 2007 and 2010 and the number of individuals that successfully fledged chicks. Regression lines were fitted for each categories, i.e. individuals that attempted breeding each year and breeders that successfully fledged chicks each year.
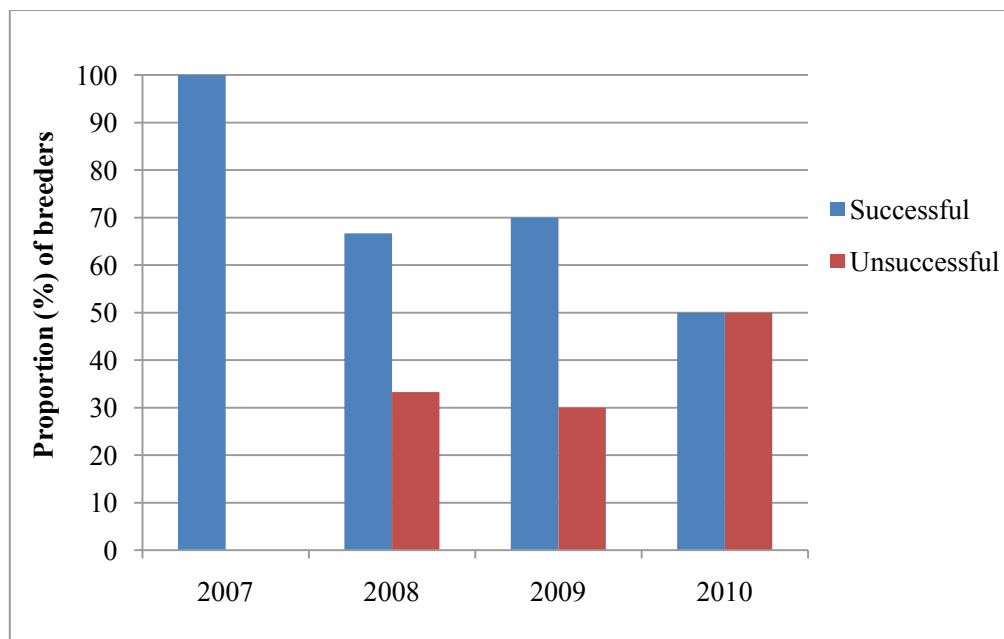
Figure 3.17 Proportion of breeders which were successful and unsuccessful in fledging chicks (including unbanded birds) between 2007 and 2010.

3.3.5 Pair-bond retentions

Due to the short period of data collection (four years) and high number of pairings involving unidentified mates (Table 3.11), I did not attempt to analyse pair-bond retention. However, I did collect the following observations on pair-bonds.

Out of the 29 pairs (that had at least one banded individual) known to have bred between 2007 and 2010, 22 pairs had at least one pair member that attempted breeding in more than one season (Table 3.11). Of these 22 pairs with recurring breeders, we can only tell for certain that two pairs (7785309/7542752 and7785310/7785029) stayed together for two breeding seasons (2008 and 2009). Females from both of these pairs were successful in breeding and raising chicks in 2008, but only 7785310 was successful in 2009. Neither female was seen in 2010.

Female 7785308 had a different mate for each of the 2007, 2008 and 2010 breeding seasons (Table 3.11). The mate from 2007 was present in 2008, indicating a mate replacement that wasn't due to the death of the male. This mate swap occurred despite the fact that 7785308 bred successfully in 2007 (but not in 2008). Neither mate from 2007 nor 2008 was seen in 2010 (Table 3.11).

Female 7719502 changed mates in 2008, but because her mate in both 2008 and 2009 was unbanded, a mate change can neither be confirmed nor ruled out. Her 2007 mate was present in 2008 but he paired with another female (Table 3.11). 7719502 bred successfully in 2007 and 2008, but died in 2009 whilst incubating.

7785303 and 7785028 both changed mates in 2009 (Table 3.11). They bred successfully in 2008. As 7785029 was only banded in 2008, we are unable to tell if he was the unbanded male of 2007 and mate of 7785310 that year.

Out of the six identified females that we knew had bred successfully for more than one season between 2007 and 2010, only two were known to maintain their mates from the previous year (Table 3.12). There were two cases of 'divorce' between 2007 and 2008 (both 7719502 and 7785308 had new mates). Additionally, between 2008 and 2009 or 2010 two females (7785028 and 7785308) obtained new mates –their previous mates were not sighted. There was one unknown case because the female (7719502) had an unknown mate in both 2009 and 2008; and one case (7785303) of either 'divorce' or 'widowed' occurred between 2008 and 2009 because the 2008 mate was unbanded and so I was unable to tell if it was present in 2009 (Table 3.11).

Table 3.11 Pair bonds 2007-2010. Data is only presented when at least one of the pair was identified. F= female; M= male; Unknown= unbanded individual.

	2007	2008	2009	2010
1	7719502 (F) 7785317 (M)	7719502 (F) unknown	7719502 (F) unknown	
2	7785308 (F) 7785311 (M)	7785308 (F) 7785031 (M)		7785308 (F) 7785029 (M)
3	7785310 (F) unknown	7785310 (F) 7785029 (M)	7785310 (F) 7785029 (M)	
4	7785303 (F) unknown	7785303 (F) unknown	7785303 (F) 7785318 (M)	
5	unknown 7785318 (M)			
6	7719505 (F) 7785302 (M)			
7	7785314 (F) unknown			
8		7785309 (F) 7542752 (M)	7785309 (F) 7542752 (M)	
9		7785028 (F) 7785317 (M)	7785028 (F) unknown	
10		unknown 7785313 (M)	unknown 7785313 (M)	
11		7785315 (F) unknown	7785315 (F) unknown	
12		unknown 7785030 (M)		
13			7785069 (F) unknown	7785069 (F) unknown
14			7785062 (F) unknown	
15				unknown 7785050 (M)
16				7785086 (F) unknown

Table 3.12   Banded females and known pair-bonds. *These females had an unbanded mate in 2008. ^This female died during incubation in 2009. Y=Yes; N= No.

Year	ID	Bred successfully previous year?	Maintained mate from previous year?	Previous mate sighted this year? (if changed mate)	Bred successfully this year?
2008	7719502	Y	N	Y	Y
	7785308	Y	N	Y	N
2009	7719502	Y	Unknown*	Unknown*	N^
	7785309	Y	Y	-	N
	7785310	Y	Y	-	Y
	7785303	Y	N	Unknown*	Y
	7785028	Y	N	N	N
2010	7785308	Not present	N	N	Y

3.3.6 Site fidelity

In 2008, out of the 20 banded birds that were present, 15 were present in 2007 and seven of them bred in 2007. In 2009, out of 37 banded birds present, 14 were present in 2008 and nine birds bred in 2008. In 2010, out of six banded birds present, five were present in 2009 and four bred in 2009 (Fig. 3.18).

In 2008, 70% (seven individuals) of the successful breeders (banded) from 2007 remained in the colony. Out of the seven birds that were present in 2008, five attempted breeding but only four were successful in raising chicks. There were no unsuccessful breeders recorded in 2007 (Fig. 3.19 & 3.20).

In 2009, 70% (seven individuals) of the successful breeders and 66.7% (two individuals) of the unsuccessful breeders from 2008 remained in the colony. All of the previously successful breeders that were present this year attempted to breed, but only three were successful. All of the previously unsuccessful breeders that were present this year attempted to breed, but only one succeeded (Fig. 3.19 & 3.20).

In 2010, 40% (two individuals) of successful breeders and 22.2% (two individuals) of unsuccessful breeders from 2009 were present. Out of the two previously successful breeders, one bred but was unsuccessful. Both of the previously unsuccessful breeders bred and both were successful this year (Fig. 3.19 & 3.20).

There was no association between breeding successfully the previous year and being present again the subsequent year ($\chi^2 = 3.069$, df = 1, $P > 0.05$).
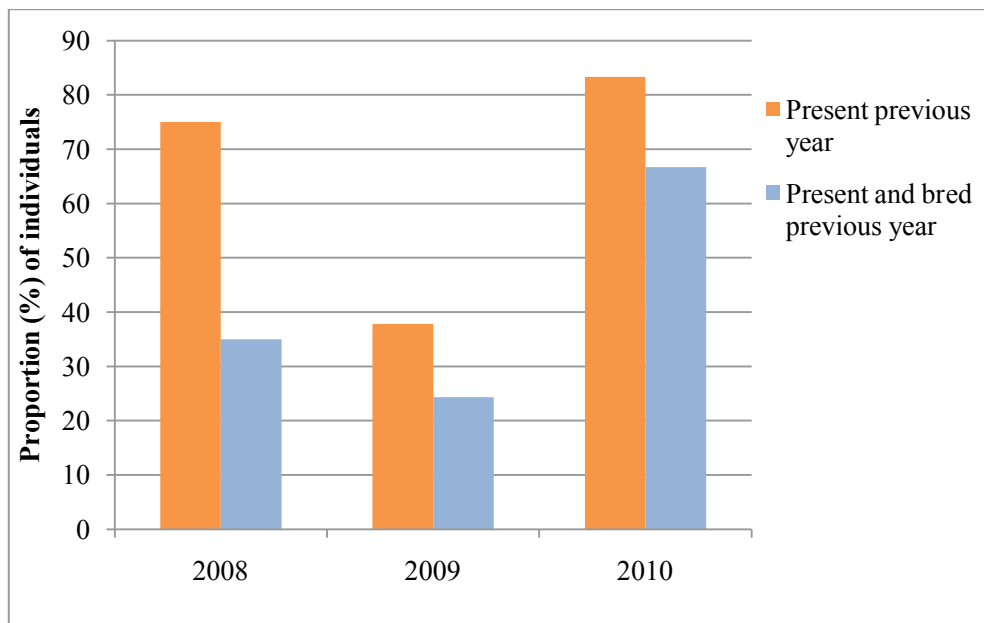
Figure 3.18 Proportion of banded birds present each year that were present in the previous year , and present and bred in the previous year.
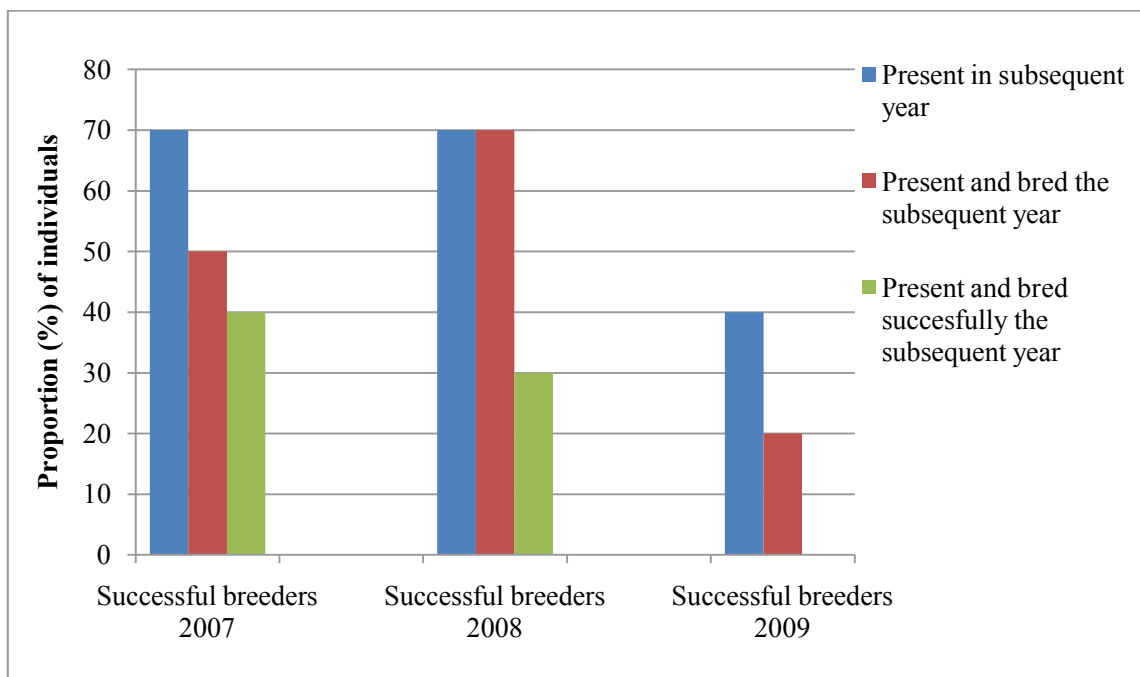
Figure 3.19 Proportion of successful breeders from 2007 to 2009 that were present, that bred, and successfully raised chicks in the subsequent year
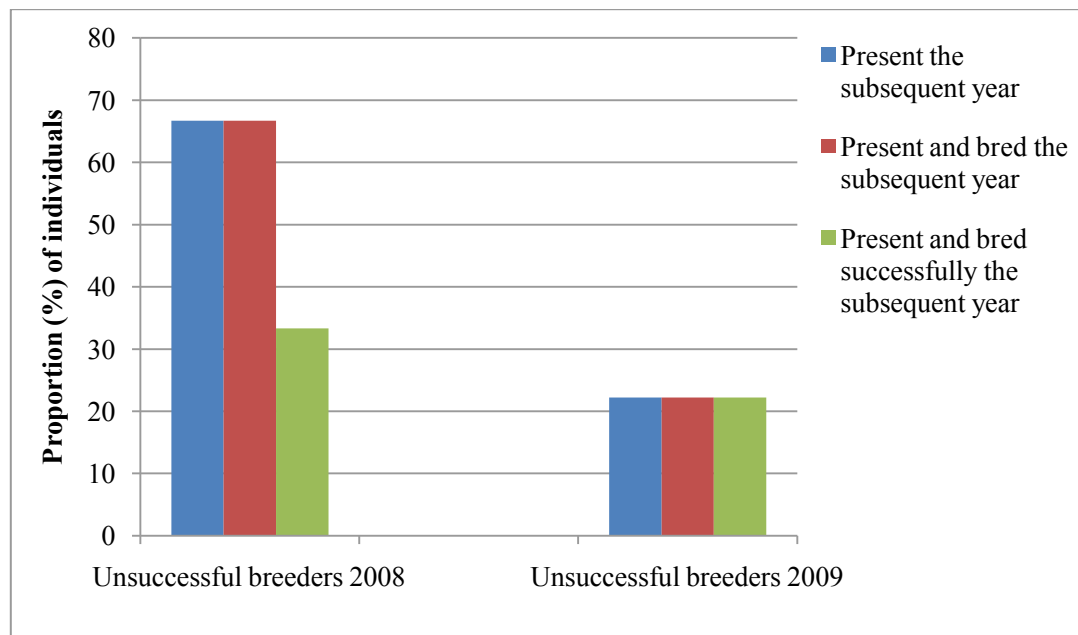
Figure 3.20 Proportion of unsuccessful breeders from the years 2008 and 2009 that were present, that bred, and successfully raised chicks in the subsequent year. There were no recorded unsuccessful breeders in 2007.

3.3.7 Change in group membership

From 2007-2009, birds were observed breeding only in the Main Breeding Area (see Habitat Description, this section). In the 2010 (one year post-fire) breeding season, there were three nests built (I suspect one was a re-nesting event) in patches of *Padus asiatica* (*Padus* Patch area) on the true left of the river, about 2km upriver from the field station. This was the first time *C. cyanus* was recorded breeding in *Padus* Patch area. This was also the first time some members of the colony nested far apart from other members.

Out of the three banded adults that bred in the *Padus* Patch in 2010, one male adult (banded in 2008) successfully fledged chicks in 2009 and 2008; one female (banded in 2009) either bred or helped in 2009; the other female (banded in 2007) wasn't observed in 2009, bred in 2008 but didn't fledged any chicks, bred in 2007 and successfully fledged chicks.

Chapter 4

Discussion

4.1 Post-fire Habitat Use in the Khonin Nuga *Cyanopica cyanus*

The home range of the *Cyanopica cyanus* colony in the Khonin Nuga valley is larger (1.862km^2) than those of the colonies in Western Spain (0.3-0.5 km^2; C de la Cruz, pers. comm.), and comparable to the Japanese colonies at two study sites in Nagano prefecture (1.351 km^2 and 2.876 km^2, respectively; Imanishi, 2002). The differences relative to Spain could be due to the higher altitude of our field site, or the different climate and vegetation, as was also suggested by Imanishi (2002) for the differences in home range size between his two study populations.

The home range of the Khonin Nuga *C. cyanus* colony could also be due the effects of the fire, as data was only available for 1¼ years post-fire. The area utilised by *Cyanopica cyanus* in 2009 and 2010 was larger than the area used prior to 2009 (K-J Wilson, pers. comm.). Perhaps limited resources and nutrients post-fire caused the birds to expand their home range. The strong association between years and successful/ unsuccessful search attempts suggests that the large fire in 2009 affected food availability, and so the birds spent more time foraging over a larger area, potentially beyond their pre-fire home range. On three occasions in 2009, colony members were located in an area ca. 2 km away from their home range, supporting this idea. Furthermore, success rates for searches were much lower in 2009 than 2010, again suggesting that the birds may have spent much time outside of their home range. However, the large amount of time spent unsuccessfully searching for the *C. cyanus* in 2009 compared to 2010 could be because I was not familiar with the field sites and thus not able to find the birds. Additionally, it must be noted that I made the observations from summer to early-autumn (mid-July to early September). I also did not differentiate between breeding and non-breeding seasons (I combined the data from June to September), whereas Imanishi (2002) did, and he noted that one of his study populations at a high altitude expanded their home range during winter and contracted in spring.

The accuracy of home range measurements may have been limited by the accuracy of available maps. The only topographic map available for the area was large-scaled (1:100,000) and outdated. It was created in 1962 and updated in 1969, most likely according to the Russian

coordinate system. However, the resulting home range size is still within the range documented for other populations.

The *Padus* Patch was the area used most often by the *C. cyanus* colony in 2009 and 2010. The significant increase in the proportion of time spent by the colony in the *Padus* Patch area in 2010 could be attributed to fruiting of the *Padus asiatica* shrubs. Furthermore, this area has the largest amount of dense *P. asiatica* shrubs amongst all six study areas in the home range of *C. cyanus*. I did not observe any fruit-bearing shrubs in 2009, most clearly as a result of the fire. Amongst the areas utilised, *Padus* Patch is the richest in plant species utilised by *C. cyanus*. For future studies to determine if *C. cyanus* prefers sites with richer species or a certain plant species, the study could include more plant species (c.f. 14 in this study) and use species abundance instead of only the presence or absence of species. Additionally, instead of using the six study areas, all areas used by the colony could be classified into different habitats, according to species composition and abundance.

The lesser time spent by the colony in Sharlan Meadows in 2010 could be because this area is the least species rich (of the utilised species), therefore making it less preferred if conditions were better in other areas, such as the *Padus* Patch. The increased use of *Betula* Woodland area probably also reflects the fruiting of *P. asiatica* shrubs in the riverine scrub in 2010.

After the fire in 2009, breeding *C. cyanus* continued nesting in the already burnt *Padus asiatica* shrubs at the Main Breeding Area, and stayed throughout the season. About 20 individuals (possibly non-breeders) did leave the colony and their home range when the breeding season ended (around early August 2009) and were not seen for the rest of the field season, which ended in mid-September (B Gantulga, pers. comm.). Perhaps finding a new site somewhere unfamiliar is not feasible, even though the fire was quite early in the breeding season and birds would have been able to breed successfully and raise chicks by autumn (cf. the latest clutch in 2010 was at the end of June). Site tenacity has been reported in some bird species in fire affected Mediterranean type shrublands (Pons *et al.*, 2003), heathlands (Brooker & Rowley, 1991), pine forests (Emlen, 1970) and eucalypt forests (Wooller & Brooker, 1980) provided some parts of their home range remained unburned. This tenacity suggests some sort of phenotypic plasticity for adaptation to their new environment conditions (Brooker & Rowley, 1991; Pons *et al.*, 2003).

In 2010 however, some birds did breed in new areas. Two breeding pairs nested in the *Padus* Patch area in 2010, and it is the first ever recording of birds nesting far apart from the rest of the

colony as breeding activities in 2007-2009 were all in the Main Breeding Area (Gantulga, 2010). It is not known whether this is just a chance and single event for 2010, or marks the adoption of a separate breeding site for this colony following the 2009 fire.

Colonisation of the Khonin Nuga valley by *C. cyanus* may be a very recent event. *C. cyanus* were not reported to be present (at least in big family units) and breeding in the Khonin Nuga Valley until 2005. There are speculations about the coincidence between the appearance of the birds and the outbreak of Gypsy Moths (M Mühlenberg, pers. comm.). A large outbreak of Gypsy Moths (*Lymantria dispar*) occurred during 2001-2006, and again in 2008 around the Khonin Nuga Research Station (Gantigmaa, 2004; M. Muehlenberg, pers. comm.; Altantsetseg, unpublished data). Both adult and larvae are an important food source for *C. cyanus* adults and chicks (Gantulga, 2010; pers. obs.).

This is the only colony known to inhabit the valley near the field station. Searches have been made by colleagues and I around the valley (following the Eroo river basin and its branch river basins) and, based on conversations I had with the local ranger and other scientists who have been working since 2002 in this field station, no other colony is known to inhabit the immediate region of Khonin Nuga (ca. 20km upstream and 10km downstream from the research station). In August 2003, 100-120 *C. cyanus* individuals were seen c.a. 2 km away in Sharlan Valley, south-east of the Khonin Nuga valley. A number of birds (ca. 6-10) made frequent visits to the Khonin Nuga valley in 2004, but did not remain in the valley (M. Mühlenberg, pers. comm.).

4.1.1 Foraging and other behaviours of the Khonin Nuga *Cyanopica cyanus*

At Khonin Nuga, *C. cyanus* were observed taking a variety of food items including insects, berries and carrion; a similar variable diet was also found in the Japanese and Iberian populations (Hosono, 1966; Madge & Burn, 1994; Snow *et al.*, 1998; Canário *et al.*, 2002). Individuals from Khonin Nuga utilised different strata (from ground level to ca. five metres in height), foraged in at least 12 plant species and performed a range of food/ prey obtaining behaviours but rarely actively pursued prey.

From my observations, *C. cyanus* always moved and foraged with conspecifics, never with other species. There were occasions in both 2009 and 2010 that a flock of Eurasian Jays, *Garrulus glandarius* (20-30 individuals) followed the *C. cyanus* whenever they were foraging, and mimicked the latter's vocalisation. *C. cyanus*'s behaviour was neutral when woodpeckers

(*Dendrocopus spp.* and *Picus canus*) were present and/ or feeding in the same area. *C. cyanus* may exert some aggressive dominant behaviour (e.g. chasing off other species) towards other smaller species such as wagtails (*Motacilla spp.*) if both are competing for food. Hosono (1975) found similar behaviour in his study in Nagano, Japan.

No obvious territorial behaviours towards conspecifics and other species were observed in this colony of *C. cyanus*, even during the breeding season. I also did not observe any sort of obvious aggression amongst group members. Reports from observations in Iberia and Japan show a mix of results, with some populations showing territorial behaviours, such as chasing (Komeda *et al.*, 1987; Snow *et al.*, 1998; S Imanishi, pers. comm.), but others not (Valencia *et al.*, 2000). This non-territorial behaviour may stem from relatedness of group members, but kinship has not yet been studied in these populations.

Behavioural observations were limited by the difficulty of observing *C. cyanus* when they foraged in dense bushes (e.g. *Padus asiatica* and *Salix spp.*). There is no other way around this problem, or to improve it without alarming the whole colony, apart from conducting many, or chance observations regarding the activities of *C. cyanus* in dense scrub. Observation events of areas on the true right of Eroo River (i.e. the Main Breeding Area and Sharlan Meadows) were limited when the water level was high, as it was impossible to cross by foot or horse. Therefore, when this happened (about two to three days in 2009 and one week in 2010), observations were limited to the true left of the Eroo, on the true right river bank and ca. 20 metres inland from the true right of the river.

4.2 Radio-tracking

VHF radio tracking was employed in this study because it is by far the cheapest tracking method and had reasonable accuracy. As far as I can determine, no VHF radio tracking research has been published for this species before. Overall, the radio-tracking attempts were not successful on *C. cyanus*, as I had difficulties getting accurate signal positioning from transmitters and securing transmitters onto the tail-feathers of *C. cyanus*.

Using VHF radio tracking is not without its problems. Tests of radiotelemetry accuracy have shown signal reception and location accuracy to be affected by several factors, amongst them reflected signals ("signal bounce") and attenuation resulting from vegetation cover (Withey *et al.*, 2001), which I think were the main reasons for difficulties in getting signals from the radio-

tracked birds. Transmitters have been found to not work as effectively in canyons and dense vegetation (Beaty & Tomkiewicz, 1990; Samuel & Fuller, 1994) because of radio waves bouncing and deflecting off reflective surfaces such as canyon walls, tree trunks or foliage. Furthermore, the problem of signal bounce is greater when transmitting at higher frequencies (i.e., > 100 MHz; Macdonald & Amlaner, 1980 in Withey *et al.*, 2001), which was the case in my study (the VHF transmitter was transmitting at > 100MHz). On many occasions I could not detect signals at all, and sometimes located signals from sites which were impossible for the birds to be at that time. Often I would rely on listening for calls from the birds (they are quite loud when the whole colony is calling and can be heard over 200 m away).

Attaching transmitters onto tail feathers appeared to be insecure because of snagging on branches. The first recovered transmitter was high on a tree branch with a tail feather attached. The long tail feathers (Fig. 2.1) could have made it more susceptible to snagging on branches. Also, I may have deployed the transmitters when the birds were undergoing moult although I did visually check the condition of the radio-tagged birds. Juvenile *C. cyanus* moult between late July and mid-November whereas adults commence moult in May (de la Cruz *et al.*, 1992). I have observed individuals losing feathers when they were caught, but it is unknown if *C. cyanus* drop their tail feathers when they are stressed or alarmed. Furthermore, these birds live in social groups and practise allopreening (pers. obs.). Birds may have deliberately removed transmitters from their own or others' tails during preening.

Attached transmitters may have affected the behaviour of the birds, particularly by increasing preening activity. However, it is unlikely that the transmitters had a significant or long-term effect on the birds. The weight of the transmitter was about 3% of the bird's body mass (adult birds weigh around 80-100g, juveniles about 70g), within the proportional weight limit suggested by Withey *et al.* (2001). Furthermore, the transmitters would be shed as the birds moult for winter, therefore creating no long-term effects on the birds.

An improvement for radio-tracking these birds would be to use a transmitter that is secured to the bird's body (e.g. with a harness modified especially for this species). However, this requires careful design and study before implementing, as some studies have shown that tagging can have some detrimental effects on birds (Samuel & Fuller, 1994; Withey *et al.*, 2001).VHF radio-tracking is the most feasible method for this type of observational study and, because of restrictions in technology there is no way to prevent interference in valleys. Radio-tracking would

also be useful for further studies of this species because of the highly mobile and unpredictable behaviour of the birds. Climbing on top of hills can improve the accuracy of signal reception but is not a feasible option in this location as a lot of time would be lost between remotely detecting the radio-tracked individuals and approaching them for visual observations.

4.3 Population Dynamics

4.3.1 Predation rates and predator identification

Four out of seven nests (57.1%) that we knew of were predated (at least one egg or chick taken) in 2010. Compared to the predation rates in 2007-2009, 2010 was the highest (2007: 7.1%; 2008: 47.4%; 2009: 28.6%; Gantulga *et al.*, in review). However, there were only seven nests in 2010 (cf. 2007: 14; 2008: 19; 2009:14; Gantulga *et al.*, in review), which may explain the high predation rate. Gantulga *et al.* (in review) found no difference in predation rates of *Cyanopica cyanus* nests when the 2010 data was included. The high predation rate in 2010 could also be due to the low number of breeding pairs (and colony size) and nesting far apart from each other (see Results for nest locations) compared to 2007-2009 (Gantulga *et al.*, in review). A larger group size and nesting close together may provide some advantages in detecting and defending nests from predators (Krebs & Davies, 1978). Although the search for nests was undergone at the start of the breeding season (early May, as in previous years), some nests could have been missed and therefore potentially underestimating the predation rates.

I did not find evidence of predators crossing any of the tracking pads deployed. This result may be due to the positioning of the pads in the field. As the nests are always in the fork of several branches leading off the main trunk, the tracking pads were mostly fixed on a vertical, or near vertical trunk/ branch leading to the nest. Perhaps it was a deterrent to potential predators because they could not get a foothold on the smooth cardboard pads. Tracking pads (tunnels) are very commonly used in New Zealand to detect predator presence and abundance (e.g. Innes, 1978; Hickson *et al.*, 1986; Innes *et al.*, 1995; Alterio, 2000) , but are normally placed on the grounds in tunnels and laid horizontally.

Some animals are fearful of novel objects in their environment (e.g. Tanaś & Pisula, 2011). Perhaps potential predators avoided the cardboard track pad because the tracking pad was unfamiliar. However, given that the cardboard was laid out for a few weeks, one would expect the animals to become conditioned to them. The ink does give a strong unpleasant scent, which

may have been even more noticeable to small predatory mammals which have a keen sense of smell. Furthermore, I re-applied the ink whenever it dried out, so the scent would have been present throughout the nesting season.

The absence of predator tracks could also indicate that predators did not approach nests from the ground. In 2010, some *C. cyanus* nested in very thick, dense bushes of *Padus asiatica* unaffected by the fire in 2009. These bushes have interlinking branches and arboreal mammals and snakes can easily travel directly from another bush to get to the nests.

Corvids typically leave no signs at the nest that they have predated (Thompson & Burhans, 2003), which could also explain why eggs were taken without leaving any evidence on the tracking pad or disturbance to the nests. There are resident pairs of *Corvus corone corone* around the field station and they have been observed taking eggs and chicks of *C. cyanus* (Gantulga, 2010). Møller (1987) observed Eurasian Jays (*Garrulus glandarius*) preying on bird's eggs in Sweden. Although the Eurasian Jay was present in the area I studied, they only descended from higher altitudes after *C. cyanus* chicks had hatched (pers. obs.). Predation by snakes is also possible, as they also leave no signs (Thompson & Burhans, 2003). The Halys Pit Viper (*Gloydius halys*) and Steppe's Rat Snake (*Elaphe dione*) are present in the study area, and are potential predators of the birds (Gantulga B., pers. comm.).

Rats and mice are known to take bird eggs (e.g. Atkinson, 1978; Bradley & Marzluff, 2003; Ronconi & Hipfner, 2009). Although they usually destroy and consume eggs at nest sites and leave tell-tale signs of broken egg shells in or near the nests, they also can carry away eggs thus leaving no signs at the nest (Major, 1991). There are small rodent species present in the valley (voles *Clethrionomys spp.* and *Microtis fortis*, shrews *Sorex spp.*, and Korean Field Mouse *Apodemus peninsulae*) (Mühlenberg, 2006), but they may be unable to break open *C. cyanus* eggs.

Siberian Chipmunks (*Tamias sibiricus*) are arboreal and are potential predators of bird eggs and perhaps chicks. On one occasion I have observed an individual in the vicinity (about 20 m) of the nest, feeding on nuts and seeds under the canopy of the *P. asiatica* bush. There is evidence from a study in the Russian Far East that suggests *Tamias sibiricus* take eggs of passerines (Forstmeier & Weiss 2002, in Forstmeier & Weiss, 2004) but the authors did note that the Siberian Chipmunk is not very well studied. Congeneric species from North America have been shown to take eggs and chicks (Schmidt *et al.*, 2008; Kirkpatrick & Conway, 2010).

Cyanopica cyanus respond to aerial predators such as *Corvus corone corone* and other threats by mobbing or giving alarm calls. Such behaviour might provide cues to predators that there are nests present. In my hours of observing at the nests, I did not detect any potential predators near any nests. However, my presence could have deterred predators.

Some other methods are frequently used to improve detection of nest predators. Artificial nests have been used extensively to study nest predation (Moore & Robinson, 2004). However, they still lack "authenticity" because of unrealistic artificial nests or eggs (Davison & Bollinger, 2000), visual conspicuousness (Storaas, 1988), and lack of parental activity (Loiselle & Hoppes, 1983; Martin *et al.*, 2000) or begging calls of chicks (Redondo & Castro, 1992) as sensory and olfactory cues to predators. This may create inconsistencies in results and limit compatibility with real nest studies (Moore & Robinson, 2004).

Clay eggs can be used to obtain teeth or beak imprints when predators attack or bite into the eggs (Møller, 1987) but care has to be taken to interpret the signs and not confuse predator identity (Fulton & Ford, 2003). Using adhesive tape/ double sided tape positioned at artificial nests to collect hairs or feathers of nest predators is an alternative method. However, this method is unreliable as it might not yield enough hair samples for identification (Suckling, 1978), be biased towards detection of mammalian predators (Yahner & Wright, 1985) and be prone to weather damage e.g. heavy rain removing the adhesive from the tape (Major, 1991).

Camera monitoring is costly, yet is the most reliable method known for predator detection and identification (Major, 1991; Thompson & Burhans, 2003), and may provide 'insights' to other nest activities such as diet of nestlings, or visitation by individuals apart from parents. Some predators are secretive (as shown in this study) or nocturnal so cameras could detect them when human observers cannot. Cameras may influence predation rates, and studies have shown a mixture of results—some show that camera monitoring did not affect predation rates at nest sites (Thompson & Burhans, 2003), whereas some show an increase or decrease in predator activity (Buler & Hamilton, 2000; Summers *et al.*, 2009).

Considering the errors and problems with the use of artificial nests and the difficulty in obtaining fresh eggs for baits in this study area, a viable option for future nest monitoring work would be to set up cameras in the vicinity of real nests, or to use a combination of artificial nests with dummy/ clay eggs, and video surveillance for confirmation of predator identity.

Another situation that would be mistaken as predation events is that parents may remove nest materials from failed nests, which gives the appearance of nest damaged by a predator. Parents might also remove their own eggs before nest desertion (Skutch 1966, Marchant 1973 in Major, 1991).

Cuckoos are present in the area. I often heard cuckoo calls (most likely the Common Cuckoo, *Cuculus canorus*) around the vicinity of nest P2 during the nesting season of *Cyanopica*, but only visually confirmed this once. I have not observed nor had any reports of brood parasitism by cuckoos on the *Cyanopica cyanus* in my study site.

4.3.2 Population dynamics of the Khonin Nuga *Cyanopica cyanus*

Colony structure and individual survival rates

There was no significant decline in the number of individuals present at the beginning of the breeding season for all years (2006-2010), although there was a drop in numbers after the major fire and harsh winter in 2009 (Fig 3.11; Results). This suggests that breeders still favoured the conditions in my study site, and the drop in numbers at the start of the breeding season of 2010 (18; down from 41 at the beginning of the 2009 breeding season) was most likely a result of increased mortality after the two environmental catastrophes. The significant decrease in the number of chicks hatched and fledged is most likely also an effect of the catastrophes mentioned. High predation as a result of reduced vegetation cover has been suggested as a reason that contributed to low fledgling success in 2009 (Gantulga *et al.*, in review), while the smaller population in 2010 may explain the few chicks hatched that year. However, there might exist other undetermined factors.

Although some individuals of this colony remained in the valley after the fire in 2009, survival analysis showed that adult survival decreased for 2009 – 2010 after the year of fire (May 2009), although it was not significant (Fig. 3.14; Results). Other studies have found similar results (Russell & Rowley, 1993; Pons *et al.*, 2003). I ran the analysis under the Cormack-Jolly-Seber (CJS) Model in MARK, which assumes an open population, and was robust enough to account for immigrations and emigrations in the colony. Due to time constraints, I did not run any tests to distinguish between permanent emigration and mortality.

Estimations of total colony size using the methodology following Davidson & Armstrong (2002) for each year were higher in some years and more variable than the visual estimations. This can

be explained by the formula which used the re-sighting rate (**p**) generated in MARK analysis, which was constant throughout the four years for adults and juveniles (Fig. 3.15; Results). This formula does not take into account existing fluctuations of colony size between seasons within each year. In 2009, ca. 20 non-breeders left the colony after the breeding season and were not sighted again that season. The formula could not incorporate information about individuals that disappeared within a season, and thus overestimated the colony size for 2009. The discrepancies between the two methods of estimation could also be due to the number of unbanded individuals present in the colony, hence making the visual estimation a more reliable method. Visual estimation used in this study and other studies from Gantulga Bayandonoi are rather accurate as search attempts for *C. cyanus* were consistent (i.e. more than one search attempt each day, from May to September).

As expected, the survival of adults dropped significantly after the fire in 2009. However, the analysis showed no variation in juvenile survival rates between years (2006-2010). Even more surprising was that juvenile survival was higher than that of the adults in three years (2006-2007, 2007-2008, 2009-2010), even in the year after the big fire. After the fire event, helping behaviour was observed (Gantulga, 2010). Perhaps the help that juveniles received as nestlings that year increased their chances of survival to fledging and independence. Studies done in two Iberian populations found that the presence of helpers significantly increased the number of fledglings (Valencia *et al.*, 2003; Canário *et al.*, 2004). Furthermore, Valencia *et al.* (2006) found that *C. cyanus* fledglings raised in nests with helpers had better immune response than those without. The survival rate of adult *C. cyanus* in the Khonin Nuga colony during normal years is comparable to adult *C. cyanus* in the Spanish population (50% annual survival rate; C de la Cruz, pers. comm.). Survival rates of juveniles are potentially similar to those of adults because once fledglings leave nests and can fly, their predation rate drops as fewer predators can take them (pers. obs.). However, their survival rate should be lower as they are not as experienced and agile as an adult in avoiding predators.

In the MARK analysis, I defined juveniles as birds that have fledged and up till one year of age, whereas adults encompass all individuals older than one year. The lower survival rate of the adults compared to juveniles could be due to a large number of older birds present in the colony. As this colony of *Cyanopica cyanus* has only been intensively studied since 2007, there are a large number of birds of unknown age and there are no studies elsewhere documenting survival

rates or longevity of this species. However, researchers documented an individual living and breeding at seven years of age in Japan (S Harada, pers. comm.) and some individuals living up to 12 years in Spain (est. annual survival of 50%; C de la Cruz, pers. comm.).

MARK could have potentially under- or overestimated survival and re-sighting rates in breeders and birds born into this colony or elsewhere. As this is most likely an open population (see below), and if individuals exhibit site fidelity, individuals will most likely return to the site where they were born or have bred successfully. In this species, males born into this colony usually stay and become helpers, whereas females are the dispersing sex (Solís *et al.*, 2008; de la Cruz, pers. comm.). In this case, MARK could potentially underestimate the survival and re-sighting rates of females, and the converse for males.

We must be cautious in interpreting this analysis because of the very small sample size: only five years of data, with limited information in the first year of study. Since calculation of survival (**phi**) and recapture/ resighting rates (**p**) are done between years, it reduces the scope of analysis to only three years (i.e. 2007-2008, 2008-2009, and 2009-2010). In 2007, only half of the fledglings were banded (Table 3.5, Fig. 3.10; Results) which could potentially bias the results.

Even though the number of unbanded adult birds in the colony has declined each year (Table 3.5; Results) there still remain a small number of unbanded birds. This suggests that this is an open population, although the same unbanded individuals could be long-term residents which have evaded capture since 2006. Given the high rate of re-sightings from year to year (> 50%) and birds that were sometimes re-sighted after being absent in one year (Fig. 3.12 & 3.13), this suggests that they spend some breeding seasons elsewhere. If this is the case, they are likely to remain close to this study site, as they are not strong fliers and do not migrate. The populations in Japan and Iberia where there is no heavy snow or snow cover, are permanently resident all year round, only expanding their home range during winter (S Imanishi, C de la Cruz, pers. comm.). The probability of banded birds being present in the study site but remaining undetected over the whole season is fairly low. Because of multiple consistent searches per year, I am confident that a bird was not present in the study site when it was not sighted in any one year.

Breeding individuals, pair-bonds, site-fidelity and social structure

Between 26% and 67 % of the total population bred between 2007 and 2010 (Population Dynamics; Results). The effective population size (size of population as estimated by the number of breeding individuals) is often substantially smaller than the actual population size (Primack, 2010), especially in cooperative breeding species where environmental conditions, social structures and longevity of the species inhibit some individuals from breeding, which in turn results in a high proportion of non-breeding individuals which act as helpers (Rowley & Russell, 1990; Arnold & Owens, 1998).

At least four banded females switched mates between breeding seasons, even though they had previously bred successfully with the mates they abandoned. Divorce rates could be as high as 25%, but I only had a small sample size. In a Japanese study of *Cyanopica cyanus*, pair-bonds were normally maintained until one of the mates disappeared (presumably died) (S Harada, pers. comm.). De la Cruz (pers. comm.) reported in a Spanish population that 39% of pairs stayed together throughout their lives; 19% divorced, and 42% switched mates annually because they lost their mate from previous years.

It has been suggested that re-mating with a new partner is a result of a loss of the previous mate (either dead or disappeared) (Ens et al. 1996, in Jacot *et al.*, 2010), or a reproductive strategy by one mate to maximise their own fitness either directly or indirectly (i.e. divorce) (Ramsay *et al.*, 2000; Green *et al.*, 2004). Divorce is often initiated as a result of one mate's low parental quality resulting in low reproductive success for that pair (Moody *et al.*, 2005). A meta-analysis by Dubois and Cézilly (2002) provided evidence that breeding success can affect divorce rates. Perhaps there are other complex and subtle factors that induces *C. cyanus* females to switch mates in the subsequent years even though they had a successful breeding event the previous year. Similar observations have been noted in Great tits, *Parus major* (Harvey *et al.*, 1979) and Black-capped Chickadees, *Parus atricapillus* (Ramsay *et al.*, 2000). Solís *et al.*(2008) found that breeding females in the Iberian population of *C. cyanus* use cues such as blue plumage colouration during pair-formation time as a signal of the quality of males. However, it must be noted that the Asian subspecies of *C. cyanus* have a paler blue colour compared to the Iberian subspecies, and no studies have yet looked into plumage colouration as quality signalling in Asian subspecies of *C. cyanus* males.

It has been suggested that individuals tend to return to former sites where they have had previous reproductive success (Harvey *et al.*, 1979; Paton & Edwards, 1996; Winkler *et al.*, 2004). I did not find any association between an individual breeding successfully the previous year and returning again the next year. However, I had limited data and had to combine both females and males for analysis. The true number of individuals that bred successfully and returned the next year could be higher, considering that individuals from some of the breeding pairs were unbanded.

There seemed to be some changes in social structure in this colony after the major fire in 2009. The *C. cyanus* would always move as a single group in 2009 and 2010, group members always remaining within calling distance. In 2006-2008, birds appeared to primarily use their main breeding area with occasional short excursions in small groups to forage within one kilometre of their breeding area (K-J Wilson, pers. comm.). Furthermore, as mentioned above, in 2010, at least two breeding pairs nested in a different area in the *Padus* Patch, far apart from the rest of the colony, and started nesting one month later than those at the main breeding area. Prior to 2010, all nesting events were in the same area.

4.4 Impact of Environmental Catastrophes on the Khonin Nuga *Cyanopica cyanus*

Cooperative breeding species generally exhibit a variety of distinctive traits, such as extreme philopatry, sensitivity to habitat quality, and the presence of large numbers of non-breeding adults (i.e. helpers). These traits may render such species unusually vulnerable or resistant to habitat loss, degradation, and fragmentation, and to the problems inherent in small populations (Walters *et al.*, 2004). A meta-analysis by the same authors, who assessed the interaction between the distinctive features of cooperative breeders and the various threats to biodiversity, found that cooperative breeding species are not more or less vulnerable to agents of future extinctions (i.e. habitat loss, degradation and fragmentation) than non-cooperative breeding species. However, they did note that cooperative breeding species display unusual dispersal behaviour (i.e. helpers stay at natal place to help parents; the dispersing sex move for only a short distance from their natal site) compared to non-cooperative ones, and this renders some species more susceptible to habitat fragmentation because of disrupted dispersal to suitable habitats.

In 2009/ 2010, Mongolia faced the most severe winter in nearly five decades. Temperatures fell to -50°C and snow covered the ground until May 2010 (FAO, 2006; Mongolia-Web, 2010;

UNICEF, 2010). This event and the fire in May 2009 may have limited food availability to *C. cyanus* (especially breeding birds), and affected the number and condition of birds present for breeding in 2010.

Cyanopica cyanus seems to have a wide range of feeding strata and diet (this study; Hosono, 1966; Canário *et al.*, 2002), and perhaps this may buffer them against environmental stochasticity compared to more specialised feeders. It has been shown that species with narrower niches tend to be more vulnerable to habitat loss/ degradation and thus extinction, compared to habitat generalists (Foufopoulos & Ives, 1999; Owens & Bennett, 2000).

Although *C. cyanus* can breed at the age of one year, as shown by data from this study and data from Japan (Komeda *et al.*, 1987), older and more experienced individuals have higher and are more consistent in reproductive success (Forslund & Pärt, 1995). The study of the Khonin Nuga colony of *Cyanopica cyanus* is not yet long enough to test this idea. Russell & Rowley (1993) discovered a delayed decline in a population of Splendid Fairy-wren after a major fire, due to decreased production of fledglings in the years after the fire (a result of high predation and brood parasitism), and the gradual replacement of experienced females by novices which were less productive and suffered higher mortality themselves.

Corvids in general are long-lived species, most living to more than 10 years of age (Wasser & Sherman, 2010). If the colony has a high proportion of older and more experienced birds, they could to some extent, act as a buffer against 'difficult years' when reproductive output is restricted or hampered by environmental or human-caused catastrophes (Pons *et al.*, 2003). Helpers are also said to dampen the negative effects of poor breeding years, e.g. years with bad environmental conditions (Walters *et al.*, 2004), as shown to happen to *C. cyanus* populations in Khonin Nuga (Gantulga *et al.*, unpublished data) and Iberia (Valencia *et al.*, 2003; Canário *et al.*, 2004).

Compared to other Corvids or cooperative breeding species (see Wasser & Sherman, 2010), the *Cyanopica cyanus*'s lifespan and reproductive output is moderate. At Khonin Nuga, *C. cyanus*'s clutch size is 5.9± 0.21, and breeding pairs raise on average five chicks per season (Gantulga *et al.*, in review) (c.f. Florida Scrub-Jays which lay about 4-5 eggs and raise, on average, two young per pair per year; Woolfenden & Fitzpatrick, 1991). Brown (1987) found that many cooperatively

breeding species have high survival rates, and longevity seems to be a contributing factor to cooperative breeding in the Splendid fairy-wrens (Rowley & Russell, 1990).

The Khonin Nuga *C. cyanus* colony is small –an average of 37 individuals present per year (starting population in May) [cf. 40-60 breeding birds in Spain (de la Cruz, pers. comm.) and up to 287 individuals in Japan (Imanishi, 2002)]. Perhaps with recent colonisation, small numbers are normal (although there was no increase or decrease in colony size over the four years), and data from this study has shown that this is most likely an open population. It would be interesting to see in the near future if numbers and geographic range do increase in the Northern Mongolian *C. cyanus* populations.

4.5 The Fire Situation in Mongolia and the West Khentii Region

As in other developing countries, Mongolia's management of natural resources suffers from unregulated use, overuse, and inadequate protection. There was a revolution in the political, social and economic situation in the 1990s. The cessation of the Soviet era and state-subsidised social services in Mongolia, combined with access to formerly restricted markets, has exposed forests and steppes to threats such as fire, overgrazing, mining activities, improper commercial logging, illegal collection of wood for construction and fuel, hay making in forest steppes, complacency in enforcement of forest rules and regulations, and damage by pests and diseases. Fires, by far, have had the most serious impact on the forests of Mongolia (Bayartaa *et al.*, 2007).

Fires generally occur in spring (March to mid June) and in autumn (September to October) (Bayartaa *et al.*, 2007). The spring fires account for 80 percent of all fires, while the fires in autumn account for five to eight percent. Fires occur during these periods because dry fuel loads are at their highest. In summer, fires are uncommon because this is the time of highest precipitation.

Between 1981 and 1999 there were on average 160 wildfires per year in Mongolia. However the average area burnt in the 1990s was around 4,771,297 hectares per year, compared to one-fifth of that in the 1980s (Goldammer, 2002). From the years 2000 to 2008 the average number of fires per year was 188, and the area burnt was an average of 3,253,000 ha/ year (Johnson *et al.*, 2009). The increase in the number of fires in the last two decades is related to anthropogenic causes. They are mostly accidents, caused by herders, loggers and hunters. Fires can start by carelessness from a campfire, tracer bullets used by hunters to hunt deer, or sparks from vehicle exhaust pipes

(Bayartaa *et al.*, 2007). In Northern Mongolia, large fires have been reported that originated from Russia, which is just north of the border, usually from farmers burning their fields (Johnson *et al.*, 2009).

Fires in the northern part of Mongolia—where it is mountainous and the forests types are dominantly Taiga—can happen naturally from lightning ignitions. The highly flammable Scotch Pine (*Pinus sylvestris*) and Siberian Larch (*Larix sibirica*), combined with shrub undergrowth in some areas presents a huge fuel load. Sometimes, fires in forest-steppe and sub-taiga ecotones are induced by fires from the adjacent steppes, which are more readily and frequently ignited (Valendik *et al.*, 1998).

Preliminary results from Oyunsanaa Byambasuren (Georg-August University, Germany), who did his studies on fire history in the West Khentii region in 2008 and 2009, showed that fire has played a natural part in the taiga forest ecosystem in the last 200 years. However, fire frequencies have increased since the 1930s, and as in the rest of the country, most of them are human-initiated (poster presentation, Oyansanaa B. *et al.*, 2010).

4.6 Fire Prevention and Management in Mongolia

The majority of ecosystems in Mongolia can be termed fire dependent (Johnson *et al.*, 2009) and fires form natural disturbances in this region (Valendik *et al.*, 1998). However, with changing fire regimes and frequencies since the last two decades, a working system must be in place to manage fire appropriately. Currently the Forest Policy Department (FPD), which is under the Ministry of Nature and Environment, is responsible for forest protection and fire policy except within protected areas. The FPD also issues permission for salvage logging or "cleaning" in burned areas (Johnson *et al.*, 2009). This, and the lack of law implementation and enforcement, raises my concern (my personal view), as to whether some people will deliberately set fire to a forest to obtain permits to log a certain area.

The sparse population, combined with limited resources in this vast country makes information transmission slow and presents challenges for fire-detection and fighting. However, in the last two decades, the existing government has re-structured their fire-management infrastructure and increased the use of satellite imagery to help in fire prevention, detection and fighting (Johnson *et al.*, 2009). Mongolia has also received international assistance from Germany, Russia and the United Nations, in terms of technology and knowledge in managing and fighting fires (FAO,

2006). Another international non-profit organisation—The Nature Conservancy, has outlined management plans to help reduce socio-economic damage while maintaining the integrity of ecosystems with appropriate and socially acceptable fire regimes in Mongolia (Johnson *et al.*, 2009, pp. 26-28).

4.7 Conclusions: Implications of this Study in the Light of Global Change

Cyanopica cyanus are still common worldwide, but the social behaviour of the species restricts the breeding population, although *C. cyanus* exhibit facultative helping behaviour (i.e. they only help in some situations). Furthermore, if biodiversity is to be preserved (i.e. not only maintaining the different subspecies, but also special behaviours) then careful management must be in place such that local populations do not go locally extinct and that gene flow in a region is preserved.

Cyanopica cyanus as a species (as with other bird species around the world) faces environmental stochasticity and catastrophes that might be exacerbated by climate change and human causes. Fires will most likely increase in frequency and intensity, and act together with other land-use changes such as habitat loss, degradation and fragmentation, plus other drivers of species loss and extinction such as overexploitation of species, and species invasion (Mooney & Hobbs, 2000). These drivers of change not only affect species worldwide individually, they may also act synergistically and upset trophic webs and ecosystem functions (Brook *et al.*, 2008). Global climate change will further exacerbate these effects as weather patterns become more extreme, variable and unpredictable (Rambal & Hoff, 1998).

Due to insufficient years of study, no conclusions can be made as to whether fire has a positive or negative impact on the habitat use and population dynamics of this colony of *C. cyanus* in the long-term. In the short-term, results did suggest that colony size and survival rates of *C. cyanus* adults were affected after the major fire and severe winter in 2009, and that social structures had changed, with the colony always moving as a group to forage over a comparatively larger area than what it was before the 2009 fire, and nesting over a wider area in 2010. *C. cyanus* seems to be a generalist and an adaptive species, considering its wide range of diet and prolific presence in modified agricultural landscapes. These traits will perhaps make *C. cyanus* more resilient to environment or human-caused catastrophes.

This study provides a baseline for further studies of the lesser-known Asian subspecies of *C. cyanus* in this region. There is still much to be found out about the biology and ecology, especially the cooperative breeding behaviour of this species. To find out more about the population dynamics of any species requires detailed long-term studies, especially if a population is small and suffers from environmental stochasticity and catastrophes.

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Appendix A Datasheet for observation fieldwork

Data sheet, Khonin Nuga Cyanopica study
Location   Date

Time start   Time finish
Group size   overflight   Max seen at once
            Estimate

Tree Sp	*Betula* tree			*Betula* shrubs	*Larix siberica*	*Padius asiatica*	*Salix sp*	Other sp	Ground
	0-2m	2-5m	>5m						
Feeding									
Gleaning									
Snatch									
Perch and pounce									
Probe									
Search									
Hawking									
Preening									
Transit									
Interactions									

Food item	Where taken

Bands recorded

Other notes

Observer:

Appendix B Photos—Life as a Masters Student: Fieldwork in Heaven

Ger—a Mongolian felt tent where all daily activities, such as cooking, sleeping, and socialising are carried out (2010)

All set to go to the Hot Springs. Photo by Khulan Enkhmaa (2010).

Gypsy Moth, Lymantria dispar larvae (left) and adult female (right) (2010)

Juvenile *Cyanopica cyanus*, a few weeks from leaving the nests (2009)

Siberian Chipmunk, *Tamias sibiricus* **(2009)**

Pika (most probably Daurian Pika *Ochotona daurica***), on the Tsangstai Mountains (2009)**

The author coming back from a day in the field. Usual way of crossing rivers in Mongolia. Photo by Heike Böhme (2009)

Author standing next to a germinating *Padus asiatica* shrub killed by the 2009 May fire at the Main Breeding Area. Herbaceous layer was already about waist-height in August 2009 (author is 1.52m). Photo by Kerry-Jayne Wilson

Mixed meadow with scattered *Padus asiatica* shrubs, Kassel area (Photo by Kerry-Jayne Wilson, 2009)

Betula platyphylla **woodland bordering herb meadow,** *Betula* **Woodland area (2009)**

Dense *Padus asiatica* form a 'canopy' with interlinking branches in the *Padus* patch study area (2010).