ABUNDANCE, MOVEMENT AND HABITAT USE OF SWAINSON'S HAWKS IN THEIR WINTERING GROUNDS, ARGENTINA

By

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In dedication to Brian Woodbridge, whose genuine interest on Swainson's hawks drew attention to their conservation in Argentina

and

Maria Elena Zaccagnini, who took the challenge at a national level and invited me to share it with her and other people

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ABUNDANCE, MOVEMENT AND HABITAT USE OF SWAINSON'S HAWKS IN THEIR WINTERING GROUNDS, ARGENTINA

By

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Knowledge of habitat use by a particular species is necessary in developing species conservation plans. Large-scale mortality of Swainson's hawks (*Buteo swainsoni*) in Argentina during austral summer 1995-96 identified the need to address several questions about relationships between hawks and their wintering ground environment. In 1996, an international and interdisciplinary research project involving numerous institutions and agencies was initiated to understand causes of Swainson's hawk mortality and to prevent future mortality events.

A research component addressed questions about the patterns of abundance; movement and habitat use of Swainson's hawks in particular wintering areas. In this study, population abundances, individual movements and habitat use, both at population and individual levels of resolution, were analyzed at a landscape scale in two study areas. These areas were located in La Pampa and Santa Fe provinces of Argentina and the study was conducted in 1996-97 and 1997-98 austral summers. Field methods included systematic surveys, conventional radio tagging of individual hawks and focal observations.

Densities of hawks varied between 4.40 and 5.02 hawks/km2 in La Pampa and 3.51 hawk/km2 in Santa Fe, with high variations in these values through the season. Hawks widely dispersed at regional level (far away from the limits of the study area) and used a defined study area with a random pattern, without constituting tight groups or flocks. Finally, both at population and individual levels, hawks selected permanent pastures (for foraging), plowed fields (for sunbathing/resting and sometimes for foraging) and woodlands (for roosting), but their clustered spatial distribution was not associated with the abundance of these selected habitat types.

These results reflected similarities in the pattern of habitat use with the breeding areas, and they could be expected from adaptations of a migratory raptor to the dynamic changes of heterogeneous agricultural landscapes, especially in relation to food availability. Patterns of habitat use showed a combination of risk factors that made hawks susceptible to pesticide applications in their wintering ground. In addition, values of population abundance found in this study as well as patterns of movement gave a baseline for the development of conservation measures directed to explore and prevent the incidence of agricultural practices, such as pesticide applications and changes in land use, on populations of Swainson's hawks wintering in the Argentinean pampas.

INTRODUCTION

Species-environment interactions have captured the attention of many researchers, both from a theoretical and an applied point of view. From a theoretical perspective, different approaches have been applied to answer questions such as why some animals are in one region and not in other ones and how the process of habitat selection for different activities occurs. From an applied perspective, understanding habitat use patterns and foraging behavior by an animal species has resulted in direct implications for its management and conservation (Morrison et al. 1998, Derrickson et al. 1998, Tella et al. 1998). In particular, understanding these habitat use patterns results specially challenging in the case of migratory birds due to their mobility and, therefore, their exposure to a variety of environments while breeding, wintering and during migration (Cody 1985, Rappole 1995, Morrison et al. 1998). These characteristics make these birds more prone suffer from impacts derived from human activities, especially from agricultural practices given the wide land coverage of these activities in different parts of the globe (Rodenhouse et al.1995).

Among migratory birds, raptors constitute an especially vulnerable group given some behavioral and biological characteristics (Newton 1979). The Swainson's hawk (*Buteo swainsoni*), a Neotropical migratory raptor that breeds in North America and migrates to Argentina for the austral summer, is specially associated to open fields, such as grasslands and agricultural environments, both in its breeding and wintering ranges (England et al. 1997). This behavior makes it remarkably vulnerable to both direct and indirect effects from certain agricultural practices, such as land use changes and pesticide applications. Information on its ecology is crucial in order to understand and reduce these impacts over its whole range.

Although Swainson's hawks' habitat use patterns and general ecology in their breeding areas have been well documented, knowledge on the wintering grounds is scarce and several authors have encouraged research on the topic as a means to gather the necessary information (England et al. 1997, Herkert and Knopf 1998, Kirk and Hyslop 1998). The present study focused on the analysis of patterns of abundance, movement and habitat use patterns by wintering Swainson's hawks in two wintering areas (La Pampa and Santa Fe provinces, Argentina). It was part of a project that started in Argentina in the summer of 1995-96 to understand and prevent massive Swainson's hawk mortalities that occurred as the result of pesticide applications to control grasshopper outbreaks (Zaccagnini et al. 1996). The final goal was to generate information on Swainson's hawk ecology on the wintering grounds in order to reduce potential negative impacts from agricultural practices on wintering populations.

Theoretical Framework

The concept of habitat (a place where an animal species spends considerable amount of time to fulfill ecological requirements necessary for normal life; Bell 1991) establishes a conceptual link between organisms and their environments (Kozakiewicz 1995). In addition, this concept is central to the study of animal ecology and its application in management and conservation (Johnson 1980, Morrison et al 1998). It is generally assumed that individual organisms are able to evaluate and select a particular habitat that would best enhance their fitness (Hildén 1965, Rosenzweig 1985). Therefore, the selection of a proper habitat would be determinant for survival and reproduction (Klopfer and Ganzhorn 1985) and would have direct implications for conservation and management strategies (Derrickson et al. 1998, Tella et al. 1998).

Migratory birds present special challenges for understanding habitat use patterns and their application to management and conservation strategies. Bird migration constitutes a magnificent seasonal shift of birds twice a year between breeding and wintering ranges (Newton 1979). This complex movement is a product of natural selection that allows individuals to survive and breed most effectively, taking advantage of different habitats according to life history requirements and seasonal environmental changes (Newton 1979, Alerstam 1990, Moore et al. 1995). But this dependence on multiple habitats in different regions at different times during the annual cycle makes them particularly vulnerable to the impact of human activities (Rappole 1995).

Although many factors interact to produce migratory movements and use of the space, birds would primarily respond to variations in food supplies, developing different strategies and migratory patterns in order to respond to these variations (Newton 1979, Dingle 1980, Alerstam 1990). Movement patterns would differ widely within and among species, populations, individuals and section of the migratory journey (Dingle 1980). There exist birds that undertake long-distance migration (e.g., between or within temperate zones), short-distance migrations (few miles between seasonally changing habitats) or altitudinal migrations (both at temperate and tropical regions). Some migrants have a nomadic life as a response to temporary and local food surpluses (such as migrating locusts, swarming insects, local fruit and flower explosions, etc.). However, some other migratory species establish territories throughout the winter months, a strategy only possible in stable environments, when the food supply is reliable (Alerstam 1990, Rappole 1995).

Migration can be seen as an adaptation to food supply, and foraging behaviors would not only influence patterns of movement, but also patterns of abundance and habitat use by migratory birds, specially when wintering (non-breeding season; Sherry and Holmes 1995). These birds would concentrate where resources are maximum, possibly involving a wide range of movements even within a season. Population abundances would strongly vary as result of temporal and spatial variations in environmental conditions at specific sites (Rotenberry et al. 1995). These variations would be manifested in time, among years, seasons or within a season, and in space, in different regions and areas within regions. For example, insectivorous migrant birds would respond numerically (changes in density) to a palatable insect outbreak. Also, climatic variations can influence migratory bird populations directly (e.g., hurricanes, drought) or indirectly by modifying insect availability (e.g., association between prolonged drought and insect outbreaks-relationship between rainfall and food supply). These fluctuations can account for strong fluctuations on bird populations at different sites and even in a given habitat type (Alerstam 1990, Petit et al. 1995, Rotenberry et al. 1995).

On the other hand, the tracking of superabundant food sources would also influence patterns of habitat selection by wintering birds, although hypotheses including competition with resident species and similarity of habitats used both in winter and breeding seasons have been proposed (Petit et al. 1995, Moore et al. 1995). These patterns of habitat use will be simultaneously determined by extrinsic factors, like weather and evolutionary forces, and by intrinsic factors, like habitat quality (given by food abundance and vegetation structure; Hutto 1985). Extrinsic factors would be more important at broad scales (e.g., regional level) while intrinsic factors would be more important at smaller scales (Hutto 1985, Moore et al. 1995). In any case, migratory birds would face a series of hierarchical decisions that would usually imply more plasticity in their ability to use different habitats or foods compared, for example, to resident birds (Klopfer and Ganzhorn 1985, Hutto 1985, Freemark et al. 1995). And this plasticity in the use of different habitat types by migratory birds (especially while wintering) is reflected on the selective occupancy of seasonal or disturbed habitats characterized by inherent structural complexity, variability and continuous change (Terborgh 1980, Moore et al. 1995, Petit et al. 1995, Sherry and Holmes 1995).

By taking advantage of seasonally changing environments across an array of latitudes, migratory birds make opportunistic use of these seasonal environments, and they could be considered as ecological opportunists (Alerstam 1990, Sherry and Holmes 1995). However, there exist individual unique patterns among different species and, in some circumstances or times in the life cycle (e.g., while breeding), migratory birds could behave as habitat specialists. Therefore, general patterns of habitat use should be taken with caution and analyzed in a case-by-case basis.

Even so, by the very act of migration and migratory life history traits, migratory birds are favored by seasonally changing environments, being especially adaptable to human-modified environments such as agricultural systems. The general opportunistic use of disturbed habitats in winter could explain the abundance and common presence of wintering migrants in human-modified habitats (Sherry and Holmes 1995). In particular, they are highly associated with agricultural areas and, in some cases they represent the majority of bird species using farmlands (Sherry and Holmes 1995, Rodenhouse et al.1995, Freemark et al. 1995).

Although some migratory species have benefited by structural changes produced by agriculture (e.g., through the increased availability of grains), many species have experienced declines and extinction associated with agriculture (Rodenhouse et al. 1993, 1995). Impacts of agriculture on migratory birds include direct effects, such as destruction of nests, harm to individuals or direct exposure to toxic chemicals and indirect effects, such as changes of food supplies or habitat abundance and distribution through habitat loss and fragmentation. Partial causes of declines in migratory species, especially those associated with perennial and deciduous forests, have been associated to changes in land properties and uses caused by agriculture (Rappole 1995). Even migratory species adapted to open habitats (such as the Dickcissel (*Spiza americana*) and Bobolink (*Dolichonyx oryzivorus*)) that could benefit from the replacement of forest habitats by agriculture have shown a decrease in population abundance. In addition, the loss of native grasslands and the disturbance in agricultural lands have influenced population declines of some grassland birds that undertake migrations and over-winter in grasslands or other open habitats (Cody 1985, Herkert and Knoff 1998).

Conservation Strategies

Migratory birds require specialized conservation strategies due to their extensive spatial needs (Terborgh 1980). For example, Mora (1997) discussed the real magnitude of "transboundary pollution" for Neotropical[•] migratory birds through the contamination with pesticides in Latin America and its effect in the breeding areas of North America. Therefore, conservation strategies for migratory birds have required the development of a global and comprehensive approach (Terborgh 1992, Roca et al. 1996, Brawn et al. 1998). These conservation strategies are founded in a sound scientific understanding of their ecology (population structure, demography and habitat use) and evolution (Sherry and Holmes 1995).

Knowledge concerning the non-breeding period of the life cycle is central to an understanding of migrant biology and conservation (Rappole 1995). While some authors have identified the importance of the over-wintering period (see Sherry and Holmes1995), there remains a critical lack of knowledge about many aspects of the ecology of most migrant species, particularly for Neotropical migrants in their wintering areas (Rodenhouse et al. 1995). Patterns of abundance, movement and habitat use of Neotropical migrants during periods spent away from the breeding areas are poorly understood, limiting the capacity to understand the way over-wintering migratory birds use different environments and analyze management alternatives for them (Rappole 1995). Facing this lack of knowledge, different authors have emphasized the importance of research on migrant wintering grounds, where they can be exposed to different situations/impacts than in the breeding areas (Herkert and Knopf 1998, Kirk and Hyslop 1998).

[•] Neotropical Migratory Birds: birds breeding in North America and migrating to wintering grounds south of the United States (Rappole 1995, Martin and Finch 1995).

The Swainson's Hawk

Almost all raptors perform some kind of migratory movement that, in addition to biological characteristics, increases their susceptibility to a variety of human-activity impacts (Newton 1979). Although only a small portion of raptors are long-distance migrants (Alerstam 1990), nearly every raptor species performs some kind of migratory movement in at least part of its ranges, with a broad diversity of patterns. In all the cases, movement patterns are broadly associated with variations in feeding conditions (Newton 1979). The appearance or disappearance of a species in a given locality often closely fits with local conditions, and year-to-year fluctuations in population abundances, movement and location of wintering areas are usually great in relation to prey (Alerstam 1990, Newton 1979). Migratory raptors are much more concentrated in winter than in summer (as a result of movement southward). They usually reduce the competition with resident species by moving around in relation to local flushes of food or variations in the occupation of different habitat types. Raptors, however, are very sensitive to human-induced environmental transformations (e.g., habitat fragmentation) and pesticide applications because of their trophic level and slow reproductive rates (Newton 1979, Alerstam 1990, Tella et al. 1998).

The Swainson’s hawk (*Buteo swainsoni*) is a Neotropical migratory raptor that breeds in North America and migrates to Central and South America during the northern winter, in a trip of about 10,000 km each way (second in distance among raptors; England et al. 1997, Fuller et al. 1998; Figure 1). It is a diurnal raptor of medium size (48-51 cm/693-936 g (male), 51-55 cm/937-1367 g (female)), wide pointed wings and long tail, being well adapted for soaring (England et al. 1997). Adults present plumage variations with three distinct phases (light, reddish or “erytrhistic”, and dark) without differentiation between sexes. Juveniles have a distinct streaking plumage (Mouchard 1996).

Its breeding distribution encompasses all of western North America, from Alaska to Mexico, including Alberta, Saskatchewan, Manitoba (Canada), Washington, Oregon, California, Nebraska, Kansas, Oklahoma and Texas (USA), and Sonora, Durango and Coahuila (Mexico; Mouchard 1996, England et al. 1997). Wintering grounds are principally located in Argentina (central provinces) and, to a lesser extent, the south of Brazil, Paraguay, Uruguay, Colombia, some places in Central (Costa Rica, Panama) and North America (Mexico, California, Florida; Mouchard 1996, England et al. 1997).

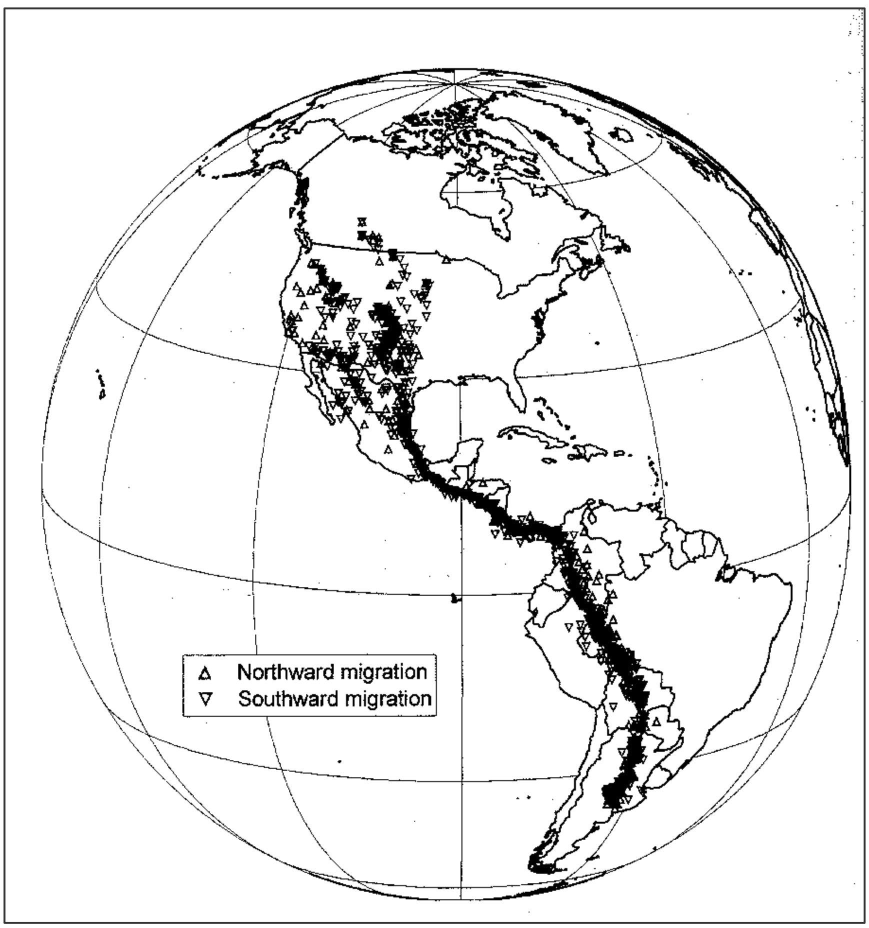


Figure 1. Swainson's hawk's migration path (reproduced with authorization from Fuller et al. 1998).

While breeding, hawks widely disperse over the whole breeding range, but while wintering, they usually concentrate in massive aggregations. Depending on the breeding areas, it is possible to find a pair of Swainson's hawks every 3-17 km2 (or lower, depending on the area) defending a territory (England et al. 1997). But while wintering, massive aggregations that could include 2000 to 12000 individuals in a single roost or 1000-4000 individuals in a foraging group with no evidences of territoriality (Woodbridge et al. 1995, Goldstein 1997, this study).

Both in its breeding and wintering areas, the hawk is highly associated with open fields, usually grasslands, and it has adapted well to environments with a high component of agriculture (Schmutz 1989, Mouchard 1996, England et al. 1997). In North America, it is a summer inhabitant of western grasslands (Clark and Wheeler 1987), and it is seen where open woods of oak, conifers, and riparian forests integrated with open fields (Mouchard 1996; England et al. 1997). Pastures (such as alfalfa, fallow fields, natural fields, hay fields and dry pastures) are selected foraging habitats (Estep 1989, Babcock 1995, Swalloow 1995) while crops are used when vegetation structure, modified by agricultural practices, allows hawks to forage (Bloom 1980, England et al. 1997). In their wintering grounds, Swainson's hawks forage over grasslands, natural and artificial pastures and harvested fields (Mouchard 1996, England et al. 1997), but they also use crops (sunflower, corn and soybean) and plowed fields (this study).

Swainson's hawk could be considered a generalist and opportunistic predator, with a varied diet that includes the more available items of appropriate size in each season, showing strong seasonal differences in diet (Schmutz 1989, Mouchard 1996). In the breeding areas, they usually consume vertebrates, principally small mammals, and occasionally insects (Bechard 1982, Schmutz 1989, Estep 1989, Woodbridge 1991). However, in the wintering grounds insects (grasshoppers, dragonflies and coleopterans) are the most common items in the diet (C. Olrog in Smith 1980, Mouchard 1996; England et al. 1997). This species hunts principally from the air, soaring in open areas, but also hunts from perches (such as poles, tree limbs or elevated ground) or on the ground (England et al. 1997). They often follow tractors and other farm machinery, capturing disturbed rodents or insects (Clark and Wheeler 1987). When breeding they forage as solitary birds, while wintering they hunt communally (England et al. 1997, this study).

Conservation Status

As a grassland raptor and Neotropical migrant, several conservation concerns arise for Swainson's hawk. Although the hawk is neither globally endangered nor suffering a general population decline or threat of extinction (England et al. 1997), population declines have been reported in California, Oregon and Nevada (England et al. 1997; Bloom 1980). It has been listed as Species of Special Concern in Utah, Nevada, Oregon and Washington (England et al. 1997). From 1983, it has been listed as Threatened by the state of California under the California Endangered Species Act (CFGC, 1998; Estep, pers.com.).

The principal reasons for population decreases have been related to habitat loss (due to agricultural and urban advance, agricultural conversion of native grasslands, conversion of riparian habitats, fire suppression), prey declines and pesticide contamination (Estep 1989, England et al. 1997). Eggshell thinning and organochlorine residues in eggs have not caused population declines (England et al. 1997). Nevertheless, acute toxicity from organophosphate insecticides has been responsible for massive mortalities in their wintering grounds (Argentina) during recent years (Woodbridge et al. 1995; Goldstein et al. 1996, Goldstein 1997, Goldstein et al. 1999), and it has been indicated as the principal cause of recent declines (Kirk and Hyslop 1998).

Massive Mortalities in Argentina

In the summer of 1994-95, Woodbridge et al. (1995) communicated the finding of massive Swainson’s hawk mortalities in the southern extreme of its wintering grounds (Argentina). In the following austral summer (1995-96), massive mortalities were recorded in different areas in La Pampa, Buenos Aires and Córdoba provinces, Argentina (Canavelli y Zaccagnini 1996, Goldstein et al. 1996). The ingestion of grasshoppers treated with an organophosphate pesticide, Monocrotophos, was the reason for massive hawk mortalities, estimated at approximately 5 % of the world population when extrapolated to the hawks' distribution area (assuming 513,000 individuals as the world population; Goldstein 1997, Goldstein et al. 1999).

The magnitude of these mortalities constituted an international alarm about the conservation of this species and the necessity of studies developed in its wintering grounds (Roca et al. 1996, Herkert and Knopf 1998, Kirk and Hyslop 1998). An international strategy of transboundary partnership (Roca et al. 1996) was developed intending to avoid new mortalities and involved national and local governmental and non-governmental institutions from Argentina, United States and Canada. With the cooperation of the North American, Canadian and Argentinean governments and several national and local non-governmental institutions, in the summer of 1995- 96 a project was initiated to determine the reason for the mortalities and to prevent future incidents (Zaccagnini et al. 1996). It was the first project developed in the country that integrated different disciplines and institutions to analyze the impact of agricultural practices on wildlife in agroecosystems (Panigatti and Zaccagnini, pers.com.).

In addition to ecotoxicolocogical studies that were involved (Goldstein 1997), there were questions about the use that Swainson’s hawks made of the environment while wintering in Argentina. Although its biology and ecology had been widely studied in North America, information on the hawk's ecology in their wintering grounds was scarce and mainly referred to occasional observations (White el al. 1989, Jaramillo 1993, Woodbridge et al. 1995, Goldstein 1997). Therefore, research questions included in the project were oriented to understand and prevent new mortalities by investigating the usual abundance of hawks in specific wintering areas and its variations during the season, the characteristics of local movements by hawks in specific areas and, specially, the habitats they select for landing and foraging on the ground.

Study Goal and Objectives

The purpose of this study was to investigate patterns of abundance, local movement, and habitat use by Swainson’s hawks on their wintering grounds, Argentina. Emphasis was placed on the analysis of habitat use patterns in specific wintering areas (La Pampa (35° 15' S, 63° 53' W) and Santa Fe (31° 50' S, 61° 57' W) provinces), but complementary observations on local movement and abundance were made in order to facilitate a broader understanding of the use hawk’s made from wintering environments. The ultimate goal was to obtain basic ecological information about this species in the wintering grounds that would allow the analysis of applied means for altering agricultural practices to reduce mass mortality incidents or other possible impacts derived from agricultural practices (such as land use changes). This information would provide guidance for the implementation of a conservation program for this species in Argentina.

The analysis of habitat use conducted from a hierarchical approach (habitat selection as a hierarchical decision-making process) has shown to be most appropriate for establishing reliable conclusions about habitat use in different vertebrates (Johnson 1980, Allen and Starr 1982, Morris 1984, 1987, Hutto 1985, Wiens 1989) and essential to the development of conservation strategies for birds (Freemark et al. 1995, Marzluff and Sallabanks 1998, Villard et al. 1998). As a migratory bird on its wintering grounds, Swainson's hawks could be expected to evaluate the relative profitability of different patches (resource tracking) as an evolutionary response to resource variability and unpredictability (Cody 1985, Hutto 1985). This behavioral flexibility (Klopfer and Ganzhorn 1985) would be detected at different scales, with extrinsic factors to the habitat, like weather and evolutionary forces, acting at higher levels (e.g., regional scale) and intrinsic factors of the habitat itself, like habitat quality (given by food abundance and vegetation structure) acting at lower levels (e.g., plot scale; Hutto 1985).

This study will focus on the analysis of abundance, movement and habitat use patterns at landscape level (defined in the order of 1-1000 km2) and two levels of resolution (populations and individuals). A mosaic of habitat patches (i.e., various agricultural crops and pastures) characterizes the wintering grounds landscape. At this scale, it is expected that hawks would need to define which habitats (plots) to use, where certain habitats might be used only in certain circumstances. For example, crop plots might be used after plowing or cutting, or foraging plots located with respect to certain vegetation features (e.g., proximity to the roosts). Therefore, it is possible to expect a wide distribution of hawks tracking different available resources across the landscape and wide variations on hawk's abundance (Newton 1979, Cody 1985, Hutto 1985, Alerstam 1990). However, as food acquisition will directly influence the use of space (Hutto 1985), it is expected that birds will not use habitats to forage in direct proportion of their availability in the area. The availability of suitable habitat types for foraging and the occurrence of insect outbreaks would determine movements within and among areas within the season, possibly following those outbreaks (Smith 1980). As Woodbridge (1991) found, Swainson's hawks can closely track temporal changes in habitat structure and prey availability. This is especially verifiable if the prey abundance and/or availability is unevenly distributed with respect to the different habitat types (Janes 1985, prey-related habitat selection).

Particular objectives for this study will be as follow:

1. To analyze hawks population abundance in defined wintering areas and its variation in time;
2. To describe patterns of movement by individual hawks at local level;
3. To describe individual patterns of activity and habitat use during the day;
4. To analyze habitat selection patterns (use vs. availability) by hawks sharing specific wintering areas; and
5. To analyze spatial distribution of hawks within the wintering areas in relation to habitat characteristics (quantity).

STUDY AREAS AND METHODS

Study Areas

It was originally planned to conduct two field seasons of study (austral summers 1996-97 and 1997-98) in the northeastern portion of La Pampa province, Argentina (Figure 2.), the place where most of the mortality events occurred in previous years

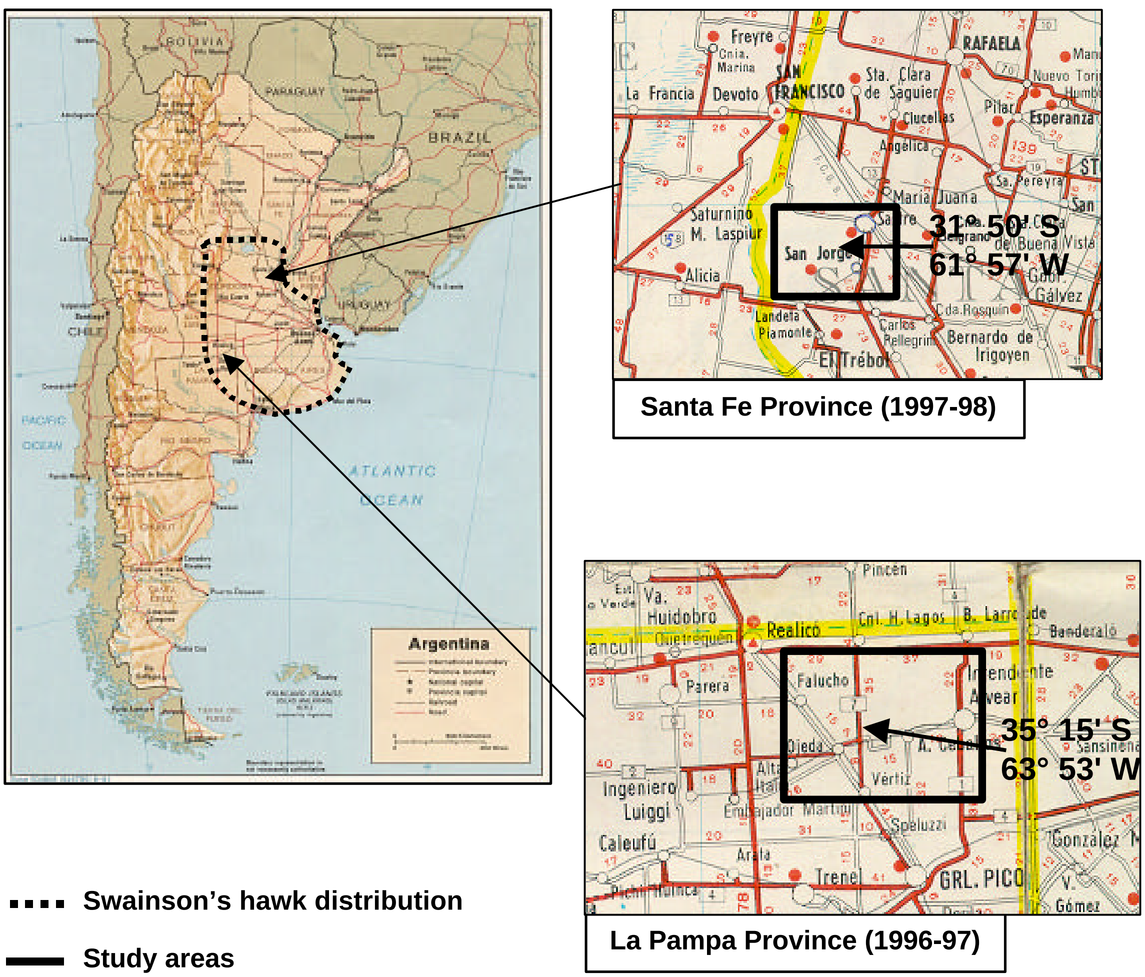


Figure 2. Swainson's hawk distribution in Argentina (from CIPA 1987) and location of the study areas.

(Goldstein 1997). However, the occurrence of El Niño in 1997-98 austral summer resulted in record flooding on the original area, with rainfall in the order of 2.5-4.0 times over the normal for the region (Figure 3). During a preliminary field trip between 15 and 20 December 1997, only isolated or small groups of Swainson's hawks were observed in the study area (total=15 hawks in 6 sporadic observations on the whole study area). Based on the information from satellite radio-tagged hawks for the same and previous summer (Fuller et al., in prep.), a new study area was selected on the central-west portion of Santa Fe province, Argentina, 380 km away from the first study area (Figure 2). This area was complementary to other areas being surveyed by other groups of observers during that summer (1997-98; Canavelli et al. 1998).

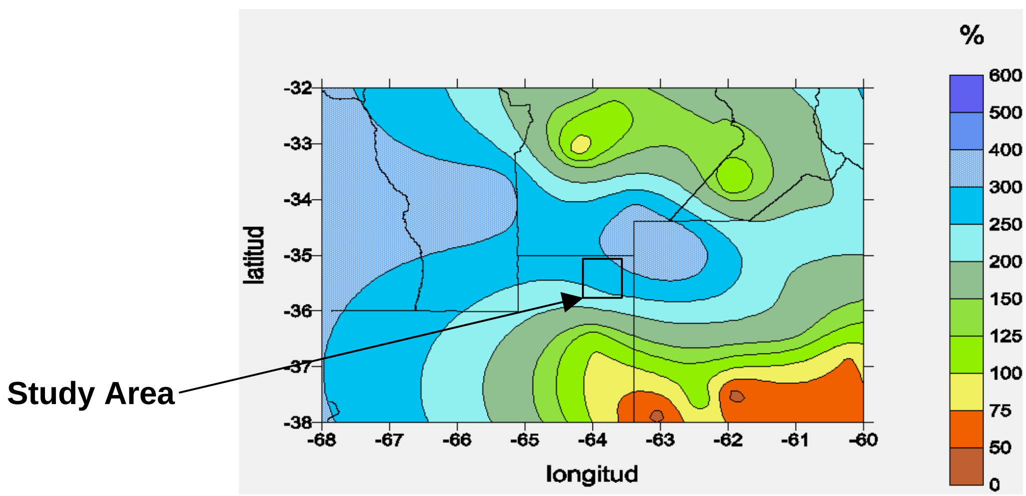


Figure 3. Rainfall anomalies in La Pampa province (1997-98) expressed in percentage (100% = normal, >100%=positive anomaly, <100%=negative anomaly). December, 1997. Series 1961-1990. (Rodríguez, unpublished).

La Pampa, Argentina. Between 28 November 1996 and 16 March 1997, the work was conducted in the northeastern portion of La Pampa province, Argentina. A 2250 km2 (50 km x 45 km) area was delimited around the principal roost at "Chanilao" ranch (35° 14' S, 63° 56' W). The area included places where several mass mortality events occurred the previous austral summer season (Goldstein 1997), allowed the evaluation of dispersal by twenty-two Swainson's hawks that were radio-tagged at this roost (see page 23) and it had the adequate size to be covered during one survey day in order to minimize double counting of hawks for estimation of population abundances. The area is included in the Occidental Pampas District (Cabrera 1976), which is characterized by a predominant sandy soil and frequent old and new dunes. General climatic characteristics are low rainfall and high temperatures. Mean annual temperature is 16°C and annual precipitation range between 600-700 mm (Casagrande et al. 1980). Natural habitats are principally grasslands of *Poa* spp. and *Stipa* spp. (Cabrera 1976) but they are being almost totally being replaced by agricultural and livestock production. Presently, croplands, low grasslands, open seasonal woodlands and salty grasslands (Casagrande et al. 1980) characterize the area. Livestock activities are principally developed on perennial pastures based in alfalfa, in addition to salty lowlands with natural species and *Agropiro* spp. Summer crops are: sunflower, corn, sorghum, millet and soybean. Winter crops are: oat, barley, rye and wheat. Remaining patches of natural woodlands are constituted by "caldenal" (*Prosopis caldenia*). Most of woodlands consist of *Eucalyptus* spp. or other introduced species.

Santa Fe, Argentina. Between 7 January 1997 and 14 March 1998, the work was conducted in the central portion of Santa Fe province, Argentina, on the border with Córdoba province (Figure 2). As only one group of two people was available this time, the study area was reduced to 900 km2 (45x20km). This area is included in the wide ecotone between the Espinal and the northern Pampas vegetative provinces (Cabrera 1976), which is characterized by predominant loess to sandy soil and slightly undulated plains. General climatic characteristics are higher rainfall and temperatures than in La Pampa, with precipitation concentrated in spring and summer. Mean annual temperature is 17°C and annual precipitation ranges between 800-900 mm (Cabrera 1976). The area has been devoted for many years to agriculture, and natural habitats have been almost totally transformed (Cabrera 1976). Presently, the area is dominated (74%) by continuous croplands, with soybeans as the principal crop. Other crops of minor importance are wheat and corn. Implanted pastures and remaining natural fields (especially in lowlands) occupied the remaining 26% of the surface, dedicated to livestock and milk production (Peirone, pers.com.). Remaining patches of natural woodlands are constituted by "algarrobo" (*Prosopis nigra, P.alba*) and other natural species such as "tala"(*Celtis spinosa*), "chañar"(*Geoffroea decorticans*) y "espinillo" (*Acacia caven*) (Cabrera, 1976). As in La Pampa, most of woodlands consist of *Eucalyptus* spp. and other introduced species.

Methods

Abundance of Hawks

Observational surveys were conducted in La Pampa and Santa Fe study areas in 1996-97 and 1997-98 austral summers, respectively, to estimate population abundance of Swainson's hawks. Variations in abundance within each area through the season were analyzed from the information generated in these surveys.

Data collection

La Pampa study area: Between 21 December 1996 and 16 March 1997, 22 systematic surveys were conducted every 3-4 days along roadways regularly spread over the study area. Two methodologies were experimented in an effort to find the most suitable method for sampling hawks abundance in conjunction with habitat use. Between 21-30 December 1996, 3 surveys were conducted using the strip transect method (Fuller and Mosher 1987) with a bandwidth of 300 m on each side. One group of two people moving in a truck at 40-60 km/h conducted the surveys, during the morning (0600-1200 H, n=1) or in the afternoon (1400-2000 H, n=2). All hawks detected during the survey were recorded on data sheets, specifying general weather conditions (cloudiness and wind in qualitative categories), observation time, observation place (using the truck odometer), number of hawks (counted if they were individual hawks or small groups, estimated otherwise), location (inside/outside the strip transect), habitat (crops and annual pastures- corn, sunflower, wheat, sorghum, millet, permanent pastures-alfalfa, natural pastures, weedy fields-; plowed field and woodland), behavior (in the air-soaring, active flight-, on the ground- on fields, on fence posts, on trees, on electric light posts), activity (feeding in the air, feeding on the ground, preening, resting/sunbathing), observers and any other observation considered as relevant to the study.

Between 31 December 1996 and 9 January 1997, the survey effort was duplicated including one more group of two people moving in a truck, covering the whole area on strip transects only during the afternoon (1400 and 2100 H). The starting point for transects was randomly selected each day as well as the group responsible for conducting each transect. Strip band was reduced to 400 m (200 m on each side of the road) in order to improve the estimations of bird abundance for birds on the ground. Five surveys were conducted using this methodology.

Finally, in 11 January 1997, the methodology was standardized establishing 6- 45 km long transects regularly spaced every 10 km (Figure 4). Strip transects were replaced by point transects, with 10 fixed stations spaced at 5 km intervals (Woodbridge 1995). At each station, Swainson's hawks were counted during a 5 min period, recording the same type of information than for strip transects except than, at each station, distances to the hawks from the observer were estimated in ranges of 10 m (for the first 50 m), 50 m (for the next 450 m), 100 m (for the next 500 m), and 500 m (for distances greater than 1000 m). These ranges were based on visibility conditions in the field and training of observers. Observations made while driving between stations were kept as separated records. Driving speed between stations varied between 40 km/hr on secondary routes (n=4) and 60 km/hr on the principal routes (n=2), and counts were discontinued if it was raining.

Two simultaneous groups covered a total of 370 km/day, each group covering 3 transects/day in two time blocks (morning: 0600-1200 H and afternoon: 1400-2000 H). Each week, the starting point/transect for the survey was randomly assigned in a way each transect was equivalently covered on different time periods (morning, midday and afternoon), in order to diminish the influence of time of the day on the counts (Watson et al. 1996). In addition, transects were randomly assigned to each group each survey day in order to diminish observer bias on different areas. A total of 14 surveys were conducted using this methodology.

<u>Santa Fe study area</u>: between January 7 and March 14, 1998, 21 systematic surveys were conducted on Santa Fe study area every 3-4 days, along roadways. Point transects were employed during the surveys, recording all the information that was described for point transects in the previous section. As only one group of two people

was available this time, only 3- 45 km transects with 10 stations every 5 km per transect were used, spread every 10 km (Figure 5).

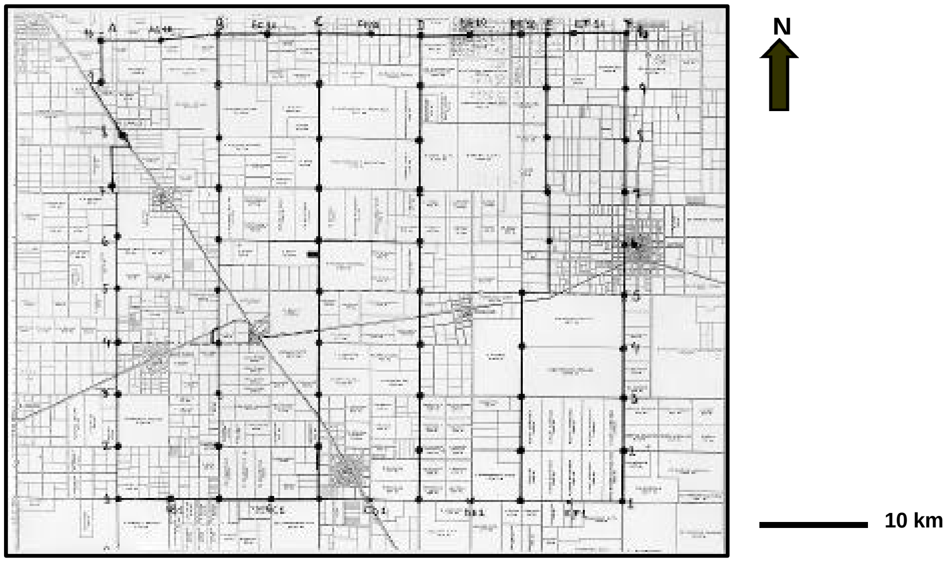


Figure 4. Survey design on La Pampa study area (austral summer 1996-97).

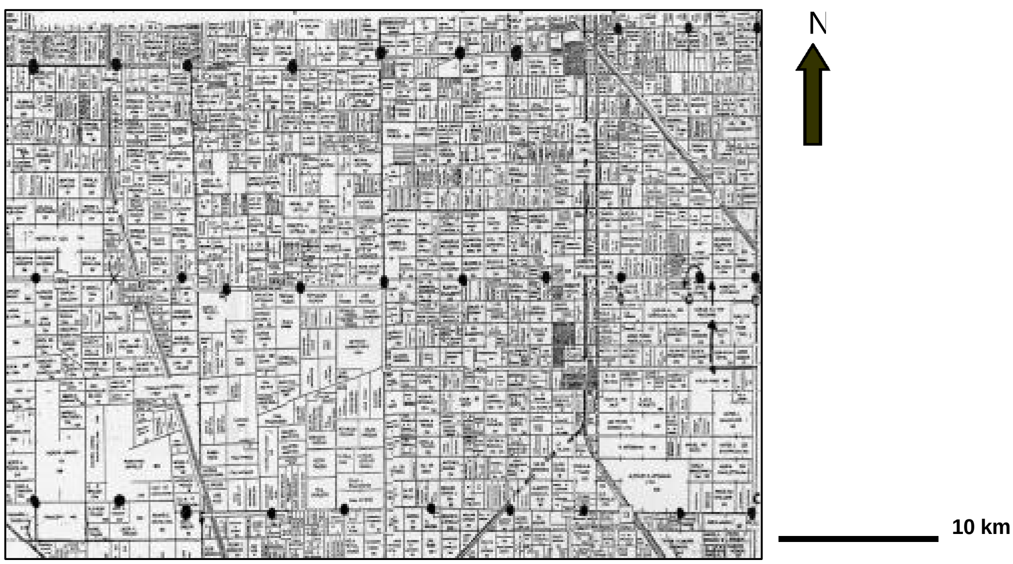


Figure 5. Survey design on Santa Fe study area (austral summer 1997-98).

Data analysis

Population abundance was analyzed through the estimation of hawk's density on each area using the program DISTANCE (Version 3.5, Release 5, RUWPA, University of

St. Andrews, Scotland). This method was selected because it corrects the estimation of density and total abundance considering counts and detectability function (Buckland et al. 1993). Only observations with hawks on the ground were included in the analysis of density. Strip transects used in La Pampa were separately analyzed from point transects, and for point transects, only information originated on the points (not on the trip between points) was analyzed and included in the results.

The lower number of hawks observed on the ground precluded the analysis of temporal changes during the season using DISTANCE. In order to analyze the variations on hawks abundance in each study area through the season, hawk's density on the surveyed area was estimated for each survey day dividing the number of hawks estimated in the surveyed area (both soaring and on the ground) by the surveyed area (estimated by adding the area of 2.5 km radius fixed-distance points, this is half of the distance between successive points). In this case, it was assumed an equal detectability on different habitat types and distances from the point. Although habitats in the pampas are widely open and detectability of hawks extended for long distances, these are very strong assumptions, and density estimations were used only for comparative purposes (not as indication of true densities). Densities estimated from different survey days were linearly correlated to maximum and minimum temperature and rainfall using PROC CORR (SAS System for Windows, v6.12) in order to explore the influence of weather as one of the factors producing changes in the abundance of hawks through the season on each area.

Movement of Individual Hawks

Original plans were to use radio-tagged hawks to describe individual movement patterns and habitat use. This was tried during the first sampling period in La Pampa study area, in 1996-97 austral summer. However, the hawks' mobility, wide range of movement and pattern of activities during the day, made it extremely difficult to find and follow individual radio tagged hawks. Therefore, it was decided to obtain information on the spatial use of the area using the presence of radio tagged hawks in the study area during the survey days, and to obtain information on individual patterns of habitat use through focal observations (see page 30).

Data collection

Hawks capture and radio-tagging: Twenty-two Swainson's hawks were captured in the vicinity of "Chanilao" Ranch (Hilario Lagos, La Pampa, Argentina, 35 14' S, 63 56' W) between 28 November and 2 December 1996. This ranch has the biggest roost in the study area, a 10 ha woodland of *Eucalyptus* sp, that was traditionally and permanently occupied by Swainson's hawks during the summer season. In addition, it was located at approximately the center of the monitoring area. The capture method is described in detail by Goldstein (1997, page 76-78), and it consisted in the use of box type bal-chatri live-traps constructed with one-half inch hardware cloth (Berger and Mueller 1959; Bloom 1987). Traps included nooses made with fishing line evenly spaced over the traps. Lures consisted in two mice (*Mus musculus*), two house sparrows (*Passer domesticus*), or a combination of one mouse and one house sparrow (Bloom 1987). Hawks were captured in the morning (0500 H), after the birds left the roost to forage and rest in an adjacent agricultural field.

For the purpose of this study, hawks were differentiated by age (adults and juveniles) based on plumage characteristics (Wheeler and Clark 1995) and by sex based on differential weight and comparative body size (Bloom, pers.com.). Radios were attached to the hawks using a harness-mounted backpack (Brander 1968, Dunstan 1972) supported by Teflon ribbons. Radios (Model: BT-3) were provided by Communications Specialist Inc. (California, USA). Radios weighted 25 g each and had an expected battery life of 180 days. Frequencies varied between 216.005 MHz and 216.525 MHz. Birds were located using a 3-element, hand-held Yagi antenna and, in some cases, an omni directional antenna was used for general search in the area (from a moving vehicle) or for confirmation of roost signals. Transmitter reception distances were about 4-5 km for hawks on the ground, 20-25 km for hawks on the roosts, and 30-40 km for soaring birds.

Estimation of animal locations: Radio tracking was first attempted by homing-in on the animal (White and Garrott 1991, page 42) circling the signals with stops every 5-10 minutes in order to make visual contact with each individual or, at least, to keep close track of the signal. Reference points were taken based on the truck's odometer reading and were later assigned Universal Transverse Mercator (UTM) coordinates in a satellite image. However, due to the difficulty in sighting and following the tagged hawks, the method was changed and readings were taken at systematic stops in the study area, usually during the surveys previously described (see pages 19-22). This method allowed the determination of presence/absence of the birds in the area and, when possible, triangulation to obtain probable locations for the hawks.

As it happened with observational surveys, a period of adjustment in the methodology took place before a standard methodology for surveys was adopted by 11 January 1997. Between 4 and 21 December 1996, date in which a defined study area was established for surveys, variable areas around the main roost were covered in 8 surveys conducted only to search for radio-tagged hawks. After 21 December 1996, the surveys used for estimation of population abundance and habitat use were used to also estimate detect radio-tagged hawks in the study area. Adjustments were made in distance between successive stops (20, 10 and 5 kms) and time of the day for making the survey (whole day, 0600 - 2000 H, or in the afternoon, 1400-2000 H). Finally, in 11 January 1997, surveys were standardized using six 45-km survey routes spaced every 10 km covered by two simultaneous groups in two time blocks (morning: 0600-1200 H and afternoon: 1400-2000 H). Fixed stop points were placed every 5 km for an optimum coverage of the study area. Surveys continued through 16 March 1997, when it was determined that all tagged hawks had left the study area.

In all the cases, two people driving a truck constituted the groups conducting surveys. The person that checked for radio-tagged hawks was the same for the whole season. At each survey stop, this person checked for radio signals using the Yagi antenna on horizontal and vertical planes. Hawks flying or soaring were more easily detected with horizontal antenna while birds on the ground or on trees were detected with the antenna in vertical position (Kenward 1987). Bearings were taken based on the signal strength and the angles of the signals were determined with respect to a true north using a compass.

Survey points were geo-referenced using a Global Position System (GPS) unit (Magellan Systems Corporation, GPS Nav DLX-10). References were taken in Lat/Lon units and then converted to UTM units (Idrisi for Windows, v.2.008, Clark University, 1998) in order to triangulate and determine birds' locations. Due to the differences in time between locations, high probabilities of bird movement between locations, different behaviors and range distance at different times, and the variation in distances of detection, error polygons were expected to be large (Kenward 1987; White and Garrott

1990). Nevertheless, hawk locations were estimated using the Best Biangulation method (LOAS 2000, Location of a signal, version 1.0. Ecological Software Solutions, Sacramento, California) in order to have indicators of movement for individual analyses. This Biangulation method only considers locations given by 2 bearings whose angle is closest to 90 degrees ("the best angle").

In addition to information on hawk locations in the study area, the presence/absence of radio-tagged hawks at the main roost where they were marked was analyzed in order to characterize roost use by the Swainson's hawks. This roost was the biggest one in the area and permanently had Swainson's hawks roosting there during the study period. Radio-checks were made late at night (after 2100 H) or early in the morning (0500-0600 H).

Hawks were progressively leaving the study area. Therefore, a trip was conducted to the north of the study area between 25 February and 3 March 1997, in an attempt to locate dispersing hawks and to complement the information about movement by individual birds. The trip covered the southern part of Cordoba Province, between 80 and 400 km north of the study area. Principal routes were covered by a group of two people in a truck and stops were made every 20 km. Stop points were geo-referenced using a GPS unit and complemented with odometer readings. Bearings to tagged hawks were taken as in previously described.

Data analysis

All the adjustments of methods resulted in a varying degree of area covered during a specific survey. Although 22 systematic surveys conducted between 21 December 1996 and 16 March 1997 covered the whole area, only the surveys between 21 December 1996 and 10 February 1997 (last day a radio was detected in the area) were considered on the analysis (n=15). Presence/absence information for hawks in the study area was analyzed by sex and age using a t-test of arcsine transformed percentages (Zar 1998). In order to test heterogeneity in the use of the area on consecutive survey days ("site fidelity"), a model for individual mark-resighting (presence/absence) was run using SURVIV (White 1983, Hestbeck et al. 1991), comparing a general (each individual has its own function of "site fidelity) vs. a constrained model (probabilities of leaving the area or coming into the area are the same for all the individuals). Weather data (minimum and maximum temperature and rainfall) were related to animal presence in the area using Correlation Analysis (PROC CORR in SAS System for Windows, v6.12, 1998).

For the birds whose locations were obtained using the biangulation method, an analysis of animal "activity area" and movement during a day and among different days was developed. Locations were plotted using ArcView and analyzed with Animal Movement extension (Philip Hooge, USGS Alaska Biological Science Center, 2000). Locations taken on different days were assumed to be independent. Due to the low number of successive observations per individual, when more than one location was present in a day, the first location within an hour was selected among the ones separated by at least 5 hours. This time interval was assumed to give enough separation to represent different behaviors at different times during the day. If more than one location was obtained in an hour, only the first location in that hour was used in the analysis. Shoener's ratio for examining autocorrelation was estimated on each case (Shoener 1981), and the test for independence was developed such as suggested in Swihart and Slade (1985, page 1182).

Activity areas for Swainson's hawks while in the study area were estimated using the Minimum Convex Polygon (MCP; Mohr 1947, Southwood 1966) and the Fixed Kernel Method (FKM; Worton 1989, Erran Seaman and Powell 1996) using the Animal Movement extension in ArcView (Philip Hooge, USGS Alaska Biological Science Center, 2000). These complementary methods were selected based on the robustness of the first one when the number of locations is low and the indication of the intensity of range use of the second one (Harris et al. 1990). For the purpose of comparisons among different individuals, the MCP was used instead of the FKM because the first method offers a more realistic estimation under the present study conditions. Although the MCP procedure has the disadvantage of being influenced by peripheral fixes and including large areas never visited by the animal (Harris et al. 1990), it offers the advantages of robustness (given the low number of locations/individual) and the inclusion of peripheral fixes given by the high mobility and wide dispersal of the Swainson's hawks in the study area (Woodbridge 1991).

Finally, an attempt to explore animal association patterns was made using general observations of simultaneous reception of signals for more than one hawk. Due to the lack of simultaneous locations for two or more hawks (i.e., locations determined by biangulation from bearings received at the same time for two or more hawks) and the impossibility of seeing individual hawks, quantitative ways of establishing animal association were limited (ex: impossibility of cluster's analysis or coefficient of animal association, or analysis of individual home range overlap -useful for comparison of static territorial interaction-, White and Garrott 1990). Preliminary inferences about animal association were made based on signals of two or more individuals received simultaneously during the surveys, focal (individual) observations and main roost use.

Habitat Use by Swainson’s Hawks

Individual and flock patterns of habitat use during the day

Individual and flock observations on habitat use were planned to be conducted using radio telemetry as a tool for identifying and following individual hawks. During the first days of December 1996, individual radio-tagged hawks were randomly selected in order to monitor their behavior and the behavior of the flock through the day. However, given the difficulty of following individual radio tagged hawks and determining their exact location in different habitat types, the methodology was changed to the use of focal observations of individuals and groups at different times of the day. These observations were conducted in La Pampa study area between 16 December 1996 and 13 March 1997 as a way to complement information from radio telemetry and help to understand the pattern of daily activities by individual hawks in relation to different habitat types.

Data collection: Based on extension of the diurnal period for December (heliofany equal to 14.35 hrs between 0604 and 2025 H, Rodriguez, pers.com.), the day was divided into three equal periods (Morning: 0600-1040, Midday: 1041-1520, and Afternoon: 1521-2000). These periods were randomly assigned to three days per week, one period per day. Searches for hawks were made based on the results (location of groups) of the previous survey day (see page 19), randomly selecting the starting point for the search. The same group of 2 people drove a truck until a group of hawks was found and then conducted the observations.

When a group of hawks was found, one of the members of the group started making individual observations randomly selecting an individual in the group (focal observations). The group was divided into equal horizontal sections of 10º and into air/ground (vertical) sections, and both the initial horizontal and vertical sections were randomly selected. A screening with binoculars was developed starting on the selected angle and section until an individual was identified. Then, an observation block of 5-minutes was conducted, followed by 5 minutes rest, and the process of selecting and observing an individual started again. This was continuously repeated during the complete time block (4.40 hrs; n=29 observations/time block/day). On the inter-observation interval, temperature was recorded using a mercury thermometer.

Given the even terrain, observations were usually made from a distance of 100-200 m (when hawks were on the ground) and at least 200-400 m (when soaring) using binoculars and a spotting scope. General weather conditions (cloudiness, wind speed and direction) were recorded as well as habitat type (wheat, corn, sunflower, alfalfa, other improved pasture, natural pastures, weedy field, plowed field, woodland, other), behavior (soaring, active flight, on the ground, on fence post, on light pole, on tree) and activity (preening, foraging, short runs, short flights, pecking to the ground, extending talons while soaring, bringing talons to beak while soaring, etc.). Individuals were assigned to foraging activities if short runs or flights were observed while on the ground, or diving from flying position (usually accompanied by an extension of one or both feet and loss of altitude; Woffiden 1989) were made while soaring. Prey capture attempts were included in the estimation of foraging rates when pecks where made during the short runs (on the ground) or diving flights. Site geographic coordinates were recorded using a Global

Position System (GPS) unit (Magellan Systems Corporation, GPS Nav DLX-10) and a diagram of the plot and surroundings plots was drawn on each observation site.

While one of the members of the team (the same every time) conducted the individual observations, the other member conducted flock observations and radio checks in order to describe flocking/roosting aggregations. During flock observations, the total number of individuals present in the area was recorded as well as their behavior, using the same categories than for individuals (scan sampling). Small groups from the total flock were randomly selected using a similar procedure to the one used for selecting individuals (random selection of vertical and horizontal sections). Relative percentage of individuals on the small group devoted to different activities was recorded. Roosting aggregations were described estimating the number of individuals leaving/arriving to the roost or resting on the ground before/after roosting.

Data analysis: Results from observations were described using relative frequencies (PROC FREQ) and mean frequencies (PROC MEANS) estimated in SAS (SAS System for Windows, v6.12, 1998). In addition, a general description of the habitat use pattern was conducted using Multiple Correspondence Analysis (Manly 1994) run with the same statistical package (SAS System for Windows, v6.12, 1998, MCA procedure). This analysis could be considered as a special case of Principal Component Analysis, although it offers a more appropriate approach for the analysis of descriptive categorical data (Lebart et al. 1984).

Due to differences in detectability of Swainson's hawks at different times of the day, an unbalanced number of observations was obtained for each hour. Therefore, in order to pool all the observations for an estimation of daily activity budget, the amount of observations for each behavior (in the air, foraging in the air, on the ground, foraging on the ground) during each hour was balanced for the amount of times the hour was completely covered. In this way, a balance was obtained and comparisons were made on the percentage of time devoted to each activity.

Habitat selection at population level

Habitat use: Observations obtained during the surveys were utilized for estimations of population abundance (see pages 19-22) and also for the analysis of habitat use patterns at population level. The present study was specially oriented to characterize the patterns of habitat use by Swainson's hawks, particularly in relation to the habitats selected for foraging or resting on the ground because it was assumed that in these situations Swainson's hawks were more vulnerable to pesticide applications. For this reason, only observations of hawks on the ground were included on the habitat use analysis. Data of hawk abundance per habitat type were re-organized in order to assign observed hawks to 5 habitat categories: crops (sunflower, wheat, sorghum), annual pastures (millet), permanent pastures (alfalfa, natural fields, weedy fields-pastures > 2 years old or fallow fields-, short-grass fields), plowed field and woodland. Groups of hawks observed at fence posts were proportionately assigned to the habitat types present next to the fence in order to have an equivalent representation of the different used habitats. If only one hawk was observed at a fence post, it was randomly assigned to one of the habitat types.

Since hawks usually move in flocks while wintering (not independent individuals) and observations were delimited on habitat type, habitat use characterization was developed considering the number of observations and not the number of hawks observed in each habitat type, as an indication of use. The frequency of observation on each habitat type was graphically described by plotting this frequency as % of observations on each habitat type. Therefore, only habitat types in which Swainson’s hawks were observed on the ground were used in the habitat use analysis. Although hawks can use native woodlands and lowland (sporadic observations outside the study area in La Pampa) and soar over urban habitats, there were no observations of Swainson's hawks on the ground in these habitat types during the surveys. For this reason, although they could be available habitats for hawks, they were considered non-used habitats and were not included on the analysis of habitat selection.

Habitat availability: Habitat availability in both areas was obtained from satellite image analysis using remote sensing methodology. The National Institute of Agricultural Technology (INTA) at Castelar (Buenos Aires, Argentina) provided satellite images for La Pampa (Mosaic Landsat TM, Path/Rows 228-84 and 228-85 from 23 January 1997) and for Santa Fe (Mosaic Landsat TM, Path/Rows 228-82 from January 1997 and 227-82 from February 1997). Images included bands 3 (red), 4 (near infrared) and 5 (middle-infrared) and they were georeferenced to latitude/longitude. The three bands were radiometrically corrected using the dark normalization method (Jensen 1996, page 116). For each area, a color composite (Idrisi for Windows, v.2.008, Clark University, 1998) was developed using the three bands with 1% of color saturation.

An unsupervised classification was first developed on each area using 18 classes (La Pampa)/ 16 classes (Santa Fe) with the Isoclust method (Idrisi for Windows, v.2.008, Clark University, 1998). After that, supervised classifications were developed using 109 (La Pampa)/ 120 (Santa Fe) training sites. Eighteen different land cover classes were represented at these training sites (alfalfa-homogeneous, rotation and old-, sunflower -

homogeneous, heterogeneous and flowering-, sorghum, corn, millet, oat, plowed fields, wheat, stubble wheat, native woodland, *Eucalyptus* sp. woodland, natural fields, lowlands and urban areas) for La Pampa, and 14 land cover classes (alfalfa, plowed fields, short-grass fields-dominated by *Cynodon dactylon*-, weedy fields, sunflower, corn, *Eucalyptus* sp. woodland, millet-standing and rolls-, other annual pastures, soybean, sorghum and urban) for Santa Fe. Supervised classifications were developed using the Minimum Distance and Maximum Likelihood modules (Idrisi for Windows, v.2.008, Clark University, 1998). After classifications were made, land cover classes were grouped in 6 new classes: permanent pastures (alfalfa, natural pastures, short-grass and weedy fields), crops (sunflower, sorghum, corn, oat, wheat, stubble wheat and plowed fields), native woodlands, *Eucalyptus* sp. woodlands, lowlands and urban areas in order to obtain the cover classes percentage in the study area. Annual pastures, such as millet, were included with crops or analyzed independently, depending on the case.

As training sites were not enough to develop error matrixes (Jensen 1996, page 250), information on proportions of land cover by each habitat category obtained from the image analysis was compared to proportions obtained from other sources in order to select the classification that performed best. State Agricultural Statistics from 1996 were used for La Pampa study area, and information from a land cover analysis developed at the National Institute of Agricultural Technology (INTA) on 1999 was used for Santa Fe Study area. The image classification method that offered the lower differences between both quantities was selected for the estimation of habitat availability (quantity) in each study area and around each point.

Habitat selection (use vs. availability): The analysis of habitat selection was explored through the comparison of use of different habitat types by all the animals in the study area, without distinction among individuals, and availability of all habitat types. This approach corresponded to the "design type I" discussed on Thomas and Taylor (1990), and comparisons were conducted following the methodology proposed by Neu et al. (1974), using the program HABUSE (Byers et al. 1984). This program performs a Chi-square goodness-of-fit test comparing the observed counts on each habitat type vs. the expected counts based on the proportion of that habitat type in the area and constructs the respective Bonferroni's confidence intervals. The estimation of confidence intervals using this method assumes that sample proportions have an approximately normal distribution, assumption that usually requires large sample sizes. As sample size in this study was small for habitat types such as annual pastures in La Pampa (rule-of-thumb: expected number of observations in each habitat type under the null hypothesis is ≥ 5), Bailey's intervals were estimated as suggested in Cherry (1996) in order to complement those intervals obtained by the program HABUSE. Bailey's intervals are more robust for small sample sizes and provide the best combination of low error rates and interval length on the estimation of confidence intervals (Cherry 1996).

Spatial distribution in relation to habitat availability

Observations from surveys were used to explore the hypothesis that hawks would condition their spatial distribution on the abundance of selected habitat types. Once habitat selection is determined, hypothesis about the role habitat plays in the distribution and abundance of a species in determined areas could be tested relating bird abundance (use) with habitat abundance (availability) at different scales (Griffiths et al. 1993, Ims

1995). To explore this proposition, the use of each point (taken as the amount of observations with hawks on that point) was related to habitat quantity at that point. Only observations with hawks on the ground made at less than 600m (La Pampa)/500m (Santa Fe) were included on each area. These distances were selected based on the best truncation distances determined in DISTANCE (differences are probably due to differences in detectability in both areas) and they were included in an attempt to control and standardize for detectability on each point.

The quantity of each habitat type at each point was estimated using a buffer analysis in Idrisi (Idrisi for Windows, v.2.008, Clark University, 1998). Buffers of 2.5 km radii, the maximum radii around each point without overlap between successive points, were developed around each point over transects in both study areas. The resulting images with the buffers were overlaid with the selected classification image and the percentage of each cover type at each point was estimated from the images using the Area operation in the same computer program (Idrisi for Windows, v.2.008, Clark University, 1998).

The hypothesis about a relationship between hawk's abundance at different points and availability (quantity) of different habitat types at that points was first explored plotting the number of observations with hawks/point and the abundance (%) of different habitat types at that point. In addition, linear correlation analyses for each habitat type (PROC CORR) and linear regression models including the 5 habitat types (PROC REG/NOINT option) were run for each study area using SAS (SAS System for Windows, v6.12). Using a different approach, a second exploration was conducted using Multiple Correspondence Analysis (Manly 1994) among points with observations of hawks and point without observations and the % of habitat type on that point categorized as greater or lower than the mean habitat abundance for the area (in an attempt to differentiate between point with high concentration of selected habitat types and points with low concentration of habitat types). The Multiple Correspondence Analysis was run using SAS statistical package (SAS System for Windows, v6.12, MCA procedure).

RESULTS

Abundance of Hawks in the Study Areas

A total of 15 surveys for La Pampa area (n= 4 surveys with strip transects and 11 surveys with point transects) and 17 surveys (point transects) for Santa Fe area were used on the density estimation with DISTANCE. Strip transect surveys developed in La Pampa with 300 m at each side of the line were not included due to the low number of replications (n=2). Another 5 surveys in La Pampa area were eliminated from the density estimation using DISTANCE due to methodology adjustments (both in strip and point transects) on those days or weather conditions that precluded the completion of the surveys. Four surveys were eliminated from density estimation in Santa Fe area due to adverse weather conditions.

Truncation distance for point transect estimations were fixed in 600m for point transects in La Pampa and 500m for point transects in Santa Fe study area after running analyses at different truncation distances (such as 2500m-no truncation-, 1000m, 500m, etc) and examining the results on the detection function (Buckland et al. 1993). The models that best fit the detection function were selected based both on the shape and the Akaike's Information Criterion (AIC; Buckland et al. 1993). Strip transects conducted in La Pampa between 31 December 1996 and 9 January 1997 gave greater density estimation for the surveyed area than point transects conducted in the same area between

Table 1. Density estimations using DISTANCE for Swainson's hawks in La Pampa (1996-97) and Santa Fe (1997-98), Argentina.

	Total Effort	No. Points	No. Observ. Clusters	Model	AIC	**Bird density (hawk/km2)** Estimate	SE	%CV	95%CI	Total N in the surveyed area (Min-Max)
La Pampa										
Strip transects	1511	-	26	Uniform	275.51	**5.02**	**2.04**	**40.73**	**2.15-11.70**	1797-4267
Point transects	658	60	41	Uniform-Simple Polynomial	114.88	**4.40**	**2.07**	**47.02**	**1.81-10.71**	2743-7611
Santa Fe										
Point transects	510	30	96	Half-Normal	267.00	**3.51**	**1.42**	**40.49**	**1.62-7.63**	1229-2903

Additional Information (estimates±SE, although special indication)

	Model	Clusters density	Average cluster size	Detection Probability	Encounter rate	Component percentage of Var(D)
La Pampa						
Strip transects	Uniform	0.04±0.01	116.6	1.00±0.00	0.02±0.005	Encounter rate:45.0 Cluster size: 55.0
Point transects	Uniform-Simple Polynomial	0.09±0.02	47.2	0.51±0.07	0.06±0.01	Detection probability:9.1 Encounter rate:25.9 Cluster size:65.0
Santa Fe						
Point transects	Half-Normal	0.44±0.15	14.1	0.55±0.08	0.19±0.06	Detection probability: 13.7 Encounter rate: 56.7 Cluster size: 29.6

22 January 1997 and 12 March 1997 (Table 1). Density estimations in La Pampa were greater than in Santa Fe, although not qualitatively different (Table 1).

To estimate Swainson's hawk population abundance of on both study areas, the densities of hawks detected on the surveyed areas were extrapolated to the whole study areas. Although the number of observations (n) and encounter rate (k) were low, the surveyed area represented between 52 and 65% of the total study areas in La Pampa and Santa Fe, respectively. Therefore, the density found on the surveyed areas was tentatively extrapolated to the whole area. The expected number of hawks in the study areas varied between 6705 and 15885 in La Pampa (x=11295 from strip transects, x=9900 from point transects, area: 2250 km2) and 1881 and 4437 in Santa Fe (x=3159, area: 900km2).

In order to explore variations in hawk population abundances in both study areas through the season and to relate these variations with changes in weather conditions, only for comparative purposes, the absolute density of hawks on each surveyed area was plotted against the time of the survey (Figure 6). In La Pampa, hawk density seemed to increase until January 9 and then gradually decreased until the middle of March. In Santa Fe, although densities reached a peak on January 29 and then decreased, there was not a clear pattern, with wide oscillations among different dates (Figure 6). In both study areas, a decrease in hawk abundance as the season advanced was positively correlated with a decrease on daily minimum temperature and not significantly correlated with daily maximum temperature or rainfall (Pearson Correlation Coefficients (PCC)=0.49, p=0.02 for minimum temperature in La Pampa, PCC=0.54, p=0.02 in Santa Fe; PCC=0.15, p=0.51 for maximum temperature in La Pampa, PCC=-0.07, p=0.80 for Santa Fe; PCC=-0.18, p=0.42 for rainfall in La Pampa, PCC=-0.09, p=0.71 for Santa Fe).

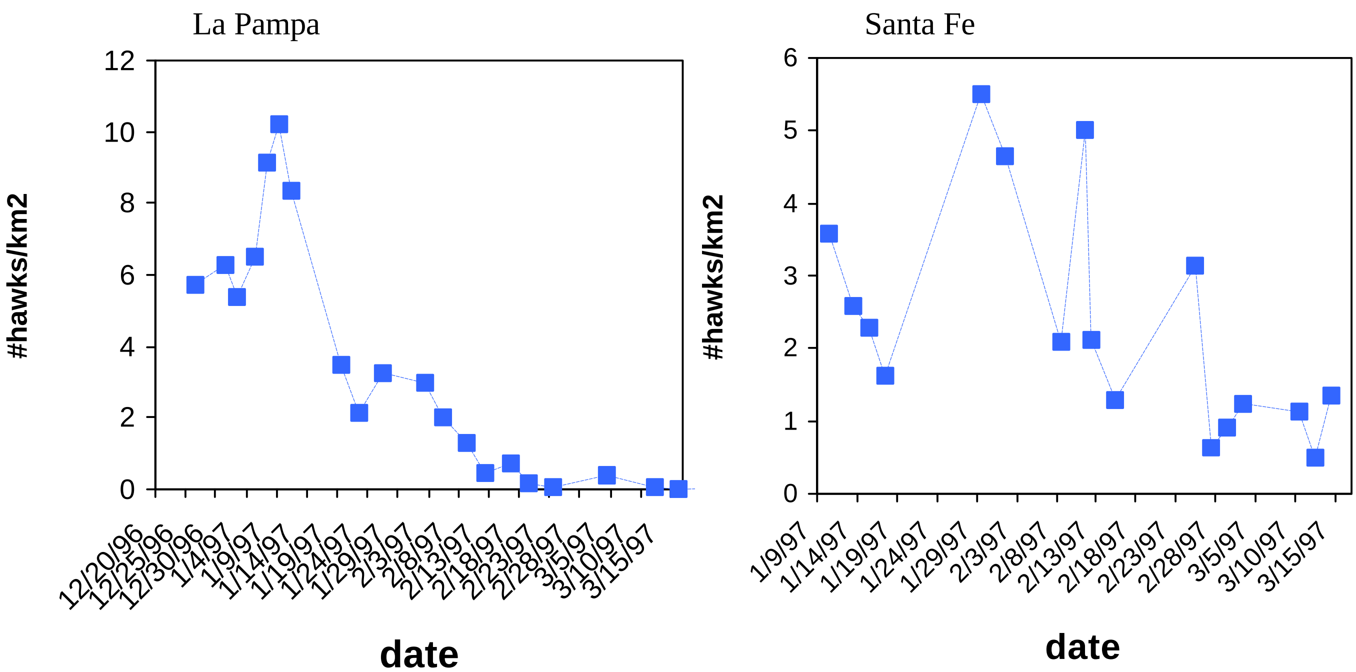


Figure 6. Estimated density of Swainson's hawks on each study area at different dates (estimated from the number of observed hawks/surveyed area).

<u>Movement of Individual Hawks in a Study Area</u>

Twenty-two Swainson's hawks were radio-tagged between November 28 and December 2, 1996. Ten of them (45.5%) were females and 12 males (54.5 %), with 16 adults and 6 juveniles (Table 2).

Table 2. Age and sex of individual radio-tagged hawks in La Pampa, Argentina (1996).

	Sex		
Age	Female	Male	Total
Adult	6 (27.27%)	10 (45.45%)	16 (72.73%)
Juvenile	4 (18.18%)	2 (9.09%)	6 (27.27%)
Total	10 (45.45%)	12 (54.55%)	22 (100.00%)

Transmitter weight (25g) constituted 2.7% of female's body weight (x=908.5g, STD=70.2g, n=10) and 3.4% of male's body weight (x=732.3g, STD=73.7g, n=11). No adverse effects that could be attributed to the transmitter were detected, in coincidence with a study developed by McCrary (1981) on red-shouldered hawk (*Buteo lineatus*) in California, where he found no adverse effect using an identical technique. Transmitter longevity performed as expected with hawks found in Cordoba province 86-93 days after being marked in La Pampa (n=12 hawks).

Signals were received from 20 out of 22 radio-tagged hawks (91%) in and around the study area in 53 days with general checks (homing and surveys) between 4 December 1996 and 16 March 1997. However, the daily success in finding different hawks within the defined monitoring area was extremely variable and low during the whole season. During the first month (December), hawks were relatively easily detected in the area. Although the methodology was not uniform in order to compare among days and/or individual tagged hawks, it was usual to find 5 to 7 hawks on one day (25-35% of 20 detected in the area), many times in very small parts of the area. Between 4 and 20 December 1996, 85% of the radio tagged birds (n=17/20) were detected in the area.

However, during the 22 survey days that covered the total area between 20 December 1996 and 16 March 1997, the probability of finding hawks in the area gradually decreased as the season advanced (Figure 7). At least one radio-tagged hawk was found in 15 of the 22 survey days that extended between 20 December and 10 February 1997 (last day with signals in the area, although searches for hawks continued until 16 March 1997). The proportion of the radio-tagged population using the area on these days ranged from 5% (n=1 hawk found in 2 survey days) to 55% (n=11 hawks found in 1 survey day; Figure 7). The mean was 4±3 radio-tagged hawks detected per survey day, i.e., a daily success of 20±13%. The most frequent situation was finding 3 out

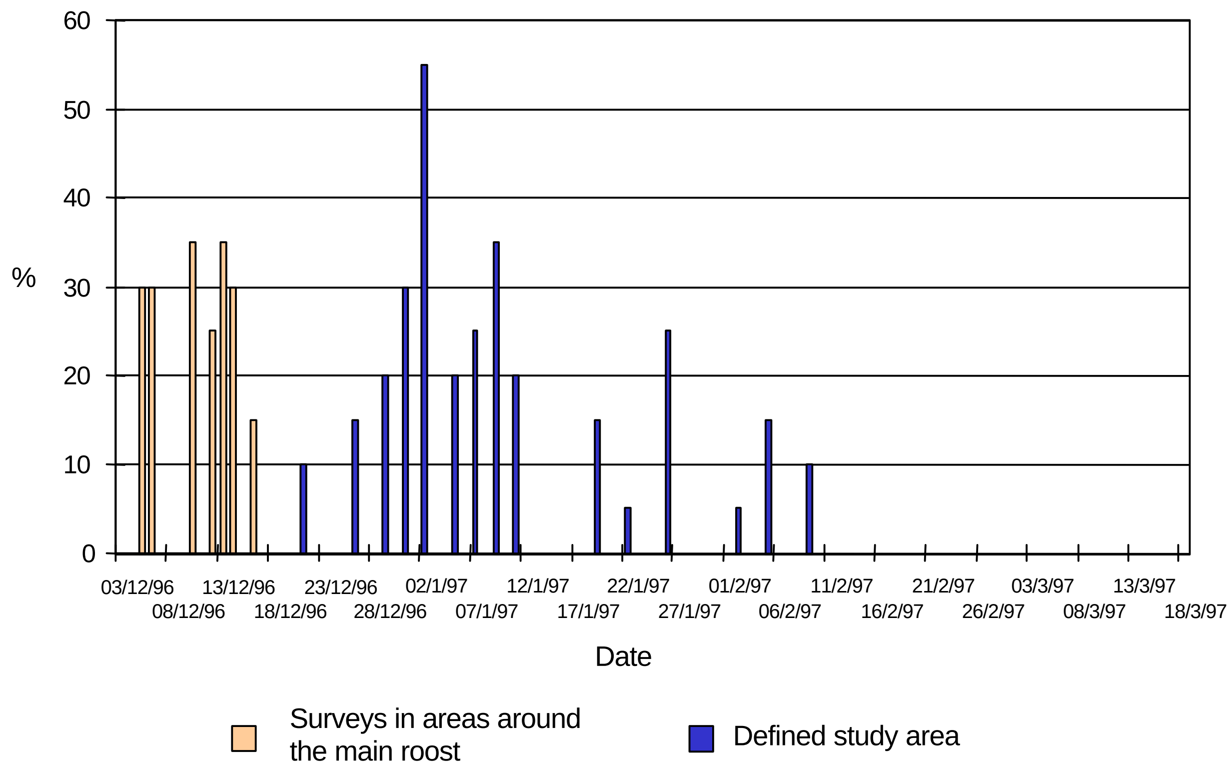


Figure 7. Daily success on finding at least a hawk in the study area during a survey day (% radio-tagged hawks found/survey day).

of 20 radios (15% of the total population) in the area per survey day, without a clear pattern of variations in the proportions at different times during the season (Figure 7). It is noticeable high percentage of radio tagged hawks found 2 January 1997 (55% of the tagged hawks). However, from the 11 radio-tagged hawks found on that day, 2 were only found in the area that day and 3 were never found again during the study period. If this day is not included in the estimation of daily rate of finding birds, the mean number of detected hawks in the area would be lower (3.5±1.8 radio-tagged hawks found/survey day, i.e., daily success=17±9%).

A possible factor influencing the pattern of use of the area by radio-tagged hawks would be variations on weather conditions. As it happened with correlations between population abundance and weather (see page 41), correlations between number of radio-tagged hawks in the area and weather were significant for minimum temperature (Pearson Correlation Coefficient (PCR)= 0.57, p=0.005) but non-significant for maximum temperature and rain (PCR=0.25, p=26 for maximum temperature and PCR=0.07, p=0.75 for rain). However, it is valid to recall that these results are only exploratory, and no causation could be inferred from them.

The frequencies of occurrence of individual hawks in the study area (i.e., the probabilities of founding a specific individual hawk in the study area during a survey day) were also low, varying between 0% (n=5 hawks not found in the area during the survey days) and 67 % (n=1 hawk found in 10 of 15 successful survey days). The mean probability was 18±20 % (i.e., a specific hawk was found 3±3 days from 15 survey days), with the most common value of 7% for a hawk being found only 1 survey day in the area (n=8 hawks). Only 8 hawks out of 20 tagged hawks has a frequency of occurrence > 20% (i.e., they were found on more than 3 survey days). From these hawks, only 4 have frequencies above 50%. Two of the 5 hawks that were never detected during the survey days were never found in the area after radio-tagged, and three of them left the area in the first days of December (less than 15 days after being radio-tagged).

It is important to notice that hawks were leaving the area as the season advanced (see page 56). Therefore, both the probability of find at least a hawk in the area as well as the frequency of occurrence of a specific individual in the study area varied through the season as a function of the potential group of hawks presents in the area during the survey days. Assuming that a hawk stayed in or around the area until it left it definitely (last day found in the area), both the probability of finding at least a hawk during a survey day (from the hawks potentially present in the area) and the probability of finding a specific hawk on one day (from the days it was present in the area) would be greater than the previously mentioned (51±29%instead of 20±13% and 28±29 % instead of 18±20 %, respectively). Therefore, the mean probability of finding at least a radio-tagged hawk from the total potentially present in or around the study area was 50% during a survey day while the probability of finding a specific individual hawk was approximately 30% on a given survey day.

No significant differences were found in the frequency of occurrence between males and females (t-test, p=0.91) or juveniles and adults (t-test, p=0.86), although females had usually lower probabilities of being found in the area than males (mean probability=0.15 for females vs. mean probability=0.21 for males). Even though these frequencies were not significantly different, they significantly varied on individual bases. The likelihood-ratio test between a general model (different "site fidelity" function for each individual) vs. a constrained model (probability of staying in the area or leaving the area is equal for all the individuals) run with SURVIV (White 1983) indicated that each individual had its own differential "site fidelity" function (χ=52.914, d.f.=32 and p=0.01). Therefore, the model that would better explain the behavior of the different individuals using the area represents a stochastic pattern, making difficult to predict the presence of an individual hawk in the area based on its presence on previous survey days.

Main Roost Use

The high heterogeneity on the use of the study area by individual radio-tagged hawks was reflected also on the use of the main roost. Between 1 December 1996 and 10 February 1997 (last day with radio-tagged hawks detected in the study area), a total of 54 out of 71 nights were checked at the main roost for the presence of radiotagged hawks (75% of the nights). From the 22 hawks radio-tagged at this roost, 10 of them re-used the roost for at least one night (45 % of the total birds) in 12 different nights (Table 3), 7 of them among the 5 first days after being radio-tagged at that roost. The remaining 3 hawks re-used the roost between 22 and 38 days after being tagged at that roost (Table 3).

Table 3. Use by radio-tagged hawks of the main roost in La Pampa study area ("Chanilao" ranch), Argentina, ordered by tagging day.

Radio ID (ordered by tagging date)	Radio-tagging date	Age	Sex	Roost use
216.005	11/29/96	Adult	Male	2 more nights after being marked (i.e., at least 3 consecutive nights at the roost)
216.345	11/29/96	Adult	Female	3 nights, 2 days after being marked
216.405	11/29/96	Adult	Female	1 night after being marked (i.e., at least 2 consecutive nights at the roost) 1 night, 1 day after being marked
216.365	11/30/96	Adult	Male	1 night, 22 days after being marked
216.145	12/1/96	Adult	Male	1 night, 35 days after being marked
216.225	12/1/96	Juvenile	Male	1 night after being marked (i.e., at least 2 consecutive nights at the roost) 1 night, 10 days after being marked 1 night, 38 days after being marked
216.265	12/1/96	Juvenile	Male	2 nights, 1day after being marked 1 night, 1 day after that
216.505	12/1/96	Adult	Male	1 night after being marked (i.e., at least 2 consecutive nights at the roost)
216.205	12/2/96	Adult	Female	1 night, 37 days after being marked
216.245	12/2/96	Adult	Female	1 night, 4 days after being marked

Hawks generally used the main roost for only one night. From a total of 14 events in which individual hawks re-used the roost, 57% of them corresponded to the use for only one night. The rest of events corresponded to the use for two consecutive nights (29%) and for three consecutive nights (14%). Only three hawks re-used the roost in more than one occasion, two of them within 3 days after being radio-tagged at that roost (Table 3).

It was not possible to distinguish any clear pattern on the use of the roost by sex or age due to the low sample size for each class. Both males and females re-used the roost for one or more consecutive nights in similar numbers (Table 3). Although most of the birds were adults, the proportion was similar to the original proportion of tagged birds by age group, making it difficult to extract a clear pattern of reuse.

Finally, the percentage of hawks that re-used the roost from the ones found in the study area during the surveys was very low. Only in 3 of 30 nights preceding or following a survey day (n=15 survey days) a radio-tagged hawk was found using the main roost. On these three nights, only 1 hawk roosted at the main roost by night, out of 4 and 7 hawks found in the area during the respective survey day (25-14% of the hawks found in the area, respectively). All the hawks found in the roost during these nights were found in the area during the survey day, indicating little dispersion for these individual hawks during the day.

Movement and Activity Areas for Individual Hawks

In order to develop individual analyses of movements during the study season, records from only 6 individual radio-tagged hawks offered more than 10 locations/individual (11-32 locations) and were included in the analysis. Although 526 events with signal reception were obtained, the wide range of detection that resulted in parallel consecutive bearings, the common reception of only one location for a hawk in the area during a day and the elimination of locations due to inter-bearing angles very different than 90 degrees, resulted in only 167 locations determined for 14 hawks. Sixty-five percent of these locations were provided by 5 hawks (n=109) and only 8 of the 14 hawks provided more than 10 locations/individual (11-32 locations). But when the criteria for selecting independent locations was applied (Shoener's ratio), many locations were eliminated, and only 6 hawks provided between 8-13 locations/individual that were used in the analysis of activity areas (Table 4).

Most of the 167 locations estimated for the 14 hawks were made during the afternoon (1521-2000 H; n=76 locations) with only 42 during the morning (0600-1020 H), 33 at midday (1021-1520 H) and 16 at night (2001-2200 H). Mean time between successive bearings for estimating locations was 18±15 minutes. The wide interval is explained by the mixture of locations coming from homing attempts (5-10 minutes between successive bearings) and locations' coming from general surveys (usually around 20 minutes between successive bearings). Mean distance of detection was 13±12 km (max. = 63 km, min. =437 m). Variable detection distance at different times of the day in association with different hawk behavior explains the wide and variable intervals. Four locations over distances from 92 and 140 km were excluded from the analysis, as a conservative way of diminishing variation among the locations.

The amount of days with locations used for activity areas estimation varied between 7 and 9 for different individuals, covering different periods in the study season. The mean difference of days between successive measures was 6±7 days, varying from 1 to 29 days, although there were cases with more than one measure/day (Table 4). Considering the time hawks were last detected in the area, these times represented between 9 and 23 % of the time the hawks were assumed to be present in or around the area (i.e., between the tagging day and the last day detected in the area).

Table 4. Areas used by individual Swainson's Hawks in La Pampa province (1996-97).

Radio ID	Age	Sex	Tagging date	Last Record*	# days covered by locations**	x ± std days between locations	# locations	Shoener's (t2/r2) ratio
216.085	A	M	19961201	19970109	9/39	5 ± 6	12	0.61
216.145	A	M	19961201	19970219	7/80	7 ± 5	8	1.38
216.365	A	M	19961130	19970126	9/57	5 ± 5	13	1.43
216.225	J	M	19961201	19970205	9/66	8 ± 8	11	2.04
216.205	A	F	19961202	19970109	7/38	6 ± 8	9	1.01
216.345	A	F	19961129	19970126	7/58	10 ± 11	9	1.22

			Activity Areas in km2 (% of the study area:2250 km2)			
Radio ID	Age	Sex	Kernel Prob. 50%	Kernel Prob.80%	Kernel Prob. 95%	MCP
216.085	Adult	Male	798.8(35)	2327.0(103)	1569.6(70)	1955.3(87)
216.145	Adult	Male	580.1(26)	2242.3(100)	1588.6(71)	1375.5(61)
216.365	Adult	Male	616.1(27)	1720.6(76)	2572.9(114)	1280.6(57)
216.225	Juvenile	Male	208.9(9)	899.7 (40)	1909.8(85)	1136.8(50)
216.205	Adult	Female	499.10(22)	1330.2(59)	2035.6(90)	767.2(34)
216.345	Adult	Female	95.19 (4)	180.3(8)	672.1(30)	557.3(25)

Age: A=Adult, J=Juvenile; Sex: M=Male, F=Female
***** Last Location included in the analysis
****** Days covered by locations from the total of days the hawk was potentially present in or around the study area (estimated from the tagging day until the last record in the area)

Minimum Convex Polygons (MCP) estimated for individual hawks varied between 557.3 and 1955.3 km^2 (Table 4). These values represented between 25 and 87% of the total study area covering different regions of the study area (Figure 8), and they seemed to be lower in females than in males. The percentage of each habitat type within the activity areas did not differ from the mean for the general study area except for plowed fields, although differences were minimum in this case (Table 5). However, although an effort was made to have independent observations, only in one case the Shoener's relationship (t2/r2) was >=2 and the test indicated independent measurements (Swihart and Slade 1985). In addition, the number of individuals per sex class was very

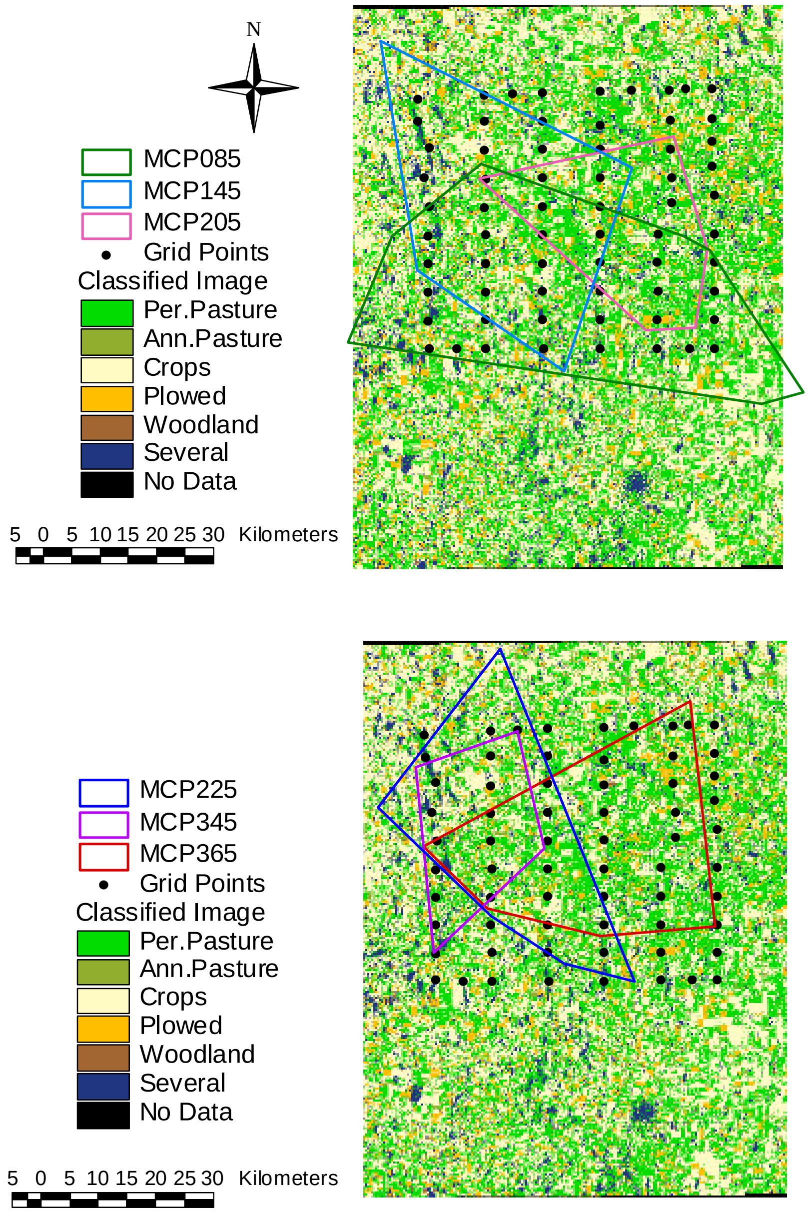


Figure 8. Minimum convex polygon (MCP) areas for individual Swainson's hawks in the study area (La Pampa, 1996-97).

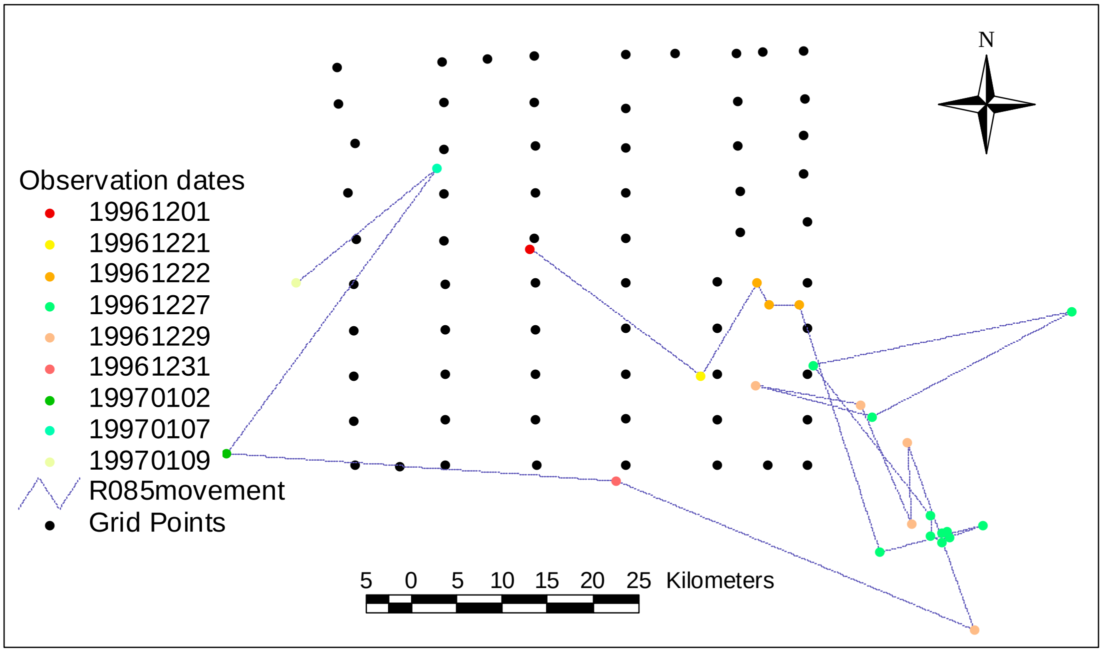
low (2 females and 4 males) to make confident comparisons by sex class. Therefore, any interpretation of the activity areas must be made with caution as well as any comparison among individuals.

Table 5. Mean percentage of each habitat type on individual activity areas compared with the percentage on the study area (p= probability associated with a two tailed t-test of the arcsine transformed values).

Habitat Type	Percentage on Individual Activity Areas (x ± std) (p-value)	Percentage on the Study Area (x ± std)
Permanent Pastures	42.0 ± 4.9 (0.97)	41.9
Annual Pastures	5.0 ± 0.8 (0.43)	4.7
Crops	42.5 ± 4.5 (0.79)	42.0
Plowed fields	10.3 ± 0.4 (0.002)	11.2
Woodland	0.2 ± 0.04 (0.38)	0.2

In the cases where it was possible to follow a hawk during a complete day (n=5), hawks remained in relatively small areas, making loops and turns in different directions (Figure 9). Hawks usually started the day in one roost and finished it in another one (or, at least, in another area). In the only case where morning and afternoon roosts were certainly identified, they were 25 km in straight line from each other. This information would suggest a relatively small area for daily dispersal, in coincidence with the fact that hawks that were detected at the main roost during previous/following nights to surveys were detected during the day within the study area (n=3). However, the low sample size and the interdependence between successive locations did not allow for making generalizations. In addition, this information was obtained only when hawks were closely followed (a minority of the cases). In most of the cases, hawks were lost before a pattern of movement could be determined, implying that daily dispersal patterns probably are wider than those showed here. More accurate information about daily dispersal would emerge from the analysis of satellite telemetry data (Fuller et al., pers.com.).

Radio-tagged hawks on the same study area seemed to not associate with each other to any degree, neither for foraging during the day nor for roosting. When a radio-



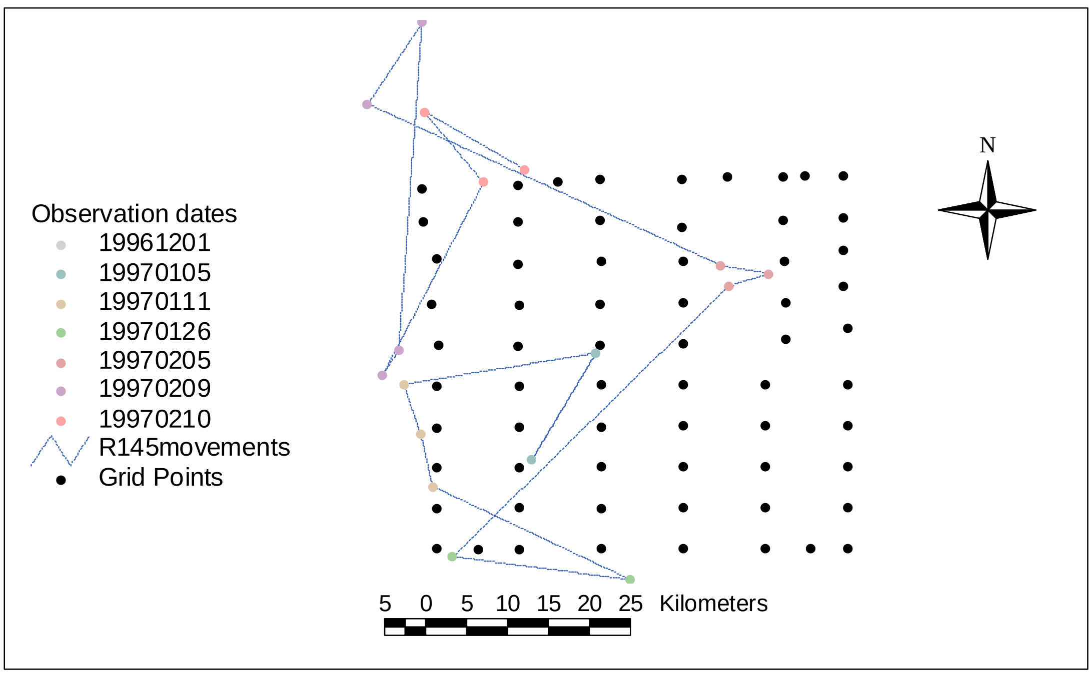
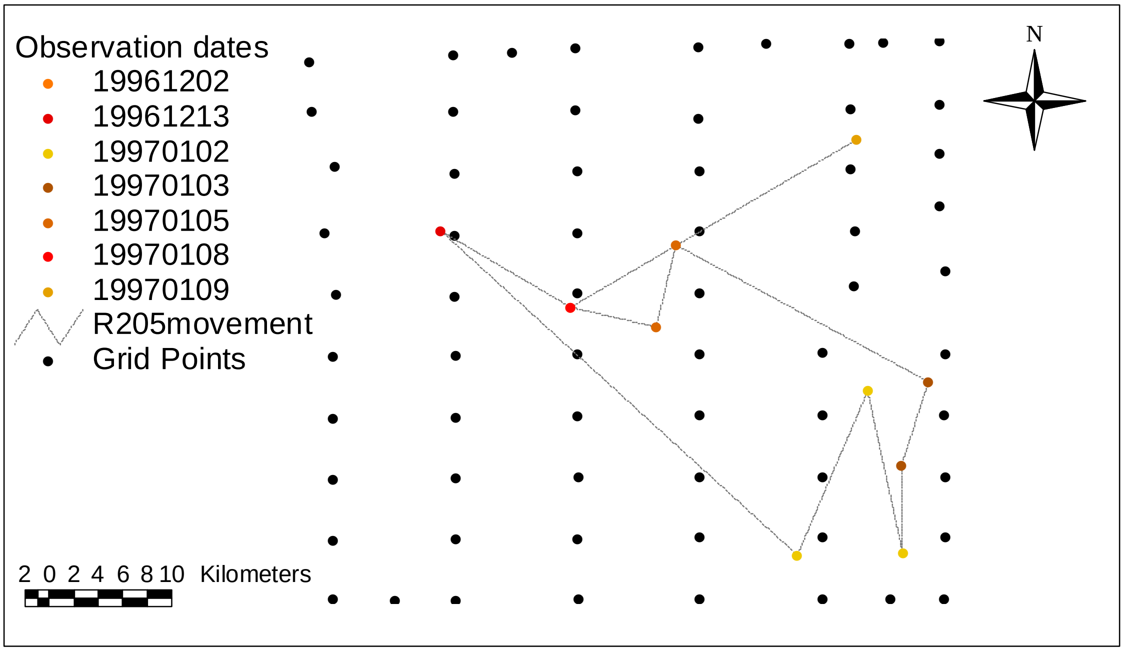
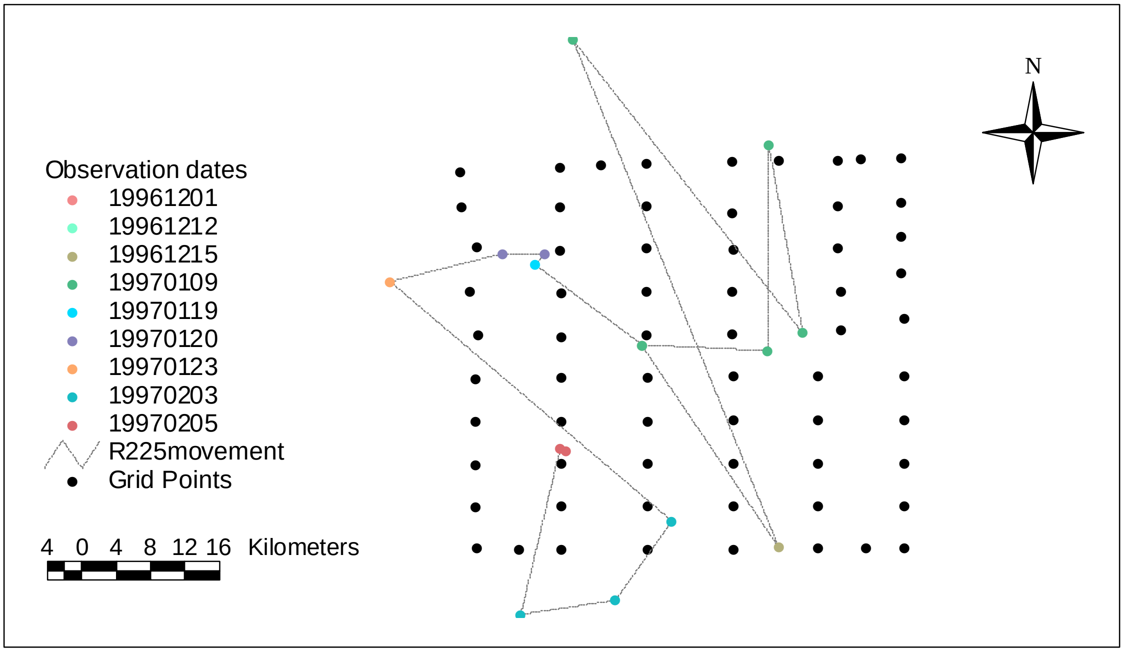


Figure 9. Movement of radio-tagged hawks in the study area (La Pampa, 1996-97).





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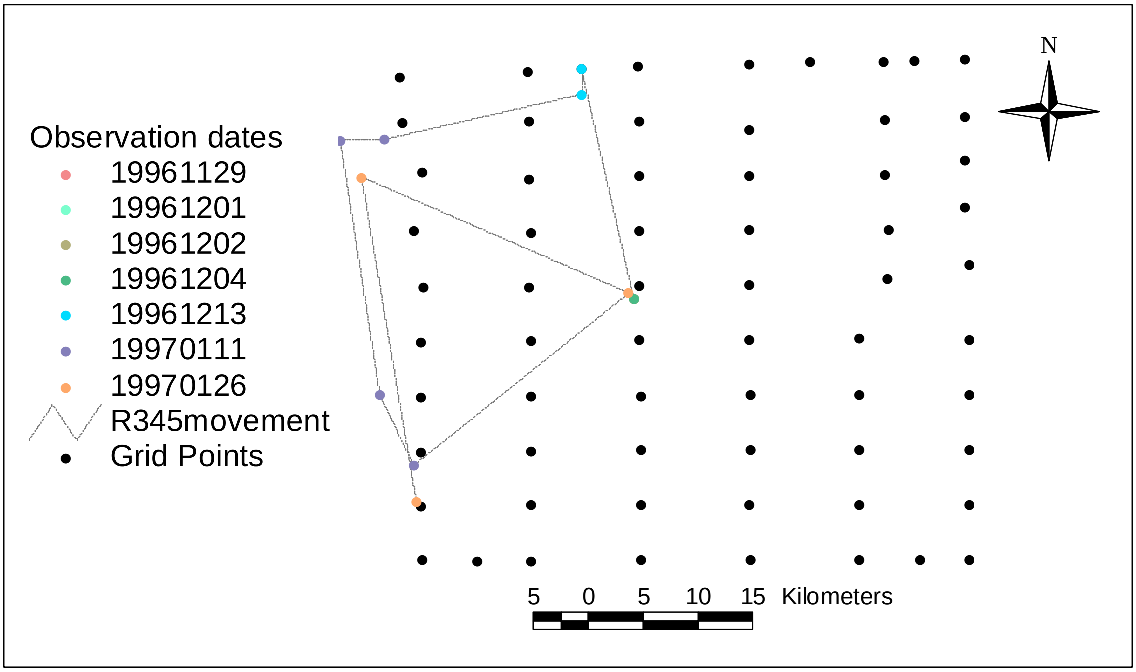


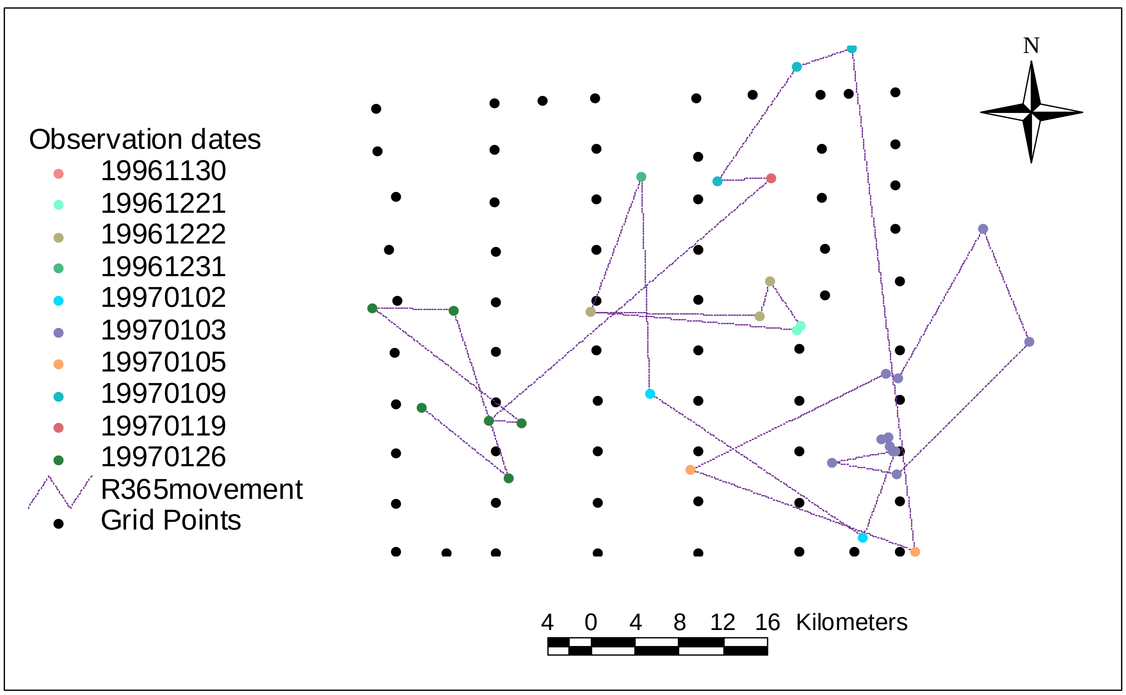


Figure 9--continued

tagged hawk was found and followed during almost a complete day (n=5), no other tagged-hawk was detected in its group. And this was also observed during individual observations (Focal Observations), in which periodic checks made at the same place recorded signals coming from very different directions and strength, suggesting that hawks were possibly moving in different areas. From a total of 22 days with focal observations, only in 8 events (36%) a radio-tagged hawk was found by the receiver. Four of these events corresponded to solitary individual hawks, with only one signal being captured by the received. In the other 4 events, 2 (n=4) or 3 (n=1) hawks were found from the same reception point, but signals were coming from different directions and with different signal strengths.

In addition, radio tagged hawks rarely shared a roost. There were 5 different events in which 2 or 3 hawks were found in the same or very proximate roosts. Three cases occurred at Chanilao, the main roost, within 3-5 days of hawks being radio-tagged at that roost. In this case, three hawks shared the roost in alternate but not consecutive days. The other two cases occurred at the end of days in which we followed the hawk nearly for the complete day. In one case, two different Swainson's hawks started the day in different but relatively close roosts and they finished on the same roost (3 January 1997). These hawks were radio-tagged at different days, and this event occurred between 32 and 34 days after radio tagging. In another case, two different hawks were found in different roosts separated only by the road (22 December 1996). These hawks were radio-tagged the same day, 21 days before this day.

Departure from the Study Area

At the end of December, there were only 18 out of the 22 radio-tagged hawks still in the study area. But this number of hawks diminished progressively as the hawks left the area (Figure 10). Hawks were leaving the area in a pattern similar to "waves" of 3-6 hawks that left the area with a separation of few days among them ("wave"1: 6 individuals on 2 January 1997, "wave" 2: 4 individuals, 9-11 January 1997, "wave"3: 3 individuals, 26-27 January 1997, and "wave 4": 3 individuals, 7-10 February 1997).

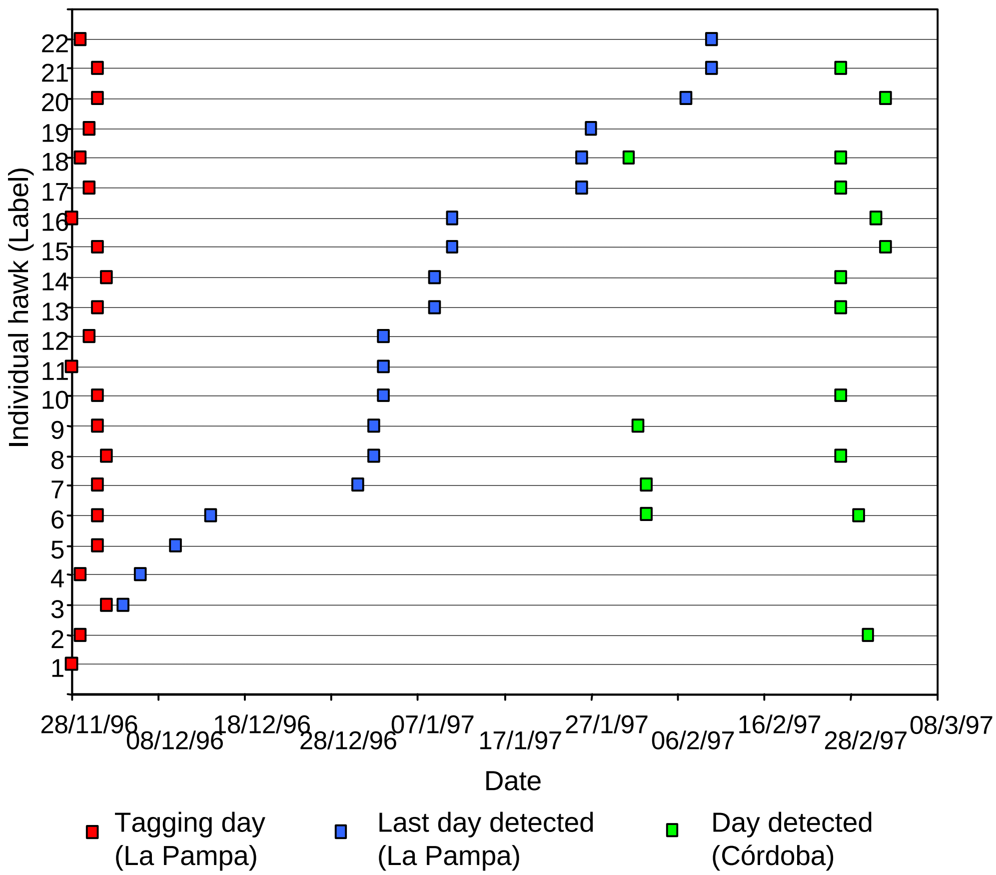


Figure 10. Progression of hawks leaving the study area in La Pampa. Note1: days are indicated as DD/MM/YY. Note 2: the Individual Hawks labeled 1and 2 were never found in La Pampa study area. Individual 1 was never found during the whole study period and individual 2 was found in the trip made to Córdoba province.

Between 24 February and 2 March 1997, a trip was conducted covering the south-central portion of Córdoba Province (3114 km). The systematic stops every 20-km detected 12 radio-tagged hawks dispersed over the region (Figure 11). Eight of these radios were found on the area around Río Cuarto, La Carlota and Vicuña Mackena

(Figure 11). One more individual was found on the north of that area and the other three near San Francisco, over Route 19 (Figure 11). Two of the 12 hawks were previously found in an exploratory trip developed between 29 and 30 January 1997 (Goldstein, pers. comm.). In this trip, researchers found 4 hawks in different areas around San Francisco, Córdoba. However, the trip did not include systematic stops for radio-checks, so it is probable that more hawks were present in the surrounding areas.

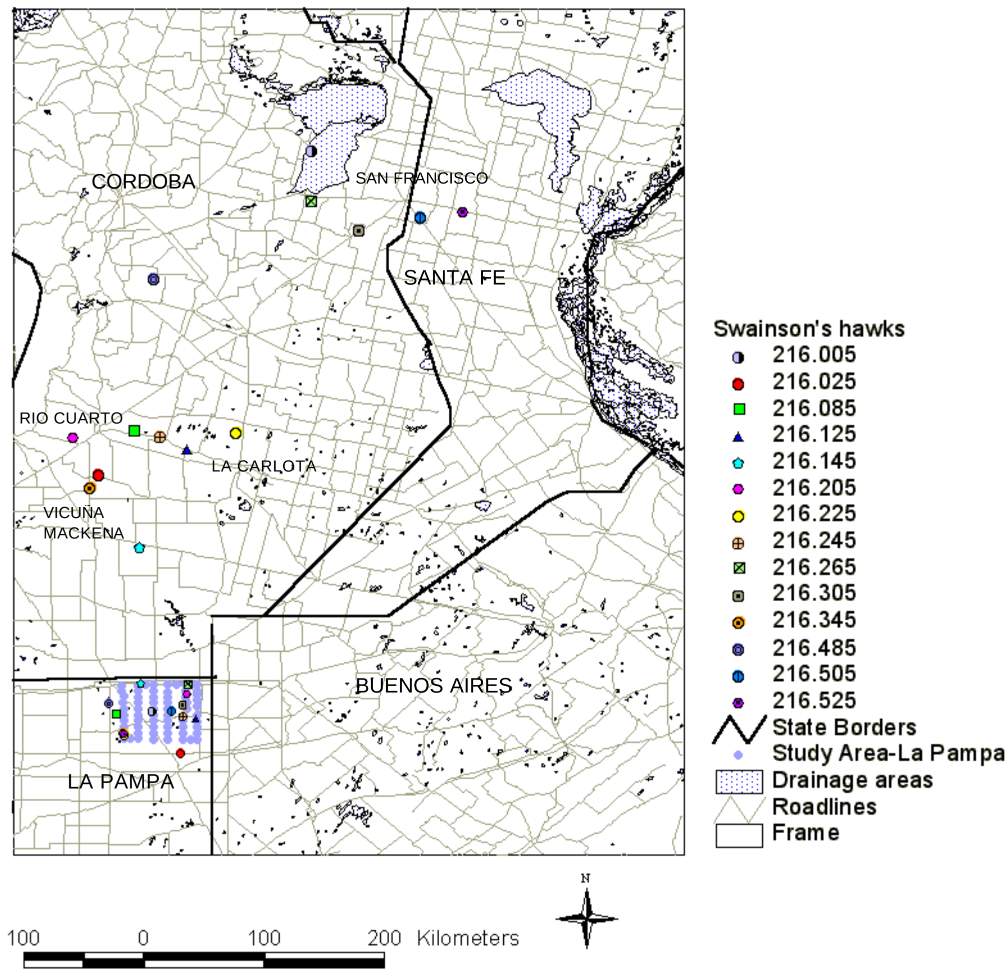


Figure 11. Last location of radio-tagged hawks in La Pampa study area and first findings on Córdoba province, Argentina (1996-97).

Habitat Use by Swainson's Hawks in the Study Areas

Individual and Flock Patterns of Habitat Use During the Day

Four hundred sixteen observations were conducted on 22 days between 16 December 1996 and 13 March 1997 with 3±2 days of difference between consecutive days. Two hundred four observations were conducted in the morning (0600-1040 H) in 10 different days, 139 at midday (1041-1520 H) in 8 days and 73 observations in the afternoon (1520-2000) in 7 days. On three days (16 December 1996, 8 and 17 January 1997), observations were made on more than one block. Most of the observations were of adults (62%, n=273) and both juveniles and adults were mainly light phase (Table 6).

Table 6. Distribution of individual observations by morphotypes.

Morphotype	Frequency (%)
Adult/Clear	237 (62%)
Adult/Black	26 (7%)
Adult/Reddish	7 (2%)
Juvenile/Clear	104 (27%)
Juvenile/Black	4 (1%)
Juvenile/Red	2 (0.5%)

Hawks spent most of the day (59%) sunbathing/resting, preening and foraging on the ground (Figure 12A), principally early in the morning and late in the afternoon. The remaining 41% of the time, concentrated at midday hours, was spent soaring, gliding and foraging in the air. The time hawks devoted to each behavior varied in relation to the hour of the day (Pearson Correlation Coefficient = -0.24, p=0.04) and, therefore, temperature (PCC=-0.41, p=0.04). As expected, these two variables (time and temperature) were autocorrelated (Pearson Correlation Coefficient=0.29, p=0.0001) and behaviors varied in relation with both of them.

Most of hawks stayed on the ground until 0900-1000 H in the morning (temperatures going from 11ºC to 29ºC; Figure 12B). Then proportions changed and most of hawks were observed soaring between 1100 H and 1600 H (temperatures oscillating between 20ºC and 38ºC). Observations made with the highest temperatures (35ºC-38ºC) were at midday only on soaring hawks. At 1700 H hawks could be observed in equal proportions in the air and on the ground and from 1800 H until 2000 H (temperatures going from 35ºC to 20ºC) most of the hawks were again observed on the ground (Figure 12B).

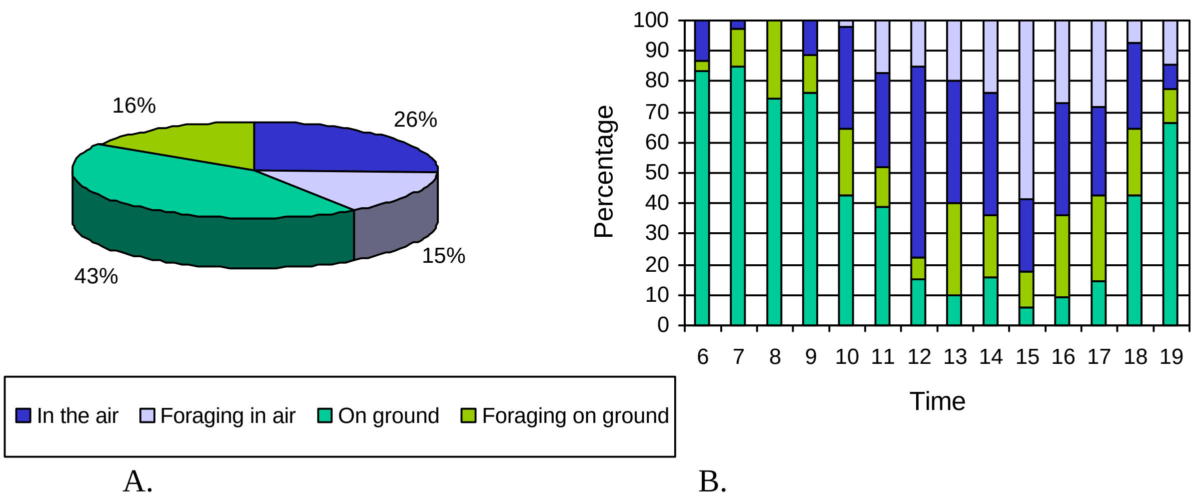
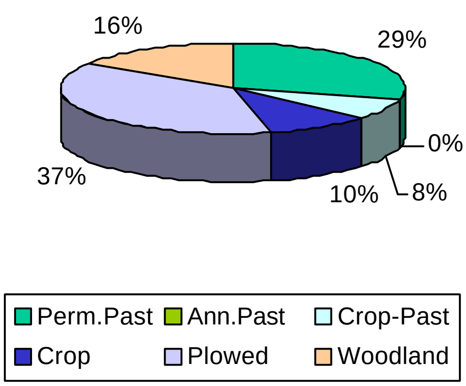
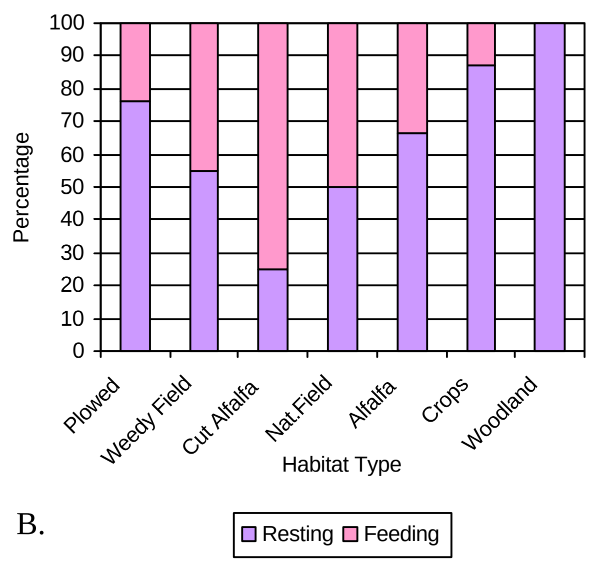


Figure 12. Daily activity pattern of Swainson’s hawks in their wintering grounds. A.Activity budget, B. Distribution of activities at different hours.

Hawks were on the ground mostly on plowed fields (37%, n=129 observations) and permanent pastures (29%, n=84 observations; Figure 13A). When on the ground, hawks were feeding or just resting (sunbathing) and/or preening, principally on plowed fields and woodlands during the morning and afternoon, and permanent pastures at midday (Table 7). Foraging occurred mostly on permanent pastures (56%; principally weedy fields, cut alfalfa and natural fields), especially at midday and during the afternoon. To a lesser extent, they fed on plowed fields (43%), especially during the morning. It is important to notice these relationships. Although more hawks were observed on the ground on plowed fields (Figure 13A), they were principally sunbathing, resting and/or preening rather than foraging (77% resting/preening vs. 23% foraging) compared with the reverse situations for hawks observed on permanent pastures (38% resting/preening vs. 62% foraging; Figure 13B). On woodlands (20% of observations of hawks on the ground), all the observed hawks on the ground were resting and/or preening in trees (Table 7). Most of the fields used during the morning or in the afternoon were next to the roost or within 500-1000 m from the roost (one/two intermediate plots).



A.



B.

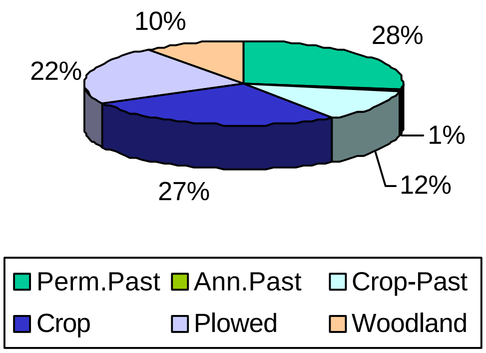
Figure 13. Habitat types used for hawks to land on the ground during focal observations. A. Percentage of observed hawks on the ground in relation to habitat type. B. Percentage of observations on each activity at each habitat type (ordered by habitat type importance for hawks observed on the ground).

Table 7. Individual Swainson's hawk behavior in different habitat types at different times of the day.

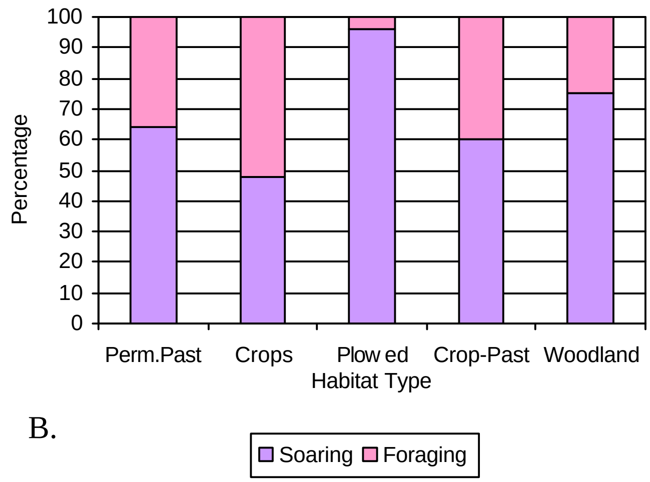
MORNING (0600-1040 h)					
	Behavior				
Habitat	On the ground	Foraging on ground	In the air	Foraging in air	Total
Perm.Past.	26 (76%)	8 (24%)	0	0	34 (17%)
Ann.Past.	0	0	0	0	0
Crops	5 (83%)	1 (17%)	0	0	6 (3%)
Plowed	**73 (68%)**	**21 (19%)**	**14 (13%)**	**0**	**108 (53%)**
Woodland	**44 (84.6%)**	**0**	**8 (15.4%)**	**0**	**52 (25%)**
Crops/Past.	4 (100%)	0	0	0	4 (2%)
Partial Total	152 (74%)	30 (15%)	22 (11%)	0	204 (49%)
MIDDAY (1041-1520 h)					
Perm.Past.	**14 (22%)**	**20 (32%)**	**20 (32%)**	**9 (14%)**	**63 (45%)**
Ann.Past.	0	0	0	1 (100%)	1 (0.7%)
Crops	3 (10%)	0	12 (40%)	15 (50%)	30 (22%)
Plowed	14 (47%)	5 (17%)	11 (37%)	0	30 (22%)
Woodland	0	0	1 (100%)	0	1 (0.7%)
Crops/Past.	1 (7%)	0	12 (85%)	1 (7%)	14 (10%)
Partial Total	32 (23%)	25 (18%)	56 (40%)	26 (19%)	139 (33%)
AFTERNOON (1521-2000 h)					
Perm.Past.	**6 (26%)**	**10 (43%)**	**3 (13%)**	**4 (17%)**	**23 (31%)**
Ann.Past.	0	0	0	0	0
Crops	0	0	3 (75%)	1 (25%)	4 (5%)
Plowed	**13 (68%)**	**3 (16%)**	**2 (10%)**	**1 (5%)**	**19 (26%)**
Woodland	6 (46%)	0	3 (23%)	4 (31%)	13 (18%)
Crops/Past.	2 (14%)	0	3 (21%)	9 (64%)	14 (19%)
Partial Total	27 (37%)	13 (18%)	14 (19%)	19 (26%)	73 (17%)
TOTAL	211 (51%)	68 (16%)	92 (22%)	45 (11%)	416 (100%)

Note: **Bold** indicates principal habitat types used on each time block.

Although soaring hawks would make evaluations of habitats at a greater scale than plot level, possible associations (e.g., availability of insects emerging from determined habitat types) with habitat types were explored. Observations of soaring hawks were evenly distributed among different habitat types (Figure 14A). However, when hawks foraging in the air were considered, a different picture appeared. All hawks foraging in the air were observed at midday (n=26 observations) and afternoon (n=17observations), mainly over crops and pastures (at midday), and crops-pastures mixture, pastures and over/next to the roost (on the afternoon; Table 7, Figure 14B).



A.



B.

Figure 14. Habitat types over which soaring hawks were observed during focal observations. A. Habitat types. B. Activity at each habitat type.

In summary, based on the observations made in this study, a day for the Swainson's hawks in their wintering ground can be divided on three periods (Figure 15): in the first period (morning), hawks were mostly on the ground, still on the roost or in plots next to them (mainly plowed fields and, to a lesser extent, pastures), sunbathing/ resting, preening and some of them feeding. As the day advances (midday and afternoon), hawks increasingly soared and fed in the air, mainly over crops and pastures. Hawks observed on the ground during midday were on plowed and pasture fields, but those foraging were mainly on permanent pastures. In addition, at this time hawks were observed feeding on the ground mainly on permanent pastures. During the afternoon, prior to roosting, most of the observed hawks were on the ground on plowed fields and pastures, staying on the ground, preening and foraging (not captured by the MCA analysis, Figure 15, but shown on Table 7).

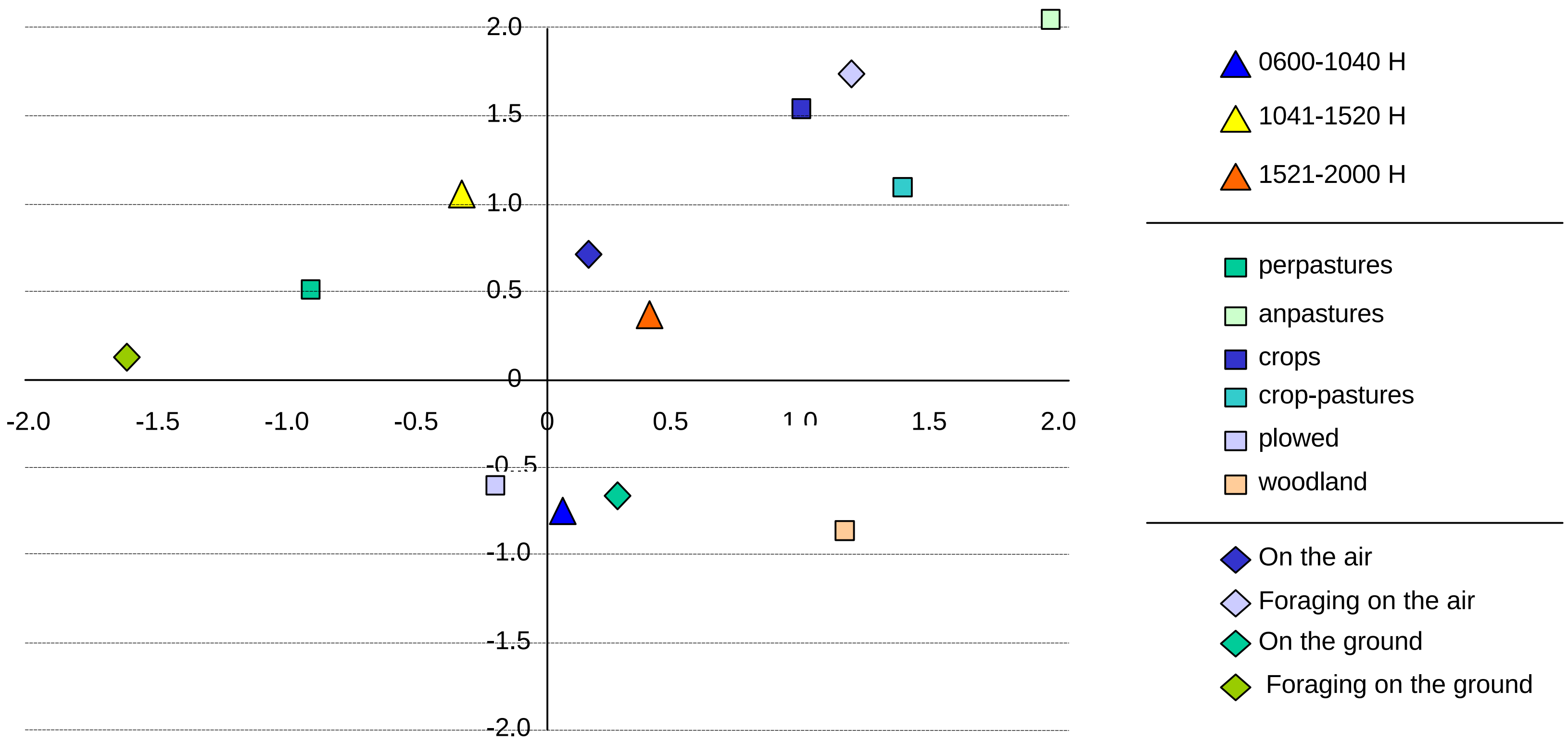


Figure 15. Multiple correspondence analysis including all individual observations of Swainson's hawks monitored in La Pampa study site, Argentina, 1996-97 austral summer. Associations could be inferred from icons located in the same quadrant and/or direction from the origin.

Foraging behavior

Although not tested in this study, opportunism in the selection of foraging plots and prey items seemed to characterize foraging behavior by wintering Swainson's hawks. Even when prey items consumed by hawks could not be identified by sight, pellets collected in sporadic occasions in La Pampa (1997) indicated that hawks principally eat grasshoppers and other insects such as caterpillars and beetles (Bosisio, Canavelli and Maceda, unpublished). In one occasion, hawks were observed "diving" into a cornfield with plants about 60 cm of height. The plot was infested with a weed ("verdolaga", *Portulaca oleracea*) and caterpillars (*Celerio lineata*) that, in turn, infested the weed. Corn plants were widely dispersed due to problems with water allocation, allowing hawks to land on the plot. Pellets collected at a nearby roost contained almost exclusively remains of these caterpillars, as it happened with pellets collected at another roost next to a plowed field. As an example of the versatility of hawks' foraging habits, fresh pellets collected on the same date at two different roosts within the study area were composed predominantly of grasshoppers, in one case, and of caterpillars, in the other one. This was observed in two different occasions, in coincidence with observations from other people in other areas (Frana, pers. com.).

Hawks were observed foraging in plots associated with agricultural practices that increased availability of food items, such as grazing, plowing, mowing/baling, harvesting and burning. Particular habitat types were fields being plowed (with the machine working on the same plot hawks were using), alfalfa fields (standing or after being mowed and bailed), row pastures being bailed, weedy and natural fields, and corn (emerging). In addition, as have been previously observed in North America and Argentina (Delhey and Scorolli 1988, England et al. 1997), in one occasion hawks were observed soaring over the smoke of grass/stubble fires in the pursuit of insects driven out by the fire (reference on other raptor species: Newton 1979, Tewes 1984, Alerstam 1990).

In spite of general observations indicating a principally insectivorous diet, there were casual observations of hawks trying to capture small vertebrates. In one occasion, a hawk was observed trying to capture a small European hare (*Lepus capense europea*) in a plowed field, although in other situation, two small hares were completely ignored by hawks resting on a plowed field. Previous references (White et al. 1983) mentioned remains from a rodent's jaw in pellets collected in Buenos Aires Province, and people working on baling pastures in the study area commented about seeing hawks preying on small rodents as the pasture was being cut. Hawks over wintering in California have been observed preying on rodents (Herzog 1996). Finally, as an indication of the versatility in the Swainson's hawks wintering diet, Di Giacomo (pers.com.) indicated the observation of a hawk feeding on a domestic chicken and probably even snails in Cordoba Province (Argentina).

From individual observations, more foraging hawks were on the ground (n=72 observations, 30 on the morning, 25 at midday and 13 in the afternoon) than in the air (n=45 observations). But considering only the time in which hawks were foraging both in the air and on the ground (midday and afternoon), the numbers were very similar (n=26 on the air vs. n=25 observations feeding on the ground at midday, n=17 observations on the air vs. n=13 observations on the ground in the afternoon; Table 7). In both cases (in the air and on the ground), most of the time was spent just resting/soaring rather than foraging (67% vs. 33% on the air, 76% vs. 24% on the ground).

Foraging rate

A total of 58 observations of hawks foraging either in the air (n=14) or on the ground (n=44) were used on the estimation of prey consumption attempts (Note: the differences between these numbers and the total of observations on foraging hawks (previously described) are given by the observation of actual prey catching attempts in the first case). Due to the distance of observation and size of the prey consumed (insects such as caterpillars or grasshoppers), it was not possible to differentiate between successful and unsuccessful attempts. Nevertheless, the capture effort, assumed as the number of attempts (pecks)/unit of time (minute) was used for comparison purposes.

Rates varied between 0.2 and 4.8 attempts/minute, with a mean of 0.9±0.9 attempts/minute. Sixty-seven percent of the rates were between 0.2 and 0.8 attempts/minute. Forty-eight percent of the total rates (n=28) were obtained at midday, with temperatures between 20-26ºC (53.4%, n=31). Lower but similar percentages of rates were determined in the morning (28%, n=16) and afternoon (24%, n=14). Although the highest rates (3 and 4 attempts/minute) were found at the highest temperature (35-38ºC), rates were not related with temperature (F=1.88, p=0.17, R2=0.03).

Rates were evenly distributed on the different behaviors. For hawks foraging in the air, rates were mainly between 0.2 and 0.8 attempts/minute (71%), with the 29% remaining on the higher rates (3 and 4 attempts/minute) found both at midday and during the afternoon. Nevertheless, at midday, most of the rates were lower than in the afternoon (≤ 0.8 attempts/minute). For hawks on the ground, 86% of the rates were ≤ 1 attempt/minute. Two-attempts/minute was found at midday (44% of observations during that block), and there was only 1 record with 3 attempts/minute.

Most of the prey capture attempts were obtained on pastures (50%, n=29) and plowed fields (38%, n=22), and there was not a clear pattern of differentiation between both habitat types. Seventy-two percent of the rates in pastures and 86% on plowed fields were ≤ 1/minute. On pastures, most of the remaining percent was on rates between 1 and 2/minute (24.1%).

<u>Flock observations</u>

Flock sizes varied between 2 and 5700 (Figure 16). Fifty-percent of the total observations were made on groups of less than 50 individuals. The rest of the observations were concentrated on groups of 100-200 individuals, with 2 sporadic observations on groups of 5100 and 5700 individuals that corresponded to roosting aggrestations observed late in the afternoon and early in the morning, respectively (Figure 17).

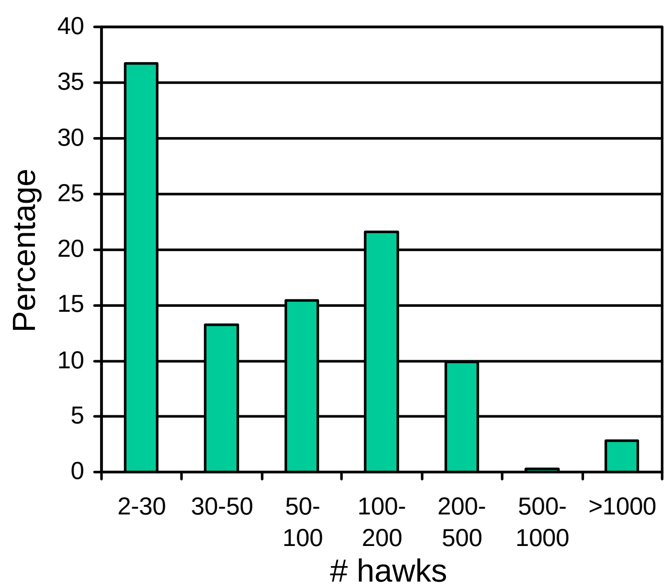


Figure 16. Swainson’s hawk group sizes observed during focal observations, La Pampa province, Argentina.

Group size was correlated with the time of day (Pearson Correlation Coefficient=-0.19, P=0.0005) but it was not correlated with temperature (Pearson Correlation Coefficient=-0.057, p=0.29). Groups got smaller as the day advanced (mean group sizes between 56 and 32 individuals, between 1200 and 1700 H), but larger groups were again observed late in the afternoon (1800-1900 H; Figure 17). Group size was correlated with cloudiness (PCA=0.15, p=0.006) and wind speed (PCA=0.17, p=0.002), with the biggest group sizes occurring with cloudiness between 75-100% and wind > 20 km/h (storm conditions; Table 8).

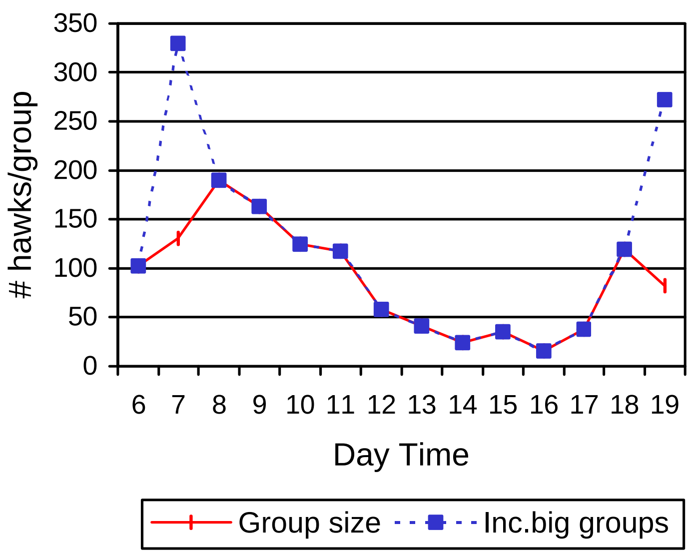


Figure 17. Average diurnal trend in Swainson's hawk group sizes.

Big groups foraging on the ground were usually observed on permanent pastures and plowed fields, with smaller foraging groups observed on crops (Table 9). From the three circumstances in which groups greater than 1000 individuals were observed, one corresponded to a foraging group (n=1500 hawks) observed during the morning on

Table 8. Swainson's hawk group size related to cloudiness and wind speed, La Pampa province, Argentina.

	Cloudiness				
Group size	0%	1-25%	26-50%	5-75%	>76%
Mean±STD (N)	72±82 (140)	126±126 (59)	85±59 (20)	67±85 (22)	150±300 (90)

	Wind Speed			
Group size	Null	Move Herbs 0-10km/h	Move Shrubs 11-20km/h	Move Trees >20km/h
Mean±STD (N)	56±74 (32)	75±72 (84)	77±75 (51)	136±238 (164)

a cut alfalfa field. The other two observations, as it was previously mentioned, corresponded to roosting aggregations (pre-(in the afternoon) and post-(in the morning)) observed on woodlands next to plowed and weedy fields. From a total of 14 roosting groups observed in the study area (n=14), group sizes varied between 40 and 6000 individuals, with a mean of 996 individuals/group. Most of the time hawks roosted on *Eucalyptus* sp. windbreaks and groves, although other exotic species also were used (such as "olmos"(*Ulmus* sp.) in La Pampa and "paraísos" (*Melia azederach*) in Santa Fe study area.

Table 9. Swainson's hawk group size (mean±STD, (N)) by habitat and behavior, La Pampa province, Argentina.

	Habitat					
	Perm.Past.	Ann.Past.	Crops	Plowed	Woodland	Crop-Past.
In the air	25±24 (36)	2 (1)	79 ±57 (25)	112±97 (18)	63±87 (29)	66±89 (17)
Foraging in the air	66±47 (7)	0	56±65 (5)	0	0	53±63 (9)
On the ground	40±76 (14)	0	0	130±81 (47)	61±153 (27)	58±78 (3)
Foraging on the ground	242±433 (39)	0	14 (1)	134±85 (53)	0	0

Habitat Use at Population Level

Habitat use characterization

During the surveys conducted on both study areas, hawks were predominantly observed using permanent pastures to land on the ground. From the total of 1058 observations with hawks made in La Pampa area, only 209 (20%) were made of hawks on the ground. A similar situation occurred in Santa Fe, where only 393 (38%) observations were made with hawks on the ground from a total of 1027 observations with hawks. On both areas, most of the observations were made on permanent pastures (55% in La Pampa, 61% in Santa Fe; Figure 18). In La Pampa, plowed fields followed pastures in importance of use, while in Santa Fe, annual pastures were the secondly more used habitat type. In this area, pastures (permanent and annual) represented the 79% of observations. The rest of observations were evenly distributed among crops, plowed fields and woodlands, without a clear dominance.

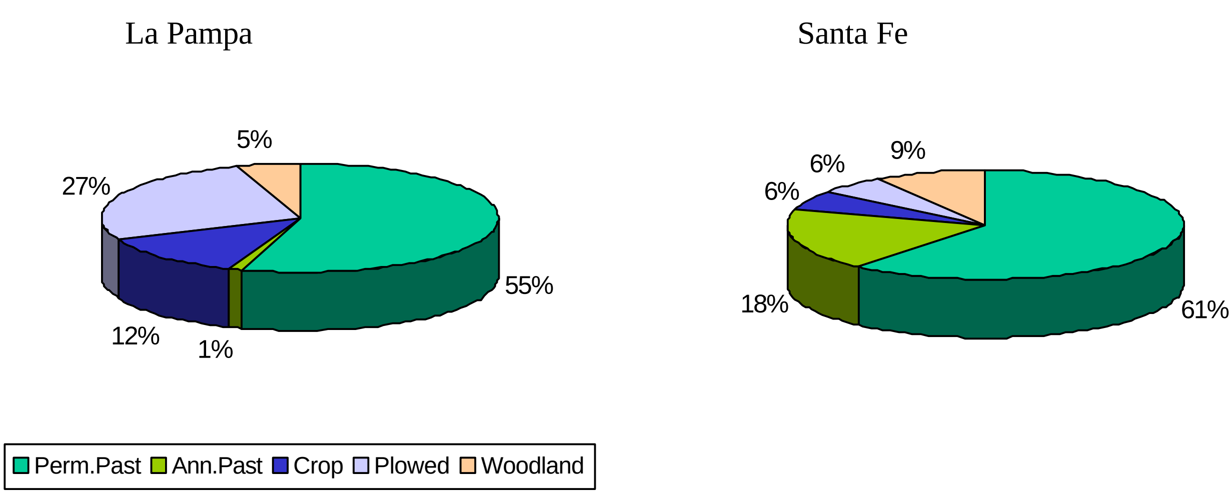


Figure 18. General habitat use (% of observations with hawks on the ground on each habitat type) of Swainson’s hawks in La Pampa and Santa Fe study areas, Argentina.

Considering habitat types in more detail, it is possible to observe some peculiarities on the wide use Swainson's hawks made of available habitats on both study areas. Among permanent pastures (fields that were not moved on an annual basis), weedy and natural fields were more used than alfalfa fields, even when the last one was cut and baled. In La Pampa, weedy fields and natural pastures comprised 70% of permanent pasture habitat observations. Although more observations were made on standing alfalfa than when cut (Figure 19), more animals (bigger groups) were observed on cut alfalfa than on standing alfalfa (n=1785 individuals in 17 observations in cut alfalfa vs. n=855 individuals in 23 observations in standing alfalfa). In Santa Fe, 83% of the observations made on permanent pastures were in weedy and short-grass fields (Figure 19). In this case, both number of individuals and observations made in alfalfa were greater in cut than in standing alfalfa.

Annual crops and pastures, subject to intensive agricultural practices, were used when operations such as plowing, harvest (wheat) or baling (millet) were developed or when the vegetation structure (plant height or cover) allowed to do so (ex: corn fields). A common picture on the cases was observation of Swainson's hawks perching on alfalfa/millet rolls (bales) during/after harvest or hawks using plowed fields while the plowing machine was moving on the field. In La Pampa, plots with annual crops and pastures were mostly used when plowed (Figure 19). Wheat was used when stubble, and corn and sunflower were used principally when emerging (plant height <40 cm), having great soil exposure. In Santa Fe, seventy-two percent of observations made on plots annually plowed were made on cut annual pastures (millet) and plowed fields, both circumstances that left open soil available for hawks.

In both areas, hawks selected permanent pastures to forage on the ground (61% of observations with foraging hawks in La Pampa, 70% of observations in Santa Fe), followed in importance by plowed fields (Figure 20). The mean number of hawks in foraging groups on the ground was 207±65 in La Pampa and 86±37 in Santa Fe. Most of them were on weedy, plowed fields and cut alfalfa in La Pampa and short-grass, weedy and plowed fields in Santa Fe.

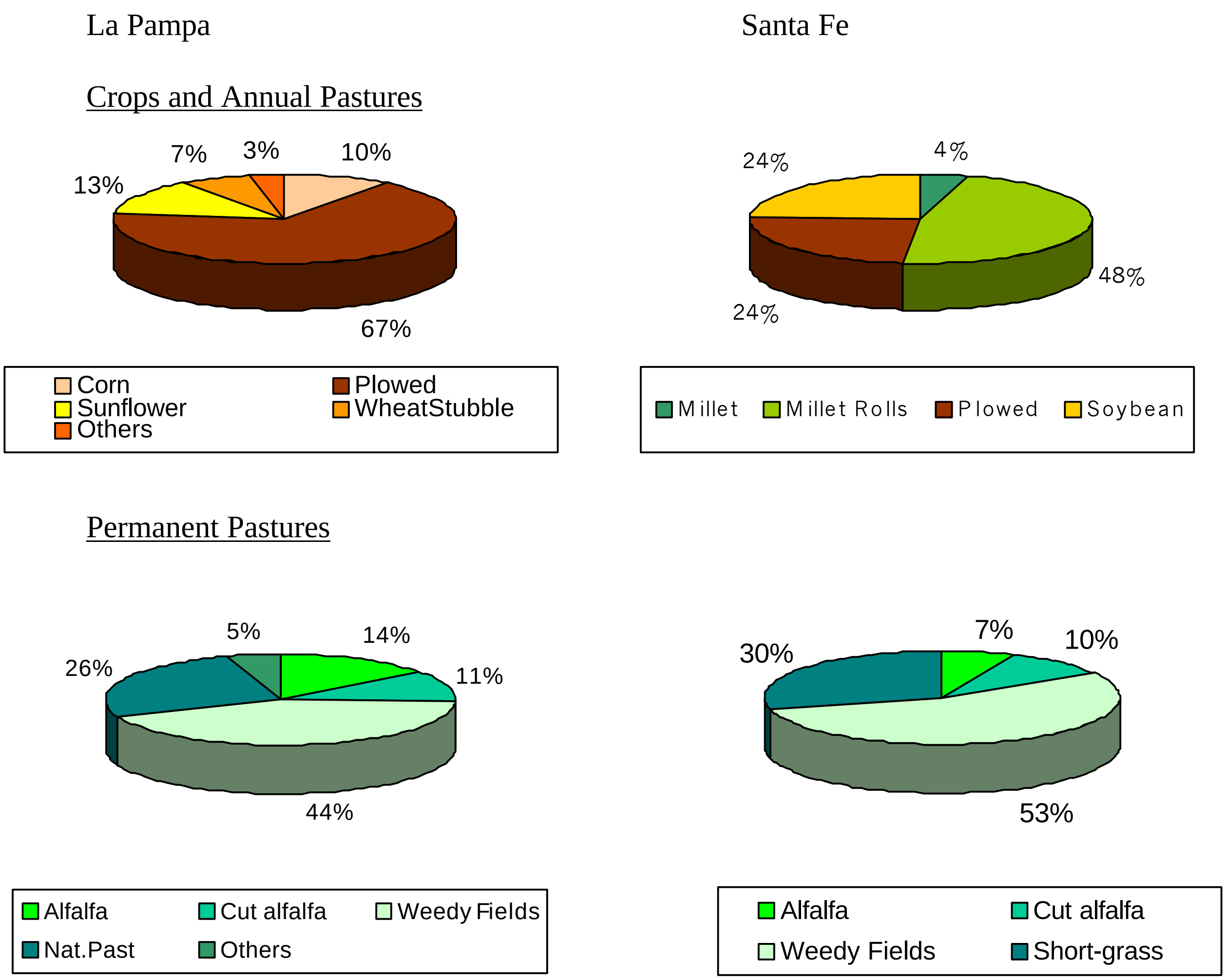


Figure 19. Habitat types used by Swainson's hawk in La Pampa and Santa Fe study areas, Argentina (% of observations with hawks on the ground).

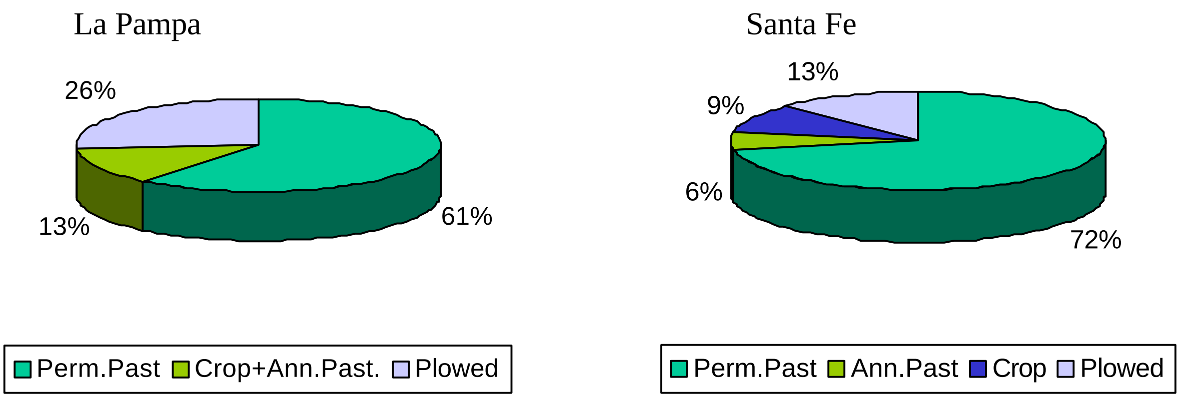


Figure 20. Habitat types used for foraging (% of observations with foraging hawks) within La Pampa and Santa Fe study areas, Argentina.

<u>Habitat availability</u>

In both study areas, crops and annual pastures comprised most of the surface (Figure 21), followed by permanent pastures. Woodlands contributed little to the general land cover. Land cover classification using the Maximum Likelihood method was selected for La Pampa area and using Minimum Distance method for Santa Fe area, based on the minimum differences between available statistics and the information from the images (Tables 10 and 11).

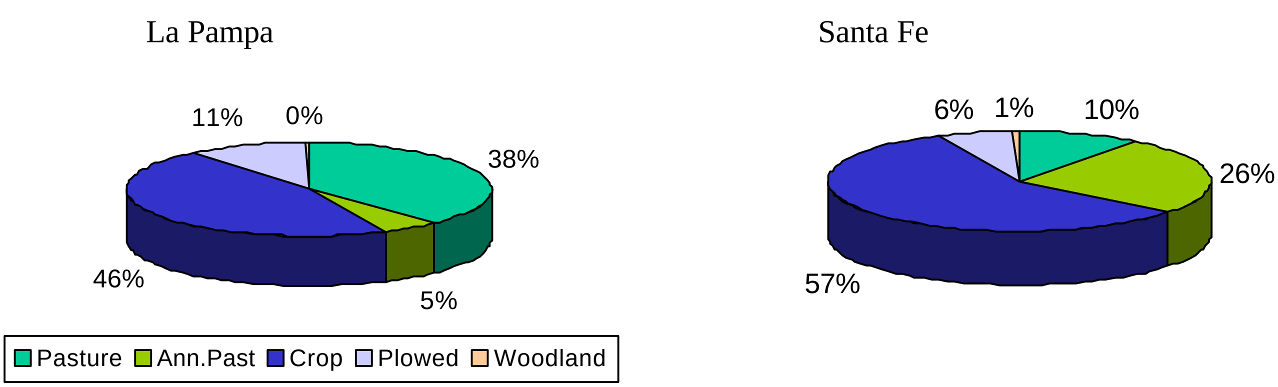


Figure 21. Abundance of used habitat types in La Pampa and Santa Fe study areas, Argentina.

Table 10. Cover of habitat types determined with different satellite image classification methods.

La Pampa

	Min. Dis.		Max. Lik.		Isoclust		State Statistics*
Habitat	Ha	%	Ha	%	Ha	%	%
Pastures**	142897.0	0.445	127708.4	0.411	68772.1	0.209	0.388
Crops ***	170141.6	0.530	179071.5	0.576	242256.5	0.735	0.571
Native W.	5934.9	0.018	358.6	0.001	11727.6	0.036	0.002
Eucalyptus	512.7	0.002	659.5	0.002			0.002
Lowland	1719.0	0.005	2913.8	0.009	6721.9	0.020	0.036
Total	321205.1	1.000	310711.8	1.000	329478.1	1.000	1.000

Urban habitat not included for comparison due to lack of state statistics
* Information from "Dirección Nacional de Estadísticas y Censos, REPAGRO 96"
** Pastures include permanent pastures (alfalfa, others), weedy fields, natural pastures
*** Crops includes annual crops, annual pastures and plowed fields

Santa Fe

	Min. Dis.		Max. Lik.		Isoclust		State Statistics*
Habitat	Ha	%	Ha	%	Ha	%	%
Pastures	27592.3	0.102	72784.1	0.273	69563.3	0.283	0.130
Annual Past.	69227.7	0.257	83258.9	0.313	38987.4	0.159	0.347
Crops	154909.0	0.575	92632.3	0.348	106087.1	0.432	0.483
Plowed	17544.7	0.065	17512.0	0.066	30779.3	0.125	0.040
Total	269273.7	1.000	266187.3	1.000	245417.1	1.000	1.000

Urban and Eucalyptus woodland not included for comparison due to lack of state statistics.
* Information based on data from INTA, EEA Rafaela, Soils Department, April 1999

Table 11. Differences between each classification method and the available statistics.

La Pampa				Santa Fe			
Habitat	Min Dis.	**Max Lik.**	Isoclust	Habitat	**Min Dis.**	Max Lik.	Isoclust
Pastures	0.057	**0.023**	-0.179	Perm.Past.	**-0.028**	0.143	0.153
Crops	-0.041	**0.005**	0.164	Annual Past.	**-0.090**	-0.034	-0.188
Native W.	0.016	**-0.001**	0.033	Crops	**0.092**	-0.135	-0.051
Eucalyptus	-0.001	**0.000**	-0.002	Plowed	**0.025**	0.026	0.086
Lowland	-0.028	**-0.024**	-0.013				

Habitat selection (use vs. availability)

Comparisons made using the program HABUSE showed that Swainson's hawks selected permanent pastures and woodlands in both study areas (Chi-square=531.8, p=0.000 for La Pampa; Chi-square=625.6, p=0.000 for Santa Fe; Figure 22). Byer's and Bailey's intervals indicated that, in addition to these habitat types, hawks used plowed fields more than available in La Pampa and as expected in Santa Fe (Table 12). Crops and annual pastures were used less than expected based on their availability.

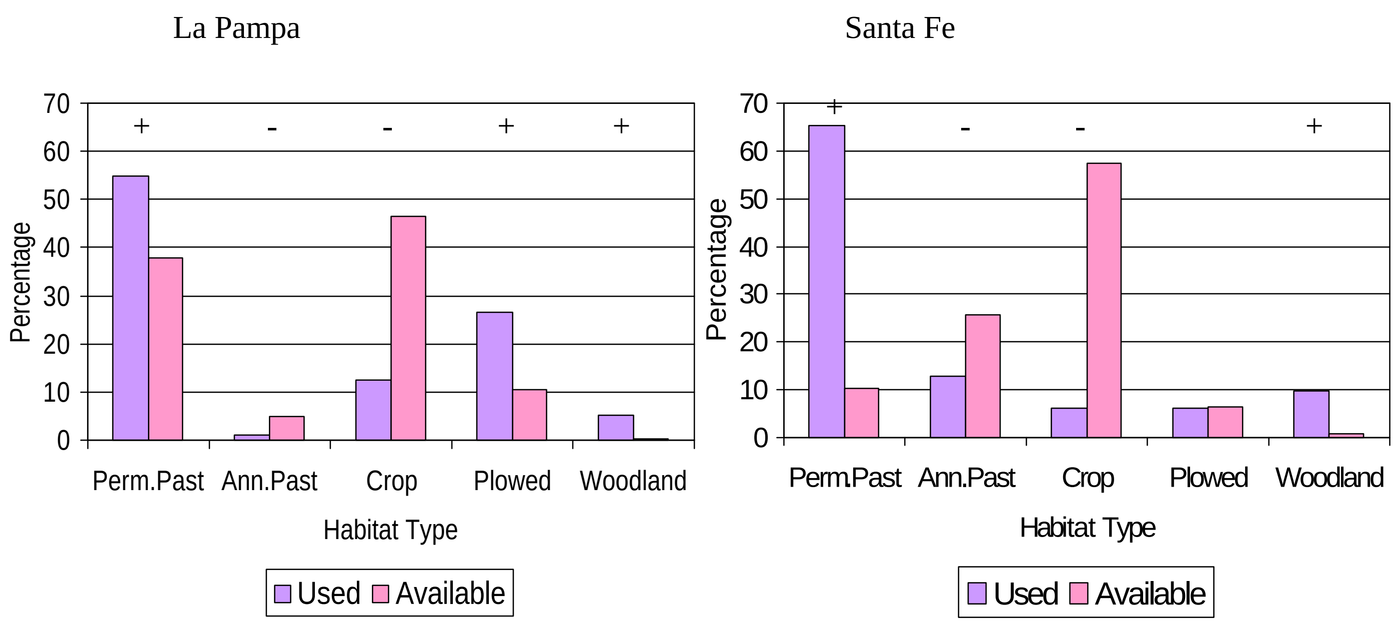


Figure 22. Habitat use vs. availability in La Pampa and Santa Fe study areas, Argentina.

Spatial Distribution in Relation to Habitat Availability

On both study areas, hawks showed a clumped distribution pattern, but this pattern was not related to the quantity of selected habitat types, at least at the analyzed scale. Hawks were irregularly dispersed in the area, with some points concentrating

Table 12. HABUSE analysis of habitat use vs. availability for La Pampa and Santa Fe study areas, Argentina (p-value = 0.05).

La Pampa

	Byer's Intervals (Habuse)				Bailey's Intervals (Cherry, 1996)		
Habitat	Observ. Use (%)+	Use Interval	Expected Use (%)++	Habitat	Observ. Use (%)	Use Interval	Expected Use (%)
Perm.Past.	0.548	**0.473-0.624 *** **	0.419	**Perm.Past.**	0.548	**0.439-0.646 *** **	0.419
Annual Past.	0.010	0.000-0.026 *	0.047	Annual Past.	0.010	0.000-0.047 *	0.047
Crops	0.124	0.074-0.174 *	0.420	Crops	0.124	0.063-0.201 *	0.420
Plowed	**0.266**	**0.199-0.332 *** **	0.112	**Plowed**	0.266	**0.177-0.361 *** **	0.112
Woodland	**0.052**	**0.018-0.085 *** **	0.002	**Woodland**	0.052	**0.015-0.110 *** **	0.002

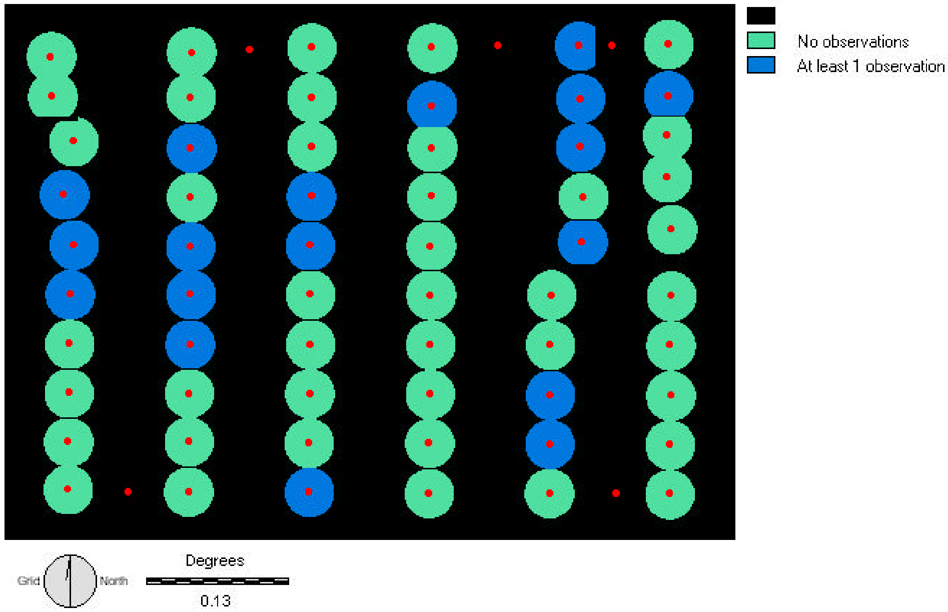
Santa Fe

	Byer's Intervals (Habuse)				Bailey's Intervals (Cherry, 1996)		
Habitat	Observ. Use (%)	Use Interval	Expected Use (%)	Habitat	Observ. Use (%)	Use Interval	Expected Use (%)
Perm.Past.	**0.611**	**0.547-0.674 *** **	**0.102**	**Perm.Past.**	**0.611**	**0.530-0.683 *** **	**0.102**
Annual Past.	0.183	0.133-0.233 *	0.257	Annual Past.	0.183	0.126-0.248 *	0.257
Crops	0.059	0.028-0.089 *	0.575	Crops	0.059	0.027-0.102 *	0.575
Plowed	0.056	0.026-0.086 **	0.065	Plowed	0.056	0.025-0.099 **	0.065
Woodland	**0.092**	**0.054-0.129 *** **	**0.005**	**Woodland**	**0.092**	**0.051-0.143 *** **	**0.005**

+ Percent Values originated on the % of observations of hawks on the ground/habitat type
++ Percent Values originated on the classified satellite image.

***** Used more than Expected /** ** Used as Expected / * Used less than Expected

La Pampa



Santa Fe

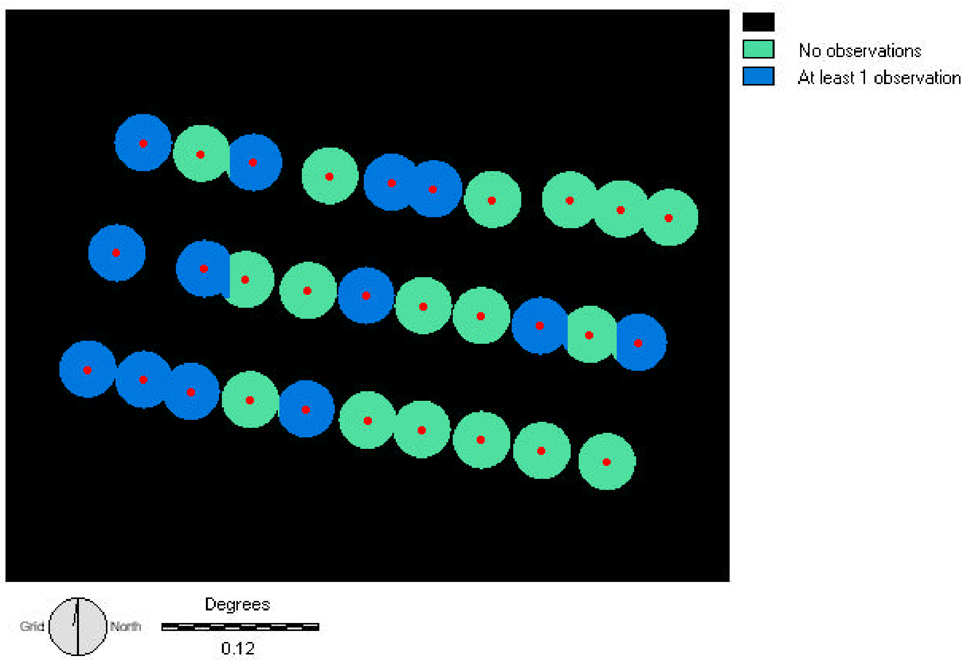


Figure 23. Spatial distribution of hawk's observations in the study areas, denoted by the number of observations with hawks on different points at 500m (effective detection distance determined by DISTANCE and a 2.5-km buffer around each point).

numerous observations and others presenting with very few or null observations (Figure 23). However, the concentration of hawks in specific points was not correlated to the availability of selected habitat types such as permanent pastures, plowed fields or woodlands at those points, at least at the analyzed scale (2.5 km radio-circle around each survey point). First explorations relating the number of observations with hawks and the relative abundance of each habitat type around each point gave no clear indication of any relationship, except when considering plowed fields in La Pampa area (Figure 24).

In addition, the linear models relating the combination of the five habitat type abundance on each point with the number of observations with hawks on each point offered significant relationships but with low explanation power (only 30% or 43% of explanation for the variance in hawk's numbers, $F= 4.64$, $p=0.0013$, $R2=0.30$ for La Pampa; $F=3.79$, $p=0.01$, $R2=0.43$ for Santa Fe area). The abundance of plowed fields on points in La Pampa area was the only parameter estimate that gave a significant relationship ($p=0.003$) in these combined models.

Looking at these relationships through a multivariate method, the pattern previously mentioned was a little more explicit and, although there was not a clear differentiation of habitat associations on points with hawks and without hawks, some tentative relationships seemed to emerge. In La Pampa, points without hawks usually had less plowed fields than mean available in the area, and points with hawks had greater percentage of pastures than the mean for the area and less percentage of crops (Figure 25). In Santa Fe, points without hawks were associated with annual pastures, crops and plowed fields in percentages greater than the mean available for the area. Conversely, points with hawks had greater permanent pastures than the mean percentage for the total area and woodland less than the mean for the area (Figure 25).

La Pampa

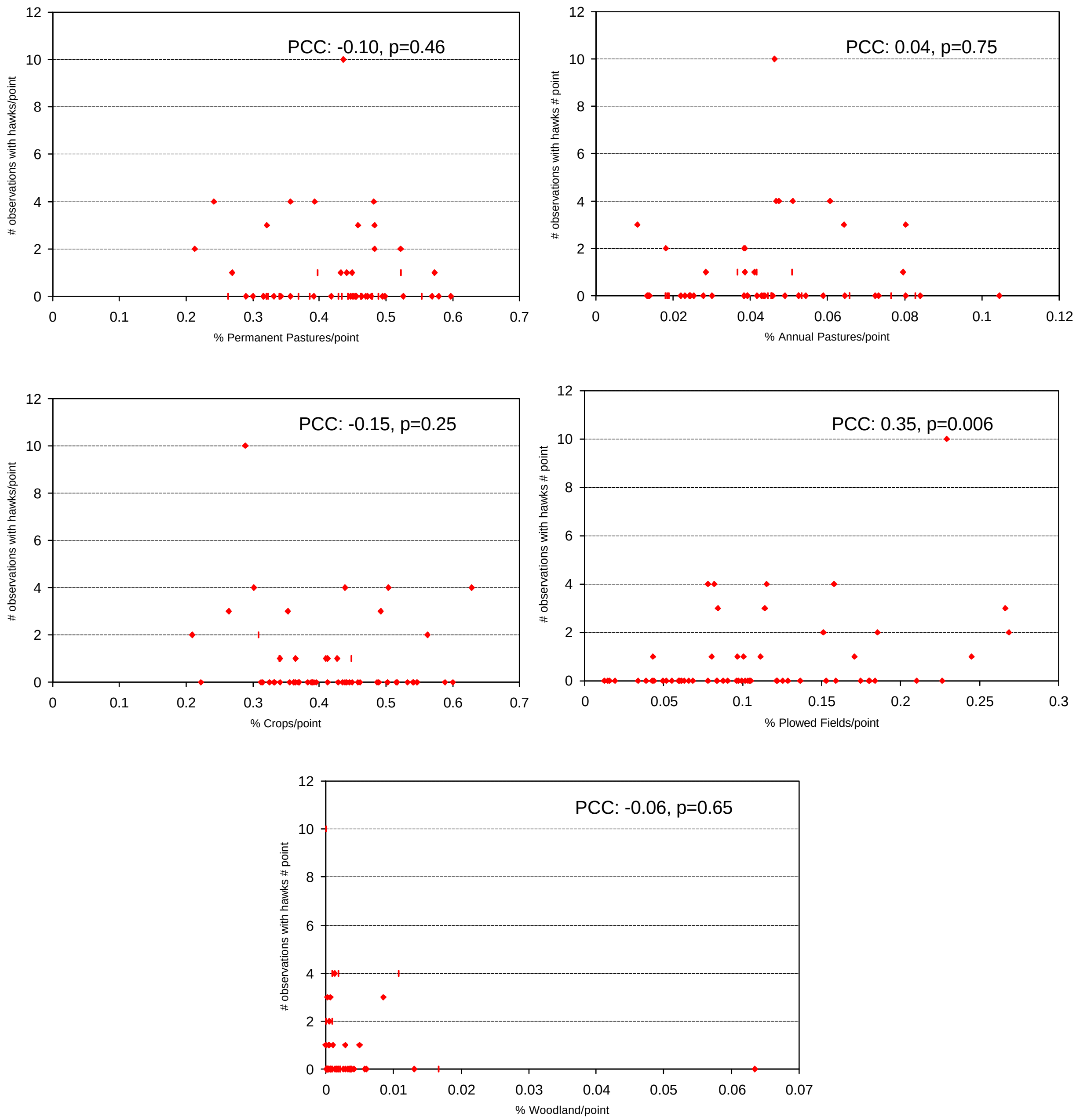


Figure 24. Plots relating the number of observations with hawks/point with the relative abundance of each habitat type at each point. Linear correlation coefficients are indicated on each graph. (PCC: Pearson Correlation Coefficient, p=Prob>R under Rho=0)

Santa Fe

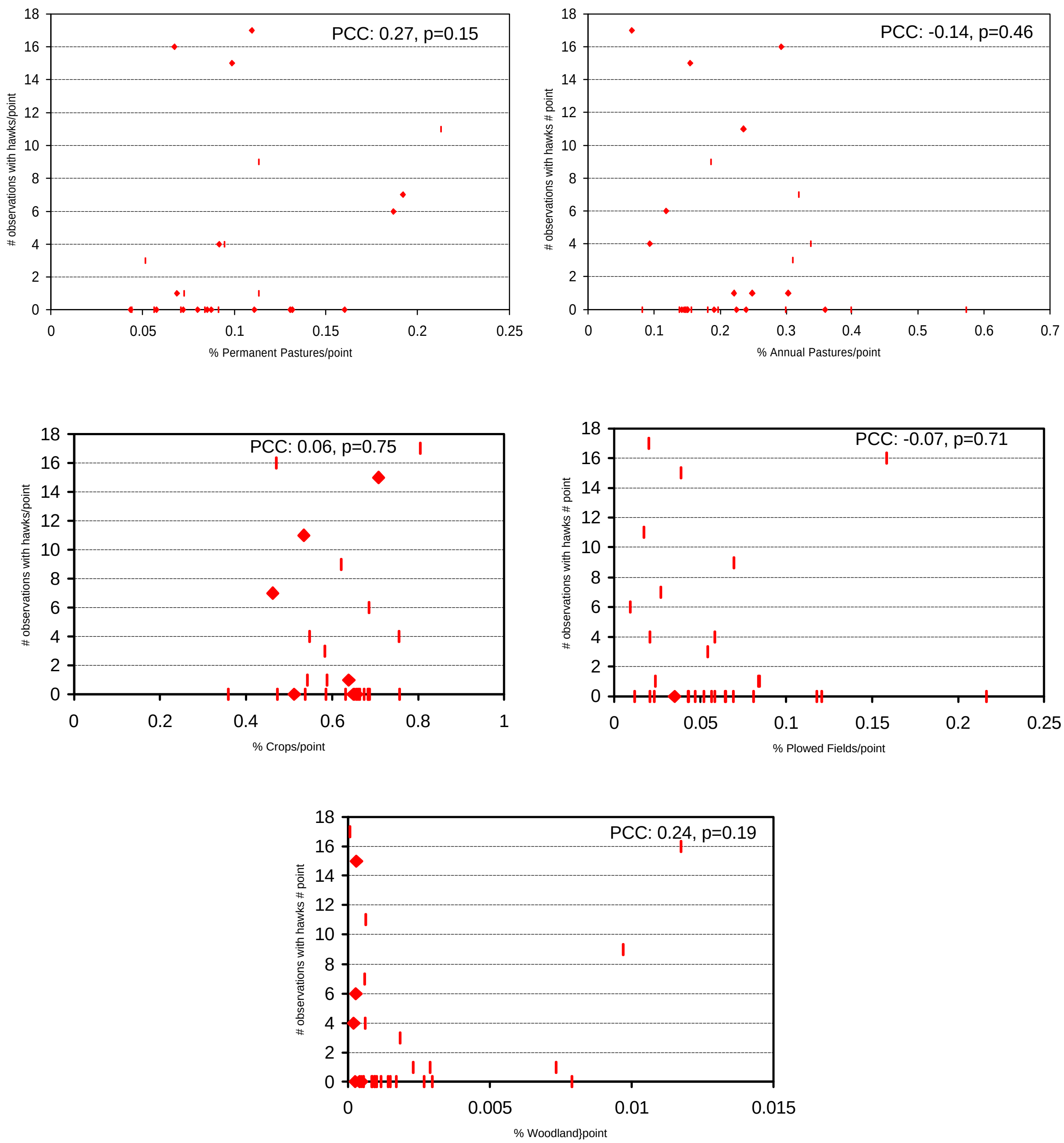
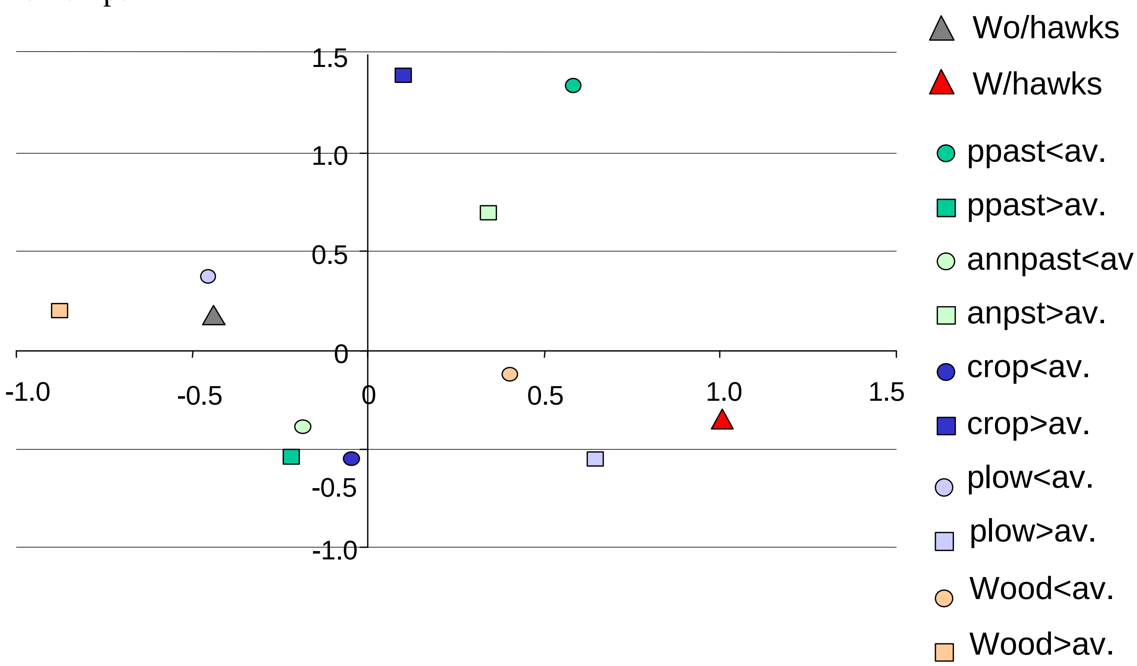


Figure 24--continued

La Pampa



Santa Fe

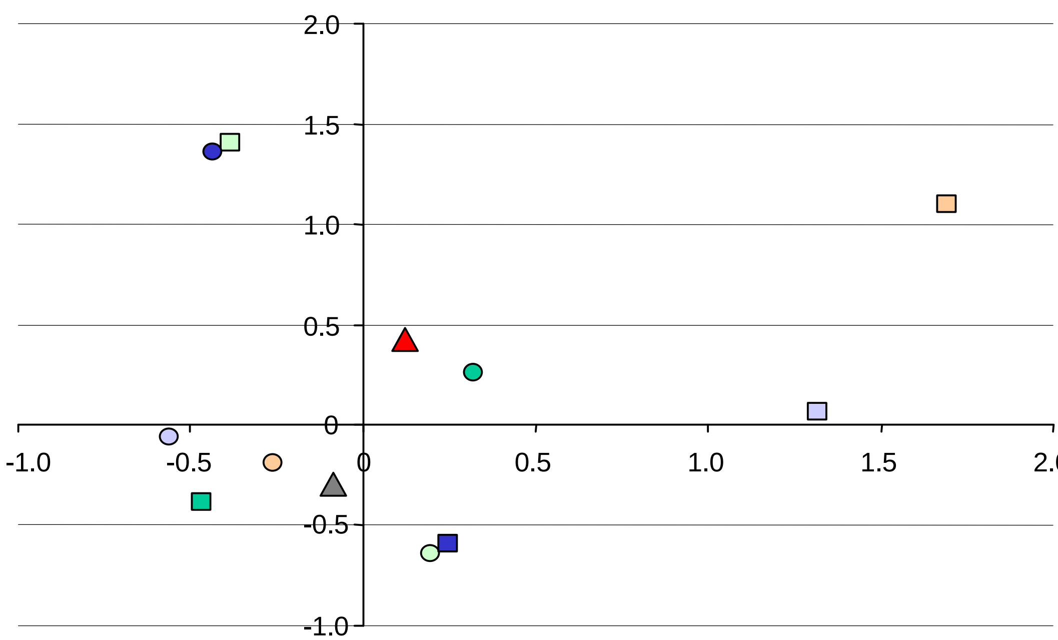


Figure 25. Multiple correspondence analysis including points with and without hawks (on the ground and at 500-600 m) and habitat abundance (< or > than the mean abundance in the area) within La Pampa and Santa Fe study areas, Argentina. Associations could be inferred from icons located in the same quadrant and/or direction from the origin.

DISCUSSION

Abundance of Hawks in the Study Areas

Abundance of hawks varied between and within study areas. In this particular study, variations in hawk abundance could be related to the methodology used in the field and during the analysis, the year in which the area was evaluated, the wintering region in which the area was included, the time of the season and the time during the day in which observations were conducted. However, from information on other raptor's wintering patterns, it is expected that the number of wintering hawks would vary spatially (within and between study areas) and temporally (within and between years), mainly in association with variations in food supply and weather conditions (Newton 1979, Alerstam 1990).

Variations in Hawk's Abundance Within the Study Areas

Variations in hawk's abundance within study areas could be conditioned by the methodology used to estimate density values, spatial heterogeneity in the distribution of selected habitats or temporal variations in habitat quality, food supply and weather conditions within the season. Both transects (La Pampa) and point-transects (La Pampa and Santa Fe) offered relatively good performance based on the number of observations of hawks obtained during the study. Both methods are commonly used for raptor counts on extensive areas (Fuller and Mosher 1981, 1987, Kochert 1986, Rivera-Milan 1995, Watson et al. 1996). In this study, continuous transects efficiently covered extensive areas, but they presented some biases due to differences in visibility conditions among secondary routes. On the other hand, point transects allowed for more control of habitat characterization and diminished biases due to differential detectability. Nevertheless, the clumped distribution of Swainson's hawks (flocking behavior, non-uniform use of the area) resulted in great variation in estimates, as indicated by many points with 0 counts and few points with many observations. A systematic sampling scheme such as the one used in this study would require extremely high sampling efforts in order to obtain lower CVs for the estimates (for example, in order to obtain a CV=10% on the density estimation it would be needed about 191 points (in Santa Fe area) and 1300 points (in La Pampa area); formulas from Buckland et al. 1993, pages 303-312). Therefore, it is considered that other sampling schemes, such as adaptive sampling (Thompson 1990, Seber and Thompson 1994, Smith et al. 1995) probably would be more appropriate for obtaining confident estimations of Swainson's hawk numbers in their wintering areas with a reasonable effort on the field, and their merit should be considered in future studies.

The lower number of hawks detected with point transects in La Pampa compared to strip transects could be explained by a difference in methodology or/and by a decrease on the number of hawks in the area (simultaneous with the change in methodology). The only way to elucidate this would be to have both methods developed simultaneously in the area. Nevertheless, based on the information from radio telemetry and relative abundance at different dates, it is possible to speculate that hawks were leaving the area at the same time the methodology was changed, and numbers were actually diminishing as the season advanced.

The program DISTANCE, used for the estimation of hawk densities, had the advantage of considering differential detectability on the estimations, usually giving more confidence on density estimators (Buckland et al. 1993). However, the difficulty of estimating the distance to the middle of the cluster (flock) and the segregation of the cluster by habitat type (not consideration of the whole cluster's size) possibly produced a slight underestimation of the actual density of hawks in the areas. Even so, previous records on wintering hawks densities would indicate densities found in this study as highly plausible. In a pilot study developed in 1994-95, Woodbridge et al. (1995) found a total of 20000(±4000) hawks in a 6400 km^2 area on northeastern La Pampa (2.5-3.75 haws/km^2, lower densities that the ones found in this study for the same region). On the other hand, Di Giácomo (1997) found a density of 7.2 hawks/km^2 in Córdoba Province, in an area where hawks usually concentrate in huge numbers.

In spite of the methodology used to estimate density in the study areas, numbers of hawks could vary within the areas in response of the spatial quantity and/or configuration of selected habitat types and temporal variations in habitat quality, food supplies and/or weather conditions through the season. The first hypotheses will be discussed in other section (see page 96) and a relationship between hawks abundance and weather could be inferred from correlation analyses. This study did not included evaluations of habitat quality and food supply in order to explore the other hypotheses. However, looking through the season within each area, observed variations are coincident with the pattern mentioned by Newton (1979, page 77) for wintering raptors. Citing studies with European and American Kestrels in Europe, he mentioned considerable variations in the number of individuals within the course of a single winter. Once again, these variations were related to food supplies.

The location of both study areas could partially explain the variations in the number of hawks within the season. The smooth decrease in the number of hawks toward the end of their wintering season (austral summer) in La Pampa was expectable given the proximity of this area to the southern extreme of their wintering distribution and the fact that hawks started moving north early in the season (mid-Jan/mid-Feb, radio telemetry results). On the other hand, the study area in Santa Fe province was located on the east of San Francisco (Córdoba), an area were satellite radio-tagged hawks usually concentrated and settled for more time (Fuller et al. unpublished). It is probable hawks concentrated around this area prior to fall migration (to the north), moving among different regions in search of food. In addition, extraordinary rainfall due to "El Niño" year could have influenced habitat and food availability, making hawks move more frequently from one area to another.

Finally, although decreases in the number of hawks within the study areas were correlated to a decrease in minimum temperature, no causation could be inferred. Variations in insect abundance (principally grasshoppers) resulting from biological traits, climatic factors and agricultural practices could have influenced the observed variations in hawk's abundance within the season in each study area, as has been observed in other wintering raptors (Newton 1979).

Variations in Hawk's Abundance Between Study Areas

Abundance of hawks in the two study areas are not completely comparable because the areas were covered in two very different years, and patterns of abundance for other migratory raptors indicate that the number of hawks in different wintering regions would vary greatly on a year-to-year basis (Newton 1979). Both study areas were included in regions where wintering Swainson's hawks traditionally concentrate (CIPA 1987, Fuller et al., in prep.). La Pampa study area was among the southern areas of arrival and concentration of satellite radio-tagged hawks in 1996-97 austral summer (Fuller et al., in preparation), with fewer satellite radio-tagged hawks found in the Santa Fe area that summer. However, this changed in 1997-98 austral summer, when more satellite radio-tagged hawks were detected in the Santa Fe area than in La Pampa ("El Niño" year). This information coincided with simultaneous counts developed in the summer of 1997-98, in which the lower densities were found in La Pampa as result of an historical rainfall and flooding of the area, while greater densities were found in Cordoba and Santa Fe (Canavelli 1998). These results reveal the impact of weather conditions on the first level of selection (regional) migrant hawks face when they arrive on their wintering grounds (Newton 1979, Hutto 1985, Alerstam 1990). In addition, they could indicate regulations on wintering hawks abundance on different wintering areas given year-to-year variations in food supply (Newton 1979). Unfortunately, the lack of systematic information on variations in insect abundance (especially grasshoppers) in both areas precludes the exploration of this hypothesis, but it merits testing in future studies given the implications for conservation strategies.

Movement of Individual Hawks in a Study Area

The low and variable success in finding hawks on a daily basis within La Pampa study area could be explained by the heterogeneous pattern of movement hawks had during the study period, in addition to the inadequacy of the study design to detect/follow this heterogeneous pattern. Hawks were continuously going in and out of the area with a stochastic, random pattern, not constituting stable groups neither for foraging nor for roosting (main daily activities while wintering). In addition, the systematic sampling scheme used to detect the hawks in the field did not adjust to the hawks' movement characteristics (wide daily movement rate and high speed of soaring individual) and wide range of detection distances (that implies many similar bearings from different points and impossibility of triangulation, Kenward 1987). Moreover, the lack of association and low probabilities of finding individual hawks could be considered as expectable given the large population of hawks in the wintering area and the relatively small number of radio tagged birds. However, the low probabilities of finding a large number of hawks in a specific area within hawk's wintering range were coincident with the ones referred by Newton (1979, page 77). He mentioned the difficulty of finding more than 1-7 wintering falcons (out of 12) in one day of observation in a specific area (particular study) and also the general pattern of individual wintering raptors staying in an area for greatly varying periods of time (individual variable movement pattern). This pattern would reflect an intrinsic characteristic of many migratory birds that need broad movements in order to exploit unpredictable and seasonal resources efficiently (Sherry and Holmes 1995, Kozakiewicz 1995).

A similar pattern of heterogeneity in the use of specific areas was observed both in the use of the main roost (used for a maximum of 3 consecutive days by individual hawks) and the change of roost places for hawks that were followed during a whole day. Although conclusions at this stage would be premature due to the small sample sizes (continuous analysis of only 1 roost and 5 occasions following a hawk during the whole day), results suggest that there is no daily fidelity to roost sites. This would coincide with several observations in the field, in which it was common to observe hawks in one roost during 1-3 days followed by roost abandonment, and then re-use for another short period of time some days later. Observations of local resident landowners also agreed with this pattern of intermittent roost use followed by short-term abandonment. Although the no-systematization of observations could introduce biases on them, they coincide with general patterns for raptors mentioned by Newton (1979) and proposed for wintering Swainson's hawks by White et al. (1989).

Activity Areas for Individual Hawks

Given the arbitrary definition of the study area and the wide dispersion of hawks in the area, the differences in amount of the study area used by individual hawks was not surprising. It is important to recall that these measures were taken during only 10-15% the time hawks were in or around the study area. Assuming a high probability that hawks were going in and out of the study area between successive points included on the Minimum Convex Polygon (MCP) estimation, the estimated activity areas would be only tentative measures of the use individual hawks made from the study area.

Locations used in the MCP estimation were enough to encompass 86% of the study area, showing the wide dispersal pattern of the hawks from their original/main roost. Therefore, it is expected that the percentage of different habitat types within each individual activity area to be very similar to the percentages for the whole study area. At least when individual hawks were detected within the study area, they did not concentrate their activities in areas with greater availability of permanent pastures, their selected habitat type (see page 94). This pattern is coincident with the one determined at the population level (see page 96).

Daily success of finding individual hawks and activity areas were lower for females than for males. This information could suggest a wider range of movement for females than males, although this is a completely exploratory result to be tested in another studies. Unfortunately, no information was available at the moment of this writing on the usual activity range for individual wintering Swainson's hawks determined from satellite telemetry (Fuller et al., in preparation). Therefore, no conclusions could be made about what proportion of the total wintering range (both from a hawk's arrival to its departure and within established regions) the activity areas found in this study represent, as well as about possible differences among sex or age classes.

Departure from the Study Area

Movement of hawks out of the study area could be determined by habitat extrinsic factors, such as a natural migration pattern in response to climatic variations, by habitat intrinsic factors, such as diminution of food availability, or both together. Although a significant correlation between radio-tagged hawks abundance in the area and minimum temperature was found, causation is not implied. Weather (minimum temperatures) during the day or a series of days previous to the waves of hawks leaving the area could be one of the factors influencing hawks to leave the area. But it is probable that other variables, related (or non-related) with weather, would cause the number of hawks to decrease (e.g., food availability, social interactions among hawks, etc.), especially considering the influence of food availability on dispersion/movement of wintering raptors (Newton 1979).

Habitat Use by Swainson's Hawks in the Study Areas

Individual and Flock Patterns of Habitat Use During the Day

Observations on individual hawks conducted in La Pampa study area in 1996-97 austral summer showed that hawks mainly use permanent pastures and plowed fields to land on the ground, although assigning different activities to different habitat types. Plowed fields were selected principally for sunbathing/resting early in the morning and in the afternoon, while permanent pastures were mainly selected as foraging habitats, especially at midday. This could be associated with particular conditions offered by each habitat type, principally in relation with food availability.

Plowed and other open fields (e.g., recently plowed or harvested crops) usually offer better conditions for the constitution of thermals during the morning than the rest of used habitat types, and probably greater availability of insects such as insect larvae or worms early in the morning and late in the afternoon. Dry and "naked" soils would provide better conditions for the constitution of thermal currents than others covered by vegetation (Rodriguez, pers.com.). Therefore, hawks would take advantage of this phenomenon principally resting/sunbathing in these habitats until thermals developed (morning) or after they disappeared (afternoon). On the other hand, insect dynamic (and availability) during the day is influenced by temperature (Murton 1971), and it is possible to speculate that insect larvae in plowed fields and crops would be more abundant on the upper layers of soil when temperatures are low, moisture high (early in the morning, late in the afternoon) or planting operations favor it. As temperature rises, larvae move to lower layers. Conversely, insects present in permanent pastures, such as grasshoppers, got more active as temperature rises, being extremely mobile at midday (Liebermann and

Schiuma 1946, Capinera and Sechrist 1982, Salto and Beltrame 1999), the time in which hawks were mainly observed foraging on pastures.

These differences in available prey in different habitats were manifested on hawk’s foraging behavior while on the ground. Hawks are adapted to pursue mobile and exposed species (from rodents to swarms of insects), both on the ground and in the air (Alerstam 1990). On plowed fields, hawks usually foraged by just standing until they saw a prey and then using short walks, runs, and pecks to the ground to catch the prey ("pouncing at and running down" grasshoppers and other insects "like domestic turkeys do", England et al. 1997). While on pastures, they performed this behavior as well, but they most commonly made short flights and jumps in addition to the short runs, apparently to flush the prey. These behaviors had been previously observed on Swainson's hawks by several authors (review in England et al. 1997).

As other migratory birds, Swainson's hawks' foraging patterns would reflect the availability of temporarily abundant, easily captureable, and often spatially unpredictable food resources (Alerstam 1990, Sherry and Holmes 1995). Although a detailed study of Swainson's hawk diet was not included in this study, preliminary observations were made during its development, corroborating information from previous reports. Hawks mainly feed on grasshoppers while wintering, although they would prey over other insects such as beetles, beetle larvae and dragonflies according to their availability (Liebermann, 1935, 1944, Pereyra 1937, White et al. 1989, Jaramillo 1993, Woodbridge et al. 1995, Goldstein et al. 1996, Goldstein 1997, Serracin Araujo and Tiranti 1996, Rudolph and Fisher 1994). Permanent pastures usually offer a greater availability of grasshoppers (and insects, in general) than the rest of the habitat types (row crops, annual pastures). On habitat types such as annual crops and pastures hawks were usually observed foraging in plots where agricultural practices increased availability of food items (Caldwell 1986), such as grazing, plowing, discing, mowing/baling, and harvesting, including burning of grasses or stubble.

It seems, from the observations in this study during the whole day, that hawks would rely more on feeding on the ground than in the air. On one hand, they spent more time on the ground than in the air. On the other hand, the type of habitats hawk selected for foraging, such as pastures and, at less extent, plowed fields, and the type of insects that usually constitute their wintering diet would suggest a strong reliance on foraging on the ground. However, biases such as unbalance amount of observations of hawks on the ground (given hawks on the ground were more numerous than hawks in the air for a longer period of time, increasing the probabilities of being observed), high temperatures at midday (creating thermal waves that made difficult the observation of behavioral details on hawks foraging in the air) and the size of the consumed prey items could influence the obtained results. Therefore, it would be premature to conclude about this specific subject, remaining as a very important topic (given its theoretical and applied implications) to be answered in future studies.

Both when feeding on the ground and in the air, foraging rates were lower than other rates estimated for the same species feeding on insects. Woodbridge (1991) estimated a foraging rate of 2-6 insects/minute for pre-migratory Swainson's hawks groups foraging on grasshopper's swarms (in the air) in California. Littlefield (1973) estimated a mean foraging rate of 1.6 worms/minute on pre-migrations hawks feeding on armyworms (*Spodoptera frugiperda*) in a wheat field. Considering that a hawk can consume approximately 100 grasshoppers/day (Johnson et al. 1987) and the total time they expend foraging during the day, the rates obtained in this study are plausible, although more research will also be needed to elucidate this point.

Finally, the observation of aggregations for foraging on the ground or roosting in La Pampa study area coincided with other aggregations mentioned by Woodbridge et al. (1995) and Goldstein (1997) in the same area. Foraging groups observed by Woodbridge et al. (1995) in January-February 1995 consisted in 50-1000 individuals, with one observation of a flock estimated in 4000 individuals. On the other hand, roosting groups has been mentioned varying between 25 and 7000 individuals (n=6) by the same authors (Woodbridge et al. 1995) and up to 12000 individuals (counted at the main roost, Chanilao, in 1995-96 summer) by Goldstein (1997). All these roosts were located in windbreaks and groves of *Eucalyptus* sp. although, as Delius (1953), Goldstein (1997) and this study mention, Swainson's hawks could use other exotic tree species for roosting. As it was previously mentioned, the casual constitution of these groups, with different individuals each time, would be another element to add at the hypothesis of use of highly seasonal or ephemeral resources.

Habitat Use at Population Level

Looking at populations of hawks sharing specific study areas during the summer season, it emerged that habitats used for foraging and roosting were selected over other habitat types, both in La Pampa and Santa Fe study areas (Argentina). Permanent pastures (mainly used for foraging), plowed fields (mainly used for resting/sunbathing near the roost) and woodland (used for roosting) were used disproportionately more than its availability in each study area. These habitat types offered patches of resources (food or roost) for wintering hawks and they were in lower proportions than the rest of the habitat types in the study areas (dominated by annual crops). Therefore, the pattern of habitat selection observed in this study would be the expected from individuals selecting particular habitats to enhance their fitness (Hildén 1965, Rosenzweig 1985).

From the optimum habitat theory (Rosenzweig 1981, 1985), underlying the analysis of hawk's abundance in relation to habitat quantity is the assumption that all the habitats in the region have the same availability to the hawks and hawks would concentrate on high quality habitats (selected habitat types). Although factors such as inter- and intraespecific interactions and a decrease in habitat quality as density increases could influence the observed patterns, especially in the case of migratory birds using unpredictable and patchy environments (Hildén 1965, Fretwell and Lucas 1970, Fretwell 1972, Van Horne 1983, Thomas and Taylor 1990, Sherry and Holmes 1995), the social behavior of hawks while wintering with no observation of visible aggressive inter- or intra-specific interactions, the wide range of movement and the continuous offer of insects in a changing agricultural landscape during the summer season would allow to speculate about a minimum influence of these factors on the observed pattern of habitat selection. Therefore, it is expected that population abundance in different habitats would reflect general habitat suitability (Kozakiewicz 1995), particularly in relation to food availability.

Although not measured in this study, food availability (determined by prey abundance and vegetation structure) could be strongly conditioning the selection of permanent pastures on both study areas for landing and foraging on the ground. This is based on the patterns of habitat use shown by other diurnal wintering raptors in temperate zones (Newton 1979, Alerstam 1990) and also the characteristics of the habitat use pattern Swainson's hawks manifest in the breeding areas (Estep 1989, Woodbridge 1991, Swallwood 1995). Sharing the characteristic of most of Neotropical migrants and Old World migratory raptors, Swainson's hawks are insectivorous while wintering (see page 92), probably depending on "boost and bust" cycles of insects availability typical from temperate zones (Alerstam 1990, Newton 1979, Petit et al. 1995, Rappole 1995). In this study, the tendency to constitute untied flocks, mainly to forage on the ground early in the morning and late in the afternoon in the proximity of the roosts, could be associated with a more efficient strategy for finding and using unpredictable and widely dispersed resources (such as insects; Bell 1991, Newton 1979). The same explanation could be given for communal roosts, which would facilitate social communication among raptors feeding on abundant, yet widely spaced and transient food-sources (such as insect swarms; Newton 1979).

On the other hand, the relationship between the principal prey of Swainson's hawks while wintering (grasshoppers) and the habitat types selected by hawks for foraging (permanent pastures) would be coincident with the kind of association found for Swainson's hawks in their breeding areas (Estep 1989, Woodbridge 1991, Swallwood 1995), but in this case the primary prey would be insects, particularly grasshoppers, instead of rodents. Grasshoppers are usually the dominant aboveground invertebrate in pastures and natural grasslands (at least when judged by biomass, Capinera et al 1997), and they constitute critical elements in the food supply of many birds and mammals on these habitats (McEwen 1987). Weedy (fallow) fields (usually old pastures or alfalfa fields) and short-grass fields (dominated by *Cynodon dactylon*) in Santa Fe province offered a higher grasshopper abundance and lower vegetation cover (resulting in greater grasshopper's availability) than other habitat types used by hawks foraging on the ground (Canavelli and Salto, unpublished). Therefore, it is possible to speculate about the strong influence that food availability had on habitat selection patterns of Swainson's hawks in their wintering grounds, as has been observed for other wintering raptors (Newton 1979, Alerstam 1990).

Spatial Distribution in Relation to Habitat Availability

From the optimum habitat theory (Rosenzweig 1981, 1985, Woodbrige 1991), it could be expectable to find a relationship between the abundance of selected habitat types (habitat quantity) and abundance of hawks, a reasonable assumption for highly vagile organisms such as this migratory raptor (Sherry and Holmes 1995). But this relationship could not be verified in this study, at least at the analyzed scale. Although hawks selected permanent pastures, woodlands and, in one of the areas, plowed fields, their spatial distribution in both study areas did not related to habitat availability (quantity), at least at the analyzed scale (2.5 km buffer around each survey point). In both areas, selected habitats were less abundant than other habitat types (particularly in Santa Fe), but this was not sufficient to determine a concentration of hawks on places with greater abundance of these habitats.

Different biological and methodological factors such as the influence of habitat configuration (spatial pattern of distribution) instead of habitat quantity (Wiens 1989, Sherry and Holmes 1995); the reliance more on aerial foraging than foraging on the ground (Woodbridge 1991); the presence of behavioral attributes like site fidelity or social facilitation (Wiens 1985); the limitation on the scale of analysis (only one and small scale); the high environmental variability or/and wide variations in population abundances would preclude of finding any pattern of spatial distribution of hawks related to habitat quantity. From the observations of movement made in this study and considering that "Swainson's hawks are mobile, wide-ranging predators, potentially capable of assessing the quality of habitat patches from afar, and exploiting widely distributed patches of preferred habitat" (Woodbridge 1991), it could be expected that neither landscape configuration nor site fidelity would greatly influence hawk spatial distribution. And results from this study are not conclusive about a predominant reliance on prey items taking in the air compared to the ground. However, it is possible to speculate that factors related to behavioral traits such as social facilitation, scale of analysis, environmental variability and variations in population abundances could have influenced the lack of concordance between hawks abundance and habitat quantity in different points.

Although no references are available about mechanisms of social facilitation acting on wintering Swainson’s hawks, the constitution of communal roost and foraging flocks could be reflecting an adaptation for exploiting temporarily and spatially unpredictable and ephemeral food resources (Ward and Zahavi 1973, Newton 1979, Alerstam 1990). Even mechanisms such as the presence of determined hawks in one plot and/or roost facilitating the aggregation of more hawks on that plot/roost could be postulated as possible acting on wintering hawks. If social interactions like these ones are actually taking place, it would be expectable to not find any pattern of association between the abundance of hawks in small areas (like the ones analyzed in this study) and the quantity of selected habitat types on those areas because hawks would concentrate in response to social factors, independently from habitat quantity o configuration.

A possible approach to explore the influence of the scale of analysis used to explore hawks distribution (habitat quantity on 2.5 km buffers around each point) would be to develop buffers around used vs. unused areas and relate hawks abundance with habitat abundance at different distances from the point (modification of Austin et al. 1996). Hawks showed a clumped distribution with greater use of some areas than others, and it is possible that a pattern could emerge at greater scales (different areas within a region, different regions). For example, the multivariate analysis developed in this study comparing points with hawks vs. points without hawks seemed to show a tentative associations between points with hawks and the abundance of permanent pastures is greater proportion than the mean available in the study area. However, aspects of design such as the lower number of points with hawk observations and the interdependence among points preclude to definitely conclude about this issue. As Freemark et al. (1995) mentioned, the understanding of the relationships between landscape structure and migratory bird abundance is best achieved if the grain and the extent of the population(s) of interest and the defined landscape closely match. In this study, given the concentration of hawks on regions greater than individual points and the wide dispersal shown by individual hawks, it is highly probable that neither the grain nor the extent of the populations were closely matched by the defined landscape scale (study areas).

On the other hand, environmental variability characteristic of a temperate agricultural landscape and wide fluctuations on population abundance could preclude of finding any association between hawks concentration on definite points and habitat quantity at that points. An agricultural landscape could be described as a steady state of a spatially shifting mosaic of patch types, in which there are always different patches of all types at all times (Rotenberry et al. 1995). In addition to this heterogeneity, density of insects such as grasshoppers could highly vary even in small areas (Przybyszewski and Capinera 1990). Swainson's hawks have adapted to these variations and would respond to and reflect this environmental stochasticity. Therefore, their distribution in the space within small areas would be probably more based on particular plot characteristics than on landscape arrangement of the habitat types, and this would preclude finding a relationship between distribution of hawks and spatial arrangement/quantity of habitat types. This tendency would be reinforced if variations in hawk's abundances through the season are high in an specific area and weakly related to habitat structures (Wiens and Rotenberry 1981, Thomas and Taylor 1990), such as was observed in this study.

A study conducted by Woodbridge (1991) in northern California (breeding areas) showed that hawks did not concentrate on areas with greater availability of selected habitat types. Swainson's hawks selected specific habitats with higher prey availability. However, they did not include greater proportions of these selected habitat types in their territories, nor concentrate territories on areas with higher availability of these habitat types, nor did they distribute themselves (as populations) in different geographic areas according to the habitat composition. Woodbridge (1991) suggested behavioral (site tenacity and natal site philopatry) and environmental factors (high temporal variability of habitats in agricultural environments) constrained density and distribution of hawk populations of tracking the available habitat.

Considering wintering Swainson's hawks would be not less influenced by food availability than when breeding and would have more freedom of movement (not tied to a nest; Newton 1979), a similar pattern could be postulated, with a combination of behavioral and environmental factors precluding hawks from occupying an ideal-free distribution in relation to high-quality habitats (population size of a species in any given landscape, and its average density over the landscape, as functions of the quality and distribution of habitat, Fretwell and Lucas 1970, Woodbridge 1991). Nevertheless, there are many probable factors that could preclude finding a strong association between the number of observed hawks and characteristics of areas at different levels. The clarification of these factors would require specific experimental designs in future studies.

CONCLUSION AND CONSERVATION APPLICATIONS

Conclusion

As Wiens (1985) and Morrison et al. (1998) stated, population level observations of habitat use reflected decisions made at the individual level. On both study areas and at both levels of observation (population and individual levels), Swainson's hawks were highly associated with agricultural environments, in similarity with the patterns of habitat use observed in the breeding ranges. In addition, as it happens with other migratory raptors in the New and Old World, the patterns of abundance, movement and distribution found in this study appeared to show adaptations to the dynamic changes in the heterogeneous agricultural landscapes, with food playing a predominant role governing dispersion and habitat use of wintering Swainson’s hawk.

On the breeding areas, individual foraging hawks have been found to track temporal changes in habitat structure, prey availability (related to agricultural practices), and relative abundance and body composition of different prey species, selecting habitats wherein prey capture/unit of effort was maximized (Woodbridge 1991). This behavioral traits, added to the spatial and temporal heterogeneity on food availability in agricultural environments would be reflected, for example, on the strong selection of habitat types such as pastures and the lack of concordance between the abundance of these habitat types and the abundance of hawks at different spatial scales, as it was found for breeding hawks by Woodbridge (1991) A similar pattern would occur on their wintering grounds, also in coincidence with the ones reported on other migratory and raptor species (Newton 1979, Alerstam 1990).

Furthermore, highly variable environments (such the ones characteristics of agroecosystems) and food availability, in addition to the freedom of movement hawks would have given they are not tied to a nest or territory while wintering, would help to explain other patterns observed in this study. For example, variations in abundance among years, among regions and within a region the same year could be related to heterogeneous variations in food availability at different scales. The same factor could explain the clustered distribution within specific areas and not concordance with selected habitat quantity. At the individual level, the heterogeneous individual patterns of movement and no constitution of tight groups/flocks, but the aggregations in communal roosts and foraging groups would be related to evolutionary adaptations to exploit heterogeneous environments and optimize success on them (Ward and Zahavi 1973, Newton 1979, Alerstam 1990).

Although results from this study could be considered as preliminary (on a case basis) and no generalizations can be made at this stage, some patterns have emerged in one of the first attempts to explicitly describe association between Swainson’s hawks and the environment in their wintering grounds. The high association of agricultural practices and Swainson's hawks has been well established in their breeding areas (Bechard 1982, Estep 1989, Woodbridge 1991, several authors reviewed in England et al. 1997), but has sporadic references for the wintering grounds (Ambrosetti 1919, Liebermann 1935, 1944, Pereyra 1937, White et al. 1989). The present study complement information obtained from other research projects conducted by Woodbridge et al. (1995) and Di Giácomo

(1997), constituting bases for more detailed studies at population and individual levels and at different spatial and temporal scales (comparisons among regions, areas within a region, plots and prey items; and among/within years). Very soon, information at the regional scale will be available from satellite telemetry (Fuller et al., in prep.). But some of the questions proposed by White et al. (1989) for wintering hawks, specially related to roost dynamics and biology, have not been answered and would merit future investigation. Finally, as it would be discussed in the next section, information originated on systematic studies such as this one would help people to understand and prevent massive mortality events or other impacts that agricultural practices can produce on wintering Swainson's hawks' populations.

Conservation Applications

Most of the risk factors for the impact of organophosphorous and carbamate pesticides applications mentioned by Grue et al. (1983) and Mineau et al. (1999) are combined in wintering Swainson's hawks. They are vulnerable to these impacts through physiological condition, such as poor fat reserves or high energy demands related with migration, and behavioral traits, such as presence in agricultural areas; foraging habits, given by an insectivore diet (with a wide range of insects as prey items) and opportunistic taking of debilitated prey; habitats used for foraging; and gregarious behavior such as constitution of foraging groups. In addition, as other migratory birds, hawks would concentrate in greater densities in wintering than in summer areas, making them very susceptible to winter habitat change and impacts on these areas (Terborgh 1980, 1992).

From this study, habitats selected for foraging were permanent pastures that included weedy, natural and alfalfa fields. Most of the mortalities reported in Argentina in the 1995-96 austral summer occurred as result of pesticide applications in alfalfa fields, with sporadic reports in crop fields such as corn, wheat and sorghum (Goldstein 1997). Although in this study alfalfa fields were used at less extent than weedy or natural fields, and crop fields were sporadically used and not selected as foraging habitats, the combination of insect outbreaks and pesticide applications (increase on food availability by the spraying machine on the plot) could have favored the congregations of hawks on these plots, resulting in the massive mortalities (range: 14-3024 individuals in alfalfa fields (n=12), 387 individuals in a corn field (n=1), 9 individuals in a wheat field (n=1) and 109 individuals in a sorghum field (n=1); Goldstein 1997).

Besides behavioral conditions, the form in which the pesticide is applied also increased the risk to the hawks. Most of the applications of organophosphorous pesticides occur during the morning or late in the afternoon (Grue et al. 1983, Bogino, pers.com.). From this study, this is a time when hawks are mainly sunbathing and foraging on the ground, and it would result in hawks both directly and indirectly exposed to the pesticide (Goldstein 1997).

Therefore, from behavioral traits and characteristics of pesticide applications, hawks would be exposed to pesticides during the whole day, both in crop and pasture fields. Although obvious, the only alternative to diminish the impact of pesticides over hawk's populations would be to gradually replace high-toxicity pesticides for low-toxicity pesticides for grasshopper and other insect's control, such as has been successfully happening in the last two years in Argentina. Although Monocrotophos was limited and withdrawn in 1996 from specific areas and crops, it continued being used for a while on crops other than alfalfa and for insects other than grasshoppers. This represented a danger for wintering Swainson's hawks given the wide range of foraging habitats and the type of prey items hawks use while wintering, and it could partially explain other mortalities occurred in following years (1996-97, 1997-98, Zaccagnini, pers.com.). Presently, the pesticide has been banned in Argentina (Resolución 182/99, Secretary of Agriculture, Livestock, Fish and Food of Argentina), so it is expected its impact over wintering Swainson's hawks in this country would be diminished if not totally eliminated.

In addition, long-term changes in agricultural practices and farmland structure influencing habitat suitability on the wintering ranges could also influence population levels (Rodenhouse et al 1995). Wintering migratory birds are highly dependent on the quality, quantity and landscape configuration of selected habitats in which to maintain high survival rates (Sherry and Holmes 1995). The recent trends on the Argentinean pampas regions of replacing grasslands and pastures with crops and the diminution of woodland patches (especially with *Eucalyptus* sp. trees) could negatively impact long-term survival of wintering hawks. However, it is expectable that hawks would possibly adapt to these changes (based on their plasticity on used habitats and diet, and preference for cultivated areas), but consequences at the population level are unknown (White et al. 1989).

A monitoring program developed at the regional level would be needed to capture normal population fluctuations in different wintering areas and relate them to changes in weather as well as habitat quantity and quality. Information from surveys to obtain bird abundance, such the ones used in this study, could be associated with remote sensing/Geographic Information Systems to monitor changes in habitat quantity and landscape arrangement (e.g., Powell et al. 1992). Ideally, this program should be coupled with monitoring of population's demography to evaluate habitat quality, but this would be more difficult to achieve. And, as Rodenhouse et al. (1995) expressed, loss in suitable habitat quantity rather than declining habitat quality is probably more responsible for changes on migratory bird populations, suggesting that conservation efforts for Swainson’s hawks should be focused on habitat management rather than population management (Sherry and Holmes 1995).

Finally, a regional approach would also be needed in extension/communication efforts and the implementation of agricultural practices compatible with Swainson’s hawks. Given the stochastic patterns and spatial extent of movement of wintering hawks, the concentration of efforts on small areas would not be effective for their conservation. Looking at regions instead of small areas, both monitoring and extension programs would assure the implementation of appropriate conservation measures directed to prevent massive mortality events or other impacts that agricultural practices can produce on Swainson's hawk populations wintering in the Argentinean pampas.

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BIOGRAPHICAL SKETCH

Sonia Beatriz Canavelli was born in Paraná, Entre Ríos, Argentina, on September 4, 1968. She graduated with a bachelor’s degree in biology at the Universidad Nacional de Córdoba in 1994. Before finishing, she started working in the Wildlife Department at the National Institute of Agricultural Technology (INTA), Paraná Experimental Station, where she was hired after graduating. Before attending the master’s program at the University of Florida, she worked in Argentina in different projects dealing with bird pest management in Entre Ríos and Santa Fe provinces. In January 1996, she offered to help researchers from the USA to investigate massive mortalities of Swainson’s hawks occurred in La Pampa province, Argentina. Since that time, she has been involved in the development of protocols to evaluate the impact of pesticides on wildlife in agroecosystems at the country level and the coordination of field work projects related to Swainson’s hawk ecology in Argentina.