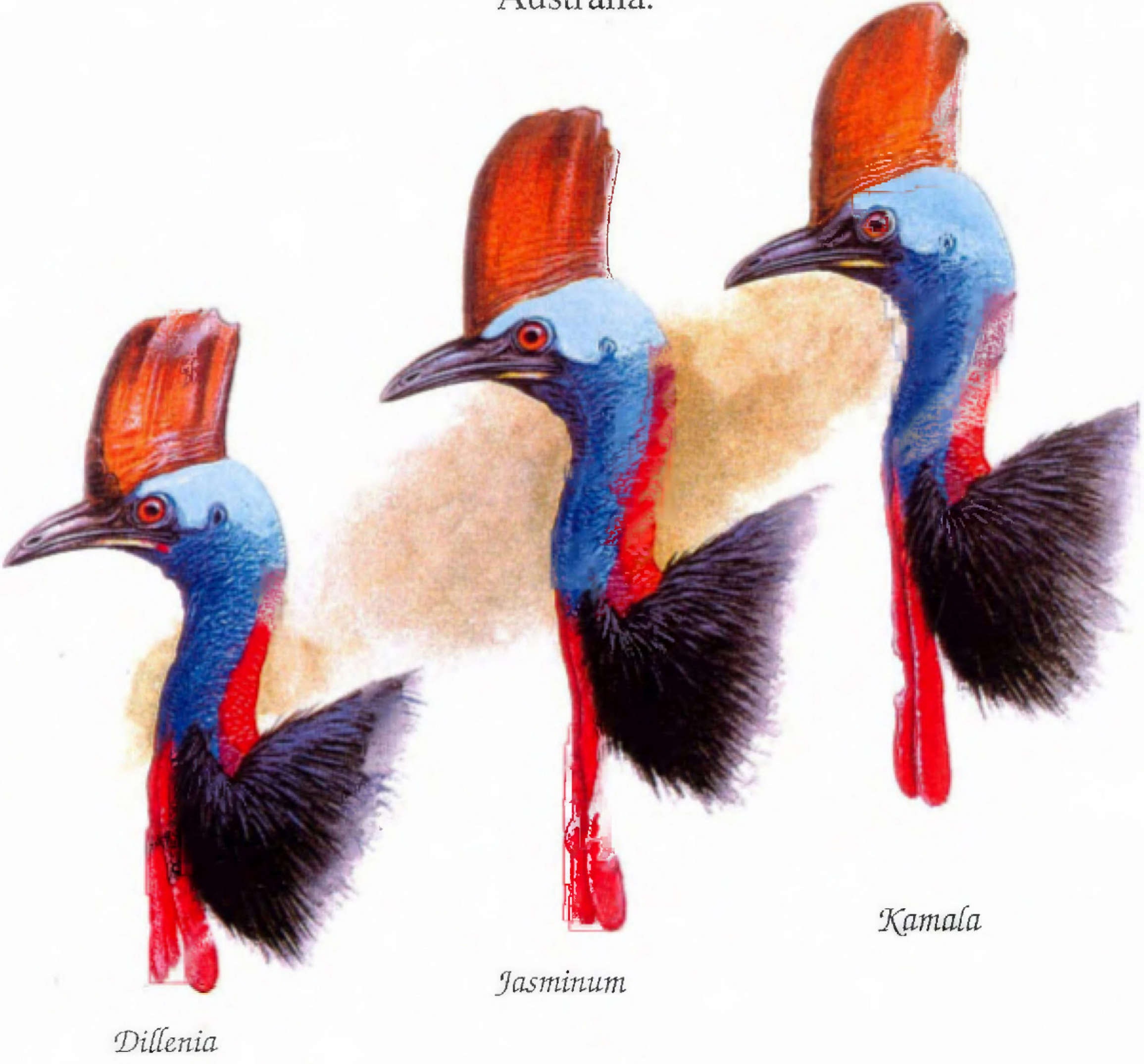
Bentrupperbaumer, Joan (1997) ***Reciprocal ecosystem impact and behavioural interactions between cassowaries, Casuarius casuarius, and humans, homo sapiens : exploring the natural-human environment interface and its implications for endangered species recovery in north Queensland, Australia.*** **PhD thesis, James Cook University.**

SECTION 2

Study 1
The Endangered Species

The Biology of the Cassowary, *Casuarius casuarius*, an Endangered Species of the Wet Tropics of North Queensland, Australia.



Three adult cassowaries resident of the Kennedy Bay National Park study site. Reproduced with permission of the artist, W. Cooper, 1992.

As best as can be determined, I am the first ecologist to have systematically observed an animal (Podilymbus gigas) go from a balanced, healthy population to zero and its habitat shift from ecologically sound to badly deteriorated within two and a half decades.

Anne LaBastille, 1990, p.18.

Chapter 4

Investigating the Endangered Species, *Casuarius casuarius*

4.1 Introduction

Given that this exploration of the natural-human environment interface is specifically concerned with endangered species recovery, the first major task is to investigate the cassowary, *Casuarius casuarius.* This is a large, flightless bird which in Australia is restricted to the wet tropic's biogeographic region of North Queensland and some small isolated areas of Cape York (Storch & Bentrupperbäumer, 1997, in preparation). Cassowaries have been listed in the State of Queensland as both *Endangered* (southern population) and *Vulnerable* (northern population; Nature Conservation Act, 1994), and federally as *Vulnerable* (Endangered Species Protection Act, 1992). However, the status is currently undergoing reassessment with the aim to revise this federal listing (Goosem, M. pers. comm. May 1997).

In this study I have embarked on a systematic biological investigation of a lowland cassowary population which is both pragmatic and theoretical. The study is unique because it is the first extensive field investigation conducted on the biology of the species in Australia, and because the cassowary population chosen for this study is wild, free-living and unprovisioned. In the absence of any detailed biological information on cassowaries prior to this research, and considering this is a "crisis" situation as evident in its decline in number and distribution (Crome & Moore, 1990), the general aim of this study has been to examine those basic aspects of biology and ecology which are particularly relevant to the pragmatic needs of conservation and management of the species (Caughley & Gunn, 1996; Clark et al., 1994; Shrader-Frechette & McCoy, 1994). Therefore, the primary emphasis is placed on the applied nature of the research.

The broad theoretical framework for this investigation is derived from conservation biology, a discipline which integrates management needs with the science of ecology. Additionally, this investigation facilitates the application of a number of specific theoretical models from behavioural ecology including those relating to social organisation, mating systems, and foraging behaviour. A conscious attempt is made to analyse and present the findings in the context of the theoretical needs of ecology, behavioural ecology and conservation science as well as the pragmatic needs of decision makers and managers.

4.1.1 Study Outline

The organisation of the biological chapters follows in part the way in which I proceeded with the field investigation and the need to address three general aspects of the species' biology: population, behaviour, and ecology. While such an organisation suggests that these biological perspectives are quite separate and distinct, they are all in fact very closely interrelated and special attention has been given to exploring this interrelatedness. Together these three perspectives provide an overview of the natural history of cassowaries.

The study is presented in six chapters. This first chapter provides a synopsis of what is known about cassowaries, it outlines the theoretical perspectives used to frame this study, and details the rationale and research focus. In the second chapter, Chapter 5, details of the study site and general investigational methodology are outlined. The emphasis in this chapter is placed on "general" methods as they apply across the whole study rather than "specific" methods as they apply to the topics covered in each subsequent chapter. The focus of the next three chapters, 6, 7, and 8, is the presentation of three specific ways chosen to explore this endangered species component of the ecosystem. Chapter 6 begins this exploration by taking a broad population perspective on cassowary biology. The initial task I set myself was to explore the whole study site so as to achieve a broad view of the resident population. This was not a time-specific task but rather a continuous process which allowed me to build up, over a period of three years, an assessment of the size, composition, density, and dynamics of this lowland cassowary population. Spatial distribution and social organisation were also examined as part of this broad population perspective. Chapter 7 focuses on a more specific behavioural aspect of cassowary biology, reproduction, which is closely linked to population-level processes outlined in Chapter 6. Chapter 8 essentially takes an ecological perspective, exploring the resource and habitat needs of cassowaries by examining activity patterns in general and foraging and movement in particular. The final chapter, Chapter 9, focuses on the integration and synthesis of the research findings in terms of the management and recovery of cassowaries.

4.1.2 Chapter Outline

This chapter provides the general framework for the study in terms of the status and shortcomings of present knowledge on cassowaries, the theoretical basis on which the study is established, and, in the context of this information, how this study advances its rationale and focus. The chapter begins with an overview of the literature on cassowaries which clearly demonstrates that, despite their remarkable appearance and size and their ecological and evolutionary significance, surprisingly little is known about the species. For the purpose of management the information that exists is still inadequate and piecemeal, with each contribution adding little by little to the knowledge of these birds. In the second section of this chapter I outline the broad theoretical framework applied to this biological investigation, conservation biology. Integration is the central theme of this theoretical framework, which is accomplished on the basis of two core perspectives, the principle needs and concerns of management, and the science of ecology. The final section of this chapter outlines the rationale, research focus and aims of the study as well as the research process.

4.2 The Endangered Species *Casuarius casuarius*: An Overview

4.2.1 Ratites and Evolutionary History

Cassowaries, *Casuarius casuarius*, belong to the Ratite group and the family Casuariidae in the order Struthioniformes. The other surviving members of this group all occur in the southern hemisphere and include: the emu, *Dromaius novaehollandiae* (Australia); kiwis, *Apteryx australis*, *A. oweni* and *A. haasti* (New Zealand); rhea, *Rhea americana* and subspecies, *Pterocnemia pennata* (South America); and the ostrich, *Struthio camelus* (Africa). While dispersal of ratites across the northern hemisphere cannot be ruled out, there is no evidence to suggest that it occurred (Cracraft, 1974). Furthermore, this lack of evidence is supported by the biogeographical hypothesis that postulates origin in and dispersal of ratites through Gondwanaland before its final break up and the subsequent continental drift (Archer et al., 1991; Cracraft, 1972; Schodde, 1982; Vickers-Rich & Rich, 1993).

Although now extinct, perhaps the most fascinating members of this ratite group in terms of size are the giant elephant bird of Madagascar, *Aepyornis maximus* (height, 300 cm; weight, 504 kgs; extinct, 1700), and the New Zealand moa, *Dinornis maximus* (height, 400 cm; weight 275 kgs; extinct 1850; Day, 1981). Indeed, it is the morphological features associated with this giantism that most defines ratites (Cracraft, 1974). While there remains a diversity of opinion with regards to the evolutionary history of ratites (see Rich & Balouet, 1984 for a review), some general statements about this history are nevertheless presented. Ratites have been separated from the main lines of avian evolution since the Middle Cretaceous period, 80-90 million years ago (Cracraft, 1974). Furthermore, using the phenology of Cracraft (1974, 1983), a number of lineages have been identified: (1) the most primitive elephant-bird, moa - kiwis lineage; and the more advanced (2) cassowary - emu lineage; and (3) ostrich - rhea lineage. Most authorities (e.g., Vichers-Rich et al., 1991), consider ratites to be descended from flying ancestors, however, Cracraft (1974) argues that morphologically, ratites are not primitive compared to many non-passerines.

Another interesting aspect of this evolutionary history is the adaptation of ratites to the habitats of the time. Because the southern continents were mostly covered in forests during the Cretaceous and early Tertiary periods (Truswell, 1990), early ratites such as elephant-bird, moa and kiwis, were, according to Cracraft (1974), adapted morphologically to living in forests rather than open habitats and grasslands. This is particularly evident in the morphology of their hindlimbs with the tarsometatarsus/leg proportions being suited to graviportal locomotion. On the other hand, while grasslands were not extensive during the Cretaceous and early Tertiary periods, their presence and subsequent expansion in response to the major climatic changes of the late Tertiary period, provided the opportunities for various adaptive response. Cracraft (1974) suggests that the Struthionoidea - cassowary, emu, ostrich and rhea - evolved in response to this habitat change which again is most noticeably reflected in the morphology of their hindlimb proportions. The proportionately longer distal elements of their hindlimbs in comparison to the early ratites such as elephant-bird, moa and kiwis, are cursorial adaptations which well suit a life-style in open habitats. In the Australian context, with the continent slowly becoming more arid during the late Miocene and Pliocene resulting in an increased spread of open vegetation communities and grasslands (Truswell, 1990), this is the time emus may have evolved or at least perfected grassland adaptations (Cracraft, 1974). Vicker-Rich et al. (1991) have found the oldest member of Casuariidae to be a “mosaic that lies intermediate between the two living families”.

4.2.2 Taxonomy and Species Description

The first detailed taxonomic and morphological descriptions of the genus *Casuarius* were provided by Rothschild (1900) and Pycraft (1900). Since then much has been written about both these aspects of the genus (e.g., Kinghorn, 1930; Le Souëf, 1930; Mayr, 1940; Storr, 1973; White, 1975, 1976). This information has primarily been derived from New Guinea, with Australian data contributing very little. Rothschild (1900) divided this genus into three groups containing eight species. Today one species from each of these groups are recognised as belonging in the genus *Casuarius*: the dwarf cassowary, *Casuarius bennetti,* the single-wattled cassowary, *Casuarius unappendiculatus*; and the double-wattled cassowary, *Casuarius casuarius*, all of which are confined to the Australasian region. However, only one species, *Casuarius casuarius,* occurs in Australia. The first specimen located in Australia (1848) was named by Wall, *Casuarius australius* (North, 1913a). Although the second specimen located (1866) was found to be identical to *Casuarius australius* , it was nevertheless named by Mueller, *Casuarius johnsoni* (see North, 1913a for discussion). Today it is commonly referred to as Australian, Double-wattled or Southern Cassowary (Marchant & Higgins, 1990; Reader’s Digest, 1982), and scientifically referred to as *Casuarius casuarius johnsonii* (Garnett, 1992a, 1992b) and *Casuarius casuarius* (Marchant & Higgins, 1990; Reader’s Digest, 1982).

Cassowaries are large birds with females larger than males (46.9 kg female, 38.2 kg male; this study). Their long, sturdy and very powerful legs make them well adapted to walking and running fast, a necessity considering their large size renders them incapable of flight. Three toes represents a reduction in number from the typical avian condition of four and is a consistent feature within most ratites (Cracraft, 1974; Vickers-Rich et al., 1991), apart from the ostrich (Bertram, 1992). The inner toe carries a long, sharp nail which, when used in conjunction with a powerful kick, can cause considerable damage to whatever it strikes out at (pers. obs.). The body plumage of adult cassowaries is composed of silky black feathers, with aftershafts as long as the principle shaft, giving the appearance of a double feather. Feathers are largely undifferentiated in colour, with variation associated with age of the bird rather than position on the body. Cassowary wings are considerably reduced but contain several black quills of varying length. Besides the legs, the other region of the body devoid of feathers in adult birds is the head, neck and wattles. Here the bare skin is brightly coloured in different shades of blue, orange, red, and purple. In adult birds a casque, which is covered in keratinous skin (Crome & Moore, 1988) over a core of bone or calcified cartilage (Richardson, 1991), protrudes from the top of the head.

4.2.3 Cassowary Biology

Several accounts have been written about a number of aspects of cassowary biology, each adding a little to the biological knowledge of the species. These accounts have primarily been based on the incidental observations of others (e.g., Crome, 1976; Crome & Moore, 1988; Goosem, 1992; Hindwood, 1962; Lucas & Le Souëf, 1911; White, 1913), or several chance observations (e.g., Fountain & Ward, 1907; Frith & Frith, 1986; Jackson & Chatswood, 1909; Jorrisen, 1978; Lumholtz, 1889; MacGillivray, 1917; Mayr & Rand, 1937; Thomson, 1935). Many accounts have collated the information available from previous publications (e.g., Crome & Moore, 1988; Grzimek, 1972; Marchant & Higgins, 1990; Mathews & Iredale, 1921; Reader's Digest, 1982). There have also been a number of contributions from captive populations of cassowaries (e.g., Fisher, 1968, 1974; Reid, 1978; Sheak, 1923; Watson, 1981; Worrell et al., 1975). However, information based on actual field research has primarily focused on diet and seed dispersal (e.g., Crome, 1976; Mack, 1995; Pratt, 1983; Stocker & Irvine, 1983), and distribution (Crome & Moore, 1990). Out of this collection of information I present here that which is most relevant to my study.

General behavioural observations suggest cassowaries are solitary (Crome, 1976; Fountain & Ward, 1907) and territorial (Crome, 1976; Jorrisen, 1978), with territory sizes ranging from 0.7 to 10 km^2 (Frizelle in White, 1913). The breeding season occurs between June and August (Thomson, 1935), June and October (Crome, 1976; White, 1913), July and September (Mathews & Iredale, 1921), but could extend from May to November (Crome & Moore, 1988). The latest laying date noted for a free-living population was 6 October (Hindwood, 1962). The breeding system is described as sequential polyandry (Clutton-Brock, 1991; Crome, 1976; Handford & Mares; 1985) and monogamy (Clutton-Brock, 1991; Handford & Mares; 1985). By collating data available from captive populations, Crome and Moore (1988) calculated: clutch size (mean ± SD = 3.9 ± 0.99; n = 12); interval between egg laying (mean ± SD = 4.08 days ± 0.79; n = 12); and incubation period (mean ± SD = 50.7 days ± 1.86; n = 9). Males incubate and rear the chicks (Fountain & Ward, 1907). The longevity records collated for captive birds suggests this is a long-lived species (range = 18 to 40 years; Crome & Moore, 1988).

A diet predominantly of fallen succulent fruits plus some animal matter was noted early on by Fountain and Ward (1907), Frizelle (in White, 1913), and Thomson (1935). In their field studies, Crome (1976) and Stocker and Irvine (1983) confirmed the diet of cassowaries to be predominantly fruit but supplemented with fungi and snails. Seasonal variation in species diversity and abundance of food supply was noted by Crome (1976), who also suggested a link between maximum availability of fruit and the timing of the breeding season.

As early as 1907 Fountain and Ward questioned the assumption that the cassowary was a forest-haunting bird. They believed it preferred the scrub-covered country. However, Thomson (1935, p.23) was certain that cassowaries "never left the tropical jungle for open country", adding that open country was in fact a barrier to their distribution. He goes on to suggest that "their eyes go opaque from the strong sunlight". While Crome (1976) found cassowaries predominantly inhabited rainforest, other anecdotal information suggests they use additional habitat types including mangroves and woodlands (Crome & Moore, 1990). There have been a few speculative comments about cassowary movement patterns (e.g., Frizelle in White, 1913; Crome & Moore, 1988), however, no evidence exists to confirm what these patterns are.

4.2.4 Distribution and Status

The cassowary appeared in the Australian fossil record during the early Pleistocene about three million years ago. It was located in New South Wales and first made known by Lydekker in 1891 (Miller, 1961). This fossil indicates that cassowaries roamed a far greater area of Australia than today. However, the existence of this species on the

Australian continent in more resent times was only documented in 1852 by Carron, botanist to the Kennedy Expedition. This discovery was made in the Iron Range area of Cape York in the vicinity of Weymouth Bay, on the 4th November 1848 (Campbell, 1901; Gould, 1857, 1865; North, 1913; The Illustrated Sydney News, 1854). Jacky Jacky, Kennedy's guide, shot one in what was believed to be the head of Lockhart River (Toohey, 1994).

Early documentation regarding the status and distribution of cassowaries in Australia has been supplied by various expeditions in the late 1800s and early 1900s to the Cape York region (e.g., MacGillivray, 1917; Mack, 1961; McLennan, 1921; Thomson, 1935), and the wet tropical region of North Queensland (e.g., Anonymous [Anon.], 1889; Broadbent, 1902, 1910; Campbell, 1901; Campbell & Barnard, 1917; Fountain & Ward, 1907; Jackson & Chatswood, 1909; Robinson & Laverock, 1900; White, 1913; White, 1946). Together these early records provide an insight into past distribution.

These early accounts document the presence of cassowaries on the east coast of Cape York in the following areas: the head of Lockhart River, Iron Range (Thomson, 1935); the Upper Claudie River, Iron Range (MacGillivray, 1917; McLennan, 1921; Thomson, 1935); the jungles of the Batavia, Pascoe, Hayes, Nesbitt, Rocky and Massey Rivers (Thomson, 1935), and rainforest north of Coen (Mack, 1961). Thomson (1935) found no sign of cassowaries in the Coleman, Edward, Archer and Watson Rivers of the west coast. This absence of birds along the west coast of Cape York has more recently been confirmed by Kikkawa (1975) and Winter and Atherton (1985), researchers who have conducted field surveys in the area. Other more recent information on the Cape York population based on field surveys have also located cassowaries in the McHenry Uplands (Australian Biological Resources Study [ARBS], 1975), and confirmed the presence of birds in the McIlwraith Range (Blakers & Crebb, 1988; Kikkawa, 1975; Cooper, W. pers. comm. August 1997), Iron Range (Bentrupperbäumer, unpublished data 1995-1996; Foreshaw & Muller, 1978; Johnson & Hooper, 1973). Early accounts of cassowaries in the wet tropic's region record their distribution as follows: narrow coastal belt between Herbert River to the south and head of Cape York (Campbell, 1901); Cairns, Mossman, Tully region (White, 1946); Mission Beach region (Jackson & Chatswood, 1909; White, 1913; White, 1946); Mulgrave River (Anon., 1889); and the Cardwell District (Campbell & Barnard, 1917).

Today cassowaries survive as three disjunct populations which have most likely been separated during periods of climate change when the rainforest components of both regions contracted significantly (Frith & Frith, 1995; Truswell, 1990). The southern cassowary population occurs within the wet tropic's biogeographic region of North

Queensland which covers an area of approximately 18,497 km^2 (Thackway & Cresswell, 1995), while the northern populations occur in forest remnants in north-eastern Cape York (Figure 4.1). The wet tropic's population currently extends from the Paluma Range in the south to the Big Tablelands near Rossville in the north, the coast line and Hinchinbrook island to the east and the Windsor Tablelands to the west. The southern-most Cape York population extends from the Stuart River in the south to the Pascoe River in the north, while the northern-most population occurs in the McHenry Uplands area and is bounded by the Jardine River in the north and Harmer Creek in the south (Storch & Bentrupperbäumer, 1997, in preparation). An extensive forest formation of Stringybark, *Eucalyptus tetrodonta* , *Melaleuca* woodlands and grasslands forms the natural but unfavourable barrier between the populations (pers. obs. 1994-1996).

These three main but disjunct populations are made up of several smaller subpopulations which are distributed widely but not uniformly throughout each region. In the wet tropic's biogeographic region, Storch and Bentrupperbäumer (1997) have currently identified potentially ten subpopulations of cassowaries. The contraction and fragmentation of these subpopulations has been due mainly to habitat loss as a result of agricultural and residential development (Winter et al., 1987), as well as some natural barriers. Since white settlement (1869), such development has greatly altered the landscape of the lowland and plateau regions of the higher tablelands (Goosem, 1992; Winter et al., 1987). What forest massifs remain are concentrated along the steep mountain ranges which separate the uplands from the lowlands. In addition, hunting pressures have been cited as contributing to local extinctions in some areas (Crome & Moore, 1990). In the Cape York region, two and potentially three subpopulations are known to currently exist (Storch & Bentrupperbäumer, 1997, in preparation,). Unlike the wet tropic's region, these populations have not been separated on the basis of habitat loss, but rather by extensive expanses of very dry sclerophyll forests.

Concern about the status of cassowaries in Australia was recorded as early as 1901. The naturalist, Archibald James Campbell (1901) wrote:

> On account of the Cassowary's naturally restricted area being taken up by planters and others, the noble bird should be rigorously protected, or it will as surely soon become extinct like the Emus of Tasmania and Kangaroo Island. It has been suggested that the large scrub-clad island of Hinchinbrook, adjacent to the mainland, be a reserve for the perpetual protection of Cassowaries. A more suitable place for the purpose could not well be found. (p.1070)

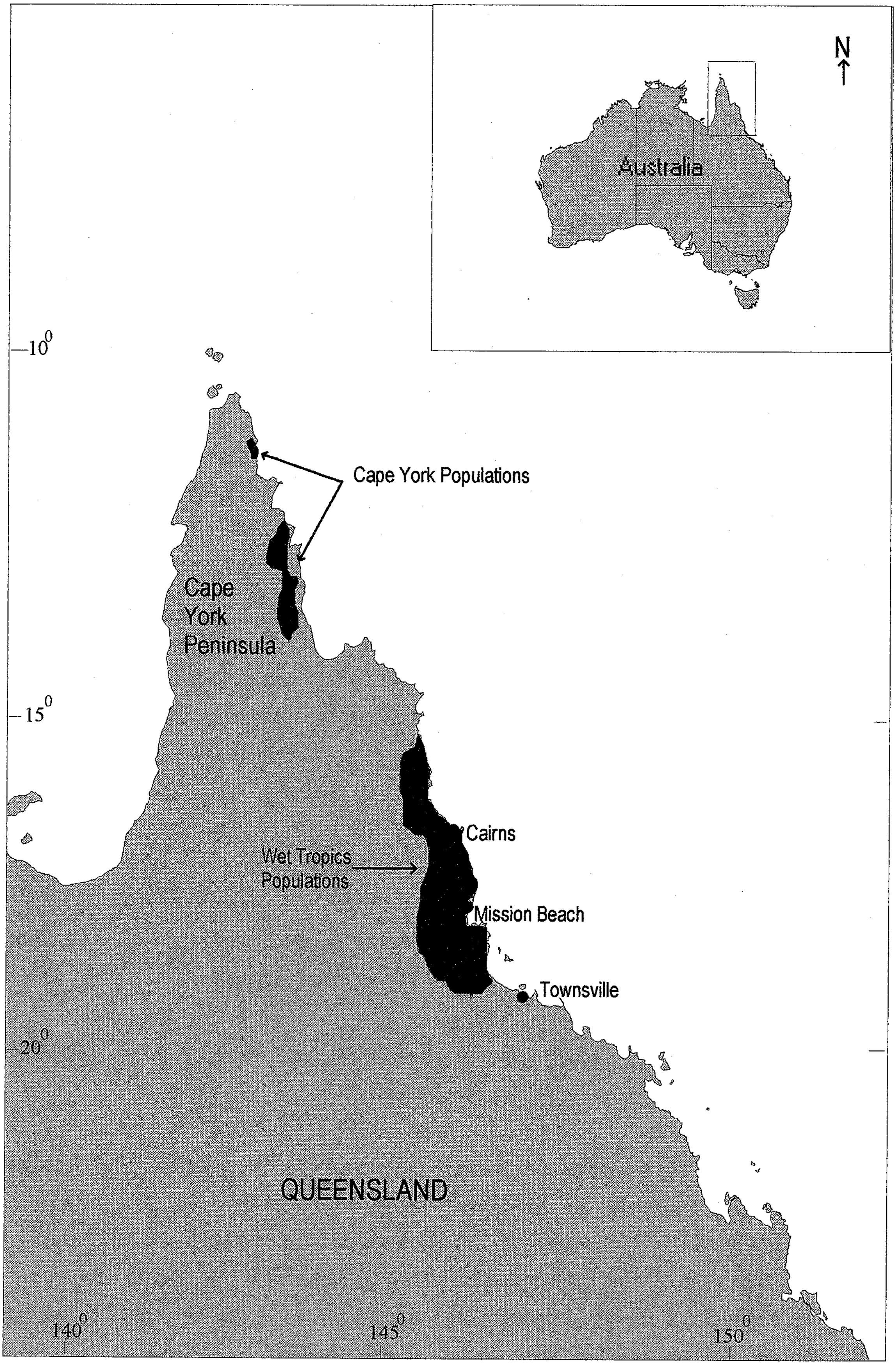


Figure 4.1 Map showing the distribution of cassowaries in Australia.

These same sentiments were again expressed in 1907 (Fountain & Ward, 1907), 1946 (White, 1946), and 1948 (Mack, 1961). White (1946) documents human occupation and hunting as the main causes of decline, whereas Mack (1961) considered the problem to be feral pigs, *Sus scrofa.* In more recent times habitat loss, attacks by domestic dogs, shooting, vehicles, disease (Bentrupperbäumer, 1988, 1992b; Crome & Moore, 1988, 1990), and feral pigs (Crome & Moore, 1988, 1990) have been cited as causing the decline of cassowaries. Based on their distribution survey, Crome and Moore (1990) estimated the total number of cassowaries to be between 1500 and 4000.

Ratites which have become extinct in relatively modern times include the giant elephant bird of Madagascar (*Aepyornis maximus*; extinct c. 1700), the dwarf emu of Kangaroo Island (*Dromaius baudinianus;* extinct c. 1830), the Tasmanian emu (*Dromaius novaehollandiae diemenensis;* extinct c. 1850), the giant moa of New Zealand (*Dinornis maximus*; extinct c. 1850), and the Arabian ostrich (*Struthio camelus syriacus*; extinct c. 1941). In all instances, extinction has been linked to anthropogenic activities, with hunting for food and plumes and egg collection being accepted as the most plausible mechanism for the extinctions (Caughley & Gunn, 1996; Day, 1981). In the case of the dwarf emu of Kangaroo Island, extinction was achieved in less than three decades by the whalers and seal hunters, while in Tasmanian, the effects of convict settlement saw the extinction of the Tasmanian emu within five decades (Lines, 1991). In addition to hunting, alteration of habitat by fire and clearing may have caused these extinctions (Marchant & Higgins, 1990). Such losses clearly highlight the rapidity with which extinctions can occur particularly when populations exist in small disjunct locations. This is of particular importance when considering the future of cassowaries in the three North Queensland disjunct locations within which are a number of subpopulations.

4.3 A Theoretical Framework: Integrating Management and Science

Integration is the central theme underlying the theoretical component of this biological study. To accomplish integration I explore the contributions of two different perspectives, environmental management and ecology. The first perspective, environmental management, highlights the applied nature of the endangered species recovery process, while the ecological perspective focuses on the science behind the practice.

Endangered species recovery is a complex mix of management and ecological concerns (Caughley & Gunn, 1996; Fiedler & Jain, 1992; Stephens & Maxwell, 1996), in addition to many social factors (Clark, 1996; Clark et al., 1994; Meffe & Carroll, 1994; Williams, 1996). There are no quick and easy solutions to the loss of species nor are there firm guidelines by which to tackle the problem. Instead, an endangered species recovery process is highly dynamic, ever changing in response to the most contemporary of economic, political and management needs and concerns, the knowledge gained from the latest research, and continued advancements in the science of ecology and conservation biology (Clark et al., 1994; Stephens & Maxwell, 1996).

While management and science "have different broad culture, goals and timetables" (Jarman & Brock, 1996), recovery of endangered species nevertheless requires collaboration of both. This, however, is fraught with tensions. Jarman and Brock (1996) have identified a lack of understanding between managers and scientists of what each has to offer the recovery process as one of the main problems for collaboration. The challenge, therefore, is to incorporate both perspectives into the endangered species recovery process by identifying management needs and "what science can and cannot contribute to species recovery" (Jarman & Brock, 1996).

4.3.1 An Environmental Management Perspective: Management Needs

While at a superficial level management may be carried out with some degree of success on the basis of limited knowledge and planning, clearly, for long-term effectiveness managers need to move beyond an "ad hoc" approach to endangered species recovery (Dickman, 1996; Meffe & Carroll, 1994). Dealing with new and unexpected problems on a daily basis has to be replaced with a more systematic approach, one that allows managers to identify and anticipate management needs rather than reacting unpreparedly to the crisis as it unfolds. Identifying and anticipating needs will require environmental managers to concentrate their efforts in a number of ways. For example, one of their first tasks is to decide on the most appropriate unit of conservation. Once decided, this conservation unit will provide a general framework around which the overall management process can be established. Secondly, those managers primarily concerned with species-level of conservation (the level of analysis and management relevant to this study), will require some knowledge of the status of every species, which species are threatened, and to what extent. Such information enables managers to focus their efforts on those species in the greatest danger of extinction. It also provides a legal framework around which policy and decision-making can evolve. And thirdly, where species are judged to be threatened, environmental managers need to identify and understand the threatening processes acting on the species. Such information is critical to the development and implementation of strategies aimed at preventing extinction.

In addressing these three very fundamental management needs, the "problem orientation" aspect (Clark, 1996) of the endangered species recovery process can begin.

4.3.2 An Ecological Perspective: Theory behind the Practice

It is essential that managers operate primarily from basic, scientifically grounded principles of management (Chapter 2, Section 2.4.1; Meffe & Carroll, 1994), because they simply cannot manage a system or a species they do not understand. The endangered species literature consistently highlights the ineffectiveness of past and current management strategies that are based on incomplete or faulty ecological knowledge (see Clark et al., 1994; Yaffee, 1994a, 1994b). Making the right decisions about endangered species recovery, therefore, relies on well-defined management goals and objectives that are derived from a deep understanding of the ecological properties and processes of the system. Nevertheless, it must also be noted that not all management questions can be answered by the scientific method alone (Jarman & Brock, 1996).

Ecology has been referred to as "the science that underpins the technology of conservation" (Harper, 1992, p.x). With its rich diversity of active subdisciplines including, population, community, ecosystem and landscape ecology, the challenge for ecology has been integration both among subdisciplines and other disciplines. However, there are those who suggest that the science of ecology has failed in this process of integration, particularly in the context of the environmental crisis (e.g., Peters, 1991). This failure has been attributed to the inability of ecology to provide a credible theoretical base for dealing with the environmental crisis. Nevertheless, much work is currently being undertaken to advance the discipline of ecology, particularly in its role as an applied science in dealing with the environmental crisis and endangered species recovery (see Caughley & Gunn, 1996; Fielder & Jain, 1992; Meffe & Carroll, 1994).

With the identification of the unit of conservation considered a principle need of environmental managers, ecology can enhance this process by providing a number of relevant concepts such as species, communities, ecosystems, landscapes. Such concepts provide managers with several pragmatic but ecologically-sound ways of framing the management process. In addition, themes such as keystone, indicator, and guild (Minta & Karieva, 1994), which have been developed on the basis of critical ecological processes, provide managers with a number of alternate theoretical concepts on which to inform their choice of conservation unit. While such concepts have now been readily adopted, there is nevertheless the constant need for managers to be aware of new developments in this area including critical assessments of current use.

In their need to know whether or not a species is in danger of extinction and, if so, to determine how threatened it is, managers again must look to ecology for assistance. To accurately assess these processes data on distribution and numbers, and changes in both over time, is required. Population ecology, a subdiscipline of ecology, provides the means by which quantitative information on current population size, trends, vulnerability, and the likelihood of extinction can be assessed (Caughley & Gunn, 1996; Fiedler & Jain, 1992; Meffe & Carroll, 1994; Perrins et al., 1991). In addition, this information has been used in the development of a scientific means of classifying species according to their risk of extinction. This has resulted in categories such as Extinct, Endangered, Vulnerable, Rare, Indeterminant, Insufficiently Known being used to define the status of species throughout the world (Dobson, 1996). Listing a species according to these categories is the first step in conferring legal protection (Carroll et al., 1996), but for this listing to be legally valid it must draw on ecological science.

And finally, in order to identify threatening processes, management must again use the science of ecology to establish a clear diagnosis of the process. Ecology has developed a number of models explaining the decline of species, for example, the declining-population paradigm which "deals with why the population is declining or has already declined to low numbers, what caused it, and what might be done to reverse the decline" (Caughley & Gunn, 1996, p.3).

4.3.3 Conservation Biology: Integrating Management Needs with Science

Clearly, the frequent and skilful action now needed to save endangered species depends on a specialised discipline to bridge the gap between the science of ecology and the pragmatic needs of management. Conservation biology is such a discipline as it represents a body of theory and practice that is particularly suited to the study of endangered species and their management.

While the real-world of management may seem quite remote from the confines of many ecological models, the systematic investigation of the natural system, and the rational discourse of carefully reasoned management plans, nonetheless, the current era of environmental management is distinguished from earlier periods by its attempt to build the foundation for action in sound scientific principles (Western, 1989).

4.3.3.1 The Unit of Conservation

A species focus in biology, conservation, and management has existed for some time with biologists naming, cataloguing and comparing species over centuries (Meffe & Carroll, 1994), conservation efforts using species as indicators of environmental crises in more recent times, and management agencies developing and implementing recovery programs for single species as a means of addressing biodiversity loss (e.g., Clark et al., 1994; Stephens & Maxwell, 1996). In addition, powerful conservation legislation including the Endangered Species Act (ESA) and the Convention of International Trade in Endangered Species (CITES) has been based on the species concept (Meffe & Carroll, 1994; Westrum, 1989), with both laws in many instances relying on the IUCN Red Data Book to define the status of plant and animal species (Dobson, 1996).

Nevertheless, the use of the species concept in conservation and management has received mixed responses with some referring to it as "a pragmatic" and "most important" unit of conservation (e.g, Caughley & Gunn, 1996), and others as "too narrow" and "inappropriate" (e.g., Meffe & Carroll, 1994; Noss, 1991; Recher, 1994). From the biological perspective, an important aspect of the concept is its definability - the species is quantifiable, it can be counted, assessed, and monitored over time and space. On the other hand, concepts that are more encompassing, for example, "ecosystem" or "community", are much more difficult to define and hence quantify, assess, and monitor (Caughley & Gunn, 1996). From a conservation and management perspective these are very important issues.

A second very important aspect of the species concept is that it identifies entities for legal attention (Clark, 1994; Kohm, 1991; Meffe & Carroll, 1994). Specific laws that have been established (e.g., Endangered Species Act and the Convention of International Trade in Endangered Species) can be used to prevent the disappearance of any plant or animal species. A third important aspect of the species concept for management is that it appears to be much easier to gain public support for single-species and thereby interest in conservation in general, than it is for concepts such as ecosystem health and genetic diversity. Most people can identify better with the loss of a species and are more willing to take action on its behalf than the loss of an ecosystem or erosion of genetic diversity which they find somewhat remote and intangible (Kellert, 1996; Noss, 1991). Nevertheless, even within the species concept there are those which extract more sympathy from the public than others (Kellert, 1996; Noss, 1991; Salwasser, 1991). In particular, species which are very visible, dominant parts of our natural environments, such as the megafauna and the "cute and cuddly", become high-profile "glamour" species (Noss, 1991; Rohlf, 1991) which draw more attention and even financial support from government agencies than most plants and insects. While this is clearly disadvantageous for the less "attractive", less "familiar" inhabitants of the environment, many argue that the charismatic species act as "flagships" (Noss, 1991) by promoting the protection of the broader landscape including habitat and other species under the "umbrella" of their large and often diverse habitat requirements (Dobson, 1996; Meffe & Carroll, 1994; Noss, 1991).

Nevertheless, many have put forward arguments which counter an exclusive single-species concept of management (see Bloomgarden, 1995; Noss, 1991; Salwasser, 1991; Walker, 1989). Perhaps the most important from the management perspective is the notion that, despite this concept of an "umbrella" species (Noss, 1991), a species focus by itself does not realistically address the larger problem of habitat and ecosystem destruction which is the real driving force in extinction. And, as highlighted earlier, a species-driven approach to conservation draws attention and valuable resources to only one part of the biodiversity crisis, "while hundreds of the lesser-known cogs and wheels (especially plants and invertebrates) silently disappear" (Noss, 1991, p.228). Furthermore, the single-species approach can suffer negative public backlash, particularly when its endangered status is linked to blocking economic progress. The classic example for this is the "owl versus jobs" controversy (Yaffee, 1994a, 1994b). Even though the larger conservation issue may be ecosystem protection, the single species used to promote its protection has been the target of considerable public anger, division and conflict. Used in this way (single species conservation versus economic interest), the species approach is left open to considerable attack because it is perceived as the enemy of economic development, public interest, property rights, etc. As a consequence it can come to be regarded as trivial in comparison to human interests. On the other hand, Salwasser (1991) highlights the problems with what he refers to as the "siege mentality" - a single-species view of conservation "causes people to approach species and habitat protection by trying to segregate them from human activities" (p.249). The public denies their responsibility for endangered species loss by perceiving areas such as National Parks as the only necessary requirements to prevent the extinction crisis.

In the management context, the species concept obviously needs to be part of the larger conservation equation, which, as Caughley and Gunn (1996) point out, does not mean considering the species in isolation. Within the species concept, a more comprehensive approach has to be taken, but how? The ecologist Noss (1991) has argued for the emphasis to be placed on those species that play a critical role in the ecosystem, rather than negating the species concept altogether or trying to assess the viability of an entire, complex ecosystem. He proposes the use of five overlapping classes of species: indicators, keystone, umbrellas, flagships, and vulnerables, which he suggests incorporate those species whose protection would encourage the persistence of higher levels of organisation. On the other hand, Mills et al. (1993) discourage the use of the keystone-concept for practical management recommendations. They suggest instead the development of management and policy guidelines that more explicitly account for the complexity of interactions in the natural system rather than the keystone/nonkeystone dualism.

4.3.3.2 Identifying "at Risk" Species

Assessing whether or not the survival of a species is "at risk" is quite a complex task. This is because in the real-world of environmental management often it is not only based on biological grounds, but is also influenced by economic and political considerations (Miller et al., 1994). Nevertheless, while limited progress has been made in dealing with the economic and political considerations, considerable progress has been made on the biological front.

To determine whether or not a species' existence is at risk, the basic ecological information required includes population size and distribution (Caughley & Gunn, 1996; Dobson, 1996). Attributes that signal a species as being at risk include low numbers, restricted distribution and small populations that are fragmented into several isolated subpopulations (Caughley & Gunn, 1996; Dobson, 1996). However, to decide if these attributes actually represent a decline, such information has to be compared with previous knowledge on distribution and abundance. A review of the literature obviously provides some clues but, clearly, repeated field surveys are the only appropriate method of estimating and consequently detecting trends in population size and distribution, and therefore the likelihood of extinction.

One of the major provisions of the ESA was to set forth eligibility and procedural requirements for listing species as endangered or threatened (Clark, 1994). The concept of assigning species to categories of threat depending on the extent of risk to which it was thought to be exposed, was initially established by the IUCN in their Red Data Book system. Under this system species were classified as Extinct, Endangered, Vulnerable, Rare, Indeterminant, Insufficiently Known (Table 4.1).

However, these categorisations are largely subjective and not accurately reflecting actual extinction risks. Conservation biologists have therefore explored ways of introducing more rigor into the classification process. Based on population biology theory and meaningful time scales for conservation action, Mace and Lande (1991) developed a new set of criteria for classifying species. They proposed the recognition of three categories of threat Critical, Endangered and Vulnerable, in addition to Extinct (Table 4.1).

Table 4.1 Definitions of categories of threat.

Category	Definition
IUCN Red Data Book (1996):	
Extinct	Species not definitely in the wild in the past 50 years
Endangered	Species in danger of extinction and whose survival is unlikely if *causal* factors continue to operate
Vulnerable	Species believed likely to move into the Endangered category in the near future if *causal* factors continue to operate
Rare	Species with *small world populations* that are not yet Endangered or Vulnerable but are at risk
Indeterminant	Species known to be Endangered, Vulnerable, or Rare but *not enough information* exists to say which of these three categories is appropriate
Insufficiently Known	Species that are suspected but not definitely known to belong to any of the above categories, because of *lack of information*
Mace and Lande (1991):	
Critical	50% probability of extinction within 5 years or 2 generations, whichever is longer
Endangered	20% probability of extinction within 20 years or 10 generations, whichever is longer
Vulnerable	10% probability of extinction within 10 years

The definitions used to form these categorisations have been based on a number of indices of population size and change in population size which would be possible to measure in a 3 to 5 year research project. Ideally, such a project would measure: (1) total population and subpopulation sizes; (2) geographical range; (3) observed, inferred or projected rate of decline; and (4) extinction probability revealed by population viability analysis.

4.3.3.3 Identifying Threats

Once the "at risk" species has been identified, the third primary concern for managers is to bring about the reversal of the species decline. This is undoubtedly the most challenging stage of the recovery process for both managers and researchers and one that has attracted much criticism. Dickman (1996), for example, criticises managers for continuing to base management on "intuition and gut feeling", rather than scientific method. On the other hand, conservation principles and the scientific method have often been criticised for the level of uncertainty and lack of consensus (Meffe & Carroll, 1994). In the real-world of every day management where resources and expertise are often limited, political and public pressure continuously present, and threats appearing on a daily basis, acting on "intuition and gut feeling" is obviously an attractive option for managers. Nevertheless, it is inappropriate and often detrimental.

The "declining-population paradigm" proposed by Caughley (1994) is one of the most recent developments in the field of conservation biology that has clearly evolved out of integrating the pragmatic needs of wildlife management with a particular set of theories on population ecology. In focusing on detecting, diagnosing, and reversing decline, this paradigm provides the much needed theoretical framework around which managers can develop and apply strategies aimed at preventing extinction.

According to this paradigm, once some pattern has been detected, such as decline in population size or geographical distribution of a species, the next step is to identify a plausible explanation, or set of explanations that account for it (Dickman, 1996). Caughley and Gunn (1996) suggest that a basic knowledge of the species' natural history often provides the first clues to possible threatening processes. Furthermore, unless the species' ecology is understood, correctly diagnosing the effects of the threatening processes can be difficult. Exploring possible causes of decline can involve looking for correlations between changes in numbers and environmental variables, using population models, testing hypotheses by experiment.

The most significant provisions of the ESA with far reaching implications, are those that define the content of recovery and threat abatement plans (Male, 1996). Male (1996) describes the philosophy of the recovery process as "one that is directed at identified problems, follows a structured methodology and is focused on achieving positive and practical conservation outcomes" (p.24). The ability to determine the success or failure of the recovery treatments is important. An absence of a measurable criterion within a designated time frame can easily leave recovery programs locked into such treatments as control of introduced predators or artificial feeding stations (Caughley & Gunn, 1996).

4.4 The Present Study

4.4.1 Rationale, Research Focus and Aims

The impetus for this study was the endangered status of the largest terrestrial vertebrate that inhabits the tropical rainforests of North Queensland, the cassowary, *Casuarius casuarius.* The more encompassing objective which gave particular direction and focus to the study was to provide critically lacking biological information essential to the species' recovery. The application of this biological information was therefore a primary goal of this study.

The environmental management agencies, Department of Environment and the Wet Tropics Management Authority, responded to public concern about the decline of cassowaries in several ways. Formalised responses included several attempts to develop cassowary management plans (see for example, Garnett, 1992b; Goosem, 1992; Kunst, 1995). Other responses included a number of "ad hoc" translocations, supplementary feeding and education programs. A feature common to all of these responses has been the uncertainty and/or lack of sufficient biological information on which to base sound management decisions and policy. The need to strengthen the type, extent and quality of biological information, and to focus, in particular, on the analysis of actual data as opposed to anecdotal information, was clearly evident in all responses.

The focus of this study was on the investigation of the key biological factors, population ecology and autecology. In addition to providing the most useful data for potential management intervention and recovery efforts, these were factors that conservation science considered central to understanding an endangered species and on which to base sound management practices (Caughley & Gunn, 1996; Perrins et al., 1991).

The general aims of this study were:

1. To determine the population ecology of this lowland cassowary population including population size, density, composition and dynamics;
2. To document the spatial and social organisation of cassowaries in terms of home ranges, social structure, and patterns and nature of interactions;
3. To examine reproductive biology including breeding and nesting activities, parental care and reproductive success;
4. To assess resource needs and habitat use as determined by activity patterns, foraging behaviour and movement patterns;

5. To discuss key conservation and management issues based on evidence assembled from this biological investigation.

Results pertaining to the first and second aims are presented and discussed in Chapters 6, the third aim in Chapter 7, the fourth aim in Chapter 8, and the fifth aim in Chapter 9.

4.4.2 The Research Process

This biological investigation involves an extensive field study of a “wild” free-living population of cassowaries over a three year period. The particular population chosen for this study was situated in a remote lowland coastal region of North Queensland (see Chapter 5, Section 5.2.1). Because only limited information was available on cassowary biology, and no information on methods of studying a wild, free-living population, this study began as an exploratory endeavour, developing and refining methods and techniques. Once I became familiar with the study site and gained at least a basic understanding of the species, the research progressed into a systematic investigation of population ecology (population size, density, composition and dynamics, social and spatial distributions) and autecology (reproductive behaviour, activity patterns, foraging behaviour, movement patterns and habitat use). Details of this research process are outlined in the following chapter.

* * *

Chapter 5

Study Site and General Investigational Techniques

5.1 Introduction

5.1 Introduction

Detailed studies of cassowaries in the field are just beginning. Improvement and refinements of methods are sure to be many as more problems arise, different questions are asked, and the reality of working with a difficult-to-observe endangered species are realised. Primarily such a study requires innovation, common sense and flexibility, combined with a knowledge of well-trialed methods and an understanding of the idiosyncrasies of natural systems. It also requires patience, determination and a strong sense of curiosity.

Field investigation of a wild, free-living cassowary population offers an opportunity to work with the bird's full pattern of activities, from various approaches, and set along a continuum from the broad to the specific. While the nature of information recorded varies according to the type of questions asked, the guidelines used in this study have been framed by existing data and urgent conservation and management needs. The mainly qualitative judgements established during previous research and the initial phases of my own observations have been subjected to quantification whenever possible.

In this study I have concentrated on obtaining basic behavioural and ecological information on cassowaries without attempting experimentation or focusing attention on only one particular aspect of behaviour. While intensive specific studies have an advantage in that a considerable amount of data on a certain topic can be collected, it was considered of greater value, in the context of conservation and management of the species, to take a broader perspective. After all, extensive biological research on free-living cassowaries in their natural habitat had not previously been conducted in Australia.

In general, my goal was to understand how cassowaries live in their natural environment; toward this goal, I tried to develop methodologies and obtain records that would be adequate in terms of accuracy of observation, quality of description and quantification, and quantity of data. While rare and shy species offer few opportunities to obtain precise and comprehensive biological data, the acquisition of high quality data (behaviour, habitat requirements), comparison with similar species, and the exploration of theoretical models, have been used as a means of overcoming this difficulty in this study.

5.1.1 Chapter Outline

This chapter outlines the methodology by which I have proceeded toward achieving this goal. In many instances the techniques adopted have been entirely my own, based on common sense and the need to be innovative considering the conditions of the field and species under study. In other instances the techniques are well-grounded in years of behavioural and ecological research on single species gone before. The methodological information outlined in this chapter is general, with more detailed specific methodology outlined in each of the following three chapters. The chapter begins with an outline of the study site, including location, reasons for choice of site, and various site characteristics. Next, the procedure associated with working with cassowaries, including identification and habituation of target individuals, is described in detail. The type of data recorded and the way in which it was used is discussed in the third section of the chapter. Finally, the chapter concludes with an outline of analyses employed.

5.2 Study Site

5.2.1 Location

Although cassowaries occur throughout the wet tropic's biogeographical region of North Queensland, providing the opportunity to choose from several study sites, in this research four primary criteria were considered critical to the choice of site. Firstly, since the primary objective of this study was to provide baseline behavioural and ecological information on a species in its natural state, working with a wild, free-living cassowary population was important. Therefore, the site had to be sufficiently remote from human habitation so that direct and/or indirect human disturbance (past and present), including human visitation, supplementary feeding, dog intrusion, roads and tracks, was absent or at least negligible. Secondly, to ensure that the study could continue uninterrupted for the period required, the site had to be Government Land (Crown Land, State Forest, National Parks, etc.). Thirdly, since I would be conducting the research entirely alone, and with field work involving tracking birds for extended periods in directions and areas unknown and unfamiliar in the initial stages, I needed to minimise my chances of getting lost and the time spent in recovering my position. Therefore, ideally the site would be delineated by natural boundaries that were readily identifiable. Furthermore, such boundaries would allow for geographically defining the population. And, finally, to maximise efficiency, convenience in terms of locality and accessibility to the site was essential.

The Kennedy Bay Reserve, R229, Parish of Rockingham in the County of Cardwell (Figure 5.1), was found to be exceedingly well-suited with all criteria applying. The relative remoteness of the site guaranteed negligible human disturbance. No public road access to the site existed and no roads or tracks were present within the site. Public access was only possible via boat or a 3.9 km walking track. While the occasional pig hunter may have ventured into the site in the past, they were never encountered during the study period. No encounters with other people occurred at all and no sign of them using the site was apparent. At the time the research began the site was a Camping, Water and Recreation Reserve which had recently been declared a National Park but not yet gazetted. By the time the study was completed it was also a World Heritage listed area.

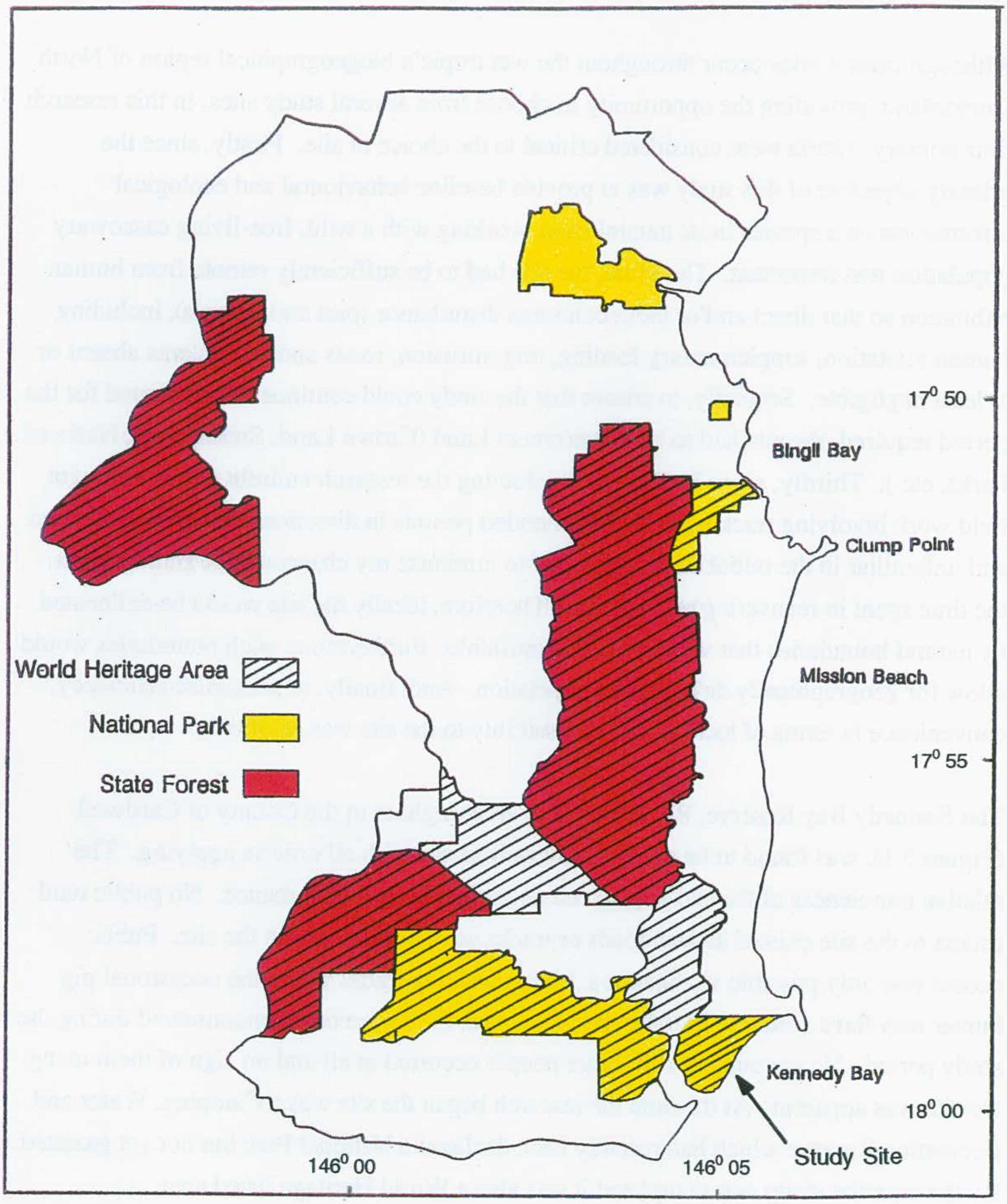


Figure 5.1 Location of study site, the Kennedy Bay National Park, relative to other National Parks, State Forest and World Heritage areas. (Adapted from Goosem, 1992)

This 319.2 ha study site was bound to the west by the Hull River, to the south-east by Rockingham Bay and to the north by the grazing property "Tam O'Shanter". These natural boundaries, together with an old fence-line, regrowth and a swamp system, provided the boundary markers of the site. The local nature of the site meant that for the first two years daily access was possible by trail bike across the Tam O'Shanter property, right of access having been granted by the property owner. However, in the third year of the study, right of access was withdrawn (see Chapter 1, Section 1.5.1). My travel route was then diverted to the Hull River, with the daily two hour trip being made to and from the study site by boat.

5.2.2 Trails and Zones

I established 20 km of trails/transects throughout the study site (Figure 5.2). These were very discretely marked, identified only with colour tape and without the removal of any vegetation. I also divided the study site into five zones each between 50 and 70 ha in area. The delineation of the zones was based on a combination of topographical features and trails. Zones A, B and C were below 20 m. Zone D and E corresponded with the two hill regions which extended from 20 m to 100 m. The trails and zones were central to many aspects of my data collection, in particular, data collected during general field surveys and mapping of tracking target individuals (see Section 5.4.2).

5.2.3 Site Characteristics

5.2.3.1 Landform

Approximately two thirds of the study site is below 20 m and includes a succession of shallow sandy beach ridges and gullies, followed by well and poorly drained alluvium mosaics, and saline soils of the intertidal mangrove zone. The remainder of the site consists of two steep (< 30 degree) metamorphic hills, maximum height 100 m.

5.2.3.2 Vegetation

The study site is comprised of highly varied and complex vegetation types which grow in a characteristic coast-hinterland zonation. A general description of vegetation types in

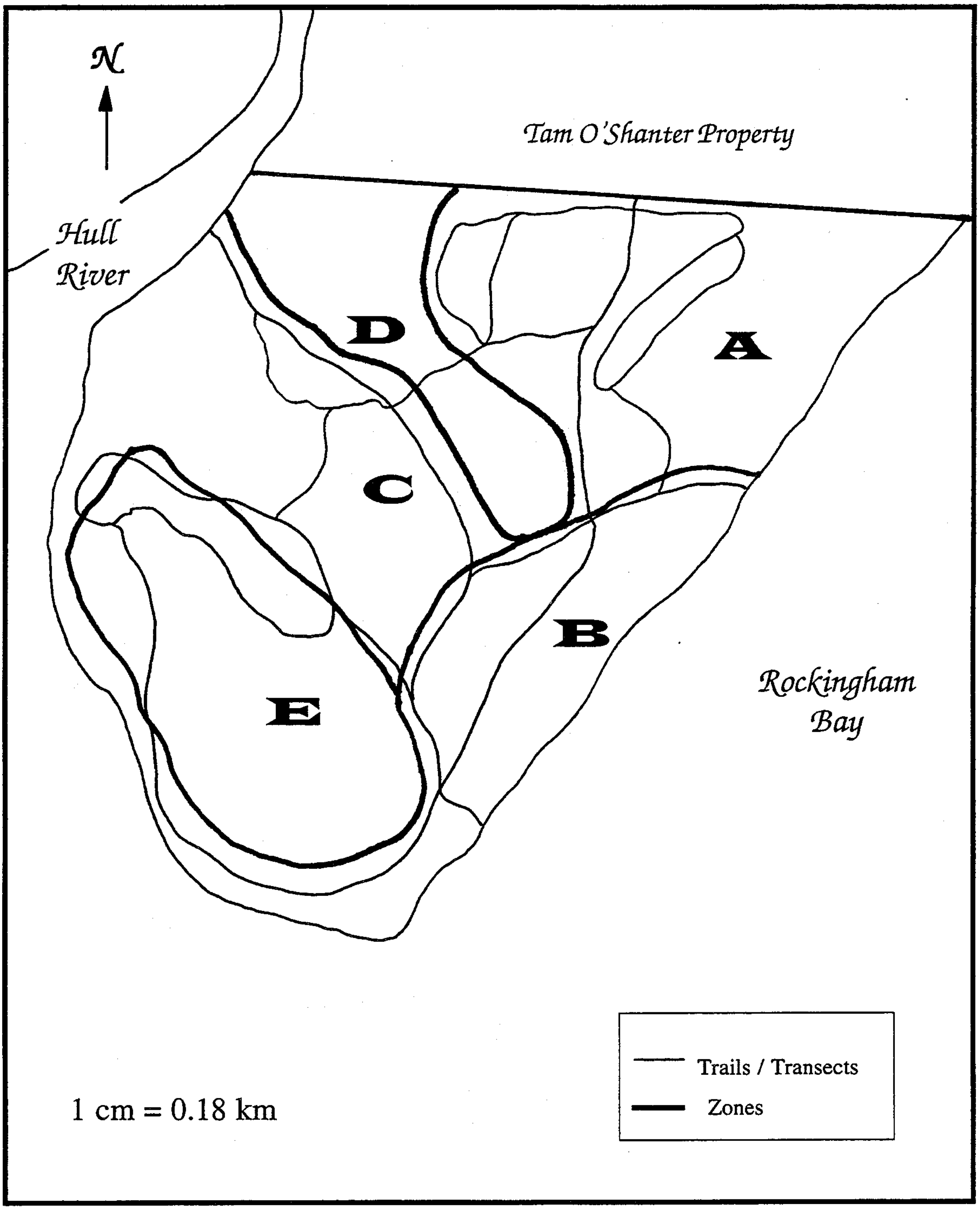


Figure 5.2 Map of study site showing trails / transects and zones (A to E).

which cassowaries reside was considered an important ecological aspect of the study. From the standpoint of cassowary ecology, five primary vegetation types were identified. The classification system was necessarily broad and, while somewhat idiosyncratic, its systematic application ensured consistency in identification and recording. Essentially it was based on landform patterns, and major floral themes and structural formations consistent with traditional approaches (e.g., Tracey & Webb, 1975; Walker & Hopkins, 1984). The primary distinction was between rainforest and non-rainforest vegetation based on descriptions used by Walker and Hopkins (1984). While rainforest was difficult to define throughout its range and therefore the classification in this study was broad and singular, classifications of non-rainforest were further subdivided into woodlands, swamp forests, beach/foreshore forests and mangrove forests. The description of structural formation, species composition of tallest, mid and lowest stratum, and growth forms provided the basis for the classification of vegetation types used in this study (see Table 5.1 and Figure 5.3).

5.2.3.3 Climate

Temperature and rainfall data were collected for Tully (1990, 1991, and 1992, Bureau of Meteorology), which is ≅ 15 km west of the study site. From this data it is apparent that the climate is tropical and seasonal with a distinguishable hot and cool, wet and dry season, although dates of initiation and termination and rainfall averages vary considerably from year to year (Figures 5.4 and 5.5).

During 1990, even though rain fell every month, the wettest time of year extended from January to June (total = 2,494 mm), with the highest rainfall recorded in March (873 mm). In comparison, the driest time of year included the months from August to November (total = 51 mm) with only 1mm of rain recorded in November. The following wet season was initiated in late December 1990 with the onset of a cyclone which crossed the coast in this region on the 25th December. This wet season extended from December to May (total rainfall = 2,020 mm) with the highest rainfall recorded in January (824 mm). The longest dry season for the study period was recorded in this year. It continued for eight months from June to January (total = 152 mm) with no rainfall recorded in September, October and December. Compared to 1990 and 1991, such a pronounced wet and dry season was not as evident in 1992. Rather, rain fell continuously throughout the year. Nevertheless, highest rainfalls were recorded from February to May (total = 1,435 mm), with the wettest month being February (526 mm). Throughout the remaining six months a total of 404 mm of rain fell (range 13 - 118 mm).

Table 5.1 Vegetation types identified in the Kennedy Bay National Park.

Non-rainforest Vegetation

(Types 17, 18, 22a, Tracey & Webb, 1975)

Beach/Foreshore (Type 17, Tracey & Webb, 1975)

Narrow band (15 - 40 m) of vegetation along the littoral zone. Tallest stratum (≅ 15 m) dominated by *Calophyllum inophyllum, Terminalia arenicola, Terminalia catapa, Terminalia muelleri*; mid-stratum (≅ 5 m) dominated by *Casuarina equisetifolia* and the lower stratum (< 1 m) consisted of shrubs including *Scaevola sericea* and *Fenzlia* spp, and vines *Ipommea* spp. and *Vigna marina.*

Woodland (Type 17, Tracey & Webb, 1975)

To the north-west of the beach/foreshore forest, *Eucalyptus tessellaris* and *Acacia mangium* form a widely spaced tall canopy (≅ 25 m) with scatterings of *Terminalia* spp. on the eastern edge. The depressions within this woodland forest are dominated by *Melaleuca leucodendron.* Understorey tree species such as *Polyscias australiana, Morinda citrofolia, Randia fitzalanii, Xanthophyllum octandrum,* are scattered throughout, as are the vines, *Alyxia spicata, Smilax australis,* and *Passiflora* spp. which dominate the lowest stratum. Toward the western boundary of the woodland forests there is evidence of rainforest invasion with species such as *Calamus* spp. appearing.

Swamp (Type 18, Tracey & Webb, 1975)

The dominant canopy species (20 - 30 m) include *Archontophonex alexandrae, Pandanus spp., Melaleuca leucodendron,* with scatterings of tall *Acmena hemilampra* and *Endiandra montana.* Mid-stratum tree species including *Elaeocarpus eumundi* and *Dillenia alata* grow on the edges and islands of the swamps. In the lowest stratum, *Cordyline terminalis* and *Hydristelle wendlandiana* are scattered throughout. *Melaleuca quinquenervia* and sedges dominant the swamp forests bordering the mangrove forests along the Hull River.

Mangrove (Type 22a, Tracey & Webb, 1975)

Several varieties of mangrove species (e.g., *Rhizophora* spp. and *Brugureia* spp.) occur in these forests which line the banks of the Hull River.

Rainforest Vegetation

(Types 2a, 12c, 13a, Tracey & Webb, 1975)

The rainforest areas occur to the north-west of the swamp forests. They consist of vine forest which would be classified as complex and/or simple mesophyll Vine Forest using the Tracey and Webb (1975) classification system. They are severely disturbed forests from cyclones and have a dense, sometimes impenetrable, understorey of *Calamus* spp. Dominant canopy tree species include *Syzygium alliiligneum, Syzygium cormiflorum, Syzygium forte, Castanospermum australe, Planchonella spp., Cryptocarya spp., Palaquium galactoxylum, Myristica insipida* and *Lepidozamia hopei.*

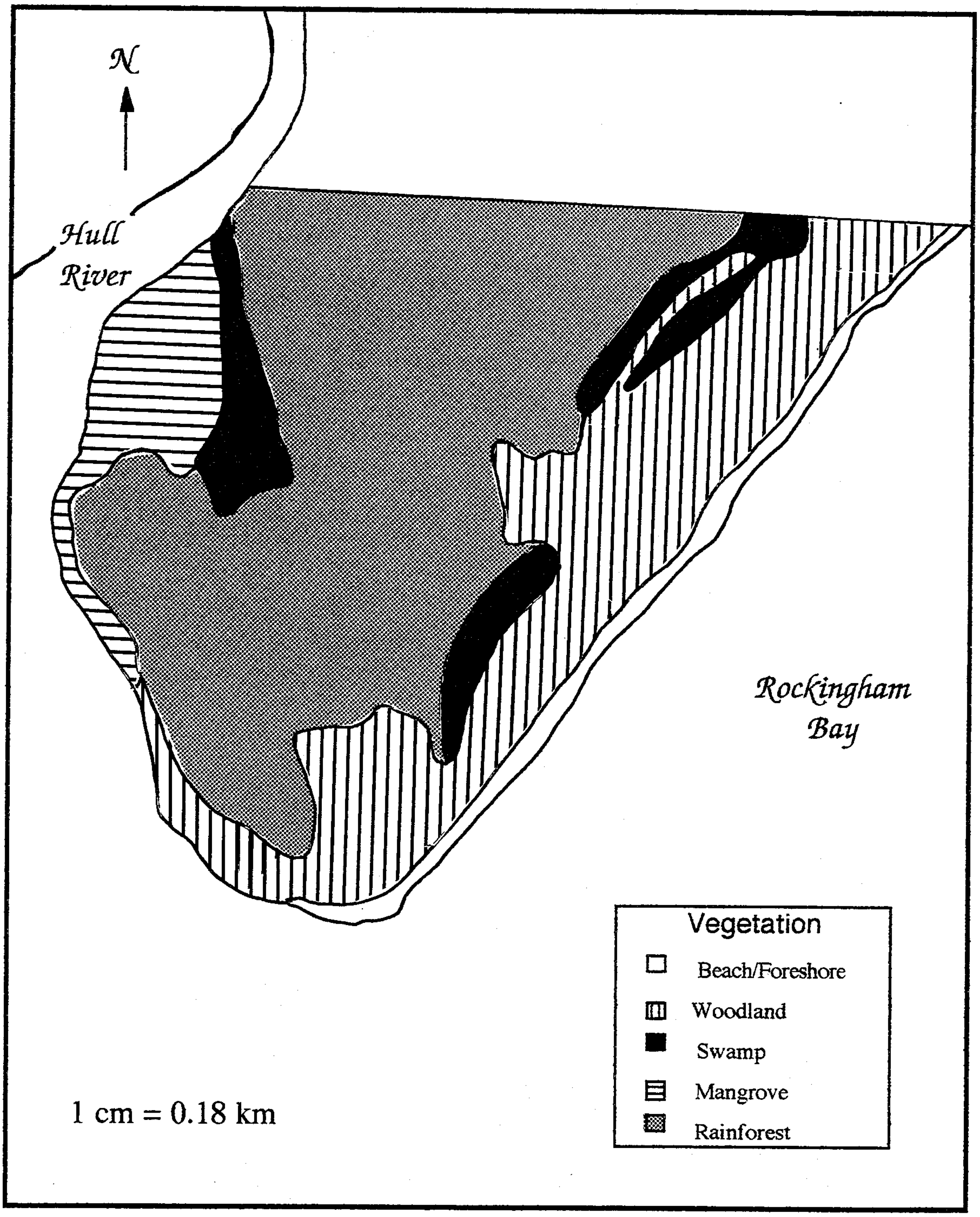


Figure 5.3 Vegetation map of study site.

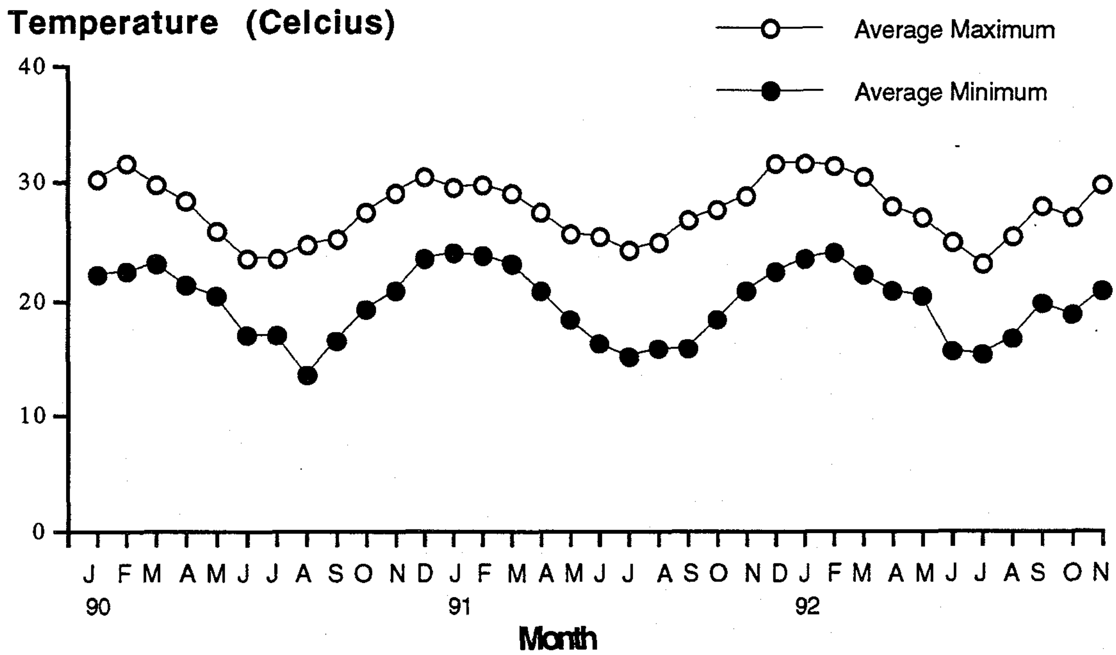


Figure 5.4 Average monthly maximum and minimum temperatures during the study period.

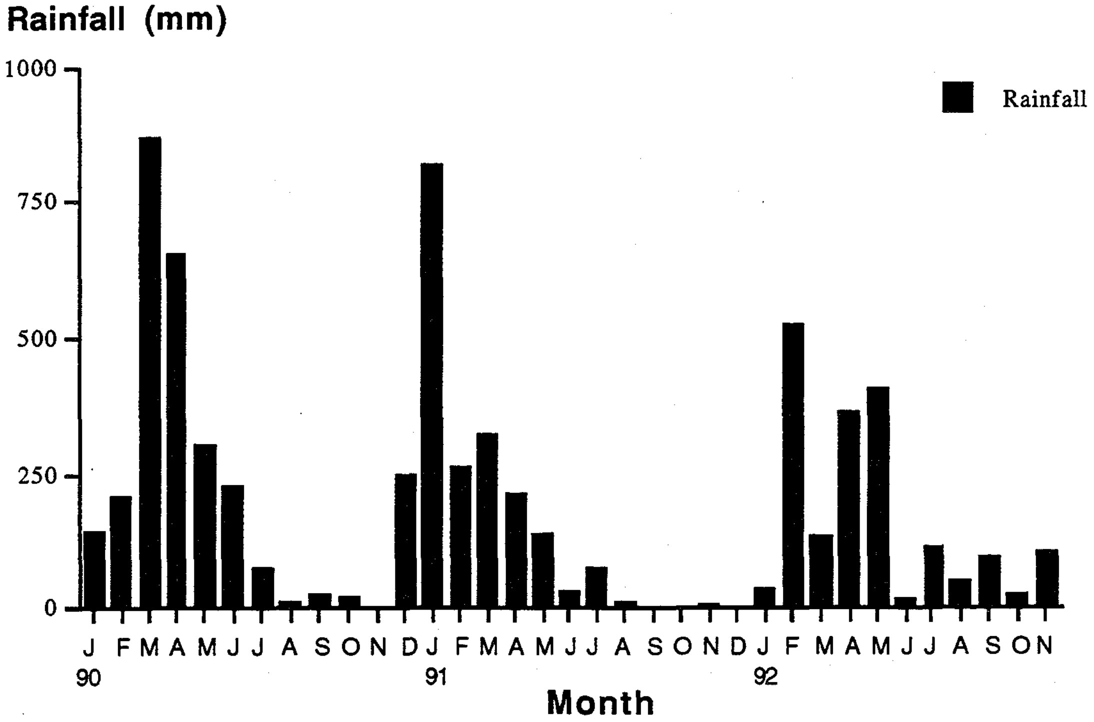


Figure 5.5 Monthly distribution of rainfall during the study period.

5.3 The Cassowaries

5.3.1 General

Given that the emphasis in this study has been placed on behavioural and ecological information, and as such has relied on working with a wild, free-living population of cassowaries, I was determined not to introduce anything new, other than myself as the observer, into the system I wanted to study. I therefore placed a high priority on maintaining a neutral relationship with the cassowaries at all times, never attempting any intervention in anything they did or anything that befell them. I never at any time employed incentives such as supplementary feeding in order to gain access to them. This I believed could distort some kinds of behavioural analyses by interrupting normal day-range patterns, possibly even accentuating aggressive interactions with others due to atypical aggregations at these feeding sites. Nor did I ever attempt to trap them, mark them or have any physical contact with them. Trapping and marking would have involved a considerable physical and financial commitment, including use of field assistants and expensive equipment, all of which were unavailable to me. In addition to the dangers for the researcher associated with handling such large powerful birds, this process would have greatly traumatised them, an experience which may have left them unsuitable for habituation and tracking. In addition, there was the possibility of serious injury to the birds to consider. These risks I was not prepared to take. Field assistants were never engaged in this study and so all my field work was conducted entirely alone.

5.3.2 Identification

Individual identification of cassowaries was essential in this study. Fortunately, adult cassowaries showed sufficient variation in their facial, neck, wattle and other morphological features such that individuals could be recognised. While subadults and chicks were less distinguishable, in most instances, after careful consideration there was also sufficient variation in features to build up profiles of these age-classes as well. Whenever a cassowary was sighted I attempted to record in detail, using written descriptions and a series of drawings, all identifiable features of the bird. The resultant identification profile of each individual consisted of detailed written descriptions of morphological characteristics, a series of drawings, and, whenever possible, a photograph (see Appendix A.1.1). Because photography was often not compatible with behavioural observations, nor was it always possible under conditions of dense, dark forests, it was only occasionally attempted. Nevertheless, a reasonable collection of photographs of individuals and certain behaviours such as incubation and hatching was established.

I named individual birds using, in alphabetic order, genus names of botanical specimens most of which were known to exist in the study site. For example, names of adult birds included: Acmena, Bowenia, Cordyline, Dillenia, Eugenia, Ficus, Helica, Intsia, Jasminum, Kamala, Leea indica, Myrstica and Neolitsea. The only deviation from this was the use of the name "Gunduy", which means cassowary in Girramay, a local aboriginal dialect (Pedley et al., 1997). In the case of chicks, their names were most often linked to their fathers as the species name, for example, (Dillenia) Alata, the first hatched chick of Dillenia, is a plant common in the study site.

5.3.3 Habituation

One objectives in this study was to observe undisturbed birds for many consecutive hours throughout the day. However, two potential problems were soon realised. Firstly, the presence of an observer could well affect the behaviour of cassowaries, and secondly, maintaining contact with the birds would be difficult. Neutralising the observer-bird interaction was therefore one of my principal tasks and this was achieved with a process of habituation.

Habituation of individuals evolved over a period of time and relied on presenting myself repeatedly and inoffensively in their environment, a technique Schaller (1965) used when habituating mountain gorillas. In general, habituating relatively shy cassowaries involved three stages: initial contact, maintaining contact, and tracking. While this process was fairly time-consuming, the considerable effort involved in the initial stages proved well worth while given the outcome achieved.

5.3.3.1 Initial Contact

Initial contact with cassowaries arose out of opportunistically locating them (from sightings and/or vocalisations) as I trekked through the forest. My immediate response on sighting a bird was to stand still or present a submissive position by squatting down. With the aid of binoculars I would then identify them. On no occasion during this initial contact period would I pursue the bird, once it had voluntarily moved out of range, as I was very conscious of minimising its initial wariness of me. I also learned that it was unwise to try and remain hidden. This in fact had the reverse effect to what was required.

With their finely tuned senses they either detected me immediately or were so threatened by my invisibility that they retreated.

5.3.3.2 Maintaining Contact

The most important outcome of this phase of habituation was to establish tolerance which would allow contact with the bird to be maintained over long periods of time. I established this in the following way. From recordings of both direct and indirect observations I identified foraging areas which cassowaries frequented on a regular basis. I attempted to arrive at these sites prior to their arrival. The regularity of my presence meant that I became accepted as part of their daily contact. Thus began the process of familiarisation which ended in a level of tolerance such that, once having sighted me, the target cassowary would continue to forage ignoring my presence. I noted during this stage that they were extremely sensitive to sound and sudden movement so these had to be avoided.

5.3.3.3 Tracking

Once a bird appeared to have accepted my presence I slowly began to move with it as it travelled through the forest. It was essential in the early stage of tracking to carefully monitor the bird's tolerance level. As soon as there was any sign of distress I would discontinue tracking. The time spent with the bird was therefore determined, firstly, by its tolerance span, and, secondly, by the accessibility of the forest, both of which I had to learn to master.

Their tolerance level depended on the observer's exceptional sensitivity to the needs of the bird, for example:

- always being totally visible;
- making as little noise as possible;
- never making sudden movements;
- predicting the movements of the bird, particularly while foraging, so as to, when necessary, move out of its intended pathway;
- never attempting physical contact with the bird or reducing distance between observer and bird to < one metre unless the bird did so itself;
- always stopping when the bird stopped so as to minimise disturbance when it was attempting to listen out for intruders.

Accessibility of the forest was very difficult when trying to maintain contact for long periods of time. Being a lowland coastal region, the forest was frequently buffeted by cyclonic weather which resulted in prolific growth of *Calamus* spp. vine thickets which are very sharply barbed.

5.4 Data Recorded

The nature of information recorded varied according to type of field work conducted. General field surveys primarily contributed ecological information while tracking focal individuals provided detailed behavioural information within an ecological context. While behavioural information was not always available in all circumstances, ecological information was.

The study encompassed a total of 35 months in the field. During the first 24 months, field work was conducted on a weekly basis (except for a report-writing break in October, 1991; Crome & Bentrupperbäumer, 1991a). The remaining 11 months were interrupted by three months of additional field surveys conducted within the Mission Beach area, but outside the study site, and one month of report writing (Crome & Bentrupperbäumer, 1991b; 1992; 1993). The additional field surveys were conducted in response to urgent requests by the management agency, Department of Environment, which was developing a Management Plan for cassowaries (see Goosem, 1992). Relevant aspects of this additional data set have been used in this dissertation.

5.4.1 Recording Equipment and Organisation of Data

Equipment used in the field was minimal, simple, light, and reliable. These were factors considered essential to this particular type of field work since it was always conducted alone, on foot and for long periods of time in dense vegetation and often wet, humid conditions. Collectively, field equipment consisted of waterproof notepads, pencils, maps, binoculars, tape measure, compass, stopwatch, ordinary wrist watch, knife, plastic bags for scats and fruit collections, hip chain for measuring distance, small camera and insect repellent.

All ecological and behavioural data were recorded in waterproof notebooks at the time of the observation. At the end of each day these field notes were transcribed into a diary and all relevant information recorded onto maps. At the end of each week data were extracted from the diaries and recorded in various hard copy files, including individual cassowary profiles, and files on particular aspects of behaviour (diet/foraging, general social behaviour, breeding behaviour, and movement patterns).

5.4.2 General Field Surveys

I systematically surveyed one zone (Figure 5.2) each week including all trails (Figure 5.3) associated with that zone together with random surveys between zone boundaries or between trails within the zone. In total, 912 h 50 min were spent on general field surveys. These general field surveys were conducted primarily to establish presence/absence of cassowaries, their differential use of habitats, identification of additional birds and behavioural interactions. During these surveys the route was mapped, progression timed in relation to zone, trail/transect and habitat type, and all sign of cassowaries (see Section 5.4.2.1) noted.

5.4.2.1 Ecological Considerations

A record of the presence of a cassowary consisted of one of the direct and/or indirect observations outlined in Table 5.2. To measure differential use of zones, trails/transects and habitats, both scat detection rates (scats per hour of survey), and sighting + vocalisation + scat detection rates were calculated. During these general field surveys I also recorded locations of topographic features such as all water courses and the quantity and quality of water present. Photographs were also taken.

Table 5.2 Indicators of cassowary presence.

A Sighting	an individual bird or a family group consisting of a male with chicks.
A Vocalisation	one individual making the same call or one individual making a continuous series of the same call.
A Scat [1]	a scat was counted as one record.
A Footprint [2]	one footprint or a series of footprints of the same size in the same area was counted as one record.

Notes: (1) Only intact scats were collected or when consisting of just one or two different but known species, seeds were counted *in situ.*

(2) When the full print was visible, size of each toe was measured. Footprints were not used in the calculation of use of areas because they were only visible in soft ground, thereby presenting a bias.

5.4.2.2 *Opportunistic Observations of other Animals*

In addition to recording data directly relevant to cassowaries, I recorded the presence and unusual behaviours of other avian, reptilian and mammalian fauna. Of particular interest were species thought to have a direct or indirect impact on cassowaries, that were rare, or would enhance my understanding of the ecosystem as a whole and the "seasonality" of that system in particular. I therefore noted the presence of other terrestrial birds including: the scrub fowl, *Megapodius freycinet*, which frequently scattered cassowary scats while foraging; the migratory noisy pitta, *Pitta versicolor* ; and the rarely seen red-necked rail, *Rallina tricolor*. The presence of a migratory frugivore, the Torres Strait pigeon, *Ducula spilorrhoa*, was also noted. Reptiles that were of particular interest included: monitor lizards (*Varinus* spp.), which were known to be nest raiders; boyd's forest dragon, *Gonocephalus boydii*; and any snakes. Mammals noted included: feral pigs, *Sus surrofa*, because of their potential impact on cassowaries as food competitors and nest and chick predators; red-legged pademelon, *Thylogale stigmatica*; and musky-rat kangaroos, *Hypsiprymnodon moschatus*, which was an important cursorial frugivore and seed disperser (Dennis, 1997).

5.4.3 Tracking Focal Individuals

Because cassowaries inhabit densely forested areas prolonged daily observations were difficult, if not impossible, on many occasions. In spite of the difficulties, a total of 351 h 45 min were spent tracking nine focal individuals for periods ranging from < one hour to 24 hours. Whenever an habituated individual was located it was followed for as long as possible. During these tracking sessions both detailed behavioural and ecological information was recorded.

5.4.3.1 *Behavioural Observations*

On first contact with a focal individual I noted time, identity, location, habitat type, and current activity/posture. I systematically recorded behaviour using a combination of continuous recording and instantaneous 5-min point sampling (Martin & Bateson, 1986). The sequence of behavioural events and number of bouts within each 5-min interval I recorded continuously, and at each 5-min point I recorded the following data instantaneously: time, activity, location and occasionally, distance travelled. In addition, I obtained an exact record of all occurrences of behaviour which was particularly important for analysing frequencies and duration of discrete events such as feeding, drinking, defecating, preening, etc.

5.4.3.2 Spatial Monitoring

When I followed a focal individual, I was able to use transect markers, various topographical and habitat features, and the hip chain, to record and map the travel route. While on some occasions tracking sessions consisted of walking continuously between a few closely spaced feeding trees, on other occasions large distances would be travelled between sparsely located feeding and drinking sources.

5.5 Analyses

I expressed results as means ± standard deviation or ± standard error. Standard deviations were reported when my intention was to describe variability within the population and standard errors were reported when my intention was to describe the precision of estimating the population mean (Zar, 1984). I used two-tailed Student's t-test on two sets of continuous data to determine significant difference between mean values (Zar, 1984), and one-way Analysis of Variance (ANOVA) on three or more sets of continuous data to determine significant difference between mean values (Zar, 1984). When the interaction term was significant, I used multiple contrasts (Fisher's PLSD test and Scheffe's test) to determine which means differed from the others.

Reporting the Statistics I used the general format used for reporting statistics: [name of statistic (degrees of freedom, number of cases) = value of the statistic, the probability of the statistic occurring by chance (secondary statistic if appropriate)], for example:

1. Chi-square test statistic	[χ^2 (1, n = 30) = 3.76, p = 0.005]
2. t-test	[t (8, n = 10) = 4.168, p = 0.0031]
3. One-way ANOVA	[F (2, 294; n = 296) = 3.492, p = 0.032]
4. Pearson product-moment correlation	[r (n = 23) = 0.156, $p < 0.05$]

The level of statistical significance was accepted at $\alpha = 0.05$. All statistical analyses were performed using the STATVIEW package available for Macintosh computers (Abacus Concepts, 1987).

Nomenclature I used the following sources of common and scientific names: (1) birds - Reader's Digest (1984); (2) mammals - Strahan (1983); (3) reptiles - Cogger (1983); and (4) plants - Copper and Cooper (1994).

* * *

Chapter 6

Population Ecology and Socio-Spatial Organisation

6.1 Introduction

Endangered species management and recovery requires basic information on population ecology and socio-spatial organisation of the species (Caughley & Gunn, 1996; Clark, et al., 1994; Dobson, 1996; Meffe & Carroll, 1994). This is because the probability of extinction is directly related to factors such as population size and distribution (Pimms, 1991). Without the empirical foundation provided by these studies an accurate assessment of population size, structure, spatial distribution and social behaviour, and the fluctuations inherent in these population parameters, cannot be made. Scientists and managers are seriously handicapped if they are ignorant of such parameters.

Knowledge of these parameters enables managers to make informed decisions relating to the development, implementation and monitoring of recovery programs and activities (Clark et al., 1994; Perrins et al., 1991), and impact assessment (Meffe & Carroll, 1994). More specifically, quantitative data on population ecology and socio-spatial organisation provide baseline information on populations which managers need to recognise, understand, explain and address population-level processes such as stochastic fluctuations, declines, and extinctions. With such a data set comparative analyses of spatial and temporal patterns may help to detect population trends. Failure to detect a trend is serious for endangered and declining species (Caughley & Gunn, 1996). For example, meaningful quantitative assessment of the species' recovery chances might identify the urgent need for changes in management policies (Dennis et al., 1991). This quantitative data also enables scientists and managers to: (1) assess what impact the prevailing stochastic variation has on long-term prospects for a species' survival; (2) seek out explanations for variation in populations; and (3) predict the kind of change in population parameters and social systems that will occur in response to changes in external circumstances.

Another important management question concerns the decision to list a species as officially "endangered" under the Endangered Species Act, or alternatively remove it from such a listing. Cassowaries are currently listed in the State of Queensland as "endangered" (Nature Conservation (Wildlife) Regulation, 1994), but are not listed as such federally (Endangered Species Act, 1992). The biological grounds for such a listing and its removal from the list requires a sound knowledge of the population ecology of the species.

In general, critical knowledge of many aspects of birds' lives and population processes is limited. Perrins et al. (1991) suggest that this, "In part stems from the sheer complexity of avian population dynamics, where intrinsic changes interact with extrinsic ones" (p.viii). Studies of population ecology and socio-spatial organisation of free-living cassowary populations are nonexistent. The information that is available is an assessment of distribution and status of cassowaries as a whole across north Queensland (Crome & Moore, 1990), rather than details of population size, structure, composition, and dynamics of specific populations. Other studies have examined aspects of social organisation and behaviour at specific sites (e.g., White, 1913; Crome, 1976), but have relied solely on incidental observations rather than systematic analysis. In addition, the information is qualitative and has been generated primarily from the casual observations which were reported second-hand. Nevertheless, they have provided the only insights to date into social organisation and behaviour and as such have made an important contribution to our understanding of this aspect of the species' biology.

Crome (1976), who reports Jorrisen's observations made in a semiurban setting, suggests that cassowaries are solitary and territorial. These observations also suggested that cassowaries generally avoid agonistic encounters by temporal variation in use of an artificially concentrated feeding area. However, when confrontation ensued, it was primarily limited to stretch display and intensive vocalisation. White (1913), in documenting Frizelle's observations made in a forest setting, reports finding cassowaries in small aggregations of adults and subadults. In reviewing the information gleaned from these two sets of observations, Crome and Moore (1988) devised two primary types of social structure, the basic social unit being the individual, or alternatively female dominated groups related by maternal descent. Within these primary structures several different scenarios were proposed, all of which were related to territory defence and/or encounters associated with that defence.

While limited to incidental observations, this information, collectively considered, does indicate that the patterns of organisation and behaviour in cassowaries are complex and differ from other ratites such as emus, *Dromaius novaehollandiae* (Davies, 1974), ostriches, *Struthio camelus* (Bertram, 1992), and rhea, *Rhea americana* (Handford & Mares, 1985), all of which form flocks. Nevertheless, all ratites do demonstrate some forms of solitariness particularly amongst males. In the absence of any quantitative analysis of population ecology, no comparative assessment in terms of other populations and other ratites can be made.

6.1.1 Chapter Outline

In this chapter, I examine these important biological considerations, which constitute the first step in this dissertation toward building up the scientific knowledge of cassowaries. In some instances, this involves expanding on what is already known, in others it is a beginning. The chapter begins with an examination of population ecology, the primary aim of which is to provide information on basic parameters such as population size, density and composition, birth rates, maturation and recruitment, and mortality rates and its causes. These parameters were chosen because knowledge of them makes it possible to describe more fully the population dynamics of cassowaries in terms of flows and because they are fundamental to the conservation and management of the species. While the field of conservation biology has recognised the importance of accounting for demographic stochasticity in species preservation efforts (e.g., Caughley & Gunn, 1996; Dobson, 1996; Meffe & Carroll, 1994), such accounting in practice has proved no easy task. Population ecology is a topic for which it is most difficult to obtain accurate, quantitative and comprehensive information (Perrins, 1991), particularly for a species which is rare, solitary, difficult to observe and an inhabitant of dense tropical rain forest. To estimate population size, composition and density by identifying all resident individuals in the population is a major task in itself, and to determine birth rates, mortality rates, age at sexual maturity, recruitment patterns and longevity requires years of sustained effort. Nevertheless, in this chapter I present data recorded over a three year period which provides a basic understanding of the patterns and determinants of population fluctuation in this lowland cassowary population.

The second section of this chapter examines socio-spatial organisation of cassowaries with the aim of providing information on the spatial pattern of individuals, and on the social determinants of pattern of distribution. To achieve this aim spatial distribution of the adult population, home-range size and overlap are examined, in addition to the social system, patterns and nature of interactions, and vocal signals.

In this chapter I show that all age classes of cassowaries are well represented in the Kennedy Bay National Park study site and that the age structure of the population is skewed toward adult birds. In addition, I demonstrate that, in this lowland population, cassowaries are solitary and territorial with stable home ranges.

6.2 Methods

6.2.1 Population Ecology

I undertook studies of cassowary population ecology in one study site, Kennedy Bay National Park. I defined the population in this study by its geographic context, that is, all individuals across all age classes located within predetermined topographically distinct study site boundaries over the three year study period. Any alteration from this definition I will identify in the text.

6.2.1.1 Population Size

I estimated population size by counting all individuals in the study site as far as possible (Known to Be Alive - KTBA). The first prerequisite was locating and determining identities of resident individuals. Birds were located using a combination of simple strategies: (1) I systematically traversed the whole of the study area at least every two months using transects and zone demarcations or area plots[1] (Chapter 5, Figure 5.2). This not only maximised my chance of locating all resident individuals but also provided information on changes in population structure; (2) once I had identified several core feeding and drinking sources, I simply waited at these sites until birds appeared. These "vigils" would last from 0.15 to ≅ three hours. The method used to identify and name individuals has been outlined in detail in Chapter 5 (Section 5.2.2).

6.2.1.2 Population Composition

From the profile of identified resident individuals I was able to assess population composition in the following way. Each cassowary sighted was assigned to one of three primary age-classes outlined in Table 6.1, and when applicable, to one of the subcategories. The age structure, the proportion of the population found in each age class, was determined using this set of information. I also recorded gender from age class adults.

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[1] a) while footprints and scats provided indirect evidence of use of areas during these general searches, a vocal response from a resident bird provided the direct evidence required to immediately locate a bird. On hearing a call, I would carefully move toward it. On some occasions this action itself provoked additional calls which further assisted in locating the bird. However, the bird would occasionally move off before detection; b) during these searches birds were often located foraging, drinking, or resting having been unaware of my approach and having presented no clues to their presence.

Table 6.1 Stages of the cassowary life cycle.

Life Stage	Age (years)	Description
Chick	**0-1.5**	**Hatching to the time chick is independent of male parent. Accompanied by male parent at all times.** Weight range: 0.350 kg at hatching (US data, captive bird, Schmitt, 1984) to 14.5 kg at six months (New Guinea data, captive bird, Reid, 1978).
Young	0-0.4	Striped plumage - longitudinal dorsal black stripes and various shades of yellowish/cream brown; neck and body region covered with pale brown feathers; wattles very small and cream-coloured; casque absent. The time when chicks depend almost entirely on the male parent for provision and identification of food. (Plate 6.1)
Old	0.5 - 1.5	Striped plumage replaced with a dull brown plumage on back of neck and body; cream-buff plumage on underside of neck and body; wattles still small, changing from cream to pale pink ; casque visible and growing slowly. Continuing close association between male parent and chick maintained, but independence developing in foraging strategies. (Plate 6.2)
Subadult	**0.7 - 4**	**Young bird now fully independent of male parent.** Weight range: 14.5 kg at 0.5 years (New Guinea data, captive bird, Reid, 1978) to 26.5 kg at ≅ three years (Australian data, free-living bird, Bentrupperbäumer, pers. obs. 1992).
Young	0.7 - 2.4	Same physical characteristics as ‘old’ chick but during latter stages hints of blue appear around the head region; brown plumage increases in darkness on upper parts of the body while lighter brown plumage is maintained on the head and neck region and underside of the body; wattles pink; casque small. (Plate 6.3)
Old	2.5 - 4	Body plumage black with brown tips; neck and head region blue and orange/red but still covered with fine black feathers; wattles pink/red, casque small. (Plate 6.4)
Adult	**> 4**	**Fully mature plumage over whole of body - glossy black feathers, bare head, neck and wattle region brightly coloured in light and dark blue, red/orange and purple ; wattles red; skin caruncculated; casque medium to large.** (Plates 6.5. & 6.6.). Weight range: 32.6 kg (Australian data, free-living bird, J. Bentrupperbäumer, pers. obs. 1990) to 85 kg (New Guinea data, captive bird, Reid, 1978).

Plate 6.1 A *young* cassowary chick.

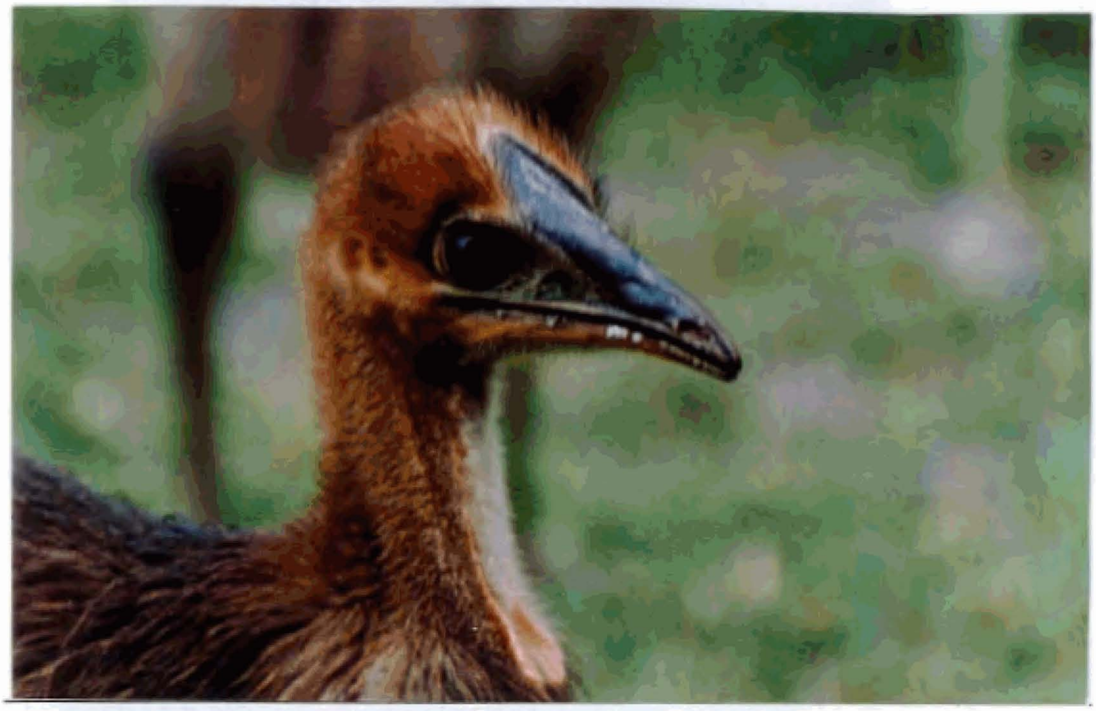

Plate 6.2 An *old* cassowary chick.

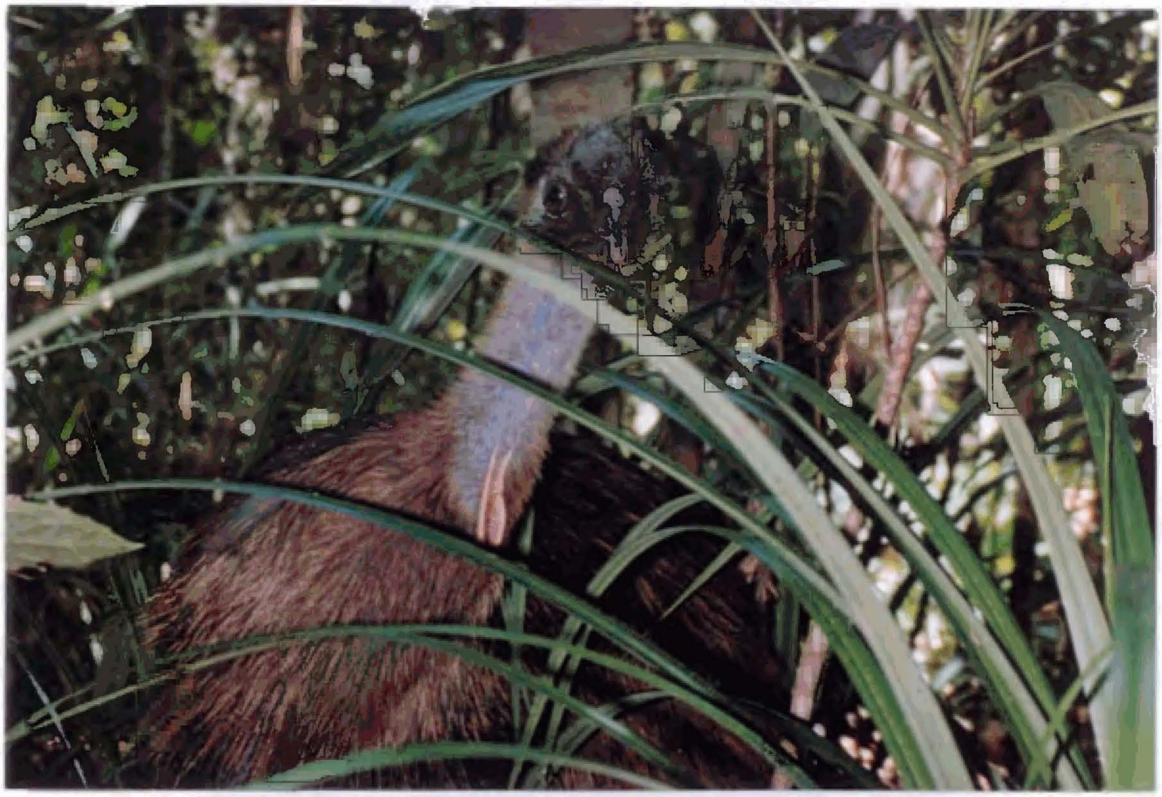

Plate 6.3 A *young* subadult cassowary.

Plate 6.4 An *old* subadult cassowary.

Plate 6.5 An adult cassowary.

Plate 6.6 Adult cassowary with tail feathers raised.

Age estimation To estimate age I identified major life history stages using a combination of parameters I determined during preliminary studies of this species. With Rothschild's (1900) monograph and the information accumulated during the course of this study, I was able to construct Table 6.1 which outlines the stages in the cassowary life cycle.

Sex determination The lack of any distinct sexual dimorphic characteristics makes positive sex determination in cassowaries difficult for the untrained observer. Consequently, since individual birds were never physically handled in this study, sex determination was possible only among adults as it was dependent on a combination of morphological and behavioural characteristics which were only developed fully in adulthood. I postulate that outside this age class it is not possible to determine the sex of cassowaries confidently without a cloacal examination as recommended by Weeks and Bush (1974). In general only minor morphological variation was evident between male and female adult cassowaries. Contrary to the suggestion that colour markings on the bare head, neck and wattle region may be a sexually dimorphic trait with females being more brightly coloured than males (e.g., Clutton-Brock, 1991; Crome, 1976), I found no evidence of this. Instead the sexes generally exhibited the same pattern and intensity of colour markings. The only variation evident was a reduction in the intensity of male colour markings toward the end of incubating a clutch of eggs. The morphological features identified in this study that reliably distinguished between the sexes included: (1) mature females were larger than males - footprint, casque, wattles and overall body size was proportionally larger[2]; (2) tail feathers of males were longer than those of females - they hung up to 20cms further below the level of the main body feathers; and (3) the possession of a penis which was visible during defaecation. These morphological features were used in combination with behavioural characteristics which were known to distinguish between sexes reliably including: (1) an adult with chicks was male[3]; (2) an incubating adult was male[4]; (3) when a known male was observed interacting[5] with a second adult during the breeding season without arousing aggressive tendencies, this second adult was identified as a female. This information was used to determine the sex composition of the breeding population.

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[2] For example: a) footprint size of mature females are significantly larger than males [t (8, n =10) = 4.168; p - 0.0031]; b) average weight of mature females is 46.9 kg (range 46.7 - 47 kg, n = 3), and mature males, 38.2 kg (range 32.6 - 44 kg, n = 3). All birds were road kills.

[3] Reverse parental care occurs in this species. Females take no part in rearing young (Section 7.3.5).

[4] Females do not assist in the incubation of eggs (Section 7.3.4).

[5] Such interactions included foraging together, pre-copulative displays, copulation, and visiting an incubating male (Section 7.3.3).

6.2.1.3 Population Density Estimates

Density estimates were calculated for both the whole (adults + subadults + chicks) population and the breeding (adult only) population. Using these two population classifications a density range was derived for those individuals sighted within the study site only and for those whose movements were known to extend beyond the study site boundary. The number of individuals in the whole and breeding populations was divided by the study site area (319.2 ha) to determine density. This was done on the basis that the entire study site was used by cassowaries (determined by direct and indirect observations).

6.2.1.4 Population Dynamics

"BIDE" Factors With a free-living population of cassowaries there was no easy way of accurately enumerating the "BIDE factors" (Meffe & Carroll, 1994) - births, immigration, deaths, and emigration - over this relatively short study period, or of confidently assessing their role in the dynamics of the population. In this population some of the processes may have remained undetected, for example, births and then sudden deaths of whole clutches. Other processes may have remained unresolved, for example, the inability to attribute loss of subadults and adults to death or emigration. This problem of unexplained disappearances is well-known in studies of wild animals (e.g., Waser et al., 1994), and even when populations such as this are under close observation, many individuals may disappear under unknown circumstances. Furthermore, on many occasions young animals may just be engaging in forays away from the natal site, searching for opportunities to disperse but not yet dispersing. Immigration, which is the number of birds coming into the study site (Colbert & Lebreton, 1991), is also very difficult to assess.

While acknowledging these problems, I scored gains and losses to the population in the following way. Births were scored under two circumstances: (1) by observing actual hatching; and (2) from sighting new chicks with resident males and estimating their date of birth from morphological characteristics. A birth rate was calculated by averaging the number born each year, over three years, divided by number (other than newborn) in the population in each year (see Caughley & Gunn, 1996). Deaths were scored when an identifiable bird was found dead or when a resident male, which was known to have chicks, was without them. Disappearance was scored when an identified individual was not sighted for one year. Because of the risk of overestimating mortality rates by not always being able to discriminate between death and emigration, the rate was presented as "death/disappearance" rather than just death. Death/disappearance rates were calculated as an average of the proportion of the population that died or disappeared each year over three years (see Caughley & Gunn, 1996).

Rate of change The population's rate of change - increase/decrease - was calculated in two ways: (1) the *finite* rate of change (λ) as the ratio of the numbers in one year to that in the preceding year (Caughley & Gunn, 1996; Dennis et al., 1991; Dobson, 1996);

$$\lambda = \frac{N_{t+1}}{N_t} \qquad \textbf{Equation 1}$$

where N_{t+1} = number of individuals in one year; N_t = number of individuals in proceeding year; and (2) Caughley and Gunn's (1996) *exponential* rate of increase/decrease (r) using the following formula,

$$r = \frac{\ln (N_t / N_o)}{t} \quad \text{or} \quad \frac{\ln \lambda}{t} \qquad \textbf{Equation 2}$$

where No = number of individuals in the first count, Nt = number of individuals in the second count, t = number of years, and λ = *finite* rate of change.

This rate r on a yearly basis was converted to a proportional decline D per year by using Caughley and Gunn's (1996) formula:

$$D = 1 - e^{r} \qquad \textbf{Equation 3}$$

e being the base of natural logarithms ($e = 2.71828$).

Maturation and recruitment The subadults and young adults which may have emigrated were not habituated so tracking them was not possible. However, patterns of maturation and recruitment within the population and across different life history stages were established by regularly sighting 16 identified individuals and observing them from the chick stage through to adulthood. While recruitment rate has been defined in some of the literature (e.g., Colbert & Lebreton, 1991) as the joint effect of birth and immigration, in this study recruitment refers to the successful maturation from one age class to the next.

Causes of mortality in a broader area To gain deeper insights into the levels and causes of mortality within cassowary populations in general, but particularly in the Mission Beach population, I used information gained from a public cassowary monitoring program. I established this program in 1986 and continued to use it in a refined format throughout the study period[6]. On a basic proforma data sheet (see Appendix A.2.1) members of the public recorded sightings of cassowaries, including: date, time, sighting, location, details of behaviour, details of informer. Through this program I was notified when a cassowary death occurred or when one was found injured or ill. In the majority of the latter instances, death occurred within a few hours or days following injury. Written details of deaths were immediately recorded and when possible the body was sighted, various measurements were taken and a photographic record was made. I have included this information in this chapter: (1) because it was important to establish all of the threats to the survival of this species; and (2) to provide a comparative analysis between the Kennedy Bay population and a proximate population which is subjected to considerable human contact.

6.2.2 Socio-spatial Organisation

6.2.2.1 Use of Space

As outlined in Chapter 5, the study site was divided into five primary zones and traversed by several unobtrusive trails (Figure 5.2) which facilitated orientation, ability to map position, as well as acting as a series of transects (Section 6.2.1.1). Once a bird was encountered, details of its location were recorded including: (1) identity of the zone and trail on which it was located; (2) if it was not located on a trail its position in relation to nearby trails; and (3) its position in relation to topographical and environmental features including altitude, hills, creeks and swamps, habitat type, and any other reliable land marks. This detailed locational data allowed the position of the bird to be plotted onto topographical maps of the study site. Maps of the location of birds in each month were established in this way.

The spatial distribution of adult cassowaries was established using the total set (over three years) of locational data of each bird. Boundaries of home ranges were constructed using the minimum convex polygon method (Mohr, 1947). The enclosed polygon area was

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[6] To provide an example of the extent of this information base, for a two year period, January 1990 to December 1991, a total of 1082 records of cassowaries in this Mission Beach Region were provided by the public via this monitoring program (Bentrupperbäumer, 1992b).

measured to estimate minimum home-range size (Seber, 1992; Worton, 1987). No attempt is made in this chapter to determine differential use of areas within this boundary and so the estimated home range is believed to be considerably larger than the utilisation home range for any one period. However, the distribution of movements within the home range, which will be addressed in Chapter 8, does contribute to our understanding of how the birds use their environment.

6.2.2.2 Social Behaviour

Behavioural interactions were most often observed opportunistically when individuals were located during routine surveys. After locating individuals, details of the behavioural interactions were immediately recorded. In contrast, to become familiar with the interactions between parent and offspring, I observed Dillenia and his offspring for 106 h 30 min in the following way: (1) in 1990-1991 Dillenia and offspring Alata and Boronia were observed and tracked on 25 separate occasions for a total of 72 h 15 min. This period extended from the time of hatching of chicks to their independence; (2) in 1992 Dillenia and offspring Cowleyana and Daemmeliana were observed and tracked on 8 occasions for a total of 34 h 15 min. This period extended from the time the chicks were ≅ 4 weeks old to 11 months old.

6.2.3 Note on Analysis

While there currently exists highly complex mathematical analyses and models in population ecology, this study has endeavoured to provide baseline data which, with the addition of a larger and more varied data set in the future, allow for such analyses to be conducted. With the data set available from this research, I have taken a much more pragmatic approach, presenting a general perspective of population ecology with limited extrapolation.

6.3 Results

6.3.1 Population Ecology

6.3.1.1 Population Size

A total of 35 individual cassowaries were identified (KTBA) in the Kennedy Bay National Park study site (see Appendix A.2.2). Excluding records from continuous tracking of individuals, cassowaries were sighted 788 times during the course of this study. On average, 0.95 (± 0.13 SE) sightings per hour of search effort were made during the routine field surveys. In most instances (94.1%), clear, prolonged observations were possible. Occasionally (5.9%) a sighting was brief, particularly in areas where the understorey was dense or when the cassowary was extremely wary. In these instances, identification was not possible. From the remaining 741 sightings I was able to identify and catalogue (and occasionally photograph; see Appendix A.1.1) the birds I encountered and thus to determine that 35 individual cassowaries were "Known to Be Alive" in my study site during the three year study period. With the exception of five newly hatched chicks which were sighted only once at the end of the study period, each individual was sighted at least twice. One was sighted a total of 132 times and on average each cassowary was sighted 24.0 (± 4.79 SE) times.

Despite regular sightings of birds within each year, in any one year the number of individuals sighted did not exceed 26 (see Section 6.3.1.2). Therefore, the total of 35 does not represent the population size in any one year. Furthermore, the regular movement of seven birds (three adults and four chicks) was known to extend northward beyond the study site boundary into private property. Constant demographic changes inevitability alter population size and structure year after year. Given factors such as the large number of sightings made (788), time spent in the field (1264.5 hours), and the extent to which the whole of the study site was surveyed systematically and regularly (912.8 hours), I am confident that at the end of the three year study period all adult, and most young members of this cassowary population were individually identified and named. Exceptions may include some transient subadults and young adults. Fluctuations in population size and structure are addressed in the next three sections.

6.3.1.2 Population Composition

Age structure The Kennedy Bay cassowary population was composed primarily of adults (46.7%), with the proportion of subadults present (27.5%)

being slightly higher than that of chicks (25.8%). In addition, over the three year period, the same 10 adults were sighted, all permanent residents of the study site (see Appendix A.2.2). Considering yearly fluctuations in population size, I estimate the total cassowary population using the study site in any one year to be within the range of 22 to 26. Table 6.2 shows the number and proportion of cassowaries in the three primary age-classes in each of the three years. The method used to determine these proportions was based on the number of different individuals sighted during each twelve month period within each age class.

Table 6.2 Age structure of the lowland cassowary population in Kennedy Bay National Park.

	Year			Mean %
	1990	1991	1992	1990-1992
Number of Adults	12 (46.2%)[1]	11 (50.0%)	11 (44.0%)	46.7%
Number of Subadults	8 (30.8%)	7 (31.8%)	5 (20.0%)	27.5%
Number of Chicks[2]	6 (23.0%)	4 (18.2%)	9 (36.0%)	25.8%
Total Number of Birds	**26**	**22**	**25**	**100%**

Note: (1) Percentage of population in each age-class is shown in brackets.
(2) Chick numbers include all those which were known to have hatched during each twelve month period even if not sighted in that period.

Fluctuations in the proportion of individuals within each age class varied from year to year. In the adult population, fluctuations in numbers was low (maximum 6%); for subadults it was higher (maximum 11.8%); and for chicks it was three times that of adults (maximum 17.8%). While fluctuation in the adult population size was evident, their numbers remained fairly stable throughout the study period. Furthermore, the same individuals were present.

These yearly fluctuations were known to be the result of a combination of four processes - births, deaths, maturation and disappearance. While emigration and stochastic environmental events such as low food availability (lean period) were suspected to effect population structure, I did not collect data to confirm this. The higher proportion of subadults compared to the preceding years proportion of chicks would suggest the steady recruitment of these chicks into at least subadulthood as well as the continued presence of some subadults in the population. Section 6.3.1.4 addresses in detail the age-class dynamics within this population.

Sex composition Of the 14 adults identified in this study, six were male, six female, and for the remaining two which were young adults, their sex was unknown. Table 6.3 provides an outline of the sex composition of this adult population. The difference in composition is likely to be the result of a spatial artefact rather than a biological reality. Sex ratio was not calculated because of lack of independent measures. The same birds were observed each year.

Table 6.3 Sex composition of adult cassowaries in the study site.

Total Number of Birds Identified	Year		
	1990	1991	1992
Males	5	4	5
Females	6	5	6

6.3.1.3 Population Density

The highest number of cassowaries recorded using the study site was 26 in 1990. The lowest number using the study site exclusively was 17[7] in 1991. Using these population figures a density range of 5.3 to 8.2 cassowaries per km^2 for the whole population was calculated. When considering only the adult (breeding) population which represents the most stable population, the density ranged from 2.5 adults per km^2 for those using the study site only and 3.8 adults per km^2 for those whose home range extend beyond the northern boundary.

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[7] This number was calculated from the 1991 population estimate (22) minus the number of birds known to extend their movements beyond the study site boundary in that year (5).

6.3.1.4 Population Dynamics

As noted previously, the size and composition of this lowland cassowary population fluctuated as a result of: birth, death, maturation and disappearance. The following describes estimations I made of age-class specific rates of survivorship and mortality within this population. Table 6.4 outlines the pattern and processes involved in these yearly fluctuations amongst the resident individuals of the Kennedy Bay population.

Chick population I recorded births in each year of the study period. Of the 19 chicks identified, 5 hatched in 1989, the year before the study began, 5 hatched in both 1990 and 1992, and 4 chicks hatched in 1991. On average 4.75 chicks hatched per year (n = 4), 4.67 without the 1989 figures. The average birth rate was 0.24 (range 0.22 - 0.25). Losses in the chick population were confined to death and maturation into subadulthood. Over the three year period loss[8] by death accounted for 10.5% of the total chick population and loss due to maturation into subadulthood, 47.4%. The average number of deaths per year in this chick population was one and the number which matured, three. The proportion of the chick population that hatched and survived from year to year was 0.80; the chick-specific average death rate was 0.20 (range 0.0 - 0.4).

Subadult population Gains to the subadult population occurred by successful maturation of chicks, which averaged three per year. While difficult to rule out, immigration was not evident. Losses[9] to this population were either classified as "disappearance", which was death or emigration, and maturation into adulthood. Fifty-two percent of the total subadult population disappeared and 15.4% matured into adulthood during the course of this study. Average number of subadult disappearances (death/emigration) was 2.7 per year, and maturation into adulthood, 0.3 per year. On average, the proportion of the population that survived or at least remained in the study site from year to year was 0.54 (average death/disappearance rate = 0.46).

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[8] Chick loss: death = 18.1% loss; maturation = 81.9%.

[9] Subadult loss: disappearance = 77.2%; maturation = 22.8%

Table 6.4 Patterns and processes involved in fluctuations across different age-classes of the Kennedy Bay cassowary population.

1989/ 1990 Initial Pop^{n}Size	**Identified**	1989 chicks Australis, Brachyandra, Insipida & Claviflorum	**Identified**	2 'old' subadults = Cordyline & Neolitsea 2 'young' subadults = SUB 1, 2.	**Identified**	Acmena, Dillenia, Ficus, Gunduy, Myristica, Bowenia, Eugenia, Helica, Intsia, Jasminum, Kamala & Leea-Indica.
	n = 4		**n = 4**		**n = 12**	
1990	**Loss:** Maturation = 4	1989 chicks matured = Australis, Brachyandra, Insipida & Claviflorum.				
	Gain / Remain: Birth = 5 Remain = 1	Alata, Boronia, Acacia, Bubbia & Caryota hatched. 1989 chick Albipila remained dependent on the male parent.	**Gain:** Maturation = 4	1989 chicks matured = Australis, Brachyandra, Insipida & Claviflorum.		
	n = 6		**n = 8**		**n = 12**	
1991	**Loss:** Death = 1 Maturation = 5	Boronia died. Albipila, Alata, Acacia, Bubbia & Caryota matured into subadulthood.	**Loss:** Disappear = 5 Maturation = 1	SUB's 1, Neolitsea, Australis, Brachyandra, Claviflorum, not sighted. SUB Cordyline matured into adulthood.	**Loss:** Disappear = 2	Myristica & Intsia not sighted.
	Gain: Birth = 4	Graveolens, Hemilampra, Cowleyana, & Daemeliana hatched.	**Gain:** Maturation = 5	Five 1990 chicks matured into subadulthood - Albipila, Alata, Acacia, Bubbia & Caryota.	**Gain:** Maturation = 1	SUB Cordyline matured into adulthood
	n = 4		**n = 7**		**n = 11**	
1992	**Loss:** Death = 2	Brassii & Delbata died.	**Loss:** Disappear = 3	SUB Albipila, Caryota, Insipida not sighted.	**Loss:** Disappear = 2	Leea-Indica & Cordyline not sighted.
	Gain / Remain: Birth = 5 Remain = 4	Benjamina, Congesta, Destruens, Brassii, & Delbata hatched. Graveolens, Hemilampra, Cowleyana, & Daemeliana remained dependent on the male parent.	**Gain:** nil		**Gain:** Reappear = 1 Maturation = 1	Intsia sighted again. SUB Neolitsea matured into adulthood
	n = 9		**n = 5**		**n = 11**	

Adult population Gains to the adult population included the maturation of subadults, which averaged 0.7 individuals per year. Immigration was not evident. Losses to this population were again classified as disappearance since either death or emigration was not confirmed. Fourteen percent of the total adult population disappeared, giving an average disappearance rate equal to maturation: 0.7 individuals per year. On average, the proportion of the population that survived or at least remained in the study site from year to year was 0.87 (average death/disappearance rate = 0.13). I propose that emigration accounted for a proportion of this figure, particularly in the case of the two young adults, Leea-Indica and Cordyline and, with the re-sighting of Intsia in 1992, she may well have just been missed in 1991 rather than disappearing.

This population of cassowaries appears to be stable. For the total population, an average growth rate or *finite* rate of population change (see Section 6.2.1.4 , Equation 1) of 0.99 per year for 1991 and 1992 combined was calculated, which suggests that this population of cassowaries is more likely to decline or remain static than it is to increase. When taking the population count for 1990 and 1992, the *exponential* rate of population change (see Section 6.2.1.4, Equation 2) was - 0.019, which indicates the presence of an overall decline in the population of 1.9% per year (see Section 6.2.1.4, Equation 3). To gain a better assessment of the population trend *exponential* rates of change were calculated for each year: - 0.17 in 1991 and 0.13 in 1992, which indicates that while there was a decline of 15.6% in 1991, there was a population increase of 13.9% in 1992. The ratio of birth to total population death/disappearance rates was 0.83, which suggests a decline in population size. However, given the short time frame of the study, it is not possible to conclude that there has been a decline or even that there is a trend.

6.3.1.5 Mortality

Mortality in the study site Determining the number and causes of death in a free-living and relatively isolated population of cassowaries was difficult. Despite considerable search effort and the disappearance of a number of birds, only one death of a resident cassowary was definitely known to have occurred over the three year study period, Dillenia's offspring, Boronia. The body of this offspring was located not during a routine field survey but rather, unexpectedly, by following its sibling, Alata. On 2 July, 1991, Alata was located at 0815 h foraging alone[10] on the fruits of, *Ficus*

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[10] It appears that Alata had recently been abandoned by the male having reached the age of independence.

drupacea, figs. After tracking this bird for 1 h 10 min and covering a distance of 0.919kms, it walked up to the body of Boronia and sat down beside it. Considering the state of decomposition of the body and the fact that it had remained untouched by carrion foragers such as monitor lizards and pigs, it was estimated that death had occurred approximately four to five days earlier. On examination of the body no clear sign of physical injury was evident. However, in discussions with a veterinary surgeon it was suggested that for the head and neck region to have decomposed so much quicker than the rest of the body, some injury to that region may well have been sustained (Reid, K. pers. comm. August 1991).

The only other death known to have occurred during the study period was that of an adult which may have used at least part of the study site. The body of this bird was located on the 13th of February 1992 ≅ 250m north of the study site boundary. It had sustained multiple gun shot wounds across the left hip region (Plate 6.7). The body was located in a cleared field which suggests that the shooting was deliberate rather than a matter of mistaken identity.

Plate 6.7 An adult cassowary which has died from multiple gun shoot wounds.

In addition to these two confirmed deaths, I suspect that Neolitsea's two chicks died within three weeks of hatching. No evidence of these two very small chicks was found when the male Neolitsea was located just three weeks after they had hatched. Various factors can obviously contribute to the death of small young. However, I suspect that Neolitsea being only a very young male was a less experienced parent than Dillenia and did not care for his chicks as well. In longer-lived birds, individuals breeding for the first or second time have been found to have a lower breeding success than older birds (Perrins, 1991; Weimerskirch, 1990). Unlike Dillenia, Neolitsea would often take routes over logs and amongst tangles of vine that proved quite difficult for very young chicks. This would delay their progress and as a consequence an unsafe distance between chicks and parent would develop which lead to frequent distress calls from the chicks. Such calls inevitably attracted the attention of potential predators including raptors (e.g., *Accipiter* spp.) and reptiles (e.g., *Varanus* spp.). Of particular concern in this environment was the large rainforest lace monitor, *Varanus varius*, which has been known to eat eggs (see Section 7.3.6.2), and newly hatched chicks (Geyle, M. pers. comm. April 1997).

Mortality in the broader area To expand our knowledge of causes of mortality in cassowaries, information from outside the study site was assembled. Table 6.5 outlines mortality figures for the cassowary population in the Mission

Table 6.5 Level[1] and causes of cassowary mortality for the Mission Beach coastal and hinterland region, 1990-1992.

Cause of Death[2]	Adults	Subadults	Chicks	% of all known deaths 1990-1992
Vehicle	7	4	3	26.4%
Shooting	2			3.8%
Dog Attack	3	5		15.1%
Pig Trap	6		1	13.2%
Unknown		1	21	41.5%
Total	**18**	**10**	**25**	
%	*34.0%*	*18.9%*	*47.1%*	

Note: 1. These numbers represent the minimum known mortality figures over this three year period.
2. See Appendix A.2.3 for photographic record of these causes of death in cassowaries.

Beach coastal and hinterland region[11] for the period 1990-1992. It has been estimated that between 50% and 60% of this region has been cleared for residential, tourist, and agricultural development (Crome & Bentrupperbäumer, 1993), the vast majority of which is below 40 m. A number of both major and minor roads traverse the region.

The minimum cassowary mortality figure for this region in the three year period was 53, giving a mortality rate of 17.7 cassowaries per year or 6 breeding adults per year. Given the adult population estimate for this region of between 84 and 134[12], these 18 known deaths would account for between 13.4% and 21.4% of the population. The majority of mortalities reported (58.5%) were known to be either directly or indirectly attributed to humans. Furthermore, it is suggested that some of the unknown causes of deaths evident in the chick population may at least be indirectly attributed to human presence in the region. The mortality figures may be biased toward human-attributed deaths since these are the ones most visible to the general public. Nevertheless, many deaths, particularly those caused by shooting, packs of farm or pig dogs, and pig traps, probably remain unreported.

This came to light in a pilot survey conducted in January and February, 1993, during which 21 rural residents were interviewed. In this survey, ten separate instances of cassowaries being caught in pig traps which resulted in the death of three birds and severely damaging the casque and beak of the fourth[13] were reported (see Appendix A.2.3, Plates 6.14 & 6.15). In addition, 5 cassowary deaths due to dogs which involved a total of 18 dogs (packs of 2, 3, and 5 dogs), were reported. It is interesting to note that 14 of these rural respondents owned between them a total of 25 dogs but only 23.8% of the respondents considered dogs to be a threat to cassowaries[14]. Other known causes of death have included diseases such as tuberculosis and aspergillosis (Crome & Moore, 1990, Blundell, J. pers. comm. 1990), injuries sustained from barbed wire fences (Storch, D, pers. comm. August 1991; see Appendix A.2.3, Plates 6.12 & 6.13), and drowning (Public Cassowary Monitoring Program, 1993).

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[11] This region covers an area of ≅ 230km^2 (Bentrupperbäumer, 1992).

[12] This estimate has been established from the survey work I conducted in 1991, 1992 and 1993 on seven Mission Beach coastal sites covering an area of 6.17 km^2 and five Mission Beach hinterland sites covering an area of 31.7km^2 together with the monitoring program information (Bentrupperbäumer, 1991, 1992a, 1992b, 1993; Crome & Bentrupperbäumer, 1991).

[13] An injury to the beak would most likely result in the eventual death of the bird. An injury to the beak of a captive bird, which was sustained by knocking against the cage of an enclosure, resulted in slow starvation until surgical intervention resolved the problem (Bentrupperbäumer, pers. obs. 1991; Appendix A.2.3; Plates 6.14 & 6.15).

[14] In a small rural town (population <500 people) in the Wet Tropics region, 72 stray dogs were collected by the local Council in a two hour period (Cairns Post, March 1997).

6.3.1.6 Pattern of Maturation and Recruitment

While it was very difficult to establish accurately the timing of maturation and level of recruitment in a short-term study and on a long lived animal, in the absence of any other information I present an overview of this process from the data available from this study. Table 6.6 is a schematic representation of the pattern of maturation, recruitment and survivorship observed in 16 resident individuals. The information available from this table is discussed firstly in terms of the total number of chicks and subadults present in three years and secondly in terms of a cohort analysis.

Ten of the 12 young (striped) chicks (83.3%) which should have matured into the old chick category during the course of this study did so successfully. The two which did not survive were Neolitsea's Brassii and Delbata, both disappearing within a few weeks of hatching (see Section 6.3.1.5). Nine of the ten 'old' chicks which should have matured into subadulthood during the course of this study, did so. One, Dillenia's Boronia, I found dead at the time of transition from chick to subadulthood. Successful recruitment of these chicks into this study site's subadult population was unknown as definite identifications were extremely difficult to obtain. Nevertheless, I was reasonably confident with the identification of five individuals[15] which were sighted on 20 occasions up to five months after they first matured into subadulthood. Of these, two were sighted up to 15 months later. However, none of the three young subadults which should have matured into old subadults, Acmena's Australis, Brachyandra and Claviflorum, were sighted after 5 months of becoming independent of Acmena.

All of the 1989 'old' chick cohort (n = 5) successfully matured into subadulthood. Subadult recruitment lasted at least 5 months for 60.0% of this cohort. Beyond five months their fate remained unknown as all disappeared. All of the 1990 cohort (n = 5) survived to mature into the old chick category, 80.0% reached subadulthood and 40.0% were successfully recruited into the study site population having been sighted eight times up to 15 months after first maturing into subadulthood. Although the study period was not quite long enough to establish if the remaining two had matured into the old subadult category, their continued presence in the study site population for 25 months after hatching suggests this would be likely.

Finally, the two 'old' subadults identified at the beginning of the study successfully matured into adulthood. One was recruited into the adult population, the male Neolitsea,

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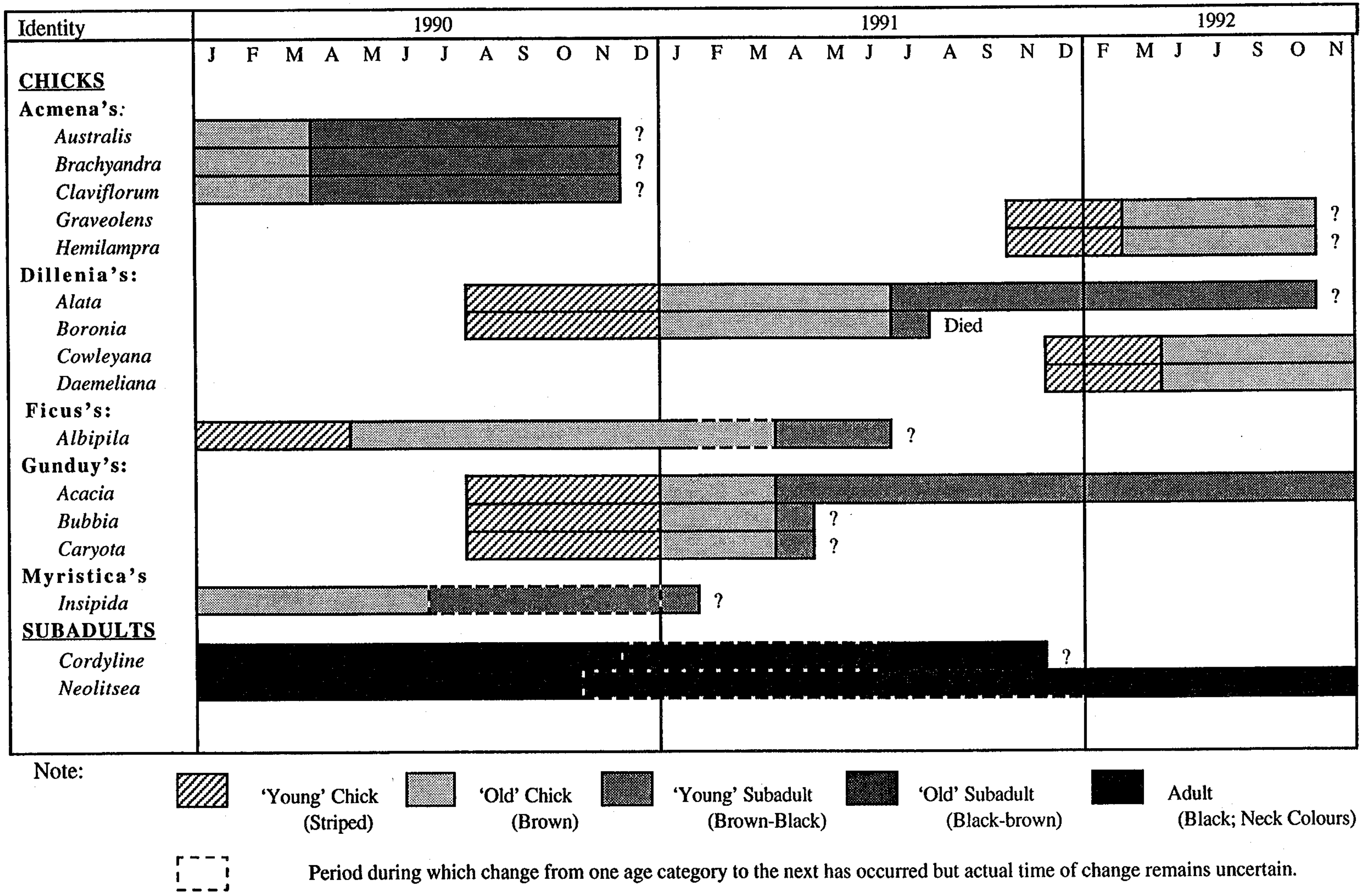
[15] Identification in this instance was confirmed with physical characteristics plus location.

Table 6.6 Schematic representation of the pattern of maturation and recrutiment in the chick and subadult cassowary population in the study site.



who produced two offspring in October 1992. However, it is unknown if the study site was his natal territory or if he was an immigrant.

6.3.1.7 Summary of Population Parameters

Table 6.7 outlines the summary of cassowary population parameters for my study site. The mean population size for the whole population was 24.3 (± 1.20 SE), and mean density 7.62 per km^2 (± 0.38 SE). Each year on average, 9.1% (± 5.25 SE) of the adult population were recruited from the subadult population, 40.5% (± 21.16 SE) of the subadult population were recruited from the chick population, and 79.6% (± 12.95 SE) of hatchlings survived. The mean death/disappearance rate for the whole population 21.4% (± 10.98 SE) per year.

6.3.2 Socio-Spatial Organisation

6.3.2.1 Spatial Organisation

Figure 6.1 and 6.2 are schematic representations of the spatial distribution of six female and six male cassowaries. Given the large number of sightings of some individuals, including those obtained from long periods of continuous observation during which individuals travelled considerable distances, each sighting point has not been included in these maps. Rather, the outermost points where each adult was seen and which was known to encompass the entire set of observations were joined providing a general picture of the spatial distribution of these females and males relative to each other. While no attempt is made to use these spatial distribution maps to determine home range shape, differential use of areas, or even to suggest that these are definitive home range boundaries, some preliminary comments can be made about home-range size and adult spacing patterns.

Home-range estimates In this study site adult cassowaries occupied mean home ranges of 75.26 ha (± 10.46 SE, range 52.1 - 136.6ha, n = 8; Table 6.8). Although female home-range sizes were, on average, 31.9% larger than those of males, no significant gender difference was detected [t (df = 6) = 0.989, p = 0.361]. The most accurate estimates of home-range size for this adult population were those of the male Dillenia (94.3ha) and the female Eugenia (136.6ha). Incidental sightings (n = 189) of both adults were made regularly over the three year study period in addition to

Table 6.7 Summary of population parameters for the Kennedy Bay National Park cassowary population, 1990 - 1992.

Population Parameters		**Adults**				**Subadults**				**Chicks**				**TOTAL**			
		90	91	92	$\overline{X}$ (±SE)	90	91	92	$\overline{X}$ (±SE)	90	91	92	$\overline{X}$ (±SE)	90	91	92	$\overline{X}$ (±SE)
Population Size		12	11	11	**11.3** (±0.33)	8	7	5	**6.7** (±0.88)	6	4	9	**6.3** (±1.45)	26	22	25	**24.3** (±1.20)
Sex Composition:	Male	5	4	5		-	-	-	-	-	-	-	-	-	-	-	-
	Female	6	5	6													
	Unknown	1	2	0													
Population Density (cassowaries/km^2)		3.76	3.45	3.45	**3.55** (±0.10)	2.51	2.19	1.57	**2.09** (±0.28)	1.88	1.25	2.82	**1.98** (±0.46)	8.15	6.89	7.83	**7.62** (±0.38)
Recruitment[1]	N	0	1	2	**1.0** (±0.58)	4	5	0	**3** (±1.53)	5	4	5	**4.7** (±0.33)	-	-	-	-
	%	0	9.1	18.2	**9.1%** (±5.25)	50.0	71.4	0	**40.5%** (±21.2)	83.3	100	55.6	**79.6%** (±12.9)				
Death/ Disappearance[2]	N	0	2	2	**1.3** (±0.67)	0	5	3	**2.7** (±1.45)	0	1	2	**1** (±0.58)	0	8	7	**5** (±2.52)
	%	0	18.2	18.2	**12.1%** (±6.07)	0	71.4	60.0	**43.8%** (±22.2)	0	25.0	22.2	**15.7%** (±7.91)	0	36.3	28.0	**21.4%** (±10.9)

Note:

1. Recruitment figures relate to the number (N) of birds recruited into the population and the percentage (%) of the population that number represents. In the chick population, recruitment = hatching.
2. Death/disappearance figures relate to the number (N) of the population which have been lost either by death or disappearance and the percentage (%) of the population that number represents.

Figure 6.1 A schematic representation of the spatial organisation of female home ranges. The map shows the outermost locations where six females were observed from 1990 to 1992.

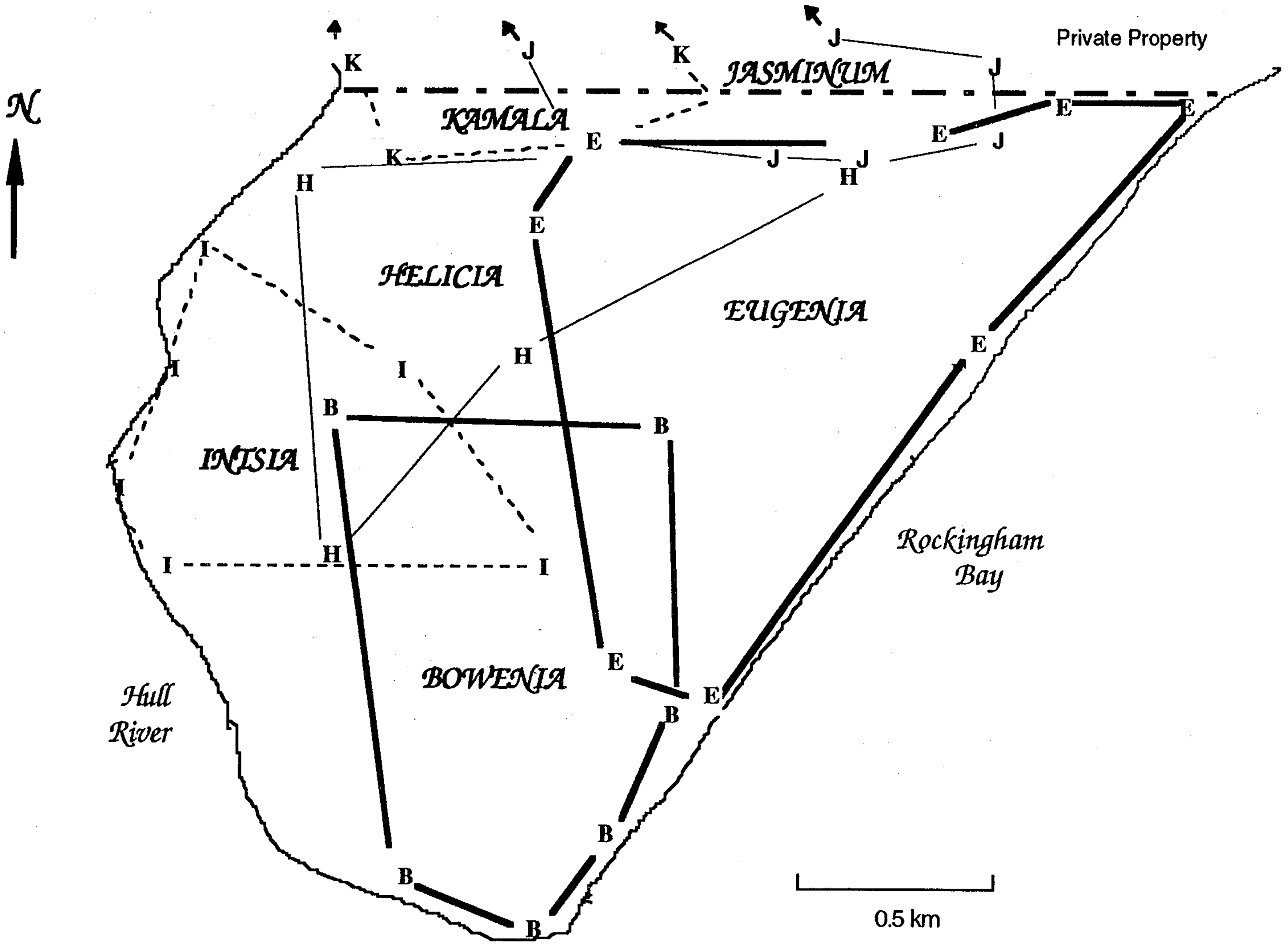


Figure 6.2 A schematic representation of the spatial organisation of male home ranges. The map shows the outermost locations where six males were observed from 1990 to 1992.

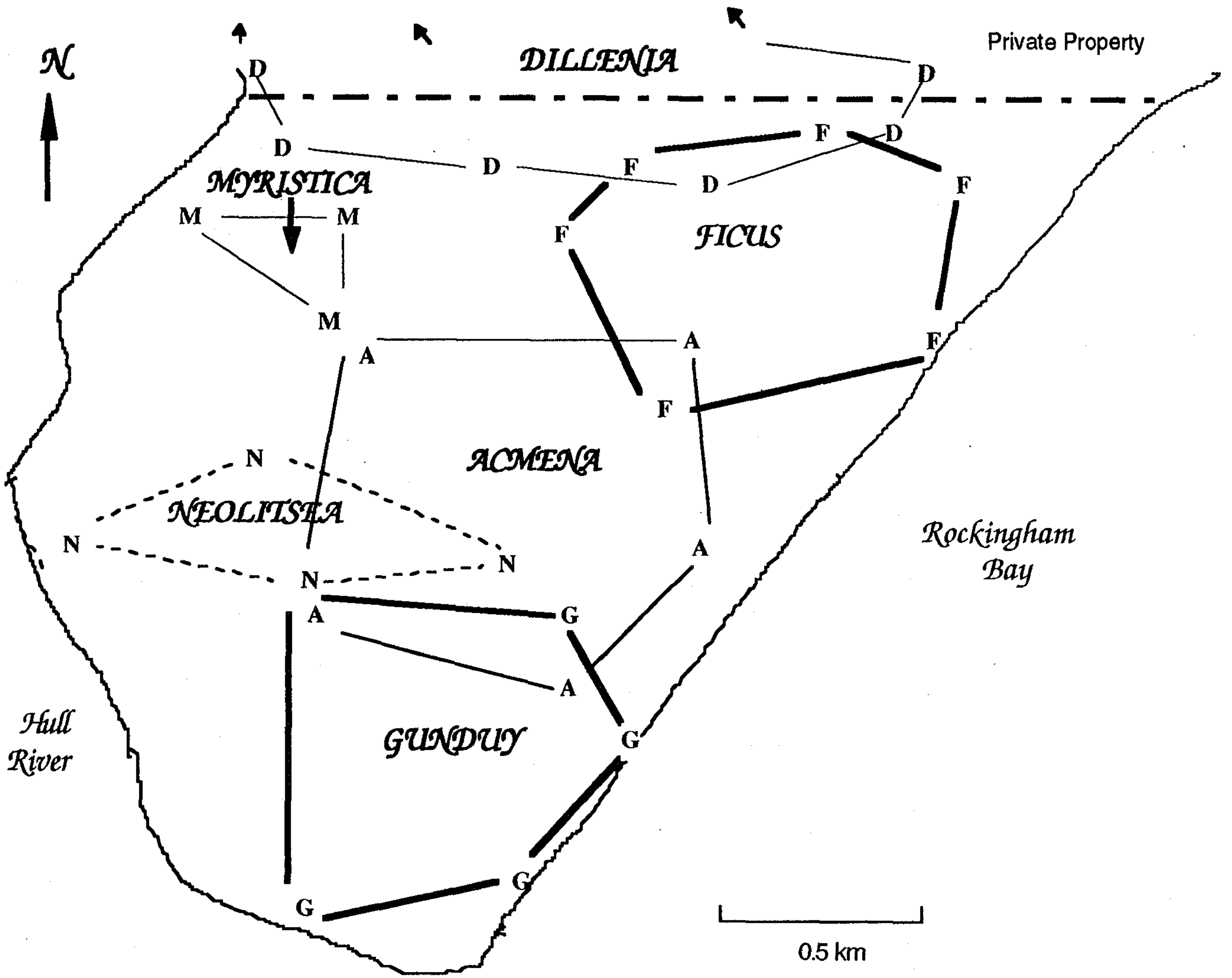


Table 6.8 Estimated home-range sizes and incidental sighting number[1] of adult female and male cassowaries in the study site.

Females	No. of Sightings	Home Range Size (ha)	Males	No. of Sightings	Home Range Size (ha)
Bowenia	25	88.0	Acmena	33	52.1
Eugenia	57	136.6	Dillenia[3]	132	94.3
Helicia	16	65.0	Ficus	44	57.5
Intsia	7	52.9	Gunduy	14	55.7
Jasminum	54	> 29.3	Myristica	3	-
Kamala	13	> 37.8	Neolitsea	17	> 31.8
TOTAL/ MEAN	**172**	**85.6[2]**		**243**	**64.9[2]**

Note: 1. Sighting numbers do not include locations at different points during continuous observation periods.
2. Home-range size means exclude the females Jasminum and Kamala and the males Myristica and Neolitsea as all are believed to be grossly underestimated.
3. Although not outlined in Figure 6.2., the full extent of Dillenia's home range into the neighbouring private property was known and therefore calculated.

numerous continuous tracking observations (316 hours) during which these individuals travelled considerable distances within these home-range boundaries.

The true extent of home ranges for the remaining adults is most probably underestimated. Furthermore, footprints and scats were located in those remaining areas of the study site not included in the adult home ranges outlined. While some may well belong to the subadult population, footprint sizes suggest that adults were also using these areas. This, together with the sighting information, suggests that the whole study site was utilised at various times of the year.

Home-range overlap There was extensive overlap of home ranges between genders (Figures 6.1 and 6.2.). For example, the males Ficus, Gunduy, and Neolitsea displayed 90 to 100% home-range overlap with females Eugenia, Bowenia, and Intsia respectively. On the other hand, intrasexual home-range overlap was on average only 15.2%. The patterns of interactions observed support this finding (see Section 6.3.2.3). Intrasexual interactions were less frequently observed than nonbreeding intersexual interactions, each accounting for 18.8% and 30.4%[16] respectively of all adult-adult interactions. Clearly larger intersexual overlap areas would provide more opportunity for nonbreeding interaction than smaller ones especially if these areas contain important food and water resources.

In addition, male home ranges overlapped with each other to a significantly lesser extent than female home ranges [t (df = 6) = 4.463, p = 0.0043]. The overlap was, on average, 10.6% and 21.2% for males and females respectively. A male home range overlapped or was contiguous with two to three other males, while a female home range overlapped or was contiguous with two to five other females. Again social interaction information supports this finding of male home-range overlap being less than female home-range overlap (see Section 6.2.3.2). The smaller number of male-male interactions (2.9%) compared to female-female interactions (15.9%) suggests that males were less likely to encounter each other due to these smaller overlap areas. The absence of a male during incubation may also contribute to a lower number of male-male interactions. For example, the male Ficus[17] was most often seen in the Ficus-Dillenia home-range overlap area during Dillenia's absence while incubating. Ficus extended his territory to encompass what was temporarily vacated. The only other time Ficus was seen in this area was when White Apple, *Syzygium forte*, was fruiting prolifically. During this period, January and February, 1991, five adults (the males Dillenia and Ficus, and females Helicia, Jasminum and Eugenia) used the same core feeding area and, although they generally avoided each other by using the area at different times, clashes were seen amongst various adults on seven occasions. For Helicia, Eugenia and Ficus this overlap area encompassed the northern most boundary of their home ranges; for Dillenia and Jasminum, it was the southern most boundary (Figures 6.1 and 6.2).

6.3.2.2 Social System

Adult female and subadult cassowaries were solitary on 52.8% and 73.8% of the occasions they were sighted (total = 249 sightings). Furthermore, during continuous but separate tracking sessions of two females and two subadults they were alone 98.7% of the observation time (total = 52 hours). Only during the breeding season did adult females accompany adult males forming short-term pair bonds (see Section

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[16] The remaining 50.8% includes 42.4% breeding interactions and 8.4% of adult-adult interactions between birds for which the sex of the partner was unknown.

[17] This occurred at a time when Ficus was still rearing a chick (1990).

7.3.2). Nonbreeding contact with conspecifics was intermittent and normally aggressive (see Section 6.2.3.2). Apart from infrequent interactions which were always antagonistic, subadults were solitary all of the time. At the risk of oversimplification (Dunbar, 1989), these results suggest that female and subadult cassowaries are normally antisocial, leading a solitary existence for most of their lives.

While adult male cassowaries were seen to live apart and normally avoid contact with each other, females and subadults (see Section 6.2.3.2), they spent a considerable proportion of their lives with dependent chicks. Of the 146 (1990), 52 (1991), and 48 (1992) sightings of the resident male cassowaries seen each year, 45.9%, 67.3%, and 70.8% of these sightings respectively were of these males with chicks accompanying them. The data available for the male Dillenia shows that adult males can have chicks in their charge as much as 73.0% of the time. Moreover, this adult male was involved in some form of parental care (incubation + rearing chicks) for 80.4% of the three year study period (see Section 7.3.1).

6.3.2.3 Pattern and Nature of Interactions

Interactions between individual cassowaries were not common and, when they did occur they were generally of short duration. Of the 443 occasions that birds were located, 21.8% involved interactions with conspecifics[18]. Thirty-three percent of interactions were breeding-related (see Chapter 7), 38.1% involved intrasexual and intersexual nonbreeding activities between adults, and 28.9% were nonbreeding interactions between adults and subadults. Because breeding interactions are discussed in detail in Chapter 7, this section focuses on nonbreeding interactions. Table 6.9 outlines the number of interactions I observed between various members of this cassowary population.

Intrasexual interactions I observed 13 intrasexual encounters between resident adults which accounted for 13.4% of all cassowary interactions observed. Of these, 84.6% occurred between females. All were overtly aggressive. The duration of female-female interactions ranged from < 5 min to 1 h 5 min. The very short interactions (< 5 min, n = 2) were *rapid pursuit* encounters which involved one female rapidly pursuing another. Longer interactions, which averaged 38.3 mins (± 4.18 SE, n = 6), involved a *conflict encounter* - a complex sequence of behavioural events involving two or more birds and which included both agonistic and "displacement"

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[18] These interactions exclude males with chicks.

Table 6.9 Number of interactions observed between resident cassowaries.

	Adult Females						Adult Males						Adult		Subadults			
	B	E	H	J	K	I	A	D	F	G	M	N	L	U	2	3	4	U
ADULTS																		
Females																		
Bowenia	-																	
Eugenia	1	-																
Helicia	-	-	-															
Jasminum	-	5	1	-														
Kamala	-	2	-	2	-													
Intsia	-	-	-	-	-	-												
Males																		
Acmena	1	1	1	-	-	-	-											
Dillenia	-	1	2	20	8	-	-	-										
Ficus	1	9	-	-	-	-	-	-	-									
Gunduy	1	-	-	-	-	-	1	-	-	-								
Myristica	-	-	-	-	-	-	-	-	-	-	-							
Neolitsea	1	-	2	-	-	2	-	-	-	1	-							
Sex Unkn.																		
Leea Indica	-	-	-	-	-	-	-	-	1	-	-	-	-					
Unidentified	-	1	-	-	-	1	1	2	-	-	-	-	-	-				
SUBADULT																		
Sub 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Sub 3	-	-	-	2	-	-	-	7	-	-	-	-	-	-	-	-		
Sub 4	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	
Alata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Unidentified	-	-	-	2	-	-	2	6	-	-	-	-	1	-	1	1	-	-
Total Interactions	5	20	6	32	8	3	5	47	11	3	-	6	2	5	2	10	2	17
Total Observations	25	57	16	54	13	7	33	132	44	14	3	17	7	21	17	31	18	24

activities (Hinde, 1970). The majority of female-female interactions involved two birds. However, on one conflict encounter the three females, Jasminum, Eugenia and Kamala, were involved.

In *rapid pursuit* interactions the only sound that could be heard was the birds crashing through the forest at surprisingly high speeds considering the closed understorey. No vocalisations were heard. The longer *conflict encounter* consisted of several *conflict displays* (mean ± SE = 15.61 ± 2.10) involving each bird in turn. These displays would range in activity level from vocalisation only to a complex behavioural sequences which generally began with the displaying bird vocalising[19] intensively, followed by pacing back and forth in front of the antagonist then suddenly charging for a short distance before stopping, preening, turning, walking back, vocalising and preening again. The female at which this display was directed, would either stand firm or retreat a little during the display. She would then perform her own *conflict display* once her antagonist had finished. This either involved the same behavioural repertoire, but with slight variations in the sequence and number of the events, or a vocal response only. After a final intense vocal session the birds would either mutually retreat, one would passively supplant the other, or one would chase the other some distance. Despite the intensity of these conflict encounters, physical contact was never observed between females. Rather, charges tended to be "bluff", reinforced by the intensity of vocalisations (average 14.7 vocal bouts per hour of observation compared to 0.22 vocal bouts per hour of observation in the normal daily routine of females; Appendix A.2.4).

These aggressive interactions occurred mainly on the home-range "boundaries", which suggests that they were territorial and as such diminished the need for a dominance hierarchy among females. Usually (63.6%), female-female interactions resulted in mutual retreats which also suggests absence of a dominance hierarchy. For example, while Jasminum appeared to be the 'winner' over Eugenia (2:0) and Helicia (1:0) in passive supplant interactions and chases, she was inturn chased by Kamala. On the other hand, in all interactions involving Eugenia, Kamala and Bowenia, mutual retreat occurred. This shift in the outcome of encounters further supports the territorial nature of these disputes rather than a dominance hierarchy.

Interactions between males were very rare, accounting for only 2% of all cassowary interactions observed, and 35.3% of intrasexual interactions. All of these interactions involved very short rapid pursuits, where a male, on seeing another male, either immediately charged its adversary or would itself immediately retreat. Complex agonistic displays such as those outlined for female-female interactions were not observed.

The small number of intrasexual interactions suggests that same sex neighbours generally avoid each other since encounters, when they occur, normally manifest some aggressive tendencies. With 64.7% of intrasexual interactions occurring between females and only 35.3% between males, and only a 10.6% overlap in male-male home ranges, this suggests that spatial avoidance is stronger between males than females.

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[19] Details of vocalisations are outlined in Appendix A.2.4.

Intersexual interactions[20] As expected, the majority of interactions observed (51.5%, n = 50) were between males and females. Thirty-eight percent of these interactions were nonbreeding, occurring when males were still caring for young chicks. In 60% of these nonbreeding interactions the male and chicks' response to the appearance of a female was to retreat. On first seeing her the male would often vocalise (see Appendix A.2.4) and pace back and forth before retreating. The female rarely provoked this retreat by any overt agonistic display but rather just stood still and watched them as they left. While subtle actions or gestures on her part may have caused this retreat, I was unable to detect any. Nevertheless, there were two occasions when female aggressive action was unambiguous. On the first, Ficus and chick were charged by the female Eugenia as they approached an important feeding area at which this female had been foraging for some time. On the second occasion, Eugenia presented a full stretch display with feathers raised to which Ficus and chick immediately responded by retreating. In the remaining 40% of interactions tolerance between the interacting parties was apparent. The male and chicks simply ignored the female displaying an indifference to her presence by continuing to either forage or rest.

Adult - subadult interactions Twenty-one percent (n = 21) of interactions observed were between adults and subadults. All interactions involving adult males and subadults (n = 16) were aggressive. Aggressive intent was normally communicated using vocalisations (n = 8). Overt aggression involved the male chasing the subadult which in most instances occurred immediately the subadult was sighted. However, two male-subadult encounters observed, which involved the same birds, lasted 30 mins and 47 mins. During this period the male vocalised 6 and 15 times respectively before the subadult ran off. In response the subadult vocalised 3 and 10 times during the interaction periods (see Appendix A.2.4). Female-subadult interactions differed in that no overtly aggressive behaviour was observed. Rather, the subadult would either present a submissive position by squatting or immediately retreating when an adult female appeared.

Male - offspring interactions The social bond between a male and its offspring was the only relationship observed between individual cassowaries that persisted beyond a few hours. It was also one which continued long after the offspring could feed themselves. Chicks always maintained close contact with the male. While direct contact (touching) was infrequent, visual contact (< 10m) was almost always maintained. On rare occasions when visual contact was lost, chicks would utter a distress

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[20] Breeding interactions will be described in detail in Chapter 7.

call (see Appendix A.2.4) to which the male would immediately respond by vocalising or running toward them. The male did not display any aggression toward the offspring during this period of parental care. On the contrary he appeared always to accommodate their needs. In the first few months when they sought protection under his tail feathers he never rejected them. Instead he would raise his feathers making access easier. While contact between the male and his offspring was close for at least 9 months, they seldom interacted other than as described. As they grew this association became more passive with the chicks merely following, foraging and resting with the male. No decrease of tolerance of the male toward the chicks as they grew was evident. He did not appear to prepare them for independence by becoming aggressive toward them.

Although cassowary young are precocial, they are wholly dependent on the male until they can forage on their own. Sibling rivalry was not observed at times of food acquisition when aggression could be most expected to surface. Even though both chicks would immediately respond to the auditory signals (see Appendix A.2.4) of the male by running toward him, they did not fight over the food available and the male did not appear to favour one or other of the chicks. On occasions when drinking from a confined source such as a tree base, one chick would wait without interfering until the other chick had finished drinking. In general, considerable and consistent tolerance was observed between all members of the single parent family unit (Chapter 7).

6.4 Discussion

6.4.1 Population Ecology

6.4.1.1 Population Size and Density Estimates

Over the three year study period a total of at least 35 cassowaries used the 3.19km^2 study site, with annual population size estimates ranging from 22 to 26 (Table 6.2). This range was known to reflect population fluctuations. While it may also have reflected some sampling variability, this was considered to be minor and restricted to the subadult population and the adult Intsia. Thus a density range of 5.3 to 8.2 cassowaries per km^2 including all age classes was established. Furthermore, and perhaps even more important, was the age-specific density estimates, particularly those which accounted for the breeding population. The mean density of different age-classes in the study site were 3.55 breeding adults per km^2, 2.09 subadults per km^2, and 1.98 chicks per km^2 (Table

6.7). Since no published density estimates for cassowaries are currently available, it is not possible to make a comparative assessment.

While it was evident in this study that variability of the species' density from year to year did not change much, some variability was apparent. The possibility of variation in the external environment limiting population size, for example, factors such as food availability, was not assessed. Until the precise relationship between food availability and the effect on cassowaries can be shown, any suggestion of density-dependent population regulation remains speculative. Nevertheless, based on field impressions and data available from Dennis (1997), food limitation is implicated in annual fluctuations in cassowary density, a factor not uncommon among many species (e.g., Cooch & Cooke, 1991; Foster, 1977; Newton, 1991; Watson, 1970). In addition, I propose that food limitation is most likely to have a greater impact on the chick and subadult populations than the adult population, for the following reasons: (1) adults, in particular males, can withstand longer periods of reduced supply since their incubation period is a period of starvation (Chapter 7); (2) familiarity with the area would benefit the adult population by the development over time of a more efficient search effort which is based on the assumption that foraging animals integrate experience over time (Cuthill et al., 1994; Stephens & Krebs, 1986); (3) a change in food availability could result in a reduction in nutrients available for egg production (Cooch & Cooke, 1991), and a reduction in male fitness and hence the ability to incubate.

In 1991 a "lean period" in terms of food availability may partially explain the lower population size and hence density estimate for that year. My subjective impression from direct observations of the existence of a lean period in 1991 was based on several behavioural observations on the feeding ecology of Dillenia's family unit. Many of these observations correspond with those described by Foster (1977). For example, there was a complete shift to alternate foods, including the substantial intake of soil and bare/spent seeds (not observed in 1990 or 1992), which would suggest the need for mineral supplements and possibly "filler". There was also an increase in consumption of regrowth species such as Lantana, *Lantana camara* (not observed in such quantities in 1990 and 1992). An increase in the range of habitats in which they searched/foraged and the variety of food items taken (Chapter 8) was also apparent, suggesting the need to exploit a greater variety of places which would provide a wider variety of food items. Furthermore, Dennis's (1997) findings on fruit availability in the nearby Atherton Tablelands supports this notion of a lean period. He found that the number of species producing fruits in 1991 was significantly lower than 1990 and 1992. The biomass of fruit was also lower by a factor of 10. Therefore, a lean period may have partially contributed to the death or dispersal of two young adults and several subadults. The lower number of hatchlings in 1991 may also have been linked to this lean period. It is important that research be continued to clarify the times of year and yearly differences during which food availability is affecting the life history parameters.

6.4.1.2 Population Structure and Dynamics

The sex composition of this lowland population was slightly skewed toward females, 1 male to 1.22 females (Table 6.7). This figure is comparable with that established by Bertram (1992) from sighting records of ostriches: 1 male to 1.25 females, but contrary to that established by Coddington and Cockburn (1995) for emus: 1.26 males to 1 female.

The age structure of this population was skewed toward older birds (Table 6.7), suggesting low annual birth rates and low recruitment into the adult population. This was confirmed with the chick production rate at just 0.24, and the recruitment rate of subadults into the adult population at 0.15, only slightly higher than the disappearance rate of adults - 0.13 (Section 6.3.1.4). In other words, subadults were just replacing those adults which disappeared rather than contributing to population growth. In this population of cassowaries it appears that the most "fragile" part of the life cycle was the survival of young birds to that point where they become established into the breeding population. This relatively low reproductive and recruitment rate, combined with delayed maturity ($\cong$ 4 years), and high adult survival (0.87), presents cassowaries as classical K-selected species (Pianka, 1978; Putman & Wratten, 1984), showing characteristics that tend to produce relatively stable populations. While the figures need to be treated with caution since they are based on a small number of years, when looking at the population as a whole, the growth rate of 0.995 suggests that this population is most probably stationary (Arms & Camp, 1982). That is, productivity level and survival rates enables this population to maintain its adult numbers. Should the population go into decline, it is most likely to be a combination of low productivity and survival rate of the subadult population rather than loss of adults. Furthermore, Perrins (1991) suggests that in natural situations, if adult mortality increases, factors causing that increase are also very likely to act on the chick and subadult populations. Therefore, an increase in adult mortality is a good indicator of a population in jeopardy. In addition, Perrins (1991) points out that in very long-lived species "a small reduction in the survival rate of adults requires a proportionally much larger increase in the survival of juveniles in order to maintain stable numbers" (p.204).

6.4.1.3 The Consequences of Human Disturbance

In the study site population of six core males, births were found to be an annual occurrence. Deaths, however, were much more difficult to enumerate and causes of mortality were largely unknown, although predation and illness have been speculated. The only confirmed deaths were recorded in the chick population and will be addressed in the following chapter (Chapter 7) as part of reproductive success. Nevertheless, additional information obtained from outside the study site identified causes of mortality in these cassowary populations which were not observed in the study site. In general, all deaths were directly or indirectly attributed to humans. The 53 known deaths recorded outside the study site between 1990 and 1992, of which 33.9% were breeding adults, highlights the considerable impact humans are having on this endangered species, particularly in areas where both humans and cassowaries interact. This excludes direct and indirect effects of habitat destruction and fragmentation. The loss of 21 chicks from unknown causes, which represents a 56.8% loss of the original chick population, is considerable compared with a 10.5% loss in the chick population in the study site for the same period. This suggests that chick survivorship may be at least 5 times less likely in populations in close contact with human settlement than those that are at least somewhat isolated. Clearly the cumulative effects of these human-related deaths, together with "natural" loss through disease, predation, and environmental events such as cyclones and fruit crop failures would be having a considerable impact on populations of cassowaries that are surrounded by human settlements.

6.4.1.4 Dispersal

The loss of birds from the population could not all be attributed to deaths, which raises the interesting prospect of emigration or dispersal. The number of birds which disappeared from the study population peaked in the subadult age class. While some of these birds may have died, others presumably dispersed from the natal area. Aggressive encounters observed between adults, particularly males, and subadults which appeared to be linked to defence and monopolising of resources, would confirm this notion of forced dispersal of subadults. However, while in most instances offspring would be likely to be forced to disperse, there is circumstantial evidence (maturation of male subadult Neolitsea into the adult population) to suggest that natal philopatry by subadult male cassowaries may occur when an adult is lost from the site. While highly speculative, this raises the interesting prospect of dispersal being female biased, with males being more likely to remain to take up parental territories when vacated. Although estimates of dispersal risk among subadults remain unknown, there is presumably a low probability of survival as these subadults are relatively inexperienced at seeking out foraging areas unfamiliar to them and/or avoiding predators (Waser et al., 1994; Weatherhead & Forbes, 1994). Overt defence of food resources by resident adults, wherever subadults disperse to, is also most likely to continue to operate. Furthermore, the longevity of cassowaries together with high adult survival, "saturated" populations, fragmented habitats and expanding human settlements suggests dispersal risk is high for subadults.

Variation in survival among the different age classes, with subadult survival rate being the lowest and adult survival the highest, suggests the presence of a relatively stable adult population in the study site. Adult cassowaries appear to remain in one place as long term residents as no seasonal long distance migration or permanent emigration was evident. This is supported by regular sightings within the study site of the same ten adults over three years, monthly sightings of at least two adults over a 14 month period (Appendix A.2.2), in addition to regular sightings of the same adults within the Mission Beach region (Bentrupperbäumer, 1992b).

6.4.2 Socio-spatial Organisation

6.4.2.1 Home Range Size and Overlap

The cassowary population of the Kennedy Bay National Park consisted of resident adults, each living within a stable home range (Figures 6.1 and 6.2), all or part of which was shared with other individuals of all ages and both sexes. This tended to produce a distribution of home ranges with sometimes contiguous, other times overlapping, boundaries. The home-range areas of individual cassowaries in the study site (0.7 km^2 ± 0.1 SE) were at the lower end of the range of the only other published estimate available (0.7 to 10 km^2; Frizelle in White, 1913), and considerably smaller than other ratites such as ostriches (16.1 km^2, Bertram, 1992). This difference in home-range size between ratites may be due to cassowaries being solitary, and emus and ostriches forming social groups. Solitary animals would require a smaller home-range area, one which is sufficient to satisfy the requirements of an individual or father with dependent chicks, taking into consideration temporal variation in resource availability. Such differences are also obviously a function of ecological factors with the forest-dwelling cassowary having access to more uniformly distributed, highly nutritious, and predictable food sources than the scrub/steppe dwelling emu and ostrich (Handford & Mares, 1985). While there was some disparity observed in home-range area between males and females, it was not statistically significant, suggesting that the level of both female and male fitness, in particular reproductive fitness, requires equivalent access to resources.

Home ranges exhibited a high level of intersexual spatial overlap. Despite this, an important feature of these home ranges was that contact between individuals was minimal outside breeding (Chapter 7). Minimal contact may well have been achieved by the way space was used (Pianka, 1978), and even resource partitioning (Lott, 1991) if essential resources were well-distributed throughout the home range (Altmann & Altmann, 1970). While not quantitatively assessed in this study, the field impression was that at any one time, various individuals spent most of their time in a small proportion of their home range, core feeding areas which corresponded with the seasonal distribution of a food source (Chapter 8). In addition, vocalisation was the principal method of remote communication thus providing the means of minimising contact between individuals.

There was also evidence of overlap in home ranges within gender, though substantially less than that observed for between gender overlap. An interesting observation of male-male overlap areas was the expansion into another male's home range during the absence of that male due to incubation, another mechanism available for minimising contact. The number of occasions that cassowaries were simultaneously in the shared portion of their ranges appeared to be linked to an essential resource in the overlap zone, the availability of which was restricted in space and time, for example, fruiting of White Apple, *Syzygium forte*, in January (see Section 6.3.2.3 and Chapter 8). In general, it appeared that the natural tendency for cassowaries to occupy only parts of the home range in any one month but cumulatively all of the home range over a year, while minimising competition with conspecifics, produced considerable differential utilisation of the area. While exclusive home ranges suggests territoriality between individuals (Lott, 1991; Pianka, 1978), the extensive intersexual and partial intrasexual home-range overlaps suggests the existence of territoriality within genders for cassowaries. Furthermore, while females and males appeared to defend foraging areas and home-range boundaries selectively against intrusion, there was no evidence of either females or males patrolling home-range boundaries. With confrontations between individuals uncommon, defence of an area was sometimes difficult to distinguish from mere antagonism. These instances suggest that cassowaries will manifest territoriality under certain conditions such as intrasexual intrusion (Lott, 1991), and possibly subadult intrusion.

6.4.2.2 Social System and Interactions

Whatever the spacing mechanism cassowaries generally avoid each other outside breeding. Despite a number of benefits that could accrue from living in groups (Dunbar, 1989; Lott, 1991), adult and subadult cassowaries live alone, which suggests that there are costs to living together and advantages to living apart for members of this ratite group. As noted earlier, Handford and Mares (1985) suggested that solitariness and territoriality in ratites was more conducive to living in forests since food was uniformly distributed, nutritious and predictable, while gregariousness suited those species living in semi-arid conditions where food was unpredictably distributed. Nevertheless, should the spatial distribution and quality of resources change due to natural catastrophes, habitat destruction and fragmentation, strict solitariness and territoriality will be very costly for cassowaries.

Solitariness and territoriality in cassowaries may also be determined by the responses of individual birds to one another (Crook, 1965). Within this study population, while interactions outside breeding were uncommon events, conflict did occur within all age groups and between both sexes. Conflict encounters were particularly aggressive between same sexes and adults and subadults and would occur at feeding areas and home-range boundaries.

The use of auditory signals, while not overly frequent, appeared to be an important mechanism for communication between individuals (Appendix A.2.4). Acoustic signals produced by individuals served to attract receptive partners, act as agonistic signals directed at neighbours or intruders, and appease and inform offspring. Adults generally exhibited overt aggressive responses to conspecifics that called within their territory and spacing appeared to be maintained by properties of the call.

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Chapter 7

Reproductive Biology

7.1 Introduction

In the preceding chapter I identified the goal of increasing our knowledge of cassowary biology as an important and urgent need for this endangered species, a view underlying the whole of this study. To achieve this goal, I first took a broad population perspective examining parameters such as population size, density, dynamics, spatial distribution and social interactions. In the present chapter, I narrow my investigation to reproduction in cassowaries, an aspect of their biology which is an integral component of population analysis and one on which the survival of the population ultimately depends.

As with population ecology and socio-spatial organisation, understanding an endangered species' reproductive biology is fundamental to its conservation and management. Advising on recovery of endangered species without gaining a basic knowledge of this aspect of its natural history, and without looking at a free-living population in order to gain such knowledge, is both unwise and irresponsible. Ignorance of reproductive biology can hinder conservation efforts in several ways. For example, without knowledge of duration, timing, and details of activities associated with the different breeding processes - courtship, mating, laying and incubation - managers cannot determine when the species is most vulnerable to disturbance, what potential impact such disturbance can have on reproductive success, and how effective various management strategies may be in dealing with the impact. When faced with small fragmented populations, managers need to know how variations in spatial distribution, sex composition of adults, and various environmental and social factors can affect the breeding system and consequently genetic diversity. For example, managers may attempt to adopt strategies aimed at sustaining such small populations by the supplementation of food. With regard to cassowaries, short-term responses of relocating problem animals and providing supplementary food have been taken before their long-term effect on the social and breeding behaviour, and ultimately population productivity, has been assessed. Finally, managers must be aware of the causes of reproductive failure rather than acting on speculation of what these causes may be. Management strategies based on self-serving rationalisations and philosophical preferences rather than information founded on scientific method have little probability of success (Caughley & Gunn, 1996; Mattson & Craighead, 1994; Reading & Miller, 1994; Snyder, 1994).

Information to date on cassowary reproductive biology has been derived from various sources, including from captive populations and some opportunistic observations of free-living birds (e.g., Birchard et al., 1982; Crome, 1976; Fisher, 1968; Handford & Mares, 1985; Sheak, 1923; Watson, 1981; Worrell et al., 1975). While alone this information is inadequate for management purposes as it is neither quantitative nor from wild, free-living populations, it provides important insights into cassowary reproductive behaviour.

Differences between captive and free-living populations are highlighted by the breeding season which in captivity may begin in March (Fisher, 1968), and in free-living populations occurs from June to October (Crome, 1976; White, 1913). While food availability and its nutritional quality has been speculated as one determinant of the timing of the breeding season (Crome, 1976), the effect of the duration of parental care on the mating system has not been explored. Jorrisen observed that courtship was initiated by the male who performed a courtship display, then led the female a short distance before copulating (cited in Crome, 1976). However, details on length of courtship period and sessions, type and sequence of behavioural events involved, and patterns of mate choice, are not available. On the basis of Jorrisen's observations of breeding activity (Crome, 1976), Handford and Mares (1985) and Clutton-Brock (1991) have classified the mating system of cassowaries as predominantly monogamous with sequential polyandry being apparent. Both emphasise that information is insufficient to arrive at any conclusive statements about the mating system.

Fisher (1968) observed in a captive population that copulation was necessary between the laying of each egg to ensure fertilisation. All studies, except for Frizelle's (in White, 1913) who mistook the male for a female on the basis of size, suggest that males are responsible for incubation and parental care. While several studies provide estimates of the interval between egg-laying and length of incubation in captivity (e.g., Fisher, 1968), no such information is available for a free-living population, nor is there any information on hatching and the post-hatching period such as process, developmental times and nature of parental care. Finally, information on reproductive success and causes of reproductive failure in a free-living population is unavailable.

This chapter examines several aspects of the reproductive biology of a free-living lowland population of cassowaries. By tracking known individuals and directly observing matings and several breeding activities I aimed to establish the duration and timing of the breeding season, nesting, laying, hatching and incubation, and the nature of courtship, mating and parental care. The purpose of this investigation was primarily to determine the behavioural mating system, reproductive success, causes of reproductive failure and to assess the implications of these findings to the conservation and management of the species.

7.1.1 Chapter Outline

The chapter begins by establishing when and over what period the breeding season occurs. I do this by developing a profile of each reproductively mature male present in the study population. Each profile was based on the breeding activities over the three year study period for each male. This profile is later used to establish possible determinants of the temporal pattern of the breeding season and the implications of the mating system.

I then examined courtship and mating activities. As well as highlighting the sensitivity and complexity of such an important activity, this information outlines sex roles in courtship and mating, patterns of mate choice, behavioural events, and length and timing of the activities. I then outline the next stage of the breeding cycle - nesting, laying, incubation and hatching. Behavioural details, duration and timing of the events, environmental variables and details of eggs produced are considered. Parental care and reproductive success are the final two aspects of reproductive biology described. I conclude by discussing these findings in the context of published information on the reproductive biology of cassowaries and other ratites. My findings are also discussed in terms of current theories in behavioural ecology and conservation science. The implications of key findings to conservation and management are addressed in Chapter 9.

The findings show that the duration of the breeding season can range from 88 to 123 days and occurs in the months May to January. Courtship and mating was found to vary in duration (42 to 52 days), time of year (May to September) and day (0800-1600) the activity occurred, length of a courtship session (26.90 minutes ± 20.02 SD), and initiator of courtship (female and male). The findings also demonstrate that incubation and parental care was solely the responsibility of the male and that the mating strategy adopted was simultaneous polygyny. Reproductive success was found to be low with a male raising an average of 0.67 young to independence each time it nested.

7.2 Methods

7.2.1 General

The reproductive biology of free-living cassowaries was difficult to study. The rarity of the species and its life habits made it difficult to find, let alone to observe large numbers of birds for long periods of time. In addition, as with all animals, reproductive behaviour was liable to be disrupted by observation, even if extreme care was taken. Despite these difficulties, detailed observations of twelve adults and 19 chicks over the three year study period using a systematic and standardised approach provides a considerable quantitative and qualitative data set that represents the first observations of reproductive behaviour in wild cassowaries.

7.2.2 Breeding Season and Availability of Males

I determined the initiation and termination of the breeding season from the behaviour of reproductively mature males present in the study site. I defined the breeding season as the period between the first sign of pair-formation and the hatching of chicks. It therefore consisted of two primary stages: courtship/laying and incubation. This differs somewhat from definitions accorded to other avifauna breeding seasons which normally includes the period of nesting only (date of first egg laid to date last chick “fledges”; e.g., Major, 1991; Rowley & Russell, 1991). Because time allocated to parental care after hatching can be highly variable and occasionally, in this study, extended beyond a year (see Section 6.3.1.6), this has been excluded from my breeding season definition and instead is defined separately as the period of parenting. Using this definition I was able to calculate the minimum duration of a breeding season in the case of a single male using direct but periodic observations totalling 123 h 35 min which began with courtship and ended with hatching. The approximate time of initiation of their breeding season I therefore calculated by estimation from the age of chicks, subtracting the length of the breeding season calculated as described above. The breeding seasons of other cassowaries in the study site were further estimated from direct observations of courtship encounters and incubation. Males were considered fully available for breeding once they had abandoned their chicks. While anecdotal information suggests that breeding may be initiated before abandonment of chicks (Crome, 1976), I did not observe this.

7.2.3 Courtship and Mating

I recorded courtship and mating in 32 of the 50 separate male-female encounters I observed. Together these encounters involved eleven different adults - six females and five males. Breeding encounters were defined as those involving courtship displays and mating. Nonbreeding encounters were distinguished from breeding encounters in male-female contact events when the male was still caring for young chicks (see Section 6.3.2.3 for details of these interactions). The courtship period was defined as that between the first sign of pair-formation and commencement of continuous incubation. The laying period was included because I observed courtship over the period eggs were being laid. Using this definition I estimated the duration of courtship from the date the first breeding encounter was observed between the male Dillenia and female Jasminum and the date continuous incubation began.

I was unable to establish precisely the duration of a courtship/mating session, as on 21 occasions I was not present at the termination of these sessions. On three occasions I was the target of aggressive behaviour by the male, while on 18 occasions, even without such aggression, I was aware that both birds were very disturbed by my presence. I was therefore not prepared to risk the possibility of disrupting and preventing such an important and obviously sensitive activity. My data set is therefore incomplete but offers important insights[1] into this previously unknown aspect of reproductive behaviour in cassowaries.

I used detailed systematic and continuous recording (Lehner, 1979; Martin & Bateson, 1988) when I observed courtship and mating of cassowaries. This included the following: identity of birds; time of initiation and termination (when available) of each courtship/mating session; and detailed descriptions of displays including body movements, postures and plumage use, body maintenance activities, vocalisations and copulation. As well as recording the frequency and duration of each of the mutually exclusive behavioural categories which made up a courtship/mating session, I also recorded the sequence in which these categories occurred and the approximate spatial relationship between the birds during these behavioural events.

7.2.4 Nests and Laying

As few cassowary nests have been described, I have included descriptions of nests which I found both within and outside my study site between 1989 and 1992. I found these nests during general field surveys ($n = 2$), after tracking habituated adult birds ($n = 2$), or after notification from the public ($n = 2$). Once found, I mapped the location of nests and recorded site characteristics including the status of the nest (active/extinct), identity of the male incubating, and clutch size. A nest was defined as active if an incubating male was present or if whole eggs were found. An extinct nest was identified by the presence of distinctive egg shell fragments and feathers. Nest site characteristics used to assess site preferences included: altitude; slope; habitat type; canopy structure; understorey structure; and distance to nearest fresh water which were determined as follows: (1) altitude with an altimeter (m); (2) slope - visual assessment (^{0}); (3) habitat type (Section 5.2.2.3); (4) canopy structure (percent crown cover classification; Walker & Hopkins, 1984); (5) understorey structure formation classes as defined by growth form (Walker & Hopkins, 1984); (6) distance to water (m, hip chain).

I obtained measurements and descriptions of eggs in the following ways: (1) during the laying period when the male was absent ($n = 2$); and (2) after the male had deserted the nest following hatching of some eggs ($n = 2$ whole infertile eggs). On a further occasion the opportunity to measure eggs post-hatching was lost following predation by a lace

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[1] I believe these insights, in the case of a free-living population, would be difficult to expand on without compromising their breeding activity. I recorded many observations up to the time one bird moved off with the remaining bird either following or remaining where they were. Nevertheless, on eleven occasions observations of actual courtship displays were recorded, two of which included copulation.

monitor, *Varanus varus*. The available eggs were weighed with top-loading scales (to 0.1kg) and length and width measured using vernier callipers (to 1mm). The long and short circumferences were measured using a flexible tape-measure (to 1mm). Qualitative characteristics such as colour and surface texture were also recorded. Photographs of nest sites, eggs and incubating males were made and egg shell samples collected from each nest when available. I did not disturb incubating males in order to obtain egg measurements and descriptions because I did not want to cause any stress (Pearl, 1992).

During the 13 day laying period I made six visits to the nest site to photograph and record orientation of eggs and their position relative to each other and any other notable nest features (e.g., evidence of nest construction or disturbance of nest). These visits lasted a maximum of 10 min when the male was absent and ranged from 45 min to 55 min when the male was present. I made as few visits as possible during this period to minimise disturbance to the females that may wish to lay since I assumed that they would be very sensitive to intrusion during this period. This assumption was based on their sensitivity to disturbance during courtship, and the observations of Bertram (1992) that ostriches are easily disturbed while laying confirmed this assumption.

7.2.5 Incubation and Hatching

To determine incubation activity patterns, division of labour if any, and the hatching process, I observed three of the four active nests for a total of 172 h 30 min during the incubation period. The nests included those of Dillenia and Neolitsea (nest 1 and 3) which were on my study site, and the nest of Mitchell B (nest 4) which was located outside my study site (1,175m north of Dillenia's nest). To observe Dillenia at the nest I sat very quietly but very visibly at a distance of 4m. Dillenia's nest provided information across the whole incubation period as I observed it on ten occasions for a total of 75 hours from the beginning of incubation to hatching: (1) two 24 hour continuous observations (solo effort); (2) four observation periods which ranged from 4 h 30 min to 7 h 50 min; and (3) four observation periods which were < 1 hour. The continuous 24 hour observation periods were conducted to determine if males left the nest at any time and whether the female visited or took over incubation overnight as occurs in ostriches (Bertram, 1992).

I discovered Neolitsea's nest in the latter period of incubation, 12 days before hatching. Mitchell B's nest was located by a farmer who was bulldozing regrowth on the property bordering the study site. As a consequence of clearing, the nest site was completely exposed. I constructed a protective covering above and across the north-westerly aspect of the nest in order to provide maximum shade cover at the hottest time of day for the remaining period of incubation (see Plate 7.1). I completed construction within two hours and immediately vacated the site. On a visit four hours later the male had returned to the nest and remained incubating for the next 26 days. I made a total of 88 h 45 min of observations at this nest from a distance of 10 m. Observation periods were classified in the following way: (1) four continuous full day observations which ranged from 11 h to 14 h (total 48 h 35 min); (2) one continuous full night observation (13 h); and (3) partial day observations - one to five times each day for 19 consecutive days (range = 10 to 45 min, total 25 h).

Plate 7.1 Mitchell B's nest, nest 1, with protective covering.

7.2.6 Parental Care

I made direct observations of parental care of chicks, which totalled 99 h 40 min, from two sources: (1) the male (Dillenia) and two chicks (Alata and Boronia) from nest 1 I observed on 25 occasions for a total of 65 h 25 min. This included the time of first leaving the nest to abandonment of chicks 323 days later. Continuous observation periods ranged from 30 min to 8 h 05 min (average = 3 h); (2) this same male (Dillenia) with two new chicks (Cowleyana and Daemeliana) I observed on 8 occasions for a total of 34 h 15 min. These continuous observation periods ranged from 1 h 15 min to 8 h 30 min (average = 4 h 30 min). Extra care was taken when tracking these family units in the early stages of post-hatching in order to avoid imprinting as both Alata and Boronia often switched to following me rather than Dillenia during this time.

7.2.7 Reproductive Success

I measured reproductive success from the time of incubation to independence of chicks and calculated it as the number of independent hatchlings produced per egg laid (Caughley & Gunn, 1996; Rowley & Russell, 1991). Three nests provided this information: nests 1, 3 and 4. Although each nest was located at different times in the incubation period I assumed the number of eggs present at any stage of incubation to represent the number present at the beginning of incubation. This assumption was based on intensive observations at nest 1 and 4 which established loss of eggs during incubation as being highly unlikely. The egg-stage was defined as that from incubation to hatching or desertion after others in the clutch hatched. The chick-stage lasted from hatching through to independence. I based calculations on losses of individual eggs and/or chicks. I also calculated annual productivity as recommended by Rowley and Russell (1991). However, for this calculation I used number of independent hatchlings per male per year. This calculation I based on the study site male population.

7.3 Results

7.3.1 Breeding Season

Two periods between initiation of courtship (14 May, 1990; 29 July, 1991), and termination of incubation (10 August, 1990; 1 December, 1991) by the male Dillenia represent both the minimum and maximum duration of the breeding season as 88 days (1990) and 123 days (1991) respectively. Using this estimate together with sightings of males with chicks and estimates of chick ages (see Section 6.2.1.2), several observations of courtship encounters and incubation, I constructed a profile of the reproductive status of five resident males of this study site. Figure 7.1 outlines the periods during which each of six males were likely to be occupied with courtship, incubation and care of chicks in 1990, 1991 and 1992, and subsequently the times they were available for breeding.

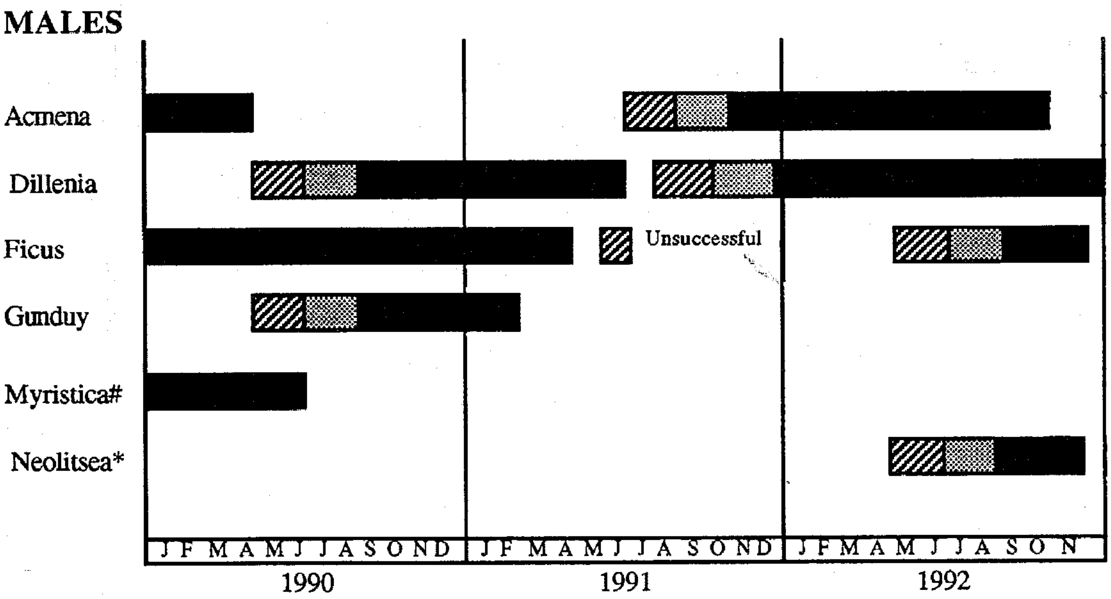

Figure 7.1 The reproductive status of five male cassowaries in 1990, 1991 and 1992. (# = Myristica was not sighted again in 1991 or 1992; * = Neolitsea was a subadult and therefore sexually immature in 1990 and 1991; Diagonal Hatching = courtship; light shading = incubation; solid shading = male parental care).

7.3.1.1 Availability of Males

This profile of the reproductively mature male population shows that the timing of the breeding season for males varied in each of the three years. For example, for the male Dillenia, it extended from May to August in 1990, from July to October in 1991, and breeding did not occur in 1992. Parental care was one factor that clearly determined the timing of Dillenia's breeding season (Figure 7.1). Intensive investment in care of chicks was common to all males. However, duration of investment varied between males.

In 1990, three out of five reproductively mature males present in the study site failed to produce new chicks. One male, Ficus, was unavailable for breeding because he was involved with parental care throughout the year. However, the reason for Acmena and Myrstica not producing chicks was unknown as the chicks in both cases had gained independence from their care-givers in the first half of the year and so they would have been available for breeding.

In 1991, two out of four reproductively mature males failed to produce chicks (Ficus and Gunduy). In neither case was their failure to produce young due to their unavailability because of parental care. All four reproductively mature males present were presumed to be sexually receptive by mid-year. In the case of Ficus, although he was without his chick in February/March and had a courtship encounter with Eugenia in mid-June, he did not produce chicks that year. Why Gunduy failed to reproduce also remains unknown as he too was without chicks in February/March. Furthermore, I was unable to determine if either male incubated or partially incubated a failed clutch. On the other hand, Myristica had not been sighted since October, 1990. In this second year the first observed courtship encounter involving Dillenia occurred 30 days after one chick (Alata) became independent of his care while at the same time the remaining chick had died (see Section 7.3.5).

Three males out of six present failed to produce chicks in 1992 (Acmena, Dillenia and Gunduy). Acmena and Dillenia remained unavailable for breeding throughout the year as they were still caring for chicks as late as October and November. Gunduy again remained unsuccessful in producing chicks for unknown reasons. However, Neolitsea reached reproductive maturity and successfully hatched two chicks, both of which died within three weeks of hatching (see Section 7.3.5).

The failure of males which have bred in the past year (or more) to produce chicks each year suggest that breeding success was dependent on males regaining their independence from the responsibilities of parental care. The period between incubation and independence of chicks lasted at least 8 months and as long as 21 months (mean ± SD = 14.2 ± 4.8 months; range = 7.8 - 21; n = 5), in which case many males would be unable to breed annually. The findings also show that male investment in breeding activity is substantial. For example, for 180 weeks of the 204 week study period (88.2% of the time) the male Dillenia was involved in some form of breeding activity; that is, courtship, incubation and parental care. The period that required the highest male investment as measured by time (incubation and parental care post-hatching), lasted for 164 weeks (80.4% of the time), and incubation, which was a period of starvation, lasted for 15 weeks (7.4% of the time).

7.3.1.2 Availability of Females

I was unable to confirm in this study that females reproduce every year. However, from the breeding interactions observed, females were definitely known to mate two in three years. Egg laying records from a captive population, however, demonstrate the capacity for annual breeding. These records, obtained from two females held in captivity since 1979 and 1988, show that they lay on average seven and eight eggs, respectively, each year (Wyatt, T.A. pers. comm. 1990).

7.3.2 Courtship and Mating

I observed 32 separate breeding encounters involving nine adults - six females and three males. These occurred between the male Dillenia and females Jasminum and Kamala, the male Ficus and females Eugenia and Bowenia, and the male Neolitsea and females Helicia and Intsia (Table 7.1). These encounters accounted for 62.0% of the total male-female interactions observed between 1990 and 1992. Information on nonbreeding encounters and home-range overlap are also included in Table 7.1 since they demonstrate a potential for the establishment of a breeding partnership. From the combined breeding, nonbreeding and home-range overlap information, it was possible to establish that both sexes had access[2] to multiple partners (males = 2 to 4 partners, mean ± SD = 3.2 ± 0.75 females, n = 6; females = 4 to 6 partners, mean ± SD = 4.5 ± 1.0 males, n = 4). However, from the breeding interactions I observed (n = 32), males only pair-bonded

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[2] Access in this instance refers to home range overlap and border.

Table 7.1 Identity and number of behavioural encounters and home range overlap observed between the adult males and females of the cassowary population at Kennedy Bay, 1990 - 1992.

		Females					
		Bowenia	Eugenia	Helicia	Intsia	Jasminum	Kamala
Males							
Acmena		1#	1#	1#	+	-	-
Dillenia		-	1#	2#	-	4#, 16*	8*
Ficus		1#, 1*	6#, 3*	+	-	-	-
Gunduy		1#	+	+	+	-	-
Myristica		-	-	+	+	-	-
Neolitsea		1#	-	2*	2*	-	-
TOTAL	# Nonbreeding	4	8	3		4	
	* Breeding	1	3	2	2	16	8

Note: # = nonbreeding encounters; * = breeding encounters; - = no behavioural encounter observed.
+ = home range overlap/boarder.

with two females in one breeding season, and this appeared to be the two with whom their home ranges overlapped most extensively (Section 6.3.2.1 and Figure 6.1). Despite the fact that at least four males were available for each female, I only ever observed females pair-bond with one male in any one breeding season.

7.3.2.1 Courtship Period

I recorded courtship between nine adults in the months from May to September, although the actual months varied according to the year. The years, months and individuals involved were as follows:

Year	**Months**	**Male**	**Females**
1990	May & June	Dillenia	Jasminum & Kamala
1991	June	Ficus	Eugenia
	July, August, September	Dillenia	Jasminum & Kamala
1992	June & July	Ficus	Eugenia & Bowenia
	July	Neolitsea	Helicia & Intsia

In 1990, courtship was initiated by Jasminum around 14th May and terminated 25th June when Dillenia began to incubate, 42 days later. In 1991, courtship was initiated by Jasminum around 29th July and last observed between Dillenia and Kamala on 11th September, 43 days later. Therefore, I estimated courtship to last at least 42 days and possibly up to 52 days. With incubation of this second clutch estimated (by aging chicks, Section 6.2.1.2) to have occurred around the beginning of October, courtship would have had to continue for another 9 days, resulting in a total of 52 days.

7.3.2.2 Courtship Sessions

Courtship sessions varied with respect to time of day they occurred, length of a session, and number of sessions in a day. The results suggest that courtship and mating occurs between the hours of 0800 and 1600, though tending to peak between 1200 and 1300 hours (Figure 7.2).

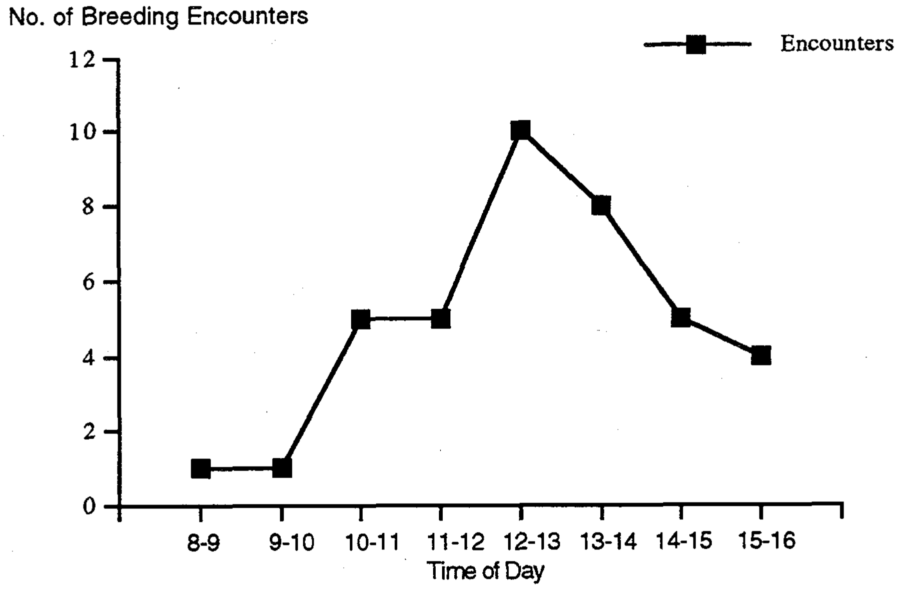

Figure 7.2 Number of breeding encounters observed in each hour of the day.

The longest courtship session observed from initiation to termination lasted 85 minutes, the shortest 5 minutes - average 26.90 minutes (± 20.02 SD, n = 29). It was difficult to establish how many courtship sessions occur in one day since continuous tracking only averaged 4 h 45 min (range 2h - 7 h 45 min) during this period. Nevertheless, on six days I recorded at least two courtship sessions per day involving the same two birds. Time between these sessions ranged from 30 min to 2 h 35 min. On one day (observation period 3 h 30 min) I recorded three courtship sessions involving Dillenia and Jasminum on the first two occasions and Dillenia and Kamala on the third. Time between these courtship sessions was 1 h 10 min and 1 h respectively. Therefore, simultaneous courtship was not only occurring across the whole courtship period but also, at least occasionally, within the same day.

7.3.2.3 Initiator of Courtship

The initiator of courtship varied between pair-bonds with males and females initiating courtship on 37.5% and 62.5% of the occasions (n = 32) respectively. In the case of the male Dillenia and the female Jasminum, courtship was always initiated by the female (n = 16 observations). However, 56.3% of her approaches were rejected, that is, he failed to follow her after initial contact was made. On the other hand, with the breeding interactions between the same male Dillenia and a different female, Kamala, he initiated the contact on all eight occasions and followed her with no sign of rejection from either bird throughout the courtship session. On four occasions Dillenia travelled up to 0.3 kms out of his current foraging area[3] to make this contact, always announcing himself with a very long deep booming call and receiving a similar call in response[4]. For the remaining birds, the initiator of breeding contact included the male Ficus (Ficus and Eugenia; n = 3 observations), the female Helicia (Helicia and Neolitsea; n = 2 observations), and the female Intsia (Intsia and Neolitsea; n = 2 observations).

While vocalisation was one component of courtship and mating (Appendix A.2.4), such a signal did not attract the attention of and hence competition from other cassowaries. Instead courtship only involved the two individuals present and continued without disruption from other members of the population. This contrasts with certain other ratites, for example ostriches (Bertram, 1992), and rheas (Clutton-Brock, 1991) where males compete for females. In addition, apart from what may have been daily courtship sessions and pair-bonding which continued throughout the breeding season, each bird maintained a solitary existence before and after each courtship session.

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[3] See Figure 6.2 and Figure 8.10 for difference between home range and foraging range.

[4] See Appendix A.2.4 for details of vocalisations.

7.3.2.4 Courtship Activity

I observed that courtship involved two primary phases of pair-bonding, the contact or pair-formation phase and mating phase, each with three discrete components, vocal, visual and behavioural. In the first phase, pair-formation was initiated with the birds tentatively making contact with each other. This involved relatively short contact sessions lasting on average 11 min (± 7 min SD; range 5 to 20 min; n = 5). The initiator of contact in all breeding encounters observed (n = 32), most often (81.2%) announced its arrival using a vocal signal (Appendix 6.4). On the remaining 18.8% of occasions they simply appeared without announcing themselves. The bird receiving the contact call first produced a visual response: a full stretch display which involved extending the head and body as high as possible with feathers raised. This was followed by a vocal response, a call distinctly different to the contact call (Appendix 6.4). These contact or pair-formation sessions occurred intermittently over a period of five to seven days. The receiver of the contact would not follow the initiator as he/she walked off, but rather continued to pursue the activity he/she was involved in prior to contact. Courtship-feeding and mating was not observed during this phase.

In the second phase of courtship the nature of the encounter changed significantly suggesting an increase in receptivity of both birds. It too involved a contact display sequence similar to the first phase. Such an encounter also included "displacement activities" (Hinde, 1970; Manning, 1979; Tinbergen, 1989) such as individual preening bouts and courtship-feeding. After this initial contact period of preening and foraging one bird would walk off with the remaining bird following. Females led with males following in 82.6% of the interactions observed.

On the eleven occasions I was able to follow, the female generally led the male some distance (20 to 30m) before stopping. She would then present a full stretch display with her head down and back to the male. The male would proceed with a display which involved walking in either a normal or partially stretched posture in circles behind her. As he walked continuously his pace quickened and the size of the circle decreased. It was at this stage that the first signs of physical contact was noted. This included bumping into her rump with his chest and occasionally gently placing his beak into her feathers. During this display the female remained calm and still, while the male grew more and more "agitated". Such a display resulted in either the female dropping to a complete squat position in front of the male with her rump toward him followed by copulation (n = 2 observations), or the female walking off again with the male in pursuit (n = 9 observations). This male courtship display preceded copulation on the two occasions I observed copulation which suggests that such a display signals the sexual arousal of the male and tests the receptivity of the female (Schaller, 1994).

On the first occasion I observed copulation, the male dropped to a semi-squat position behind the female, very slowly moving forward placing his feet on either side her body[5]. Once successful in attaining this position, with the female remaining still and hence receptive, copulation began. Copulation lasted 0.8 to 1.3 minutes with presumed ejaculation occurring after 20 to 28 pelvic thrusts. After copulation the male immediately stood, walked away a few paces and began to preen. The female also stood and after some grooming activity slowly walked off. On the other occasion, the female remained squatting and after several vocal, visual and behavioural signals the male initiated a second copulation. The time between this first and second copulation was 27 minutes. At the end of this second sequence the female suddenly jumped up while the male was still mounted throwing him off backwards in the process. As he stumbled and ran off she charged after him vocalising aggressively.

7.3.3 Nests and Laying

Cassowaries are ground-nesting birds and although they produce large eggs (132.5 x 93.6 mm ± 5.4 x 3.2 mm)[6], nests are difficult to find. During the course of this study I found one extinct nest and two active nests. Details of locations and sites of these three nests and three others located outside of the study site[7] are shown in Table 7.2.

There was no evidence at the nests observed to suggest that actual construction of a nest occurs prior to laying. In terms of leaf litter sign, females do not appear to discriminate where on the forest floor they lay their eggs as no nest cues are present. Dillenia's nest (Nest 1), first found on the 12th June, 1990, provided the most decisive evidence of this. Two eggs were found on the leaf litter of the forest floor. No scrape was evident nor was there any extra accumulation of leaf litter underneath or near the eggs. Furthermore, Dillenia made no attempts at nest construction during the 10-13 day laying period (n = 6 observations).

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[5] In a way similar to that observed when he would squat down on the eggs (Section 7.3.4).

[6] Mean egg size was calculated from pooled data of eggs known to originate from free-living cassowaries in north Queensland including: this study (n = 4); the Courtney-Haines (1981) collection (n = 5); and the White (1913) collection (n = 6).

[7] I was notified of the two active nests outside the study site by members of the public. The extinct nest I located during a field survey.

Table 7.2 Details of nest sites located in the Mission Beach area, 1989-1992.

Nest No.	Identity of Male	Active/ Extinct[2]	Clutch Size	Altitude (m)	Slope (degree)	Habitat	Canopy	Understorey	Distance water (m)
Study Site									
1	Dillenia	Active	3	0-10	5	Rainforest / Regrowth Edge	Closed	Closed	150
2	Unknown	Extinct	-	40-60	10	Woodland	Closed	Closed	400
3	Neolitsea	Active	2	40-60	10	Rainforest	Closed	Closed	200
Outside Study Site[1]									
4	Mitchell B	Active	3	0-10	10	Regrowth	Open	Closed	150
5	Garners	Active	3	0	0	Woodland/ Mangrove Edge	Open	Closed	50
6	Unknown	Extinct	-	0-10	10	Woodland	Closed	Closed	300

Note: (1) Outside Study Site = Nests located in areas of Mission Beach other than the study site.
(2) Extinct = nesting has finished but remnants of egg shell and accumulation of feathers identify this as a nest site.

Nests did not appear to be located in the same site each year, and the majority of environmental features of the site varied (Table 7.2). One feature that appeared common to all nests was the closed structure of either the immediate or at least proximal understorey. In the study site nests this was provided by Lawyer Vine thickets, *Calamus* spp. In the other nest sites, dense regrowth, tall tufts of grass and vine thickets provided a similar understorey. This tendency to nest in a closed or semi-closed understorey was also noted by Frizelle (in White, 1913).

I did not observe laying despite the opportunity being available at nest 1[8]. Two eggs had already been laid which were left unattended when the nest was first located. Dillenia did not begin to fully incubate until 10 to 13 days later when a third egg was laid[9]. During the laying period Dillenia continued to court two females as well as attend the nest for short periods of time each day. Attendance time increased from 15 minutes to a minimum of 55 minutes per visit just prior to incubation (n = 6 observations). Activity during these daily visits included walking around the eggs, turning them, picking up leaves and twigs and throwing them on his back while in a standing position, squatting down over the eggs, and repeating the twig/leaf tossing behaviour. Observations during additional brief visits to the nest suggest that it was left unattended for a large part of the time during the laying period. In spite of this, nest predation had not occurred over the estimated 13 - 15 day period that the first two eggs were left unattended.

In the interval between layings I was able to take several measurements and record qualitative characteristics of the first two eggs laid in nest 1, Dillenia's nest (Table 7.3). The only other egg measurements and descriptions obtained were two eggs from a nest outside the study site (nest 4, Mitchell B's nest). All of these cassowary eggs were fairly uniform in their elliptical shape (Table 7.3). Mean clutch size from this sample was 2.75 (range 2 - 3). Mean egg weight (519g) represents approximately 11% of the adult female weight. Qualitative differences in the egg shell characteristics such as colour and surface texture were evident. The colour variation from pale dull brown/green to bright apple green was striking as were the variations in the texture from distinctly granulated surfaces to fine granulation.

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[8] The decision not to take advantage of this opportunity was again based on my concern for the welfare of the females and their laying. I was not prepared to take the risk of the females failing to lay on account of my presence at the nest site. A longer term study which would involve their habituation prior to the breeding season would undoubtedly provide information on female laying activity.

[9] I was concerned that what was becoming an unusually long interval between egg laying (mean ± SD = 4.08 ± 0.79 SD; although one 11 day interval has been recorded in a captive situation) could have been attributed to my daily visits to the nest site. I therefore on occasions left prior to Dillenia's departure and stopped my visits for four days prior to the 25th June. This has resulted in the 10 to 13 day estimate for the interval between the sighting of the first two eggs and the laying of the third.

Table 7.3 Details of cassowary eggs at two nests, nests 1 and 4.

		Egg Details				
Nest No.	Identity of Male	Size (length x width) mm x mm	Size (length:width)	Weight. (grams)	Colour / Granulation	Comments
1	Dillenia	132 x 91	1 : 0.69	565	Dull green Fine granulation	2nd hatched
1	Dillenia	127 x 89	1 : 0.70	490	Dull brown/green Fine granulation	unhatched
1	Dillenia	NA[1]		NA	Bright green Fine granulation	1st hatched
4	Mitchell B	130 x 97	1 : 0.75	560	Pale green Coarse granulation	1st hatched
4	Mitchell B	125 x 87	1 : 0.70	460	Pale green Coarse granulation	unhatched
4	Mitchell B	NA		NA	Pale green Coarse granulation	unhatched
	Mean	**129 x 91 mm**		**519 g**		

Note: (1) NA = size and weight not available.

7.3.4 Incubation and Hatching

Incubation by the male was continuous and lasted at least 49 days for nest 1. I determined this through regular (10 visits totalling 75 hours) and continuous (4 h 30 min - 24 h) observations during the period between discovering the third egg and continuous nest attendance by the male, and hatching of the first egg. Continuous incubation did not begin before formation of the full clutch of three eggs. An increase in time spent attending the nest on the day before continuous incubation (see Section 7.3.3) was the only behavioural evidence that incubation was to begin.

During the 172 h 30 min of observations made at three nests (1, 3, and 4) the males performed continuous diurnal and nocturnal incubation. All observations confirmed that they were never absent from the nest and incubation by females did not occur. Furthermore, incubating males were not observed foraging or drinking during these observation periods. Incubation was therefore a solitary activity and a period of starvation. At nests 3 and 4 males Neolitsea and Mitchell B received brief visits (<10 min) from females on 5 occasions (0.05 visits per hour of observation). During these visits the males did not leave the nest, did not vocalise and did not alter their complete squat position other than to present a submissive posture by dropping the beak forward.

The closest a female came to an incubating male was 4 m. This suggests pair-bonding is maintained to a degree during incubation. On several occasions boom calls were heard close to nest 1, Dillenia's nest, and on one occasion the female Jasminum was located 25 m from the nest. On these occasions the female may have intended to visit the nest but was disturbed by my presence.

The activity pattern of an incubating male consisted of four primary components (derived from 81 h 30 min of observations at nest 1 and 4, Table 7.4): (1) the squatting male was totally inactive other than occasionally raising his feathers and flicking his head (Plate 7.2) - he usually appeared to be sleeping during this period; (2) the squatting male would preen; (3) the squatting male would pick up nearby leaves and twigs and toss them on to his back and/or to his side; (4) in a raised squat the male would turn the eggs (Plate 7.3). Egg displacement was not observed at these nests. The egg-turning behavioural sequence, therefore, was not associated with egg-retrieval. In addition to turning eggs, this behavioural sequence would include activities such as intensive preening, raising and shaking feathers, and picking up leaves/twigs as described above. If standing, the male would also walk around the eggs stretching his body and legs (Plate 7.4). On returning to the eggs he would carefully place a foot beside them, drop down to a raised squat position and either cautiously shuffle forward over the eggs or roll the eggs under his partially raised body (Plate 7.5). He would then drop down completely over the eggs and gently rock from side to side for a few seconds before becoming inactive again.

During incubation males were inactive for 95.4% of their time. Periods of up to four hours were spent in a totally inactive state. However, this inactivity was most often interrupted with bouts of preening (mean ± SD = 1.35 bouts per hour ± 1.70 SD) which accounted for 0.8% of the observation time. Picking up leaves and/or twigs, which averaged 0.9 bouts per hour, also accounted for 0.9% of the observation time. Egg-turning was an infrequent activity (mean ± SD = 0.47 bouts per hour ± 0.86), particularly in the latter stages of incubation. Nevertheless, it accounted for 2.9% of the observation time with a bout lasting from 7.3 min to 15.0 min.

Nest 1 was the only nest at which an actual hatching was observed (Plate 7.6 and 7.7). This was the second hatching and it occurred at 1545 h on the 10th August from one of the first two eggs laid. The first chick was estimated to have hatched one to two hours earlier. The male was not observed assisting the chick in anyway during hatching. He did not break the egg shell prior to its hatching nor did he remove the portion of shell in which the chick was still partially enclosed. No attempt was made to remove the egg shell from the nest once the chicks had hatched or to consume shell fragments.

Table 7.4 Observations of diurnal incubation activity at nests of Dillenia and Mitchell B, nests 1 and 4.

Date	Observation Time		Squat - Inactive	Squat - Preening			Squat - Pecking Twig/Leaves			Egg-Turning		
	start	total (h : min)	% of total time	% of total time	mean no. mins per bout	mean no. bouts per hour	% of total time	mean no. mins. per bout	mean no. bouts per hour	% of total time	mean no. mins. per bout	mean no. bouts per hour
DILLENIA (Nest 1)												
25 June	0930	7 : 50	82.8%	3.3%	0.3	5.9	2.2%	1.5	0.9	11.7%	9.2	0.8
6 July	0830	8 : 00	93.2%	1.0%	0.3	1.7	0.3%	0.3	1.3	5.5%	9.0	2.7
26 July	1000	8 : 00	87.1%	0.7%	0.2	1.7	0.3%	0.2	1.6	11.9%	8.1	0.9
27 July	0500	4 : 00	100.0%	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0
1 August	1100	4 : 30	98.0%	0.7%	0.3	1.3	1.3%	0.6	0.7	0.0%	0.0	0.0
6 August	0850	7 : 10	97.0%	0.8%	1.1	0.4	2.2%	0.9	0.7	0.0%	0.0	0.0
Total / Mean		39 : 30	93.0%	1.1%	0.4	1.8	1.1%	0.6	0.9	4.9%	4.4	0.7
MITCHELL B (Nest 4)												
23 September	0600	12 : 00	97.2%	0.5%	0.4	0.8	0.2%	0.3	0.3	2.1%	15.0	0.1
30 September	0600	11 : 00	97.0%	0.4%	0.3	0.7	0.4%	0.3	0.7	2.2%	7.3	0.2
4 October	0600	11 : 30	99.1%	0.1%	0.3	0.3	0.8%	2.6	0.2	0.0%	0.0	0.0
11 October	1000	8 : 30	98.0%	0.5%	0.4	0.7	1.5%	1.9	1.6	0.0%	0.0	0.0
Total / Mean		42 : 00	97.8%	0.4%	0.4	0.6	0.7%	1.3	0.7	1.1%	5.6	0.1
TOTAL/MEAN		**81 : 30**	**94.9%**	**0.8%**	**0.36**	**1.35**	**0.9%**	**0.86**	**0.80**	**3.3%**	**4.86**	**0.47**

Note: Observations made during hatching and between hatching and leaving the nest are excluded as during these periods activity patterns changed considerably.

Plate 7.2 Incubating male, Dillenia, totally inactive.

Plate 7.3 Dillenia turning eggs.

Plate 7.4 Dillenia standing over nest and picking up leaves.

Plate 7.5 Dillenia squatting back down over eggs.

Plate 7.6 Dillenia's first chick, Alata, hatched.

Plate 7.7 Hatching of Dillenia's second chick, Boronia.

In both nest 1 and 4 the males remained at the nest for a further 64 hours and 62 hours respectively after the eggs hatched. During this period they continued to incubate and turn the remaining eggs. Compared to the period before hatching, attention given to the unhatched eggs in this 62-64 hour period increased considerably. At nest 1, during two continuous observation periods (7 h 45 min and 7 h 15 min), I observed nine bouts of egg turning. These all occurred in the second day after hatching of other eggs (1.24 bouts per hour for the second observation period compared to 0.7 bouts per hour prior to hatching). No egg-turning activity was recorded in the first observation period. Seven of these bouts occurred between 1210 and 1400 with an average of 15 min between each bout. Only one of these egg-turning bouts involved the male standing. Egg turning and general agitation of the male was more apparent at nest 2 in this early post-hatching period. In two continuous observation periods at this nest (13 h and 10 h 45 min), I recorded 48 egg-turning bouts (2.0 bouts per hour compared to 0.1 bouts per hour prior to hatching). Time between the bouts ranged from 1 min to 2 h 50 min. On one occasion the male was observed following a standing - walking - squatting - turning eggs routine three times in 2.46 minutes. Such clusters of egg-turning bouts were not uncommon with this male and on all occasions the bout began with the male standing.

Other signs of increased male agitation during the early post-hatching period included: the male at nest 1 suddenly charging a subadult that came within 10 m of the nest; hissing at a lace monitor that walked by. At nest 4, on one occasion, the male charged at me coming to within one metre of where I was sitting. This was followed by a series of grunts before he returned to the nest. Such aggression directed toward myself was also experienced at nest 1 the first day the male left the nest with the two very small chicks. This type of behaviour was not observed during incubation, but only after the chicks had hatched.

7.3.5 Parental Care

Length of time chicks remained dependent on their care-giver varied considerably (mean ± SD = 377.2 ± 146.6 days; range = 184 - 584; n = 5). Like incubation, rearing of chicks was solely the responsibility of the male and it was a continuous 24 hour per day process. The female, rather than assisting the male, often reacted indifferently toward them. During these encounters the male and chicks appeared either distressed, presenting a submissive posture by squatting or immediately retreating, or indifferent (see Section 6.3.2.3). Males were very wary of all animals especially during the early stages of chick rearing.

The cassowary chicks were precocial and 64 hours after hatching were seen to follow the male parent in his search for food. His responsibility for their survival in these first few weeks included not only finding and providing food but also protecting them from predators (see Section 7.3.6.2). The mode of feeding these chicks was quite distinctive as outlined in Appendix A.3.1. Very young chicks were not seen to consume whole fruits, instead relying on the male entirely for the provision of edible size fragments of fruit flesh. This involved the male parent dislodging the fruit flesh from the seed by continuously chomping or masticating the fruit between his beak. The chicks would then pick up and consume the dislodged pieces of fruit that had fallen to the ground. However, the male's role changed over time, slowly shifting from food provider to food locater/identifier because, as the chicks grew, they were more capable of swallowing whole fruits. Only when fruits were very large (e.g., *Faradaya splendida* , size = 90 x 60 mm, Cooper & Cooper, 1994) would he continue to break them up for the chicks. However, the location and identification of different food items continued to be an important role for the male parent throughout the whole chick rearing period as foods available were constantly changing in type and location with the seasonality of production (Section 8.3.2.2).

Dillenia terminated parental care of his two chicks, Alata and Boronia, 323 days after they hatched. The abandonment of the remaining chick, Alata, appeared to have coincided with the death of Boronia from unknown causes (see Section 6.3.1.5). For this surviving chick, abandonment by the male appeared to be a very stressful time evidenced by his continued attempts at locating the male using a distress vocalisation. After abandonment, this chick gave distress vocalisations[10] 96 times in 6 h 30 (14.8 calls per hour; 3.4 vocal bouts per hour). During a 5 h 15 min tracking session four weeks prior to abandonment, Alata vocalised in this same way 5 times (0.9 calls per hour; 0.2 vocal bouts per hour) to which Dillenia had responded immediately by running toward the call and relocating the chick which had strayed.

7.3.6 Reproductive Success

7.3.6.1 Survivorship

Reproductive success, as defined by survivorship of eggs present at incubation through to independence of chicks (independent hatchlings/eggs), was 25% (Figure 7.3). Of the eight eggs from nests at which the fate of eggs was known (nests 1, 3, and 4), five

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[10] See Appendix A.2.4 for details of this vocalisation.

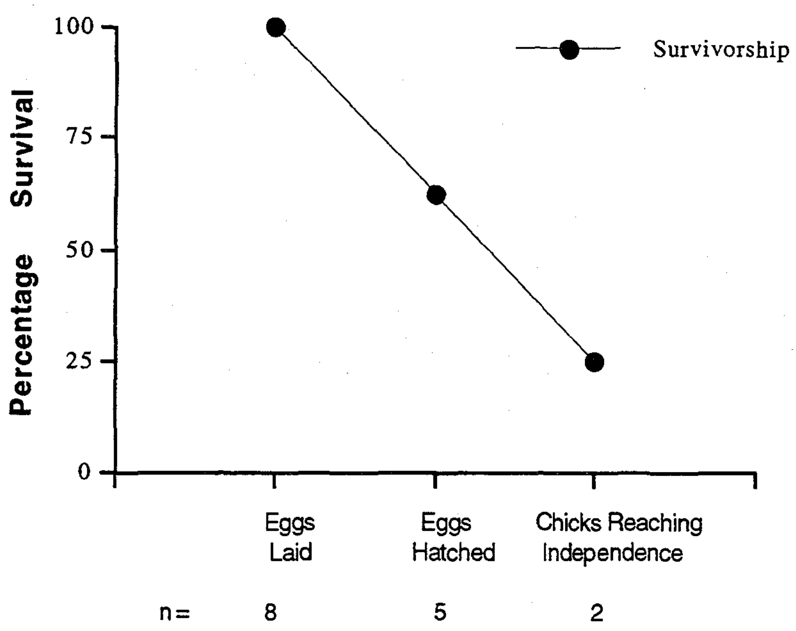

Figure 7.3 Survivorship of young cassowaries. Measurements are percentage of eggs surviving through the incubation phase, hatching to independence.

hatched, giving a hatching success rate of 62.5% in this sample. However, no clutches completely failed to produce hatchlings. All produced at least one successful hatchling (nest 1 = 2; nest 3 = 2; nest 4 = 1). Of the five chicks which hatched from these nests, two survived to independence. Therefore, 25% of eggs produced young independent of parental care, and 40% of hatchlings reached subadulthood: one chick from nest 1 and one from nest 4. Given the limitations inherent in such a small nest sample, it nevertheless shows that a male raises as few as 0.67 young to independence each time it nests. However, on average, only 43% of the male population in the study site successfully incubated and produced chicks each year.

7.3.6.2 Loss of Eggs and Hatchlings

Hatching failure accounted for 50% of breeding failure and chick death accounted for the remaining 50%. Desertion of eggs was the only cause of failure at this stage and all eggs that were deserted appeared to be infertile. No predation of eggs occurred during the incubation periods observed at the three nests nor during the laying period at nest 1. This was despite evidence of extensive feral pig, *Sus scrofa*, activity within 30 m of all nests[11]. Feral pigs were sighted in each of the 31 months of the study period (n = 553 sightings; one pig per 2.30 hours of field time). At nest 4 during the night one large pig was observed at 2310h walking to within 3 m of the nest. It did not attempt to dislodge the male from the nest nor did the male chase it. Instead the male remained completely still during this encounter and the pig continued on its way. Other than this one encounter, pigs were not observed at or near the nests during the 172h 30 min of nest observations.

A large lace monitor, *Varanus varius* (≅ 1.5m), was observed consuming the putrid white foamy contents of an unhatched egg 4 h 17 min after the male and chicks had left nest 1. Although monitor lizards were sighted less frequently than pigs (one monitor per 10.50 hours of field time), they were always present in the study site and were often sighted digging into nests of scrub fowl, *Megapodius reinwardt*, to obtain eggs. In addition, a group of three monitor lizards has been observed completely destroying a cassowary nest containing four eggs which were near to hatching by successfully dislodging the male from the nest (Geyle, M., pers. comm. May, 1997).

While the cause of loss of two hatchlings from nest 3 was unknown, I consider the most likely cause to be predation. Illness indirectly linked to a 'lean-time' was probably the cause of death for the chick from nest 1. The behaviour of this chick for at least two months prior to its death indicated that it may not have been well. It was constantly vocalising in a distressed manner while at the male's side and appeared to be a much fussier forager, and ate less than its sibling. Although unable to be confirmed in this study, fruit availability appeared to have been considerably less in 1991 compared to 1990 and 1992. A study conducted not far from this study site but at a higher altitude found this to be the case (Dennis, 1997).

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[11] Pigs have been implicated in the past as nest predators (Crome & Moore, 1990).

7.4 Discussion

7.4.1 The Behavioural Mating System

This study provides initial quantitative data on "mating patterns" (Ahnesjö et al., 1993) and thereby establishes a benchmark for any further research on cassowary reproductive biology. In general, the findings suggest a highly complex and variable mating system which is most likely to be as dependent on male availability as it is on ecological, physiological or behavioural/social constraints, as is often proposed (e.g., Clutton-Brock, 1991; Davies, 1991; Handford & Mares, 1985). As pointed out by Ketterson and Nolan (1994), this complexity and variability highlights the inadequacy of using traditional terms like *monogamy* and *polygyny*. And even the term "mating pattern" may be more appropriate than "mating system" (Ahnesjö et al., 1993).

In this study, males were found to bond with two or more females simultaneously in a single breeding season, which would suggest simultaneous polygyny (Clutton-Brock, 1991; Davies, 1991; Handford & Mares, 1985), a breeding system comparable with other ratites including ostriches (Bertram, 1992), and rhea (Clutton-Brock, 1991; Handford & Mares, 1985) but in contrast to that other rainforest dwelling ratite, the kiwi (Marchant & Higgins, 1990). Once pair-bonds were established they endured the whole breeding season, with evidence that these same bonds re-establish each year provided the male is available for breeding. No evidence of male monogamy was found which contrasts with the information available in various publications (e.g., Clutton-Brock, 1991; Crome, 1976; Handford & Mares, 1985).

The availability of males appears to be a limiting factor in annual breeding (Figure 7.1). Despite an equivalent number of males and females, more females are available for reproduction in each year than males. Therefore, simultaneous polygyny would maximise the reproductive output of the population. The cost of monogamy for the female is a restriction of breeding opportunities (Davies, 1991) whereas the cost of polygyny would be compensated for by females being free to breed annually or more frequently.

While breeding encounters involving a female and multiple males were not observed in this study, this does not eliminate the possibility of each female breeding simultaneously or sequentially with several males, provided the sexual receptivity of males synchronises with the female as suggested by anecdotal evidence (Crome, 1976). Male-female territory overlaps (see Section 6.4.2.1), and nonbreeding male-female interactions observed (see

Section 6.4.2.3), provide the opportunity for extra pair-bonding between females and more than one male to occur. In addition, continuous incubation by a male once a clutch is formed would leave the female unattended and available for sequential polyandry (Davies, 1991). The limiting factor for females in establishing these extra pair-bonds would be the availability of males which is first and foremost determined by the duration of their investment in parental care, which can be reduced to two in three breeding seasons. With the likelihood of females breeding each year (Section 7.3.1.1), multiple associations over a life time at least would be the only way they could secure annual mating opportunities even if they normally mated with the same partner in the successive years that he was available. Reduction of reproductive output makes monogamy inefficient in this situation (Davies, 1991). Multiple matings in a single breeding season which could lead to multiple paternity may also occur given that a female's territory overlaps with a number of males and she is unable to continue to mate with the same male once he begins to incubate.

Combined with published accounts, the mating strategy in cassowaries appears to include simultaneous polygyny (confirmed in Section 7.3.2.2) and include sequential polyandry (Crome, 1976; Handford & Mares, 1985). However, because of substantial parental investment, males have a lower potential reproductive rate, and it is females that would most often need to compete for the limited supply of available and fit males. It is therefore likely that territory overlap, male availability, and male fitness are conditions which give rise to the mating system in this species. Nevertheless, the mating system cannot easily be defined by one party in the system nor even over a study period of three years.

7.4.2 Nests, Eggs and Incubation

General observations at several nests and intensive observations of a male during the laying period suggest the absence of active nest construction prior to incubation, which is contrary to what other authors propose (e.g., Coates, 1985; Campbell, 1901; Mathews & Iredale, 1921; Reader's Digest, 1982). An assumption of pre-laying construction may have been construed from observations of the nest during the incubation period with the male having been flushed from the nest, or at the completion of incubation after the male has left, rather than in the laying period. Intensive observations of two males at their nests during incubation indicate material collected around the nest is most likely associated with a particular "displacement activity" (Hinde, 1970; Tinbergen, 1989) performed daily by the male during incubation rather than active nest construction prior to laying.

The simultaneous breeding encounters observed between single males and at least two females suggests the two females may lay in the same nest. Determining maternity of eggs without directly observing laying or using genetic analysis presents a challenge to the researcher. While qualitative characteristics of eggs such as colour variation would be affected by age and staining from leaves and soil and consequently change over time, the composition of the granulated surface of each egg could be a consistent feature and one that could possibly give a clue to the identity of the female as found in ostriches (Bertram, 1992). Major female ostriches, defined as those who spend most time and invest most energy in the nest (Bertram, 1992), used this combination to identify their own eggs so that they could expel the eggs of other females. A similar combination of egg characteristics may possibly be used to determine maternity of cassowary eggs in a longer term study.

Initiating continuous incubation only after the laying of the final egg in the nest of three eggs observed here suggests that the clutch was only then considered complete. This begs the question as to whether clutch size determines a complete clutch. Although difficult to ascertain, matching clutch size to male fitness, that is, the ability of the male to provide care over a long period of time and the inevitability of infertility within the clutch, may be at least as important in this species as the cost of egg production to the female. Several theories have been proposed for patterns of avian clutch size many of which may apply to cassowaries. Based on Lack's (1968) theory of clutch size, the optimal size is directly linked to the number of young the parent can provide enough food for. In developing this theory further, Mangel et al. (1994) found clutch size to have direct fitness consequences in terms of trade-offs between offspring size and number, present and future reproduction, and parental and offspring interests. The long period of parental care of young (See Section 7.3.5), and the marked seasonal fluctuations in food availability (see Section 8.3.2.2), are certainly major considerations in cassowaries. However, clutch size may also be partially attributed to the egg productivity ability of female cassowaries, with food and perhaps mineral resources limiting the number of eggs they can lay (Clutton-Brock, 1991), as is the case with ostriches (Bertram, 1992). This egg-productivity limitation, combined with the fact that, while two females may lay in the same nest they may also be laying in multiple nests which would further reduce their output in a single nest, could explain clutch size. There is also the notion of a "local adaptive peak" (Davies, 1991), which suggests that in this instance a clutch of three represents an incubation limit because adding an extra egg reduces not only hatching success (Hill, 1980 in Davies, 1991), but increases substantially cost to male fitness which would inevitability arise from having to care for more young (Clutton-Brock & Godfray, 1991). Bertram (1992) has linked the duration of the incubation period to an optimal clutch size in his study on ostriches. On the other hand I propose another possible explanation which is linked to the possible inevitability of infertility in clutches. Given an estimated infertility rate of 37.5% in this study population, an experienced male may be reluctant to incubate a clutch of less than three considering the substantial costs of incubation and the little scope for adjustment in response to infertility should it prove to be a common cause of nest failure. Although difficult to ascertain, matching clutch size to male fitness, that is the ability of the male to provide care over a long period of time and the inevitability of infertility within the clutch, may be at least as important in this species as the cost of egg production to the female.

Any further laying, once continuous incubation commences would be unlikely for two reasons. Firstly, continuous incubation is incompatible with sustained sexual behaviour, a necessity for the development of a fertile egg (Fisher, 1968), and secondly, it would result in unsynchronised hatching (Bertram, 1992). The need to synchronise hatching is critical in this species as young must all be capable of leaving the nest with the male at the same time. It would partially explain the unwillingness of the male at nest 1, to incubate continuously until the whole clutch was laid.

7.4.3 Male Parental Care and Reproductive Success

Male:female division of labour was reversed in this species compared to most animals and birds. This was in addition to size dimorphism, with females larger than males although not brighter in colour. Continuous uniparental male care lasted on average 14.2 months (range 7.8 to 21 months). Although it began once the clutch was initiated, it was not continuous until after the clutch was completed. It continued through the whole incubation period (49 days) and the care of young until their independence (mean ± SD = 377.2 ± 146.6 days; range = 184 - 584; n = 5). This care extended beyond the point at which the young were capable of obtaining their own food, a feature common among long-lived animals (Clutton-Brock & Godfray, 1991).

The most often cited reason for male parental care in ratites is the cost of egg production to the female (e.g., Clutton-Brock, 1991; Bertram, 1992). This must be set against investment, particularly during incubation which is a period of starvation, which would be a substantial cost to male fitness in general and male reproductive fitness in particular (Clutton-Brock, 1991; Clutton-Brock & Godfray, 1991). On the other hand, assuming that females reproduce every year (see Section 7.3.1) and males only every 2.5 years (see Section 7.3.6), reproductive effort may be equal, that is, reproductive fitness and hence parental care may be related to frequency of reproductive effort, particularly if females lay in more than one nest each season.

Hairton (in Clutton-Brock & Godfrey, 1991) found that periods of starvation can affect reproductive success in subsequent breeding attempts by reducing reproductive performance. This may partially explain why, despite being available, that is independent of chicks, some males failed to produce young in a subsequent breeding season. However, because some males did reproduce in sequential years (e.g., Dillenia) this relationship between male fitness and reproductive success may differ between individuals, possibly due in part to the quality of habitat each occupies. Although empirically unconfirmed in this study, the period of starvation during incubation and poorer quality habitat may be a combination sufficient to render males such as Gunduy reproductively unsuccessful despite being reproductively available.

Ketterson and Nolan (1994) have found that some form of parental care by males is not unusual in birds. However, uniparental male care that involves both incubation and care of young is decidedly rarer (Handford & Mares, 1985). Nevertheless, it is not uncommon in tinamous and ratites (Clutton-Brock, 1991; Handford & Mares, 1985). There have been a number of life history, morphological, and behavioural characteristics associated with uniparental male care in other ratites which have also been found in this study to apply to cassowaries. For example, the production of precocial young (Clutton-Brock, 1991; Temrin & Tullberg, 1995), sexual monomorphism (Ketterson & Nolan, 1994), and simultaneous polygyny and sequential polyandry combined with male care are considered relatively common among ratites (Clutton-Brock, 1991).

A particularly interesting aspect of this uniparental male care in cassowaries is the likelihood of reduced relatedness of males to the young they care for due to possibility of multiple matings by females and how that effects parental effort. Parentage, that is the proportion of young in a clutch that are offspring of the care giver, is often offered as an explanation for variation in parental behaviour (Westneat & Sherman, 1993).

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Chapter 8

Resource Needs and Habitat Use

8.1 Introduction

To complete the biological component of this endangered species study I present in this chapter an ecological perspective which examines the needs of cassowaries in terms of the natural resources on which they depend for survival. To frame this investigation I use the concept of activity patterns, focusing specifically on activities such as foraging and movement.

The protection of natural resources on which a species depends for survival is the key to managing a species (Beatley, 1994; Meffe & Carroll, 1994). Effective management of an endangered species, therefore, presupposes a basic understanding of patterns of resource needs and habitat use, without which a managed recovery process is almost certainly unobtainable. Many researchers have also suggested that an increased knowledge of the needs of species makes managers *more likely* to set a course of action and then follow it (e.g., Clark et al., 1994). However, the Endangered Species Act (1992) and Nature Conservation Act (1994) stipulate that action is a requirement rather than a possibility. Once a species has been listed as endangered, a series of protective standards and provisions are put into play which includes the designation of critical habitat for the species of concern. Critical habitat is defined in the Acts as those specific areas which contain "physical or biological features (1) essential to the conservation of the species, and (2) which require special management considerations or protection" (Beatley, 1994, p.14). The designation of habitats critical to the persistence of a listed species on the basis of ecological rather than economic or political grounds relies on knowledge of the resource needs and habitat use of that species.

What cassowaries do in their everyday life, what and how much they eat, how often they drink, what strategies they use to obtain food and water, how far they travel and how their movement patterns change in space and time, are topics which provide an insight into the resource needs and habitat use of cassowaries. From an ecological perspective, an animal's feeding behaviour is central to many aspects of it's biology, be it population size and density, energy budgets, niche identification, habitat choice, mating systems, territoriality, etc. Food availability is a major factor influencing population dynamics in animals (e.g., Innis, 1989; Moermond et al., 1987; Pianka, 1978; Watson, 1970).

From the management perspective, a study on foraging ecology and related behaviour provides information on the primary resource needs - food and water - thereby allowing managers to identify types of habitat that provide such essential requirements. It follows that predictions can then be made about how changes to the availability of such resources will impact on the species' persistence. Despite the theoretical and conservation importance of such a study, empirical work on foraging ecology and related behaviour of cassowaries is limited to diet analysis (Crome, 1976) and seed dispersal (Stocker & Irvine, 1983). The most comprehensive study on the diet of cassowaries in Australia was based on the analysis of 273 droppings collected over a period of 23 months (Crome, 1976). This study found that cassowaries were primarily frugivorous, that the diet frequently changed in relation to fruit availability, and that fruit was seasonally and erratically distributed. The study also raised the prospect of a link between availability and nutritional quality of food and timing of the breeding season. The study on seed dispersal by cassowaries (Stocker & Irvine, 1983) also found that cassowaries were primarily frugivorous and that most seeds retain their viability having passed through the gut. The role of cassowaries as the sole disperser of several species of rainforest plants has been raised in a number of articles (e.g., Crome & Jones, 1990; Crome & Moore, 1990; Crome & Bentrupperbäumer, 1993; Stocker & Irvine, 1983). Most of the additional information concerning foraging ecology and related behaviour is either anecdotal, based on incidental observations, or specific to captive populations.

An assessment of habitats in localities where birds are known to occur and the differential use of those habitats is also made possible by examining spatial and temporal movement patterns and their relationship to habitat types. In the research conducted by Crome and Moore (1990), they were unable to determine if habitat selection by cassowaries occurred. However, they observed cassowaries using a range of habitats, including mangroves, *Melaleuca* and *Eucalyptus* woodlands, and beach foreshore areas.

8.1.1 Chapter Outline

This chapter begins with a general assessment of activity patterns, which provides a framework for analysing more specific activities such as foraging and travelling. This assessment demonstrates that this lowland population of cassowaries spend equivalent proportions of their day foraging, travelling and resting. I then examine foraging ecology and related behaviours - the foraging strategies cassowaries use to procure food, the composition of their diet, and how this varies in response to seasonal variation in resources. This examination shows that cassowaries feed primarily on fruits which have fallen to the ground. Seasonality of supply was very evident. In addition to fruit, they supplement their diet with other plant foods (blossoms, leaves, fungi), animal and invertebrate matter and inorganic substances (soil, rocks, shells). Finally, I examine movement patterns and habitat use which demonstrates differential use of home ranges and use of all habitats, rainforest, woodland, swamp forest and beach foreshore.

8.2 Methods

8.2.1 Activity Patterns

I determined cassowary activity patterns from direct observations on five focal birds (Table 8.1). Sometimes these observations were continuous for 24-hour periods, other times for only one hour. Alata was included among the focal birds once becoming a subadult. Direct observations of two cassowary chicks (Alata and Boronia) were not combined in this data set with the other age categories for the purpose of establishing activity patterns.

Table 8.1 Details of five focal cassowaries on which continuous observations were made.

Individual	**Gender**	**Age**	**# hours**[1]	**From**	**To**
Dillenia	Male	Adult	240.25[2]	Jan 90	Nov 92
Eugenia	Female	Adult	30.00	Jan 90	Sept 92
Intsia	Female	Adult	28.15	May 90	Nov 92
Cordyline	Unknown	Subadult	10.00	March 90	Nov 91
Alata	Unknown	Subadult	11.60	July 91	Sept 91
Total			**320 hours**		

Note : (1) Only records from contact periods ≥ one hour used.
(2) Nesting observations are not included.

In all calculations where data were pooled the unbalanced data set, i.e. the disproportionate time spent observing the adult male, Dillenia, was addressed by calculating a mean value for each individual first, then calculating the mean of the means of the five individuals (with a sample size of 5, and the standard error of the mean).

8.2.1.1 Night Routine

My assessment of the night routine was based on a total of five full night observations (60 hours) and information from 30 roosting sites. During night observations I made continuous records of activity and posture of the birds. At roosting sites I recorded details of all cassowary sign: (1) number and size of droppings; (2) presence/absence of feathers; and (3) presence/absence of body imprint. I collected droppings for diet analysis and feathers for colour assessment. I recorded a variety of environmental data at each roosting site including: altitude; slope; habitat type; canopy structure; understorey structure (see Chapter 7, Section 7.2.3). I used these data to characterise roosting site preferences.

8.2.1.2 Day Routine

Daily activity pattern I recorded daily activities including travelling, foraging, resting, and body maintenance on five focal birds (Table 8.1). I used a continuous recording technique out of which records (n = 3,025) from 5-minute sampling points were extracted (see Section 5.4.2.1). I only used records obtained when the contact period with a focal bird was ≥ one hour. I always maintained a distance of ≤ five metres with a focal bird which enabled me to make observations with the naked eye and instantaneously record these observations in a note book.

Monthly activity pattern I determined monthly activity pattern from 1,682 observation records obtained from one focal bird, Dillenia. It was from this adult male that I was able to obtain regular monthly observations for a continuous twelve month period, March 1990 to February 1991, and thereby view the activity pattern within the context of a whole year.

8.2.2 Foraging Ecology and Related Behaviour

8.2.2.1 Foraging Strategy

I recorded the foraging strategy used by five focal birds (Table 8.1) during 320 hours of direct observations. I dealt with the unbalanced data as outlined in Section 8.2.1. I also recorded many incidental foraging observations of the remaining adults, subadults, and chicks during the course of this study. However, I quantified foraging and related behaviour from prolonged intense observations and not incidental observations.

8.2.2.2 Diet

To obtain as complete and reliable a data set on diet as possible I surveyed the whole study site every two months (Section 5.4.2) for a period of 30 months, the minimum time needed to account for irregularities in fruiting patterns such as crop failures and alternatively atypical fruiting abundances of this tropical region (Innis & McEvoy, 1992). During these surveys I collected cassowary scats. In addition, I made direct observations of actual food swallowed by five focal birds (Table 8.1). This ensured that items not readily identifiable in scats would be picked up during foraging observations.

Actual food swallowed While tracking focal birds I recorded number and identity of items swallowed and the strategy used to obtain each item. In total, over a period of 202 hours and 20 months, I recorded 2,728 foraging sessions[1] during which 65,890 food items were swallowed.

Analysis of scats I sighted a total of 3,829 scats in the study site over 30 months, of which I collected 2,185[2]. Because seeds were voided whole and in many instances with pericarp still intact, identification of fruit was a straight-forward procedure. I prepared each scat by washing it with water through a 1mm-screened tray. I then identified and counted all items remaining on the screen (n = 378,821).

I identified fruits to species level with the assistance of Tony Irvine (CSIRO Botanist) and Wendy Cooper (Cooper & Cooper, 1994), and classified 'other' items at the broad level including the following:

(1) vertebrates	birds; toads (Bufonidae);
(2) invertebrates	beetles (Coleoptera); worms (Lumbricus); cicadas (Homoptera); snails (Mesogastropoda);
(3) inorganic	soil; rocks; sea shells.

I made a reference collection of fruits eaten, preserving at least 10 sample seeds of each species by drying them. From these samples I developed a working chart of coded and identified seeds which was used in the field, and monthly charts which were stored as a back up reference. I also photographed fruits and leaves of identified seeds when possible.

To obtain a more detailed analysis of diet, procedures such as microscopic examination of scat contents or germination trials would be required. This would assist in identifying fine-seeded fruits (< 1mm) and any vertebrate or invertebrate components that may well

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[1] A foraging session consisted of a period of continuous, uninterrupted food intake.

[2] I used the seeds from these scats to establish a cassowary food plant nursery. In the first two years, approximately 25,000 cassowary food plants from these scats were planted out in the region, having been distributed to farmers, community groups, and other interested members of the public for reforestation programs.

have been lost in the methods used in this study. However, fine-seeded fruits such as figs, *Ficus* spp., were often identified from intact pericarp, and direct observations of food intake identified items such as earth worms and soil.

I calculated monthly and yearly proportion of different foods in the diet on the basis of number of items present (frequency of occurrence). For fruits, I then converted these items to whole fruit numbers when such fruits were known to contain more than one seed. This provided consistency in the analysis of both scat contents and food intake observations since whole fruits were observed being consumed by adult cassowaries and hence regarded as one food item rather than fragments of fruits or single seeds. In this study the importance of a food item was based on the number of items present in the diet as opposed to both physical (size) and chemical (nutritional) characteristics. I well acknowledge that this method may over-represent the importance in the diet of small items and those of low nutritional value.

Defaecation rates During observations of foraging, etc., I recorded each defaecation of one focal bird, the male Dillenia. I calculated defaecation frequency by dividing number of defaecations by total observation period. These were calculated for each month and over the course of the year. I only used those observation periods longer than one hour and excluded the incubation period.

Water intake I recorded the following information when a focal bird was drinking: (1) number of drinks taken; (2) length of drinking session; (3) drinking source (tree base, swamp, permanent creek); and (4) subjective estimation of quality and quantity of water present. Because cassowaries drink by scooping up water into their bill (Section 8.3.2) each single drink was identifiable. I therefore defined a drink as a single “bill full” and a drinking session as any number of “bill fulls” taken consecutively. Water intake data was established from a total of 354.33 hours of direct observation of four cassowary chicks and one adult cassowary. I only used those observation periods that were longer than one hour. I combined water intake data from the four chicks (196 hours of observation). Because of the unbalanced data I calculated the mean values for each of the two groups of two chicks which had similar observation periods (group 1 = 64 hours per chick; group 2 = 34 hours per chick), and subsequently calculated the mean of these means, presenting these as the final value. Water intake for the male Dillenia is presented separately. For this adult male I analysed the data set for hourly, monthly, and yearly patterns of water intake.

8.2.3 Movement Patterns

8.2.3.1 Day-Journeys

I recorded directly on to maps the travel route and location of foraging and drinking of five focal birds (Table 8.1) and four chicks while tracking these birds. I mapped the travel routes using a combination of my trail/transect system, several well-known reference points, and when possible, compass bearings from some of these known points of reference. While the exact continuous travel route of focal individuals may not have been accurate in the early phase of the study, familiarity with the area and the considerable number of reference points established over time made possible a reasonably accurate assessment of the daily movement routes. Initially, I used a hip chain, but discontinued its use because the considerable accumulation of cotton after tracking sessions was found to disrupt the progress of cassowaries, particularly when they used the same travel route repeatedly. Other researchers have also found small terrestrial birds caught up in hip chain cotton (Dennis, A. pers comm. June 1997). On those occasions when the hip chain was used, I was able to record distance travelled.

8.2.3.2 Differential Use of Habitats

In addition to data available from the diet analysis, I also documented differential use of habitats in the study site by recording sign of cassowaries in various habitat types during general field surveys. The system used to identify these habitats has been outlined in detail in Chapter 5 (Section 5.2.2.3), as has the methods for identifying sign, be it sightings, vocalisations, and scats (Section 5.4.2.1). Since I conducted regular surveys on a two monthly basis in 1991 and 1992, I used records from these two years in this analysis. I calculated indices of habitat use or sign density for each major habitat type and all sign (sighting + vocalisation + scats) by dividing the number of sign found in the various habitat types by the time spent searching these habitats. To establish preferential use I then standardised this measure to relative habitat availability in the study site. I completed 651.15 hours of search effort in these general surveys.

8.2.4 Note on Analysis

While the unbalanced design (i.e. the disproportionate time spent observing the male Dillenia) can potentially affect some of the analysis in this chapter, I have outlined how I address this issue in Sections 8.2.1 and 8.2.2. However, much of the chapter presents results that are not affected by the unbalanced design. What these results provide are "a set of valuable insights on the behaviour and requirements of the birds that could only come from observations that are sustained and intensive enough to detect unusual behaviours" (Johnson, C. pers comm. February, 1998). Furthermore, it should be noted that such detailed information is difficult to collect for a balanced sample considering this is an endangered and hence difficult species to study and the relatively short time available for this study.

8.3 Results

8.3.1 Activity Patterns

8.3.1.1 Night Routine

Sleeping Solitary subadult and adult cassowaries roost on the ground in the forest once daylight ceases and rise to forage soon after dawn. Although not observed, I expect this same behaviour to occur for the family unit - male and chicks (5 continuous nights of observation). Roosting posture involves the bird sitting with the underside of its body flat on the ground (Plate 8.1).

Plate 8.1 Roosting posture of an adult cassowary.

Other than grooming immediately before and after sleeping, cassowary night activity appeared to only involve defaecation. They would mainly defaecate while in a semi-crouched position. During routine day field surveys I located a number of overnight roosting sites ($n = 30$). These sites were identifiable by the tell-tale cluster of scats (mean ± SE = 5.6 ± 1.65, range 3-13) at the perimeter of the actual roosting spot. In addition, roosting sites were littered with feathers which were probably dislodged during the grooming activity observed before and after sleeping. Occasionally (5/30), a body imprint on the ground was also identifiable. I only classified those sites with the combination of scats + feathers and/or body imprint as roosting sites. This may have resulted in a number of potential sites being dismissed due to uncertainty[3].

From these estimates I suggest that in addition to variation in scat size, sites where a large number of scats were present may well indicate the presence of a family unit rather than a solitary subadult or adult. The considerable size variation of scats present at some of these roosting sites (6/30) also suggests that these were most probably used by a male with chicks. During diurnal tracking sessions, I never observed cassowaries defaecating more than once in a particular spot ($n = 230$ observations of birds defaecating), such as was evident at roosting sites.

Other than as the family unit of a male with chicks, cassowaries remained solitary while sleeping. They did not appear to return to any particular sleeping site but rather roosted where they were at that time of day. Roosting sites were significantly more likely to be > 20 m altitude [χ^2 (1, $n = 30$) = 3.76, $p < 0.05$] but were not influenced by the relative availability of rainforest or woodland [χ^2 (1, $n = 30$) = 0.29, p = n.s.]. No roosting sites occurred in swamps or beach/foreshore areas, all of which were < 20 m altitude. In addition, this data suggests that cassowaries choose an area that is dry and with some form of vegetative cover (100% under closed forest canopy; 77% in closed understorey). However, as will be shown in the diurnal activity pattern, sleeping site selection may also be linked to the close proximity of a food source.

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[3] Although dispersed differently, large numbers of scats were often located in an area of intensive foraging activity.

8.3.1.2 Day Routine

Activity level Cassowaries were active (72.54%) throughout the day, with inactivity, such as rest periods and body maintenance (27.46%), being interspersed among intensive activities such as travelling and foraging (69.71%), and agonistic interactions (2.83%). The daily activity routine consisted predominantly of travelling (mean ± SE = 35.03% ± 2.97), foraging (mean ± SE = 34.68% ± 4.20), and resting (mean ± SE = 19.96% ± 3.94), with preening (mean ± SE = 7.50% ± 0.47), and the miscellaneous activities - vocalising, defaecating, and agonistic interactions - (mean ± SE = 2.83% ± 1.43) occupying only a minor proportion of the day (Figure 8.1).

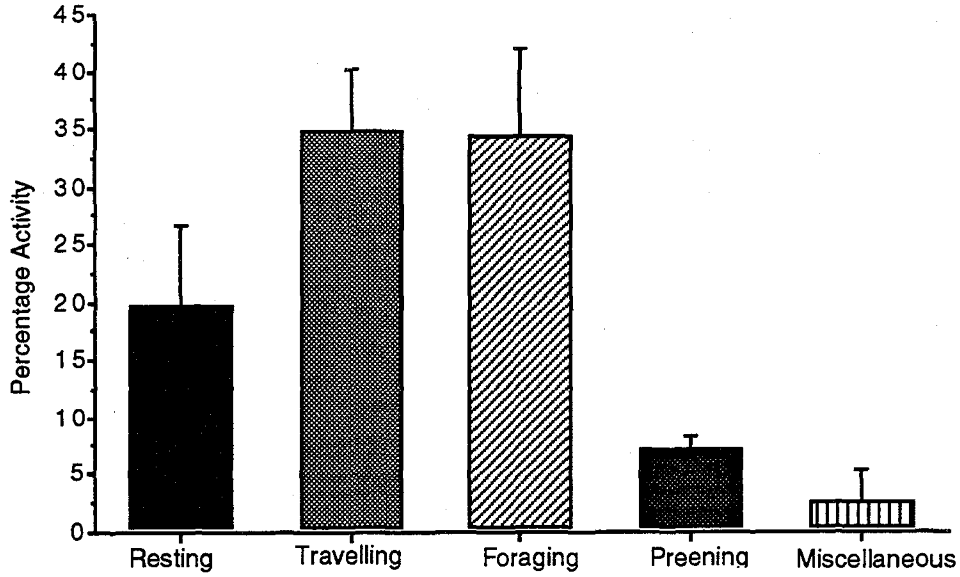

Figure 8.1 Proportion of time spent by cassowaries (mean ± SE) in various diurnal activities between 0700 and 1800.

Activity level and time of day Activity patterns varied according to time of day. Cassowaries displayed a daily cycle with an early morning (0800-0900) and late afternoon (1700-1800) peak in foraging activity (Figure 8.2).

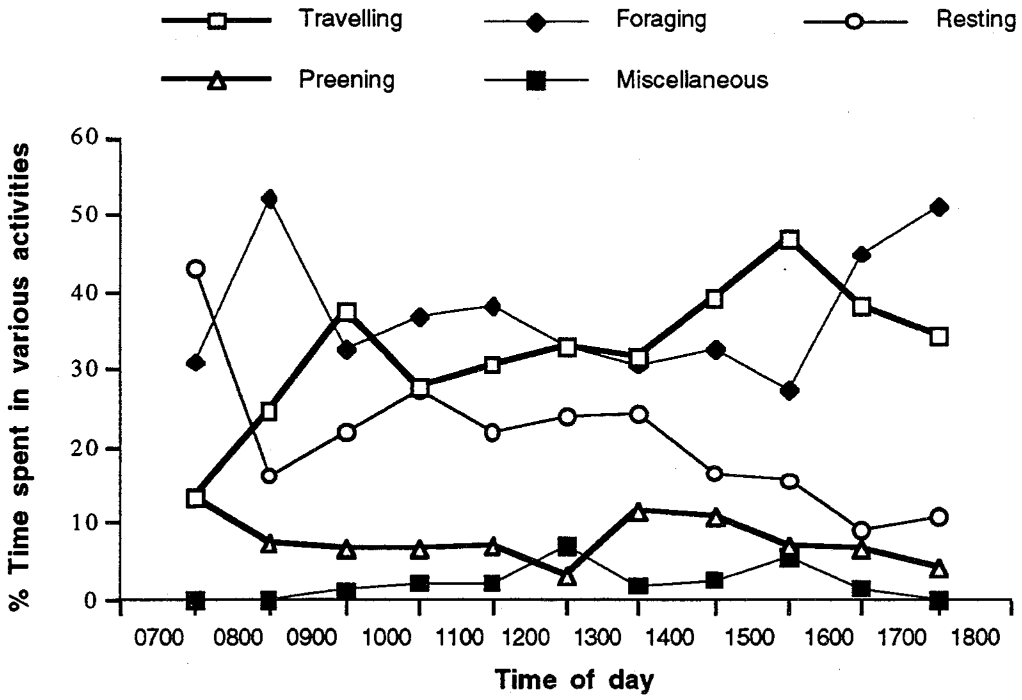

Figure 8.2 The daily activity cycle by time of day.

In addition to these peaks, foraging was the predominant activity throughout the day (mean ± SE = 37.36% ± 2.89%, range 27.19% - 51.98%), apart from a period in the early morning (0700-0800). Between 0700 and 0800, cassowaries spent a large proportion of their time resting (43%), and involved with body maintenance activities such as preening (13%), which peaked at this time. In addition, the proportion of time spent travelling in the early morning was the lowest (13%), and the foraging to travelling ratio skewed strongly toward foraging (1 : 0.42).

Activity level and time of year On the basis of Dillenia's breeding-related activities[4], the year (1990) under study was divided into three distinct periods: *pre-nesting* - March to mid-June when courtship and mating took place; *nesting* - end-June to mid-August, when incubation occurred; *post-nesting* - end-August to July when Dillenia was caring for the chicks[5] (Figure 8.3).

In the *pre-nesting* period, Dillenia spent an equivalent proportion of time travelling (mean ± SE = 29.5% ± 3.86) and foraging (mean ± SE = 27.0% ± 3.24), slightly less time resting (mean ± SE = 23.0% ± 7.89) and preening (mean ± SE = 16.5% ± 5.04), and only a little time engaged in miscellaneous activities (mean ± SE = 4.0% ± 1.35). During this period he was occasionally involved in courtship activity (Chapter 7), and apart from the rare foraging interaction with females (n = 3) as part of the courtship activity, his foraging activity was solitary. Travelling during this period appeared to be related to obtaining and searching for food and to courtship activities (Chapter 7).

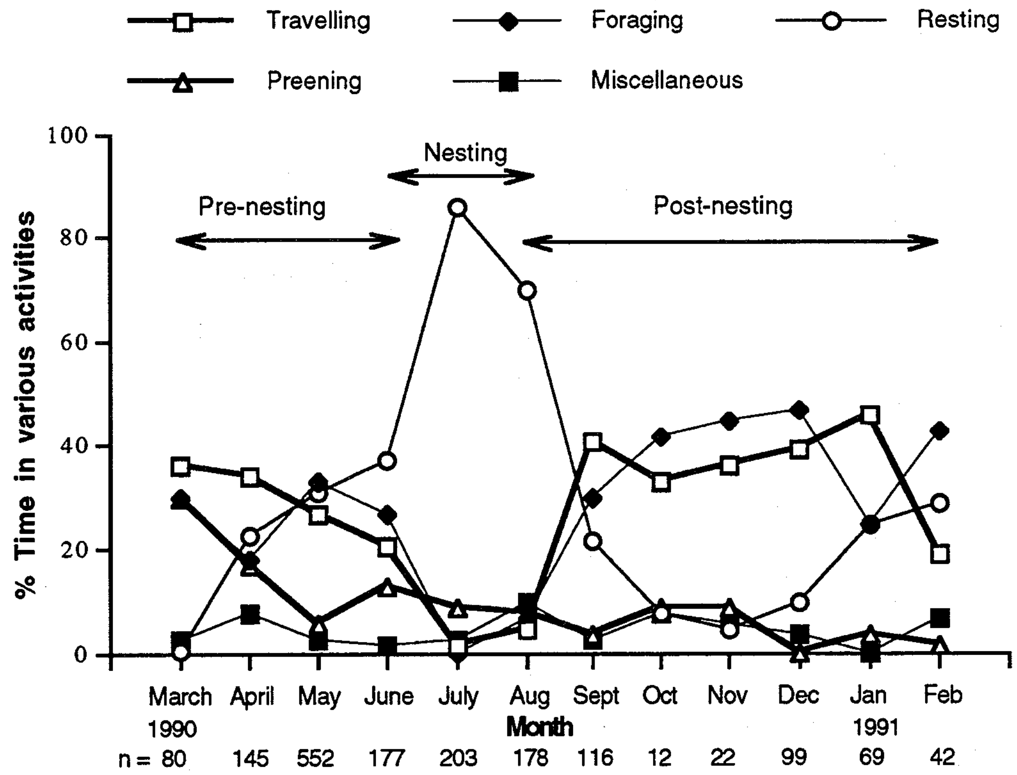

Figure 8.3 The monthly distribution of activities of the male Dillenia.

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[4] The data used for the development of an activity profile of the male Dillenia included observations made at the nest.

[5] Although caring for the chicks extends beyond March 1991, tracking was not continued on a monthly basis after this period.

During the *nesting* period, from the 25th June to the 10th August, Dillenia was continuously incubating, which accounts for the very high proportion of resting time (86%). Apart from occasionally preening (8%), turning eggs (3%), and some displacement behaviour (picking up and throwing leaves and twigs on to his back and around the nest; 3%), Dillenia did not forage, drink or move from the nest site. Details of the *nesting* period have been described in Chapter 7 (Section 7.3.3).

In the *post-nesting* period, Dillenia spent a high proportion of time travelling with one month old chicks (September 1990 = 41%). In addition, foraging activity reached the levels of the *pre-nesting* period within the first month after incubation (September 1990 = 30%). The amount of time Dillenia spent travelling was greatest in January 1991 (46%), during which time the foraging to travelling ratio was strongly skewed toward travelling (1 : 2). Since no courtship activity occurred in this month, these findings may indicate a period of low food availability and hence the need to increase search effort. However, overall the amount of time spent travelling was not statistically different between the *pre-* and *post-nesting* periods [t (df = 8) = 1.129, p = 0.1457]. Nevertheless, it is possible that the biological significance is that travelling in the *pre-nesting* period may be linked to courtship activity whereas in the *post-nesting* period it may be linked to low food availability.

Foraging activity reached its highest level in December 1990 (47%), and it was, overall, significantly higher in the *post-nesting* period compared to the *pre-nesting* period [t (8, n = 10) = 2.226, p = 0.0283]. When not caring for chicks (*pre-nesting* period), Dillenia spent significantly more time preening than when caring for chicks [t (8, n = 10) = -2.687, p = 0.0138].

8.3.2 Foraging Ecology and Related Behaviour

8.3.2.1 Foraging Strategies

Ground-foraging technique The primary method used by adult (mean ± SE = 95.73% ± 2.40; n = 3) and subadult (mean ± SE = 88.8% ± 0.10; n = 2) cassowaries for obtaining food was the *ground-foraging* technique: pecking fallen fruits and other food items directly from the forest floor. This strategy accounted for 95.1% (mean ± SE = 92.96% ± 2.16; n = 5) of all foraging observations (n = 2,728). All incidental foraging observations during the field study confirmed this method of obtaining food as being the most important. The findings from the diet analysis (see Section 8.3.2.2) also show that the majority of plant food species consumed were only available to cassowaries from the forest floor as they were fruiting at medium to high canopy level (Stocker & Irvine, 1983). Availability of these food items to cassowaries therefore depended on dislodgment from the source by birds, wind, rain, and ripening. When fru was scarce, cassowaries would actually run toward the sound of a falling fruit in order to secure it. When in abundance, they appeared quite selective, often rejecting partially ripe or alternatively over ripe/spoilt fruits. Such rejection was also observed by Mack (1995) in his study of *Casuarius bennetti* in New Guinea.

The rate at which a cassowary consumes food items varies considerably. For example, when foraging on Broad-leaved Lilly Pilly fruits, *Acmena hemilampra* (Plate 8.2), the highest pecking rate[6] recorded for the male, Dillenia, was 51.60 per minute (mean ± SE = 33.28 pecks per min ± 1.33; n = 24).

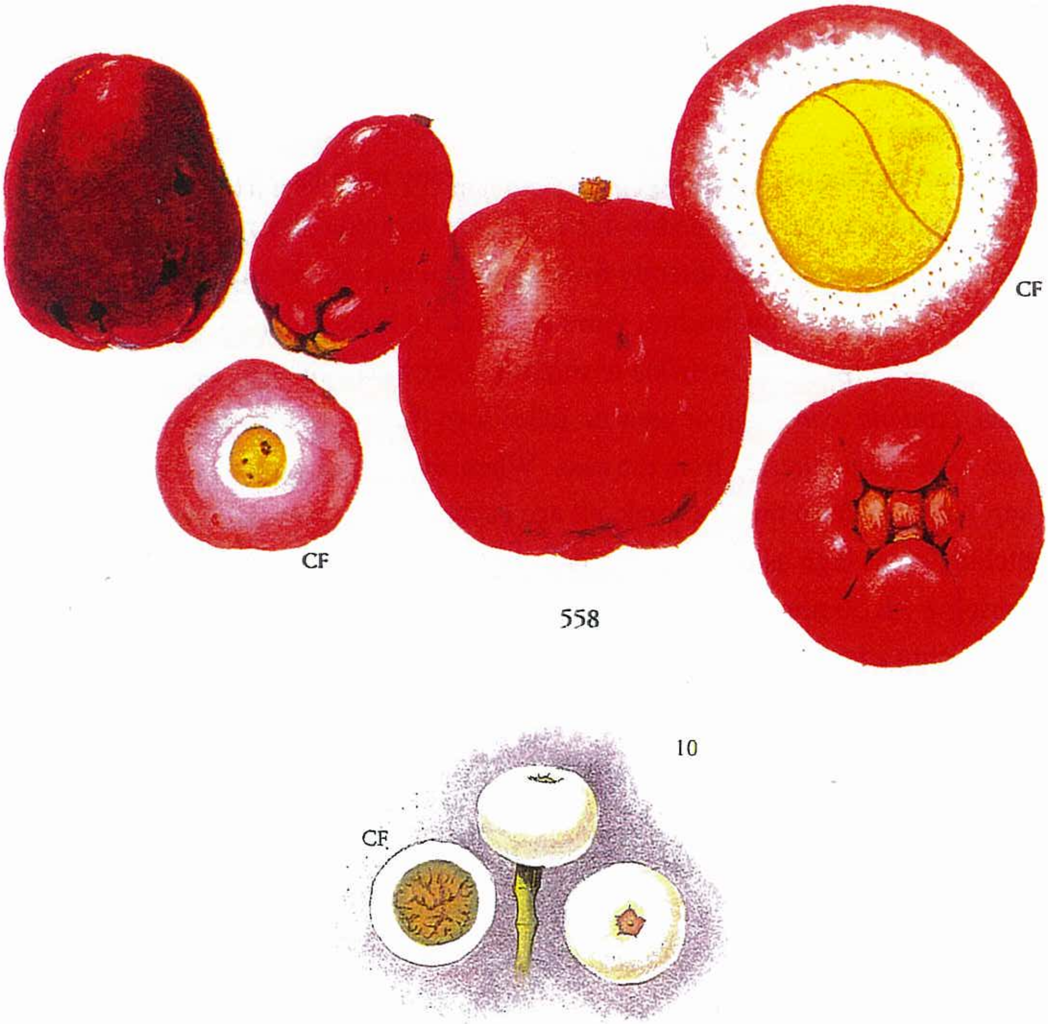

Plate 8.2 *Syzygium alliiligneum* (No. 558) and *Acmena hemilampra* (No. 10) drawn to scale. (Source: Cooper & Cooper, 1994; Reproduced with permission of the artist).

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[6] This was based on 260 *Acmena hemilampra* being consumed in one continuous 5-minute foraging session. It was clear from the extensive foraging observations that one peck = one fruit.

In comparison, when foraging on fruits of Onionwood, *Syzygium alliiligneum*, the highest pecking rate recorded was 16.00 per minute (mean ± SE = 8.33 pecks per min ± 0.38; n = 28) [7]. The significant difference in pecking rate [t (50, n = 52) = 19.27, p = 0.0001], could be influenced by fruit size; Onionwood, *Syzygium alliiligneum* (40 x 43 mm) being approximately 3.5 times larger than Broad-leaved Lilly Pilly, *Acmena hemilampra* (diameter = 11-17 mm; Cooper & Cooper, 1994; Plate 8.2).

Another possible determinant is fruit fall density. At the time of the highest pecking rates of each of these fruits, I recorded fruit fall densities of ≅ 1,000 per metre^2 (*Acmena hemilampra*), and ≅ 200 per metre^2 (*Syzygium alliiligneum*). During periods of high availability, Dillenia consumed 1,464 *Acmena hemilampra* and 167 *Syzygium alliiligneum* in one continuous 3 h 30 min observation period, during which actual foraging time accounted for 36 minutes. Such findings illustrate the large quantities of food that this bird is capable of consuming in its natural environment.

Retrieval technique A less common method for obtaining food involved the *retrieval* technique: retrieving a food item directly from its source or place of lodgement. This technique was recorded in 4.9% of 2,728 foraging observations (134/2,728). Retrieving a food item directly from its source was observed when birds foraged on foods that grew on low bushes, vines or trunks of trees (e.g., Lawyer Vine, *Calamus* spp., Figs, *Ficus* spp., *Cordyline terminalis*, Cardwell Cabbage, *Scavolia sericea*, Lantana, *Lantana camara*); or grew on fallen logs (fungi); or food items such as bird eggs which were taken directly from the nest. When attempting to obtain fruits of figs (*Ficus* spp.) directly from the tree trunk, all age categories of cassowaries were observed stretching up as high as they could and even jumping up in order to secure the food item. During a 1 h 50 min foraging session[8] at a single fig tree, the male Dillenia was observed jumping a total of 43 times. Sixteen of the fruits obtained in this way were given to the nine month old chicks who were also jumping up but not high enough to secure the ripe fruit.

If the cassowary wanted a fruit which had not fallen to the ground but instead was caught up (e.g., in Lawyer Vine, *Calamus* spp.), it would attempt to retrieve it from the tangle of vine. This retrieval behaviour was also observed when fruit had fallen into water. However, there appeared to be some variability in depth to which individuals would submerge their head in order to secure a food item. For the male Dillenia, this did not extend beyond the base of his beak. On the other hand, observations on subadults

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[7] This was based on 48 *Syzygium alliiligneum* being consumed in one 3-minute foraging session.

[8] This foraging session was interspersed with resting and preening and was part of one 5 h 15 min continuous tracking session.

showed they were willing to submerge their head completely. This depth variation may just be an idiosyncratic behaviour of certain individuals, or a factor of food abundance, or an indication of dietary opportunism by subadults who would take food items adults appeared less willing to pursue.

When food was available on a bush and within reach (e.g, Lantana, *Lantana camara*), pecking rates reached 44.0 per minute (mean ± SE = 24.84 pecks per min ± 1.58; n = 24). In a one hour observation period[9] during which foraging accounted for 57 minutes, 1,165 berries of *Lantana camara* were consumed directly from the bush.

Foraging strategies used by young chicks differed from those of the adults and subadults. A description based on intensive observations made from the time of hatching of the chicks Alata and Boronia to the time Alata was abandoned by the father Dillenia is presented in Appendix A.3.1. In summary, during their first month chicks relied on the male parent to provide and identify food. The male provided food by dislodging the flesh of the fruit from the seed using a continuous masticating action with the fruit between its beak. The chicks would pick up the dislodged pieces of fruit from the ground. Taking food directly from the male's beak was not observed. By ten days old the chicks had clearly connected the sound of the mastication with the provision of food as they would run to the male on hearing that sound. During the first month there was a gradual shift from total reliance on the male to provide food to an increased ability of consuming whole fruits which were at least of a size they could swallow. By four months chicks were foraging almost entirely on their own. However, they continued to rely on the male throughout the parental care period for the identification of new fruits and the mastication and retrieval of fruits that were too large and inaccessible.

Drinking strategy When drinking, cassowaries always obtained water by a scooping action, submerging the front of their beak into the water. A scooping action was followed by raising the head; this ensured water was drawn into the bottom section of the beak and swallowed. Birds were seen either to stand or squat in order to drink (see Section 8.3.2.3 for further details).

8.3.2.2 Food Intake

General This study confirmed cassowaries to be primarily frugivorous, with 99.8% of their diet devoted to fruit, 0.2% to 'other' items.

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[9] This almost continuous foraging bout was observed during a 8 h 30 min tracking session.

Furthermore, they exploited a wide variety of fruits and other foods. In total, the observed diet consisted of 117 different food items including fruits, blossoms, leaves and twigs of 91 identified plant species and 16 unidentified plant species from 37 families, and 10 'other' items, including fungi, animal and invertebrate material and inorganic matter such as soil and rocks. Monthly variation in the diversity of food items present in the diet ranged from 7 to 33 over the three year period and averaged 19.37 per month (± 1.22 SE) (see Figure 8.4).

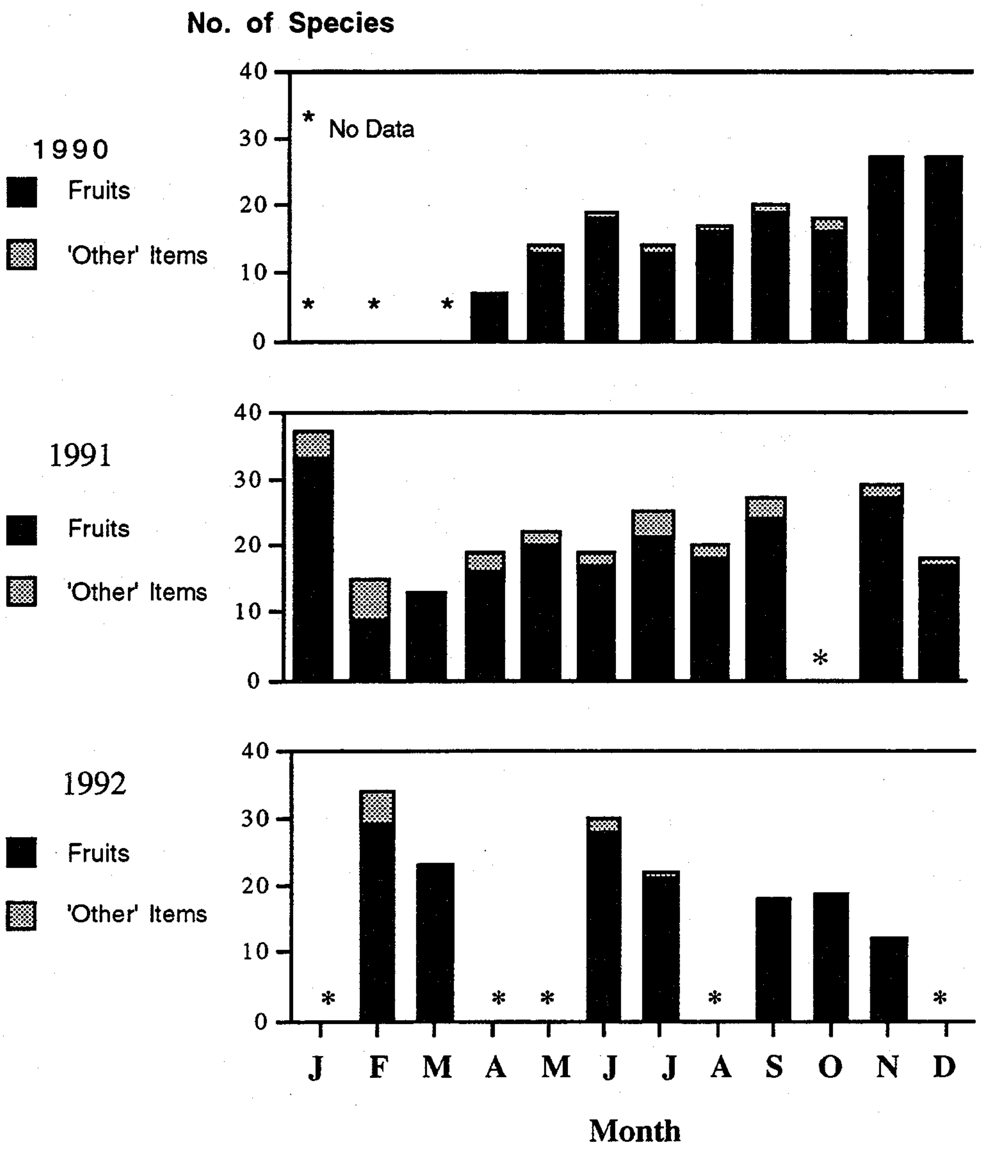

Figure 8.4 Number of fruit species and 'other' items present in the diet of the cassowary over the three year period, April 1990 to November 1992.

Details of the dietary composition for the period April 1990 to November 1992, using combined data from scat analysis and food intake observations and the calculated proportion of food in the diet each year and month, are presented in Appendices A.4.1, A.4.2, A.4.3.

Plant food In this study site cassowaries consumed the flesh of fruits of 107 different species, always voiding the seeds intact. Based on the proportion of food items present in a 27 month period, three species appeared to be particularly important in the diet, accounting for 54.1% of the total food items consumed: Broad-leaved Lilly Pilly, *Acmena hemilampra* (36.9%); *Alyxia spicata* (9.6%); and Solitaire Palm, *Ptychosperma elegans* (7.6%). However, 38 species of plants formed > 5% of the diet in any one month (Appendices A.4.1, A.4.2, A.4.3.).

Despite the evidence that cassowaries feed on a considerable number of plant species in any one month (mean ± SE = 19.37 ± 1.22; range 7-33; n = 27; Figure 8.4), fruits of one or two species often dominated[10] the monthly diet (mean ± SE = 1.30 ± 0.56; n = 27). This may be due to factors such as the abundance and/or large crop size of the fruits and the food preferences of the birds (Moermond et al., 1987).

'Other' items 'Other' items, which only accounted for 0.2% of the diet, included fungi, animal and invertebrate material such as toads, birds, eggs, snails, worms, and various insects, and material such as soil, rocks and sea shells. They were found to supplement the diet in 20 of the 27 month period. Number of different other items present in the diet was highest in February 1991 (n = 6), and February 1992 (n = 5) (Figure 8.4). Nevertheless, they accounted for only 0.6% (February 1991) and < 0.1% (February 1992). These items supplemented a diet that at the time was predominantly White Apple, *Syzygium forte* (97.8% - February 1991), and Beach Cherry, *Eugenia reinwardtiana* (32.4% -February 1992).

While most of these other items were found in the diet throughout the year, earth worms appeared only in February. This corresponded with continuous heavy rains which caused local flooding bringing the earth worms to the surface and thereby making them easy pickings. Their presence in the diet was first discovered from food intake observations in this study. While fungi and snail shells were easily distinguished in the scat samples, having passed through the digestive system fully intact, some items could only be identified from small fragments or by having observed the actual consumption of such

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[10] Fruits were deemed to be important at > 5% and dominant if they contributed ≥20% of items present in the monthly sample.

foods. An example of how efficient the digestive system is in the breakdown of such material is provided from a captive subadult. When this bird was fed small birds such as Sparrows (*Passer domesticus*) and Indian Mynahs (*Arcidotheres tristis*), no animal matter was found in the faeces (Storch, D. pers. comm. June, 1997). This suggests that the other item component of the diet, particularly animal matter, may be underestimated from scat samples alone.

Of particular interest among these 'other' items was soil which was found to supplement the diet in February, April, May, July 1991 and February 1992 (Appendices A.4.2 and A.4.3). Soil appeared in distinguishable quantities in 0.4% of the scats analysed (9/2,185). Although consumption of small lumps of soil was first observed with newly hatched chicks (Chapter 7), traces of soil were only discovered in scats in February 1991, and it was not until May 1991 that the consumption of soil in large quantities was observed by adults and *old* chicks. These birds were observed consuming soft red Podzolic soil (McDonald & Isbell, 1984) by digging their beaks into mounds found around the roots of fallen trees. While these findings suggest that soil consumption occurs at low frequencies among free-living cassowaries, it nevertheless may be an important supplement at certain times of the year (e.g., lean periods). Reid (1987) has recorded captive cassowary chicks periodically ingesting soil.

Patterns of phenology Given that cassowaries eat predominantly fresh fruits, and that the diet analysis contains data from food intake observations as well as droppings, I assume that the diet of these birds reflects the fruiting phenology of this tropical lowland region. Therefore, these results, together with my field impressions, enable some general statements to be made about the patterns of fruit production in this region. The most noticeable aspect of the pattern was the distinctive seasonal distribution of many species each year (e.g., *Alyxia spicita*, Solitaire Palm, *Ptychosperma elegans*, and Onionwood, *Syzygium alliiligneum*). In contrast, other species produced only once during the study period (e.g., White Apple, *Syzygium forte* , and Brown Walnut, *Endiandra montana*), or produced every second year (e.g., Broad-Leaved Lilly Pilly, *Acmena hemilampra*). In addition, there were those species which may have produced every year but productivity varied considerably (e.g., Alexandra palm, *Archontophoenix alexandrae*). The number of plant species present in the diet also showed a slight change in seasonal diversity with a peak in the latter part of 1990 and in the early part of 1991 and 1992 (Figure 8.4).

Diversity and pattern of habitat use Given that cassowaries are predominantly frugivorous, dietary analysis is a good indicator of the diversity of habitats used by cassowaries, and the pattern of that use. In general, the data shows that for the acquisition of food this cassowary population uses a complex habitat structure (Table 8.2).

Table 8.2 Dominant species in the diet and the period of their importance grouped according to habitat.

Common Name[1]	Species	Months
Rainforest		
Lawyer Vine	*Calamus australis*	January - March
Daintree Hickory	*Ganophyllum falcatum*	February
Grape	*Cissus penninervius*	February
Iron Malletwood	*Rhodamnia sessiflora*	May - June
Broad-Leaved Lilly Pilly	*Acmena hemilampra,*	May - August
Wild Current	*Antidesma erostra*	May - August
Onionwood	*Syzygium alliiligneum*	June - July
Strangler Fig	*Ficus drupacea*	June
Tarzali Silkwood	*Cryptocarya oblata*	July
Northern Laurel	*Cryptocarya hypospodia*	July - December
Black Ash	*Planchonella obovoidea*	August - December
Native Olive	*Chionanthus ramiflorus*	September
White Aspen	*Acronychia acronychoides*	September - October
Northern Tamarind	*Diploglottis diphyllostegia*	September - October
Cairns Pencil Cedar	*Palaquium galatoxylum*	October - November
Mountain Blush Walnut	*Beilschmiedia collina*	November
Dungulla	*Planchonella chartacea*	November
Unknown	*Acmenasperma claviflorium*	November - January
White Apple	*Syzygium forte*	November - February
Tar Tree	*Semicarpus australiensis*	December
Bumpy Satinash	*Syzygium cormiflorum*	December - January
Woodland		
Ivory Basswood	*Polyscias australiana*	March - August
Fig	*Ficus hispida*	April - May
Alxylia	*Alxylia spicita*	May - February
Mistletoe	*Amylotheca dictyophleba*	May - August
Quandong	*Elaeocarpus augustifolius*	July - August
Bollywood	*Litsea leefana*	August - October
Swamp		
Alexandra Palm	*Archontophoenix alexandrae*	May - August
Solitaire Palm	*Ptychosperma elegans*	July - October
Swamp Satinash	*Syzygium angophoroides*	November -December
Swamp-woodland-rainforest edge		
Quandong	*Elaeocarpus eumundi,*	April - May
Brown Walnut	*Endiandra montana*	April - May
Beach/foreshore		
Damson	*Terminalia sericocarpa*	January
Beach Cherry	*Eugenia reinwardtiana*	February.
Cardwell Cabbage	*Scaevola sericea*	March
	Fenzlia spp.	September

Note: (1) Common names from Cooper & Cooper, 1994.

Defaecation frequency Defaecation frequency for the male, Dillenia, was on average 0.71 per hour (± 0.357 SD) (Table 8.3). Intervals between defaecations ranged from 15 mins to 235 mins (mean ± SD = 64 mins ± 32 mins).

Table 8.3 Defaecation frequencies[1] for the male Dillenia.

Month	No. Scats/hour of Observation	Interval between Defaecation (hours:minutes)	
		Mean ± SD	(range)
1990			
March	0.24	-	-
April	0.47	-	-
May	0.96	0:55 ± 0:19	(0:30 - 2:00)
June	0.85	0:43 ± 0:11	(0:35 - 1:10)
August	0.31	-	-
September	0.42	1:35 ± 0:42	(1:05 - 2:05)
November	1.27	-	-
December	0.41		-
Average ± SD	**0.62 ± 0.37**	**0:53 ± 0:21**	**(0:30 - 2:05)**
1991			
January	0.79	1:00 ± 1:03	(0:15 - 1:45)
February	1.60	0:40 ±0:04	(0:35 - 0:45)
May	0.30	-	-
July	0.52	2:11 ± 0:46	(1:45 - 3:55)
August	0.61	1:36 ± 0:10	(1:25 - 1:50)
September	1.17	1:06 ±0:07	(0:55 - 1:15)
Average ± SD	**0.83 ± 0.47**	**1:28 ± 0:45**	**(0:15 - 3:55)**
1992			
February	0.80	-	-
June	0.88	0:54 ±0:07	(0:45 - 1:05)
September	0.57	-	-
October	0.74	1:10 ± 0:37	(0:35 - 2:25)
November	0.71	1:15 ± 0:28	(0:55 - 1:35)
Average ± SD	**0.74 ± 0.12**	**1:03 ± 0:27**	**(0:35 - 2:25)**
AVERAGE ± SD OVER THREE YEARS	**0.71 ± 0.36**	**1:04 ± 0:32**	**(0:15 - 3:55)**

Note: (1). These rates are based on observation periods of ≥ one hour. Time observing Dillenia while incubating is excluded from calculations.

The highest defaecation frequencies were recorded in February 1991 (1.60 defaecations per hour), which corresponded with the fruiting of White Apple, *Syzygium forte*. In one 2 h 40 min period, Dillenia defaecated five times a total of 241 *Syzygium forte* seeds, which in fresh weight is equivalent to 5.3 kg of *Syzygium forte* fruit. During this period all scats contained only *Syzygium forte* seeds; the pericarp on approximately 30% of which remained fully or at least partially intact. Such high defaecation frequencies, together with the considerable amounts of undigested fruit evident in the dropping samples, suggests very low retention time of *Syzygium forte* in the digestive tract. This is supported by observations made on a captive subadult which had been starved for 12 hours and then fed *Cordyline* spp., a retention time for this food item of just 20 minutes was recorded (Storch, D. pers. comm, 1991), and the estimated retention time of food in captive chicks of between 68 and 72 minutes (Reid, 1987).

While not assessed in this study, I predict that defaecation frequencies will vary considerably with quality and quantity of food available. With Dillenia's monthly defaecation ranging from 0.24 to 1.60 per hour, number of defaecations (droppings) could range from 2.4 to 16 per 10 hour day at different times of the year. It would therefore follow that low frequency of defaecation, which would be translated into low scat counts during general field surveys, may indicate periods of low food availability or high digestibility rather than low cassowary numbers. The relationship between monthly detection rates of scats and sightings of different individuals confirms this assumption (Figure 8.5). Although there was considerable variation in the detection of scats between months (mean ± SD = 2.59 ± 4.11 per hour, range 0.03 - 20.00, n = 653.25 hours), scat detection rate was not significantly correlated with the number of different individuals in the study site [$r (n = 23) = -0.156, p > 0.05$]. Therefore the use of scat density as an indication of cassowary density will lead to erroneous conclusions.

Peaks and troughs in scat detection rates occurred in different months each year, the distribution of which appeared to parallel the various patterns of fruit productivity. For example, the peak in detection of scats in May, June and July, 1990, corresponded with Broad-Leaved Lilly Pilly, *Acmena hemilampra,* being the dominant component of the diet[11] in these months (67.2%, 72.4% and 84.1% respectively), and the November 1991 peak corresponded with the prolific fruiting of Swamp Satinash, *Syzygium angophoroides* (34.7% of the diet in this month). The highest peak in detection of scats, February 1991, once again corresponded with the fruiting of White Apple, *Syzygium forte*, which accounted for a considerable 97.8% of the diet. Finally, the peak in

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[11] Diet has been established from both food intake and scat analysis.

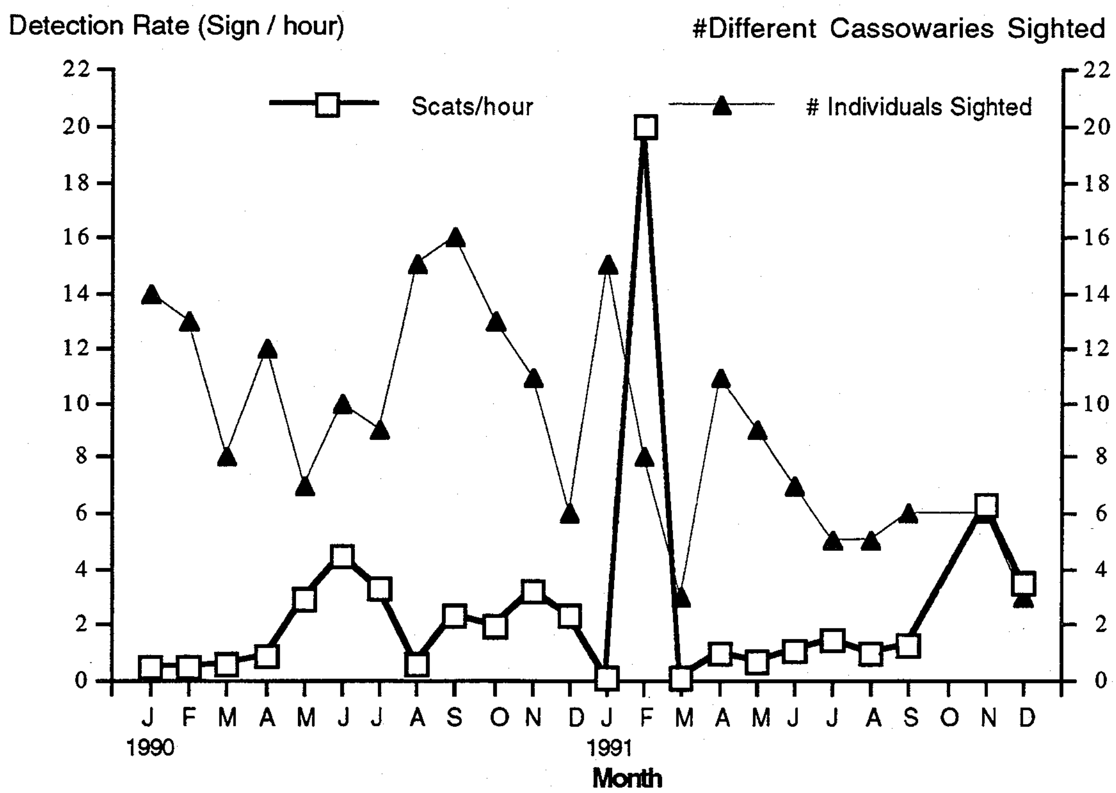

Figure 8.5 Detection rates of scats per hour of search effort and counts of different individuals in the study site, individuals per hour of search effort, in 1990 and 1991.

November 1991 corresponded with the fruiting of Dugulla, *Planchonella chartacea*, (42.2% of the diet in that month).

8.3.2.3 Water Intake

Water intake and time of day Drinking sessions were distributed throughout the day (Figure 8.6). The first drinking session observed occurred between 0900 and 1000 hours, the last 1600 and 1700 hours. However, this sample was biased because the observations were not evenly distributed throughout the day. The probability of drinking at least once during each hour of the day was therefore estimated using the following equation (Altmann & Altmann 1970):

$$\text{Probability of drinking} = \frac{\text{No. of days on which cassowaries were observed to drink at least once during the hour interval}}{\text{Total No. of days during which cassowaries were observed during the interval}}$$

Equation 8.1

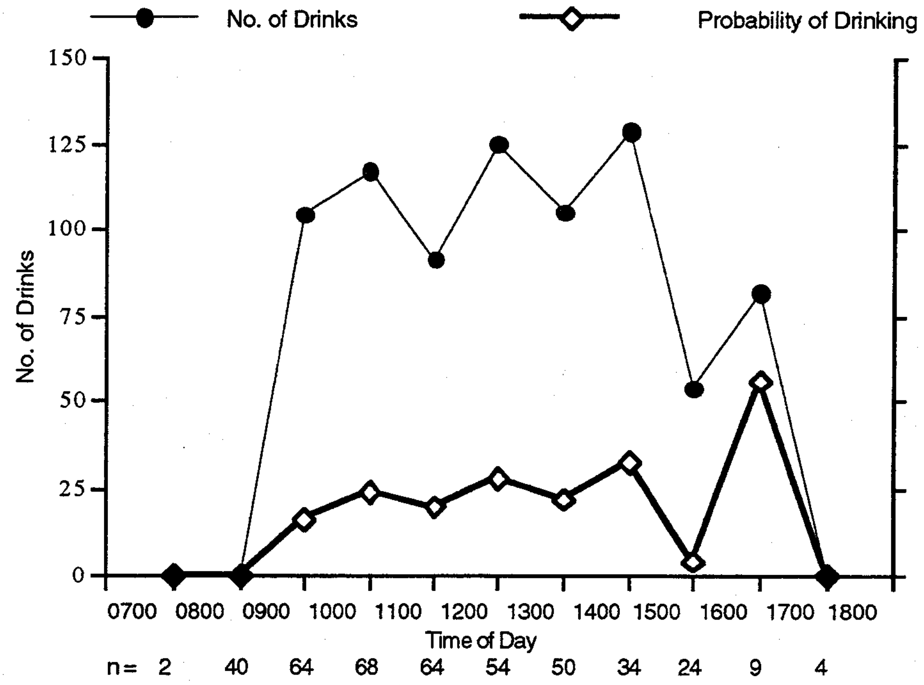

Figure 8.6 Distribution of drinking sessions throughout the day.

A peak in the probability of drinking (0.56) occurred between 1600 and 1700 hours. For the period between 0900 and 1500, the probability of drinking ranged from 0.16 to 0.32.

Water sources The adult male cassowary, Dillenia, and four chicks used three primary sources of water in this study site: (1) tree bases and (2) swamps which were both temporary, being directly dependent on rainfall; and (3) permanent creeks which were dependent on springs (Table 8.4).

Table 8.4 Drinking rates[1] (drinks, "bill fulls", per hour of observation) and frequency of drinking by the male, Dillenia, at three primary water sources.

		WATER SOURCE			
		Permanent	**Temporary**		
	N (hrs)	Creek	Tree Base	Swamp	**TOTAL**
1990					
March	10.42	-	3.84	-	**3.84**
April	10.98	-	-	1.67	**1.67**
May	50.42	0.06	0.12	1.58	**1.76**
June	10.25	-	-	-	-
August	6.24	4.01	-	-	**4.01**
September	6.10	1.64	-	1.64	**3.28**
October	1.50	-	-	-	-
November	3.25	-	-	-	-
December	3.45	-	-	4.93	**4.93**
% of drinking activity		*29.0*	*21.0*	*50.0*	*100.0*
1991					
January	6.33	-	-	-	-
February	4.33	-	-	-	-
May	13.50	-	-	-	-
July	20.10	-	0.05	1.44	**1.49**
August	6.83	0.15	-	6.30	**6.45**
September	4.50	0.22	-	0.67	**0.89**
% of drinking activity		*4.1*	*0.7*	*95.2*	*100.0*
% of drinking activity (Dillenia)		**19.0**	**12.4**	**68.6**	**100.0**
% of drinking activity (Chicks)		**28.5**	**26.7**	**44.8**	**100.0**

Note: (1) These rates are based on observation periods ≥ one hour.
(2) Percentages are calculated as number of drinks taken at that water source/total number of drinks taken.

Temporary water pools varied in size from those located in hollow tree bases (0.15 to 0.30 metres wide) to the extensive swamp system (2000 x 500 metres). They also varied with rainfall with all sources being completely inundated with clear deep water during the wet season (January to May, see Section 5.2.2.2). By the end of each dry season

(November, see Section 5.2.2.2), water in all tree bases and most of the swamps had dried up completely. What remained in the swamps was a scattering of muddy, algae-infested pools. Only one permanent spring-fed creek was located in the study site. Another was situated on the northern boundary. The Hull River, which formed the western boundary of the study site, was saline at all times of the year.

The data suggests that in this study site cassowaries were very dependent on temporary water sources, particularly swamps, at which 68.6% and 44.8% of all drinking activity for the adult and chicks respectively was observed. The use of swamps as a water source was highest in 1991 for the adult (95.2%). In contrast to the temporary water sources (combined use = 81.0% adult; 71.5% chicks), the data suggests that permanent creeks are used less frequently (19.0% adult; 28.5% chicks). This is to be expected given that only two small creeks were located in and at the boundary of the study site.

The decision to use a particular water source is obviously dependent on water availability but it may also partially depend on the location of the foraging range at a particular time of year. For example, despite the extremely poor quality of the swamp water, which by the end of each dry season was often reduced to small mud holes (≅ 45 cm x 20 cm), and required the birds to walk up to 30 cms deep in mud in order to drink, Dillenia and chicks continued to use this source. The permanent creek which was ≅ one kilometre from their current foraging area, but still within their home range, was not used as an alternative. Nevertheless, it must be noted that in spite of improved quality of water, the permanent creek was also reduced to a small pool.

Frequency of drinking The adult cassowary were observed to drink at the rate of 2.39 drinks per hour while chicks drank at the rate of 2.46 (± 1.32 SE; Table 8.5). The number of drinks taken per drinking session averaged 8.28 (± 1.06 SE; range 1 to 33, n = 52) for the adult, and 7.89 (± 1.29 SE; range 2 to 29, n = 50) for the chicks, while the number of drinking sessions per hour of observation was 0.33 (adult) and 0.30 (± 0.12 SE; chicks). During those continuous observation periods when I recorded multiple drinking sessions, intervals between sessions ranged from 10 mins to 275 mins (mean ± SD = 105 mins ± 75 mins; n = 32). The highest number of drinking sessions recorded in one continuous observation period (5 h 50 min) was five during which a total of 23 drinks were taken. However, on one occasion, even after a continuous observation period of 6 h 30 min, drinking was not observed at all[12].

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[12] Despite Dillenia coming into contact with water twice during this tracking period, he failed to drink. It rained continuously throughout this day. Majority of the food intake for tracking period consisted of *Ficus hispida* (69.3%). This fruit may well have contained sufficient water to obviate the need for drinking or been damp from the rain.

Table 8.5 Details of water intake for the male, Dillenia, and four chicks.

Age Category	No. of hours observation	No. drinks per hour	No. drinking sessions per hour	No. of drinks per drinking session
Adult (n = 1) Dillenia	**158.33**	**2.39**	**0.33**	**8.28 ± 1.06 n = 52 sessions range = 1 - 33**
chicks (n = 2) Alata & Boronia	128.00	1.14 ± 0.005	0.18 ± 0.01	6.29 ± 0.84 n = 22 sessions range = 2 - 15
chicks (n = 2) Cowleyana & Daemeliana	68.00	3.78 ± 0.46	0.41 ± 0.03	9.18 ± 1.55 n = 28 sessions range = 3 - 29
Chicks (n = 4)	**196.0**	**2.46 ± 1.32**	**0.30 ± 0.12**	**7.89 ± 1.29 n = 50 sessions range = 2 - 29**

8.3.3 Movement Patterns

8.3.3.1 Daily Movement Patterns

Progression rate Average daily travelling rate of cassowaries was observed to be measured at 0.381 km per hour (± 0.039 SE, range 0.041 - 1.129, n = 159 hours). The longest distance travelled in one continuous tracking period (6 h 25 min) was 4.420 km. However, in one 10 hour continuous tracking period, a total distance of 4.340 kms was covered. Movement during foraging was typically much slower (0.118 km per hour) than that preceding movement to foraging and/or drinking areas (0.92 km per hour).

Day-journeys Single day journeys of the same individual at different times of the year suggest that seasonal movement patterns of cassowaries within their home range vary. Figure 8.7 provides an example of how varied day-journeys were for the same target individual (Dillenia) in two different months and two different years. In May, 1990, the day-journey chosen as an example was concentrated in and around the swamp forests, where, in a 5 h 50 min tracking period, Dillenia only travelled 0.853 km. This slow progression rate of 0.146 km per hour was associated with foraging on the fruits outlined in Table 8.6.

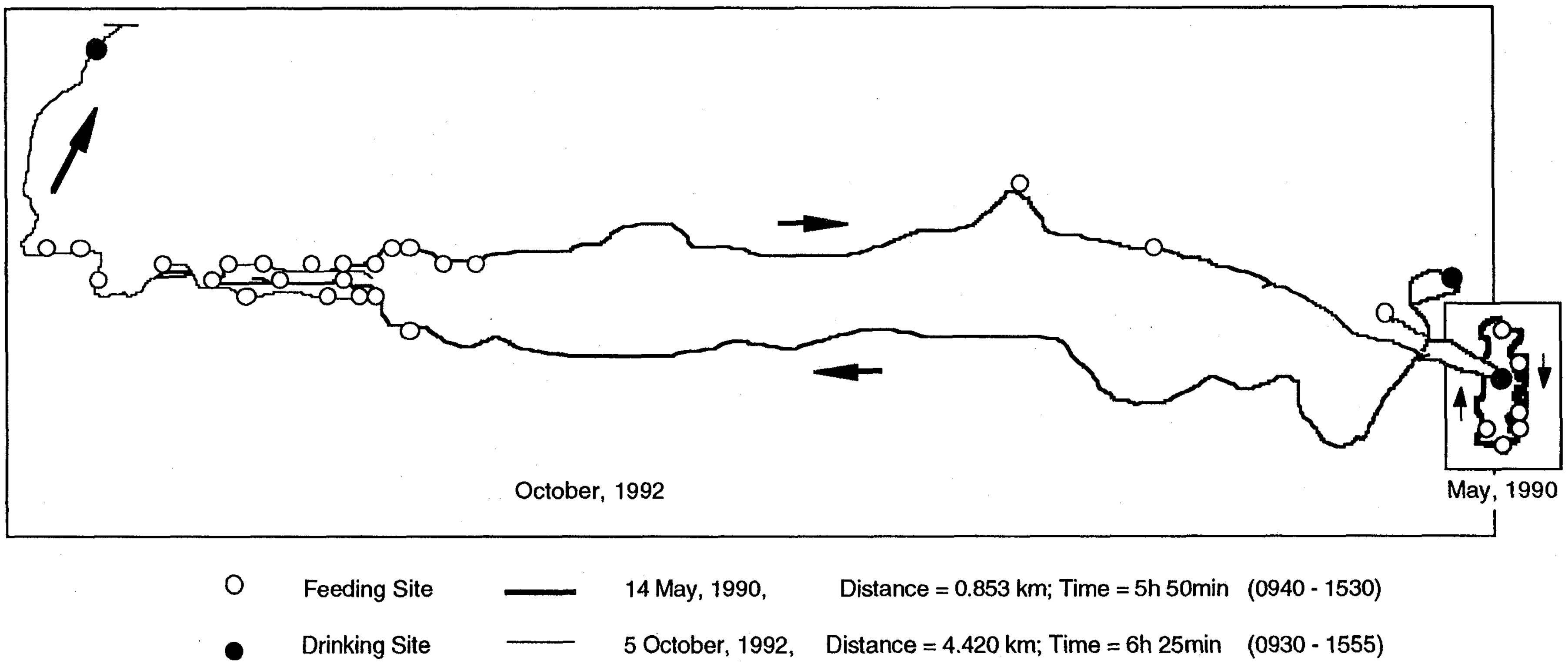

Figure 8.7 Two day-journey routes of the male Dillenia showing feeding and drinking sites.

Table 8.6 Fruits consumed by Dillenia on 14 May 1990 in a 5 h 50 min tracking period.

Common Name	**Species**	**No. of Fruits**	**Percentage of Diet**
Broad-leaved Lilly Pilly	*Acmena hemilampra*	683	57.1%,
Quandong	*Elaeocarpus eumundi*	281	23.5%
Brown Walnut	*Endiandra montana*	232	19.4%,
Total	3	1196	100%

A total of 41 trees of these three species were located within this ≅ 0.18km^2 section of swamp and rainforest-swamp edge. Under all Broad-leaved Lilly Pilly, *Acmena hemilampra* trees a carpet of ripe fruit existed at the time (≅ 1,000 per m^2). During foraging, progression was continuous but slow, with the bird never consuming all fruit available in one spot. The dominant activity for the period was foraging (67.1%), with the remaining 32.9% of the time spent resting and preening. In addition to the clumped distribution of the food supply, water was plentiful in the area, and as breeding activity had just begun, the female was approaching the male, leaving him to continue foraging rather than having to travel outside of his foraging range in order to seek her out (Chapter 7).

In contrast, on 5 October 1992, Dillenia travelled 4.42 km during a 6 h 25 min tracking period. This progression rate of 0.69 km per hour appeared to be largely associated with travelling to foraging and drink areas. Dillenia spent 44.4% of the time travelling, 40% foraging and 15.6% resting and preening. The need to travel more was obviously linked to the food sources being far more sparsely distributed (55 trees in ≅ 1.08km^2). Furthermore, the number of fruiting species consumed during this period was greater (n = 9; Table 8.7).

Table 8.7 Fruits consumed by Dillenia on 5 October 1992 in a 6 h 25 min tracking period.

Common Name	**Species**	**No. of Fruits**	**Percentage of Diet**
White Aspen	*Acronychia acronychioides*	418	15.6%
Tarzali Silkwood	*Cryptocaryia oblata*	1	0.05%
Northern Tamarind	*Diploglottis diphylistegia*	1311	49.4%
Northern Rose Walnut	*Endiandra hypotephra*	5	1.7%
October Glory	*Faradaya splendida*	1	0.05%
Bollywood	*Litsea leefeana*	359	13.4%
Pandanus	*Pandanus spp.*	27	1.0%
Solitaire Palm	*Ptychosperma elegans*	445	16.6%
Onionwood	*Syzygium alliiligneum*	35	1.2%
Unidentified		39	1.3%
Total	9	2641	100%

8.3.3.2 Differential Use of Habitats

The findings show that in each of the two-month survey periods cassowaries used rainforest, swamp and woodland habitats with swamp habitat being the most important in 9 of the 12 two-month periods (Figure 8.8). In addition, all four primary habitat types, rainforest, swamp, woodland, and beach/foreshore (Section 5.2.2.3), were used by cassowaries in this study. The amount of sign (sign per hour search effort) relative to habitat availability (per hectare) in the study site, was highest in the swamp habitat (mean ± SE = 0.096 ± 0.002, range 0.026 - 0.324), followed by woodland (mean ± SE = 0.027 ± 0.009, range 0.0.003 - 0.104), beach/foreshore (mean ± SE = 0.026 ± 0.018, range 0.0 - 0.178), and finally rainforest (mean ± SE = 0.018 ± 0.005, range 0.003 - 0.064). Furthermore, there was a significantly greater visitation of the swamp habitat compared to all remaining habitats [F (3, 44; n = 47) = 5.233, p = 0.0035; Fisher's PLSD]. Clearly, the preferred habitat for cassowaries in the Kennedy Bay National Park was the swamp habitat. There was no significant difference between 1990 and 1991 in the use of any of these habitats. This is probably because the variability was so great rather than the patterns were the same.

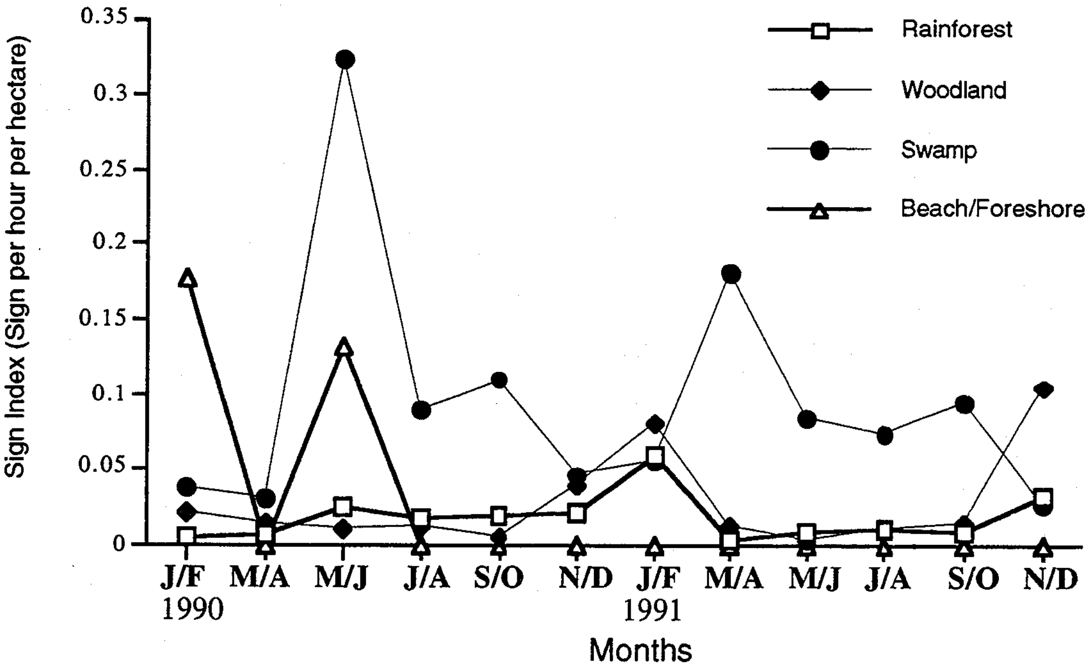

Figure 8.8 Detection rates of sign of cassowaries in the different habitat types.

The occupation of each habitat varied from month to month which parallelled in part the seasonal changes in fruit supply evident in the diet (Section 8.3.2.2). For example, in May / June 1990, the preferential use of the swamp habitat corresponded with the abundance in the diet of the rainforest-swamp edge species, Broad-Leaved Lilly Pilly, *Acmena hemilampra*, (72.4% and 84.1% respectively); and in March / April 1991 it corresponded with the abundance in the diet of the swamp species, Alexandra Palm, *Archontophonix alexandrae*, (53.0%).

8.4 Discussion

8.4.1 Activity Patterns

Accommodating basic needs such as foraging, travelling, preening and 'other' activities, including defaecating, vocalising, etc., accounted for 80% of the daily activity of cassowaries, while inactivity to conserve energy accounted for 20% (Figure 8.1). These activity patterns are consistent with the activity levels of another ratite, ostriches, *Struthio camels*. Pre-nesting male and female ostriches spent 33% of their daylight hours feeding, 29% travelling, and 9% preening Bertram (1992).

Continuous daily movement associated with foraging suggests that a cassowary's possible need to conserve energy may be overridden by the need to continue searching/foraging. Another possible explanation is that this continuous movement aids digestion. In addition, it appears that foraging and travelling were not displacing each other, that is, cassowaries were both constantly on the move while foraging and constantly foraging while travelling. In contrast, the reduced travelling time during the morning and afternoon "peaks" in foraging suggests that during these periods cassowaries were exploiting a foraging patch with greater food density (Pianka, 1978; Stephens & Krebs, 1986), especially since either activity was not displaced by resting. In general, this pattern of activity suggests that cassowaries exploit those parts of their home range which are most productive at any one time (Figure 8.7; Stephens & Krebs, 1986).

In addition, direct travelling to various foraging and drinking areas gave the impression that cassowaries are familiar with the locations of these food and water sources and that they integrate their experiences over time (Cuthill et al., 1994; Krebs & Kacelnik, 1991). This suggests that they were orientating on the basis of memory (Beddekoff et al., 1997), and that familiarity with their home range enabled them to exploit with greater efficiency the seasonality of various fruits and changes in the water sources. This would be considered a reasonable assumption considering the longevity of the birds.

8.4.2 Foraging Strategies, Diet and Seasonality of Supply

This study confirmed that cassowaries are predominantly ground foragers. From general observations it appears that variability in foraging techniques among the different age classes may have been influenced by such factors as morphology (overall size of bird) and experience/age (Moermond, 1990). Furthermore, some partitioning of food may have been implemented by use of different sizes of fruit by these different age classes. While the significance of alternative strategies was not assessed, they obviously play an important role in further increasing the diversity of food items accessible to cassowaries (Moermond et al., 1987). Cassowary chicks clearly acquire foraging skills through "learning", an important mechanism in many animals (Giraldeau et al., 1994; Stephens, 1991).

A diversity of food items including fruits and other plant foods as well as animal and invertebrate matter and inorganic substances, were present in the diet of this lowland population of cassowaries at all times of the year. By frequency of item present fruit, however, comprised the bulk of the diet (99.8%), confirming previous findings that cassowaries are obligate frugivores, being primarily dependent on fruit for their survival (e.g., Crome, 1976; Stocker & Irvine, 1983). Although the minimum of 91 identified plant species present in the diet was somewhat higher than Crome's (1976) and Stocker and Irvine's (1983) findings of 67 and 78 plant species respectively, these studies, together with this diet analysis, identify a total of 172 different plant species from 56 families in the diet of cassowaries. This large number of fruit species and the diversity of 'other' items represented in their diet suggests that cassowaries are relatively flexible and opportunistic in their use of fruits in particular, and food in general. Given that their mobility is restricted by flightlessness and the distances they can travel restricted by a home range structure (Chapter 6), their dietary requirements obviously have to be met by opportunistically using all available foods within these home ranges apart from times of glut in supply. Furthermore, the diversity of food types used supports the notion that total frugivory is most probably rare, particularly amongst young birds (Crome & Jones, 1990). The attention given by the male Dillenia to identifying and supplying high protein food items for his chicks, for example, earth worms and insects (Section 8.3.2.2), while failing to consume them himself, suggests that this high protein source may well constitute an essential dietary supplement for chicks.

The diet analysis also showed that many important plant species used by this cassowary population fruit synchronously, with the sequence of plant species present in the diet remaining basically the same over the three year period. This corresponds with a number of studies on the phenology of tropical species (e.g., Crome, 1975; Dennis, 1997; Stocker & Irvine, 1983), which demonstrate the seasonality of many fruits. However, as evident from the analysis, the time of appearance and disappearance of the fruit in the diet shifted slightly from year to year, which may well be related to a shift in the initiation and termination of fruiting due to varying weather conditions (Foster, 1977). Assuming that cassowaries will seek out and consume a food item once it becomes available, this dietary analysis also suggests that the actual period of fruiting of a number of species varies considerably. For example, Solitaire Palm, *Ptychosperma elegans,* was present in the diet for up to seven months although in low numbers in the beginning and end of this period. On the other hand, a species such as *Acmenasperma claviflorum* was present for only two months. For other species, their presence in the diet may appear to be unusually long. Two explanations are offered for this finding. The first is that cassowaries consume the blossoms as well as the fruit of some species, for example, Bumpy Satinash, *Syzygium cormiflorium,* White Apple, *Syzygium forte, Pandanus spp.* and Mistletoe, *Amylotheca dictyophleba* (the leaves of this species were also consumed). With these items included in the diet analysis, this would partially explain the early appearance of these plant species in the results presented. The second explanation is based on observations made during foraging sessions and partially explains the late appearance of some species such as Brown Walnut, *Endiandra montana.* Cassowaries were observed to occasionally consume just bare seeds, which may well be related to the need for "filler" at times of low food availability or the need to add roughage to aid digestion since the consumption of rocks was rarely observed (Barlein, 1996).

In line with this phenological perspective, the current diet analysis also suggests that the reliability of some plant species on an annual basis varies considerably. For example, Broad-Leaved Lilly Pilly, *Acmena hemilampra,* was the most important food item in the diet in June and July 1990 and 1992, but appeared in very low numbers during the same period in 1991; White Apple, *Syzygium forte* accounted for 97.8% of the diet in February 1991 and only 0.3% in February 1992. Such yearly variation and even failure of crops was evident in many species. However, for some species such as Brown Walnut, *Endiandra montana* , and Quandong, *Elaeocarpus eumundi* , which dominated the diet in April 1990 (69.9% and 22.4%), partial crop failures appeared to extend beyond two years with only traces of these species present in the diet in 1991 and 1992. These therefore could be considered as more-favoured atypical plant foods which, when in high abundance, may be displacing normal foods (Innis & McEvoy, 1992).

Cassowaries are able to cope with increased variation in fruit availability by: (1) large home ranges (Chapter 6); (2) low population size and densities (Chapter 6); (3) their ability to travel reasonably large distances (Figure 8.7); (4) the diversity of foraging strategies adopted (Section 8.3.2.1); and (5) their ability to use a wide range of food sources (Appendix A.4.1). During times of high fruit abundance, evidence of discrimination among fruits of different quality was apparent, with spoilt or old fruit being rejected. On the other hand, in times of fruit scarcity, cassowaries were much less selective and consumed all or most fruits available. Such findings are consistent with other studies on food choice in frugivores (e.g., Foster, 1977; Moermond & Denslow, 1983).

In this study it was clear that a considerable variation in scat sign can occur from month to month, year to year (Figure 8.6). This highlights the erroneous conclusions that can be drawn when using scat density as an indication of cassowary density and scat presence/absence as a measure of cassowary presence/absence. Census surveys therefore must not associate scat numbers with population size.

Cassowaries drink water at all times of the day (0800 to 1700; Figure 8.6), and year (Table 8.4). While it is clear that cassowaries can endure long periods of no water intake (Chapter 7 - incubating males), the frequency at which they drink during a normal day suggests that water is an important component of their diet. However, studies on emus found the water requirements of this ratite to be relatively low (Dawson et al., 1983), and although they will drink daily if conditions are hot and water is available (Dawson et al., 1984), they have successfully adapted to arid habitats by the conservative way in which they handle their water and electrolyte regulation (Dawson et al., 1985).

In this study site sources of drinking water included permanent creeks, tree bases, and swamps. Swamps were the most frequently used (Table 8.4), and for most of the year were the largest and most readily accessible water source for all resident cassowaries. The distribution of the swamp system throughout the study site ensures that all home ranges encompassed at least a portion of a swamp system during the wet season (Chapter 6). Nevertheless, swamps are temporary sources and quality and quantity fluctuates considerably. During the hot, dry period (October to December) when the water in swamps was at its lowest level, what little water remained was greatly impacted by feral pig activity, thus reducing its quantity and potentially impacting on the cassowary's ability to obtain adequate water.

8.4.3 Movement Patterns and Habitat Use

During their normal day routine and when not resting, cassowaries are continuously on the move and foraging (Figure 8.2), which means in a 10 hour day they travel on average 3.8 kms. However, the actual distance travelled in any one day can range from as little as 0.853 km in 5 h 50 min to 4.420 km in 6 h 25 min. The pattern of movement associated with this distance travelled, together with foraging activity, suggests that the distribution of food resources in both time and space and the quality and abundance of those food resources is the most likely influence on progression rate, particularly in the nonbreeding season. Furthermore, this pattern of movement clearly demonstrates that cassowaries use their home range differently at different times of the year. In any one day and possibly even over the period of a month they will not cover their whole home range (Chapter 6), but rather exploit a section of the home range which provides the essential requirements for food and water at that time. Obviously, when resources are clumped in space, an individual can restrict its activities to a small area of high resource density, as evident in May 1990 (Figure 8.7). On the other hand, when resources are widely distributed, much larger areas of the home range need to be covered, as evident in October 1992 (Figure 8.7). In the nonbreeding season, movement patterns of cassowaries can be explained primarily by distribution and abundance of food, which in turn is dictated by the fruiting phenology of the forest.

The diet analysis and the assessment of movement patterns shows that cassowaries in their natural environment use a complex array of habitats including rainforest, swamp, woodland and beach/foreshore. All of these habitats were found to provide their essential requirements of food and water and so could not be considered as commuting areas only. Habitat usage based on scat, sighting and vocalisation detection rates supports this finding (Figure 8.8). Furthermore, the most important habitat for cassowaries was swamps, which were used throughout the whole year, but to varying degrees each month. However, while some habitats may be important only briefly in the annual cycle of food production, the significance of these short periods may be critical to the survival of those birds whose home ranges encompass them. Such habitats should therefore not be dismissed or devalued without further studies. The pattern of use of habitat types was found to parallel the phenology of fruits in each of the habitat types.

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Chapter 9

Key Conservation and Management Issues

9.1 Introduction

The biological characteristics of cassowaries and the principle threats are two of the primary determinants of sound conservation strategy. This study has provided a preliminary overview of both of these determinants. When setting management objectives, managers have to know a species' biological, behavioural and ecological requirements and the relationship to be conserved, which involves monitoring population trends in space and time, identifying and assessing impacts on these trends, developing management strategies in response to these trends, and evaluating strategies in place. In this chapter I explore a number of management themes and suggestions for ways of addressing key conservation and management issues based on evidence from the analyses presented in the preceding chapters.

9.2 Free-living Cassowaries in their Natural Environment

9.2.1 Key Biological Characteristics

All age classes of cassowaries were well represented in the Kennedy Bay National Park study site, occurring at an average density of 7.62 per km^2 (3.55 adults per km^2; Chapter 6, Table 6.7). Annual variation in density was most evident in the subadult and chick population, which reflected reproductive success and possibly dispersal (Chapter 6, Table 6.4). The population density was lowest in 1991, which was most likely due to the availability of fruits being lower in that year compared to 1990 and 1992 (Chapter 6 & 8; Dennis, 1997). The adult population remained stable during the study period, both in size and resident individuals. The absence of seasonal long distance migration or permanent emigration meant that the same adults were present at all times (Chapter 6, Table 6.4). The age structure of this population was skewed toward adult birds (Chapter 6, Table 6.2), with low annual birth rates (0.24) and subadult recruitment rates (0.15), and high adult survival (0.87) maintaining this relatively stable adult population. The most "fragile" part of the cassowary life cycle was the survival of young birds to become established into the breeding population.

Cassowaries were solitary and territorial with stable home ranges (mean male range 0.65 km^2; mean female home range 0.86 km^2; Chapter 6, Table 6.8). All or part of the home range was shared with other individuals of all ages and both sexes. Intersexual home range overlap was extensive (90 - 100%). On the other hand, same sex home range overlap was minimal (males 10.2%; females 21.2%), with aggressive encounters occurring at borders and in overlap areas. Only part of the home range was used at any one time during the nonbreeding season, which appeared to be primarily associated with seasonality and distribution of fruits (Chapter 8).

The duration of the cassowary breeding season ranged from 88 to 123 days (Chapter 7, Figure 7.1), and occurred in the months May to December. Courtship and mating was found to vary in duration (42 to 92 days), time of year (May to September), and the time of day (0800-1600; Chapter 7, Figure 7.2) the activity occurred. It also varied in length of a courtship session (26.90 minutes ± 20.02 SD), and with respect to initiator of courtship (female 62.5%; male 37.5%; Chapter 7). While both sexes had access to multiple partners (males 2 to 4 partners; females 4 to 6 partners; Chapter 7, Table 7.1), the mating strategy observed was simultaneous polygyny, with two females pair-bonding with a single male in a breeding season. Male cassowaries were solely responsible for incubation, which lasted at least 49 days. Incubation was a period of starvation and inactivity for males (95.4% of their time was spent totally inactive; Chapter 7, Table 7.4). Parental care was the sole responsibility of males, with offspring remaining dependent on the male parent for at least 184 days (average 377.2 days; Chapter 7, Figure 7.1). This considerable male investment in parental care meant that the availability of males was a limiting factor in annual breeding. Reproductive success was found to be low, with a male raising as few as 0.67 young to independence each time it nested.

Cassowaries were active throughout the day, mainly foraging and travelling (69.71%), with inactivity and miscellaneous activity accounting for 27.46% and 2.83% respectively (Chapter 8, Figure 8.1). Foraging activity peaked in the morning between 0800 and 0900 and in the afternoon between 1700 and 1800 (Chapter 8, Figure 8.2). Cassowaries were predominantly ground foragers (95.1%), pecking fallen fruit and other food items from the forest floor. The other principal foraging strategy was a retrieval technique (4.9%) which involved a number of tactics to obtain the food item from its source or place of lodgement. Fruits (native and introduced) comprised the bulk of the cassowary diet throughout the year (99.8%, Figure 8.4), confirming previous findings that they are obligate frugivores (Crome, 1976; Stocker & Irvine, 1983). As with other cursorial frugivores (see for example Dennis, 1997), the diet was supplemented with additional items, including plant foods (blossoms, leaves, fungi), animal and invertebrate matter (toads, birds, cicadas, beetles, worms, snails, eggs), and inorganic substances (soil, rocks and shells). Although less sought after than fruits, some of these items may be important in that they provide critical protein and mineral supplements.

Cassowaries used a complex array of habitats including rainforest, swamp, woodlands and beach/foreshore (Chapter 8, Figure 8.8), all of which provided food (Chapter 8, Section 8.3.3.2), and some of which provided water (Chapter 8, Table 8.4) at various times of the year. In the nonbreeding season movement patterns reflected the seasonality and spatial variability of food supply in the home ranges (Chapter 8, Figure 8.7). Therefore, all of the home range was rarely covered in a single day or even month.

9.2.2 Principle Conservation and Management Implications

The implications for cassowary conservation and management of the results from this study are several and significant. Firstly, the low density (Chapter 6, Table 6.7) at which this long-lived species occurs makes it particularly vulnerable, because of the large areas of habitat required (Chapter 6, Table 6.8) to sustain the population (Pimms, 1991). In addition, it appears that animals with a large body-size have greater variation in density with location compared to small-bodied animals (Pearl, 1992). This would suggest that cassowaries may be more vulnerable to localised extinction because human disturbance may differentially affect their densities.

Secondly, adult cassowaries are unlikely to be able to shift their home range into adjoining cassowary territories in the event of total habitat loss, degradation or other incursions, because of their solitary social organisation (Chapter 6). Therefore, in the event of any diminution of a cassowary territory that impacts on the carrying capacity of that territory, a bird is likely to perish or fail to produce offspring. The solitary social organisation and stable home range structure of cassowaries (Chapter 6, Figures 6.1 and 6.2) also has implications for translocation[1] of adult birds should this be considered as a management option in situations of "problem" or "at risk" birds[2]. Translocation of one adult bird into another area is likely to result in considerable competition between conspecifics which would result in the displacement of a resident adult or the eventual loss of the translocated adult, because territorial behaviour ensures that surplus individuals are excluded, to die or leave (Newton, 1991). In addition, longevity and hence familiarity with the location and seasonality of resources in their own home range suggests that adult cassowaries may be unable to adapt quickly enough to new areas, particularly if they are areas of suboptimal habitat. Another important consideration in translocation is the transmission of disease and possibility of genetic pollution (Pearl, 1992).

Thirdly, cassowaries are not capable of a rapid reproductive effort. Substantial male parental investment (Chapter 7, Figure 7.1), low chick survivorship (Chapter 7, Figure 7.3), and low annual productivity (Chapter 7, Section 7.3.6.1), means that cassowaries are unable to re-establish a devastated local population after a major disaster, natural or unnatural, or to rapidly recolonise an area from which a population has been eliminated. This is because the rate at which a population recovers from a decline depends in part on the species' reproductive rate (Pimms, 1991). Furthermore, cassowary populations contain a larger proportion of adults to subadults and chicks. Any alteration of the age structure will lower reproductive output and slow population recovery. Another factor that acts against the cassowaries is their long-deferred maturity. This means that, after a decline in population, it may take many years for numbers to recover.

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[1] "Translocation" is defined as the intentional movement of a bird from one area with free release to another (IUCN, 1987, in Armstrong & McLean, 1995).

[2] So called "problem" birds refer to those situations where cassowary-human interactions are potentially dangerous mainly because hand feeding has resulted in habituation of birds. "At risk" birds are those which are unlikely to survive due to road crossings, loss of habitat, lack of water, etc.

9.3 Conservation Area Considerations

Because of the considerable anthropogenic changes to the landscape, many species now exist as metapopulations (Levins, 1968), with unnatural habitat heterogeneity from clearing, creating a series of subpopulations which interact by dispersal between them (Carroll et al., 1996; Caughley & Gunn, 1996; Meffe & Carroll, 1994; Newton, 1991; Simberloff, 1988). Key conservation and management issues relevant to the recovery of cassowaries that arise out of such a fragmented landscape include: the extent of habitat which must be set aside to protect a species such as the cassowary; the appropriate number, size, and configuration of conservation areas; and the functional connectivity between habitat patches.

9.3.1 "Core" Conservation Areas

> **Management efforts would be most productive if they were directed at ensuring that the Kennedy Bay National Park, a potential "source" population of cassowaries, receives maximum protection.**

Kennedy Bay National Park is an important area to the conservation of cassowaries because it supports a stable and what appears to be a high density adult population (density range 3.45 - 3.76 per km^2), and subadult and chick populations with density ranges of 1.57 - 2.15 subadults per km^2 and 1.25 - 2.82 chicks per km^2 (Chapter 6, Table 6.7). Furthermore, and perhaps even more significant is the high adult survivorship (0.87) and a birth rate (0.24) which exceeds the death rate for chicks (0.20). These findings suggest that Kennedy Bay National Park is an area which produces sufficient young each year to maintain this adult population at a stable level and surplus young (Chapter 6, Table 6.4) for dispersal into the nearby Mission Beach area.

Given these demographic factors and the evidence available on the impact of human settlement on chick mortality and breeding densities in the nearby Mission Beach region (Chapter 6, Section 6.4.1.4), the Kennedy Bay cassowary population may well be a "source" population which is important to the survival of nearby Mission Beach "sink" populations (Carroll et al., 1996; Caughley & Gunn, 1996; Meffe & Carroll, 1994; Newton, 1991). Even though the breeding population continues to produce young in areas of human settlement around Mission Beach (Bentrupperbäumer, 1992b), the five fold increase in loss of chicks in this area compared to the study site and the annual mortality rate of 6 adults per year (minimum) (Chapter 6, Section 6.4.1.4), suggests that reproduction may be insufficient to balance mortality. Their survival, therefore, may well rely on dispersal from populations such as that in the Kennedy Bay National Park.

An important implication of this source-sink concept in the management of cassowaries is the careful consideration that must be given to preserving areas on the basis of habitat-specific reproductive success and survivorship (source habitat) as opposed to population density, the criteria most often used for critical habitat classification in endangered species recovery programs (Carroll et al., 1996; Meffe & Carroll, 1994). Pulliam's (1988) theoretical models of sources and sinks showed that, although just 10% of a metapopulation may be found in source habitat, it maintained 90% of the population found in the sink (Meffe & Carroll, 1994). The important point made here that "it is not necessary to destroy all the patches for the metapopulation to go extinct" (Caughley & Gunn, 1996), has significant implications for management of cassowaries. Management and conservation efforts based exclusively on population size and density rather than productivity may therefore be ineffective, and if source populations are not identified and protected in a conservation plan, obviously the whole metapopulation could be threatened (Meffe & Carroll, 1994).

While there is the emphasis here on providing maximum protection of the Kennedy Bay National Park, there is the additional concern of whether this cassowary habitat area will be viable over the long term given the clear-felling of forests in 1991 in the neighbouring private property which has isolated this park (see Section 9.3.6). Therefore, not only should maximum protection be awarded to the park, additional measures such as connectivity and protection of water sources must be considered to sustain this cassowary population. The long-term viability of this habitat island, which is surrounded by the sea, a river and agricultural activity, will inevitability depend on greater attention being given to placing stringent controls on adjacent uses and activities (Beatley, 1994) and within park uses and activities.

9.3.2 Habitat Size

> **For management purposes, it would appear from this study that a "source" population requires a minimum habitat size of 400 hectares.**

The size of a conservation area needed to sustain viable populations of animals is a key management issue that requires a complex mathematical process reliant on difficult-to-obtain data, particularly when species are rare (Caughley & Gunn, 1996; Harris & Silva-Lopez, 1992). In this study, while I was unable to provide sufficient information for such a mathematical assessment, the biological data collected over a period of three years does enable some general statements to be made about minimum habitat size for cassowaries. Firstly, a conservation area should be large enough to support at least 11 adult cassowaries, the size of the breeding population required to produce three subadult cassowaries per year (Chapter 6, Section 6.3.1.4). This is the number of subadults which appears necessary to at least sustain a stable breeding population as well as provide for subadult dispersal into marginal areas. Given caveats such as habitat quality (Section 9.3.3), environmental variations (Section 9.3.4), natural catastrophes (Section 9.3.5), and connectivity (Section 9.3.6), such a source population of cassowaries requires at the very minimum 400 ha, the area[3] occupied by this breeding population. The recent extinction of the cassowary population on Mt Whitfield, Cairns (400 ha), provides a clear illustration of the need to address environmental and demographic factors when considering the size of a conservation area (addressed in the following Sections).

9.3.3 Habitat Quality

In conservation area selection, managers must recognise the importance of habitat quality, in particular, the importance of landscape habitat mosaic, to cassowary population dynamics.

The important aspect of the source-sink concept is that the probability of maintaining a source population is not only a function of habitat size, it also depends on habitat quality (Carroll et al., 1996; Caughley & Gunn, 1996; Meffe & Carroll, 1994). As Caughley and Gunn (1996) point out, a source population "not only exists longer but fares well enough for individuals to disperse to recolonise (the) other patches" (p.159), because it occupies a high-quality habitat. On the other hand, sink populations, which occupy poor-quality and often fragmented and degraded habitats, cannot sustain their population levels, especially in the face of extrinsic forces such as natural and unnatural catastrophes.

Population size, density, age class representation, productivity, population stability and home range size are obviously important biological indicators of quality of habitat for particular species (Meffe & Carroll, 1994). The task for managers is to determine the important ecological features which are associated with these indicators. From the evidence available in this study I propose four possible ecological determinants of high-quality habitat for cassowaries: food availability; habitat heterogeneity; water availability;

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[3] This area included the 319.2 ha study site plus approximately 80 ha of neighbouring private property to the north which formed part of the home range of three adults.

and landscape features.

While this list of determinants is not intended to be final and conclusive, or to suggest that it allows for an adequate description of cassowary habitat so that lines can be drawn on maps, it does highlight some ecological features of cassowary habitat that need to be considered both in future research and when selecting conservation areas. Firstly, from the evidence available from this research, the availability of fruit throughout the year is obviously essential to provide for the predominantly frugivorous diet of cassowaries (99.8% fruit; Chapter 8). Furthermore, the need to have access to a considerable diversity of plant species is also evident. The diet analysis identified the consumption of a total of 107 plant species from 37 families at a monthly average of 19.37 species (± 1.22 SE, Figure 8.4). Such diversity appears to accommodate for the seasonality of food supply (Section 8.3.2.2).

Secondly, habitat heterogeneity is also an important determinant of "high" habitat quality for cassowaries. A complex mosaic of habitat types was used by cassowaries including, rainforest, woodlands, swamp forests and beach foreshore (Chapter 5; Table 5.1 and Chapter 8, Figure 8.8). This complex habitat mosaic within a relatively small area not only provided greater diversity of food sources, it also accounted for seasonality of supply (Section 8.3.3.2). Thirdly, availability of water throughout the year from a range of sources is essential (Chapter 8, Table 8.4). Water intake data (Chapter 8, Table 8.4 and 8.5) suggests that cassowaries require regular access to water. And finally, landscape features of the study site which may well be associated with the high-quality habitat include: (1) a predominantly lowland aspect (66% < 20m, Chapter 5); and (2) the continuous nature of the vegetation cover.

9.3.4 Environmental Variations

> **Density limitation in relation to food supply, in particular the "bottleneck" or "lean-time" period, must be considered in any management decisions on conservation area selection.**

Although various demographic factors are known to affect annual variations in species' density (Chapter 6, Section 6.3.1.4), in an undisturbed environment such as Kennedy Bay National Park, this variability may also be linked to external factors such as food availability (Chapter 6 and 8). Food supply is most likely associated with limiting adult numbers and hence determining the carrying-capacity of the site (Newton, 1991). The possibility of considerable effects on overall cassowary density of changes in food availability within an otherwise protected and stable population, has important implications for management, particularly when calculating minimum sizes and types of habitat for conservation areas.

While I did not obtain specific data on food availability, behavioural observations such as substantial intake of soil, regrowth species, and bare seeds, the death of a chick and a low birth rate (Chapter 6 and 8) provided circumstantial evidence of a food shortage in 1991. This, together with Dennis's (1997) fruit biomass data, formed the basis of the proposal that annual variability of population density and the adult population level may be linked directly and/or indirectly to food shortages (Section 6.4.1.1). Furthermore, a limitation on density is most likely specifically linked to a "bottleneck" in food supply, rather than general low food availability. This is a phenomenon not uncommon in tropical forests (Foster, 1977). Nevertheless, while the season of greatest food shortage, the "lean period", was observed only at a certain time of the year (May to July, Chapter 8) which parallels an annual cycle of lowered food availability in tropical North Queensland (Crome, 1976; Dennis, 1997), the real bottleneck may not necessarily be an annual event but rather one that occurs only in certain years, perhaps every two to three years (Innis & McEvoy, 1992).

The idea that the timing of the cassowary breeding season is adjusted in relation to food supply (Crome, 1976) was not confirmed in this study. However, the lower birth rate in 1991 (0.22) compared to 1990 and 1992, does suggest a link between annual productivity and food supply. Managers must therefore not only consider the possibility of overall density limitation due to food supply, but also productivity limitation.

9.3.5 Natural Catastrophes

> **With spatial distribution, quality of resources and population levels effected by unpredictable natural catastrophes such as cyclones, core conservation area size and number becomes an important management consideration.**

Unpredictable catastrophes present the strongest argument for saving several populations of a species (Dobson, 1996; Newton, 1991). In addition, "All demographic models of extinction probabilities for small populations converge upon the conclusion that the relationship between population size and its probability of extinction depends very heavily upon the frequency and nature of catastrophes (e.g., Ewens et al., 1987; Shaffer, 1987)" (Woolfenden & Fitzpatrick, 1991, p.554).

One natural catastrophic event which is known to affect cassowary populations is cyclones. Cyclones are an annual event along the wet tropics region of the North Queensland coast. On average one per three years actually crosses the coast during a cyclone season which extends from November to April (Goosem, 1992). Cyclones can produce wind gusts of up to 250 km per hour (Cyclone Winifred, 1986, Bureau of Meteorology), which buffet the coastal forests continuously for up to 5 days. This inevitably causes considerable disruption to cassowaries and their habitat. It has been difficult to obtain empirical evidence of the impact of cyclones on cassowary populations, particularly because many are not direct and hence not evident in the short-term. Nevertheless, observations of structural damage to the forests, "unusual" behaviour of cassowaries and mortality records following Cyclone Winifred (Bentrupperbäumer, 1988), suggest the impact may well be considerable.

The most significant structural damage to the forests as a result of Cyclone Winifred was the loss of canopy cover. Hopkins and Graham (1987) found that there was a "total defoliation of all trees greater than 3 m high accompanied by universal crown damage....to most of the canopy and subcanopy trees" (p.25). This resulted in total loss of leaves, fruits, buds and blossoms, and in many instances, complete tree crowns. The most apparent immediate effect on cassowaries of this massive and widespread canopy defoliation was heat stress[4] (Bentrupperbäumer, pers. obs. February 1986), caused by increase in temperatures at the ground level due to exposure to direct sunlight (Hopkins & Graham, 1987). The black adult plumage, while suited to cool rainforest conditions, obviously added to heat stress. The medium-term effect was food loss due to this total loss of fruits, buds and flowers. However, the interesting and unique finding reported by Hopkins and Graham (1987) was the unusual burst of flowering following this cyclonic disturbance. While this may have been highly advantageous for cassowaries in the long-term, they had to first survive the considerable "bottleneck" in food supply in the short and medium-term.

From the period February 1986 to September 1988, cassowary mortalities on roads accounted for 70.8% of all reported deaths (6.54 per year; Bentrupperbäumer, 1988). In comparison, in the period 1990 to 1992 road kills accounted for 26.4% of all reported deaths (4.67 per year, Chapter 6, Table 6.5). The considerable number of road kills in the period following Cyclone Winifred (February 1986) may have been associated with increased movement of birds for the purpose of foraging as the result of the loss of both

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[4] During the first six weeks following Cyclone Winifred (February 1986), three cassowaries (adult male, female and subadult) visited my garden daily (at different times) to sit under the garden sprinkler. Such behaviour had not been observed before nor since. In addition, they would take food and water that was supplied.

the immediate and medium-term food supply. Greater search effort would therefore have been required to obtain sufficient food. In addition, during this time birds were attracted to road sides, having become habituated to being hand fed by passing motorists. This is likely to have contributed to many of the road deaths during this period.

In the absence of habitat alteration by humans and associated threatening processes, it is speculated that cassowary populations would be as resistant to a natural catastrophic event such as a cyclone as many other native animals in the region. However, it is current circumstances of considerable habitat fragmentation and loss and increased pressures from roads and dogs (Section 9.3) that leave the much smaller and fragmented subpopulations of cassowaries vulnerable in the event of a natural catastrophe such as cyclones.

9.3.6 Connectivity

> **Connectivity from this potential "source" population to marginal areas must be maintained to facilitate the dispersal of offspring.**

Dispersal of subadult cassowaries from the natal area must occur in order to maintain the genetic viability of local populations and to "encourage metapopulation dynamics whereby a declining population in one reserve might be rescued by dispersal from another" (Caughley & Gunn, 1996, p.325). Because of this link between populations through dispersal of offspring, "the fate of populations is interconnected" (Carroll et al., 1996). As is evident from the stability of the resident adult population in the study site in terms of numbers and identity of individuals present, annual birth rates and annual changes in the composition of the subadult population (Chapter 6, Table 6.7), some dispersal of this subadult population has to be taking place. This is because it is unlikely that all disappearances of subadults from the natal area are due to deaths. While it remains unknown how successful this dispersal is, it is clear that as natural habitats become increasingly fragmented by human activity, movement of the subadult population becomes increasingly important to the maintenance of local populations (Newton, 1991). One of the prime ecological factors affecting transfer from source populations to neighbouring sink populations is the regime of habitat disturbance between the two populations (Blondel, 1991; Merriam & Saunders, 1993).

During this study, the habitat disturbance which occurred was the clear felling of forests in the 288 ha private property which formed a 2.2km boundary to the north of the study site. This action isolated the study site from the forests to the north (Plate 9.1).

Plate 9.1 Aerial photo showing the Kennedy Bay National Park study site and clear felling of forests (1991) in the private property to the north.

The only contiguous forest that remained was a narrow corridor (60 - 100 m) along the eastern edge of the Hull River and some isolated forest fragments. Today the narrow corridor is all that remains. The biological and management implications of this action are significant not only because of loss of habitat, but also because this private property forms the only land link for the study site. The clearing has totally isolated the Kennedy Bay National Park from the only forest tracts to the north that it can be linked with, thereby creating a *forest island* or *insular habitat* [5] (Harris & Silva-Lopez, 1992).

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[5] Harris and Silva-Lopez (1992, p.203) define insular habitat as "that which occurs when the flows of energy and matter across the habitat island edge become totally dominated by flows to or from a non forest landscape matrix".

The effects of the reduced habitat size and increased isolation on the resident cassowary population is further amplified by the severe edge effects of a 2.2 km fenced and cleared boundary. Subsequent to the clearing I occasionally observed two adult cassowaries moving across sections of this cleared land (maximum distance between forests = 200m), which was part of their original home range (Chapter 6, Figure 6.1 an 6.2). However, observations of subadults travelling through cleared areas were not made, suggesting they may have a different tolerance to open areas than adults.

The loss of so much of the forest in this private property and the very real possibility that subadults will not travel across cleared land, highlights a very important management concern - that of facilitating the movement of dispersing subadults when habitat destruction has created an insular habitat. The challenging question for managers is how can this be achieved? In the absence of any information on dispersing subadults it is extremely difficult to provide definite solutions. However, the biological information available from this study provides some insight into what can be expected.

Firstly, it is important to note that while the remaining narrow (60 - 100m) forested corridor along the eastern edge of the Hull River facilitated the seasonal movement/foraging requirements of two adults (male Dillenia and female Kamala, Chapter 8, Figure 8.8), this corridor continued to be used because it was the only forested portion of their original home range that remained in the private property. Secondly, the solitary social organisation and the fixed adult home range structure (Chapter 6, Figures 6.1 and 6.2) meant that this remaining forested corridor was only used by these same two resident adults and their offspring. Thirdly, since it is likely that subadults avoid cleared areas, in order to locate the 60m forested corridor they would have to travel along the 2.2 km cleared and fenced boundary. And fourthly, in order to avoid agonistic interactions with the two resident adults (described in Chapter 6), subadults would need to time their movement through the corridor to correspond with the period of lowest food availability because this is the time when these adults are most likely to be in other parts of their home range (Chapter 8, Figure 8.8). The success, therefore, of such a narrow linear corridor design in facilitating the dispersal of subadults is questionable.

Clearly, corridors for the purpose of dispersing subadult cassowaries have to be considered separately to those needed to facilitate breeding activities, feeding, drinking, etc. (Meffe & Carroll, 1994). Meffe and Carroll (1994) warn that, "A corridor that does not function in its intended way can actually be detrimental by serving as a "death trap" or "sink corridor" that pulls individuals away from source areas and exposes them to increased mortality but does not effectively deliver them to the intended reserve" (p.287). Clearly the efficacy of corridors remains speculative (Caughley & Gunn, 1996). The important message for managers therefore, is that reliance on a narrow linage corridor for dispersal of cassowary offspring is inappropriate given the lack of any empirical evidence. It may also be inappropriate for a male with small young given that such areas are more likely to be accessible to predators such as dogs (Section 9.4.3).

In conclusion, the markedly artificial boundary along the Kennedy Bay National Park with its fence line and cleared land are undoubtedly operating on emigration and dispersal of offspring. In the long term, the notion of completely isolated conservation areas is untenable because of the reduction of gene flow and the inability to recover from low levels should the population be impacted on by catastrophes such as cyclones, disease, predation, etc. (Western et al., 1989). Attention to planning and management of the areas between conservation reserves therefore has to be an important priority of the environmental management agencies.

9.4 Threatening Processes

Humans have caused a number of major changes in the ecological setting of cassowaries. As with most endangered species, concentrations of humans are lethal to cassowaries, acting as "spatially defined population sinks" (Mattson & Reid, 1991). As suggested in Chapter 6 (Table 6.5), the interface between cassowaries and human populations appears to correspond to a mortality gradient. It is ultimately because of the environmental context that species conservation is so critically affected by how humans impact the environment (Harris & Silva-Lopez, 1992). As habitats are lost, fragmented and degraded, essential natural resources for cassowaries such as food, water, shelter are eliminated and threatening agents such as roads and predators are increased.

9.4.1 Habitat Loss

Loss of habitat inevitably means loss of cassowaries.

There is general agreement amongst biologists that total area decrease of habitat is harmful to species in every way (Simberloff, 1988). Empirical species-area relationships demonstrate this for both community diversity and individual populations (Harris & Silva-Lopez, 1992; Simberloff, 1988). Because cassowaries are predominantly frugivorous (Chapter 8, Section 8.2.2), require access to water for drinking (Chapter 8,

Table 8.4), nest mainly in closed understorey and/or canopy areas (Chapter 7, Table 7.2), and become heat stressed after excessive exposure to sunlight (Section 9.3.5), the elements of a habitat that are critical to its survival include fruit, water, nest areas and shelter. Therefore, the conversion of a habitat from a highly diverse natural ecosystem which provides these essential elements, to cleared landscapes in which they are absent or considerably compromised, is clearly the most important threat to the survival of cassowaries. In addition, under circumstances of complete habitat loss, strict solitariness and territoriality (Chapter 6, Section 6.3.2.2) means that important and unexpected modifications of the landscape can render inaccessible part, if not all, of a bird's home range. In the event of any incursions into the home range, the bird is unlikely to be able to shift its home range into an adjoining cassowary's territory because of the social organisation. A cassowary may perish or fail to produce offspring at any diminution of its territory that impacts on the carrying capacity of that territory.

Habitat loss through clear felling of forests for agriculture (sugar cane, bananas and grazing) and residential/resort development has been most significant in regions where cassowaries exist. For example, the amount of rainforest cleared in the lowland plains (< 80 m) of the wet tropics region has been estimated at 56.9% (1983 estimates; Winter et al., 1987). What remains is extensively fragmented. Ten years later this figure is expected to be considerably higher. Species normally survive permanent habitat loss by migration and dispersal and are thus dependent on corridors of contiguous suitable habitat (Mattson & Reid, 1991). However, cassowaries do not migrate and in many instances the option of dispersal of offspring is also no longer available because of habitat fragmentation (see Section 9.3.6).

9.4.2 Habitat Fragmentation and Degradation

Small amounts of habitat degradation could lead to large decreases in population growth through the combination of loss of resources and increase in threatening processes such as roads, dogs, etc.

Although total habitat loss is clearly a very dramatic conservation and management issue, degradation of habitats and its effect on species' activity and survival is also a serious problem which must not be overlooked (Doak, 1995; Lacy, 1992; Redpath, 1995). Habitats degraded by patterns of clearing and development, logging, road systems, invasions by exotic plant species and feral animals may look superficially similar to intact habitats. However, such degraded habitats lack the food, increase the chances of predation and expose cassowaries to threats not present in their natural habitats.

Furthermore, because of the often slow transformation from optimal to suboptimal and unsuitable conditions for a species' survival, the impact of habitat fragmentation and degradation is very difficult to measure. In this study while I was unable to provide any clear evidence of the actual effects of fragmentation and degradation on cassowary populations I was able to provide some preliminary evidence of possible effects through the impact of roads and dogs.

In his research on the phenomenon of habitat degradation and its implications to the management of grizzly bears, Doak (1995) found that small amounts of degradation led to large decreases in population growth and added a warning to managers that it was not possible to assume the safety of incremental degradation - very small losses could result in rapid declines of previously stable populations.

9.4.3 Roads

Road kills represent the primary recorded known source of mortality of cassowaries.

Mortality from collisions between motor vehicles and cassowaries, particularly adults, represents the primary known source of mortality for this endangered species in the Mission Beach region (26.4%, Table 6.5, Chapter 6; Bentrupperbäumer, 1988, 1992b). Given that cassowaries are long-lived, slow-reproducing animals with high investment in parental care and low survivorship (Chapter 7), each road death will have far reaching consequences, significantly lowering of the population's reproductive fitness.

Several minor and major roads serve to fragment large tracks of World Heritage listed State Forest and other cassowary habitat areas throughout the Wet Tropics region. At minimum, these fairly high-volume traffic streams have a major isolating effect on populations existing on either side of the road (Harris & Silva-Lopez, 1992; Schonewald-Cox & Buechner, 1992). Because subadult cassowaries need to disperse from their natal areas (Chapter 6), roads may well act as a barrier to this dispersal. At maximum, these traffic streams are death traps when roads bisect the home ranges of adult birds and the movement corridors of dispersing subadults. Movement patterns of adults, which are primarily associated with foraging (Chapter 8, Figure 8.2) and breeding activity (Chapter 7, Section 7.3.2.4), mean that roads that bisect their home ranges have to be crossed at certain times of the year in order to pursue fundamental life activities.

In addition to subdividing the landscape, roads serve to remove habitat; a 30 m wide road, which is the width of sections of the main Mission Beach roads, covers 30,000m^2 for each kilometre of its length. Roads also facilitate the movement of disturbance (e.g., pollutants, exotic plant species and feral animals) in natural areas (Schonewald-Cox & Buechner, 1992). Of particular concern to cassowaries is movement of dogs (Chapter 6, Table 6.5) into their areas. Effects of edges are also known to extend for long distances into the interior of patches (Schonewald-Cox & Buechner, 1992).

Results from the cassowary monitoring program (Bentrupperbäumer, 1992b) show that in addition to simply crossing roads (92% of all road-associated sightings), cassowaries seek out roads to forage on road kills (e.g., toads, frogs, bandicoots, snakes), natural and exotic fruits growing along road edges (2%), and food supplied by passing motorists (6%), often for the purpose of a photograph. In addition, 65% of road sightings of cassowaries were recorded along sections of the road that passed through National Park, State Forest and Crown Land Reserves, while 35% were recorded on sections which passed through private land. As well as broad crossing/use areas, specific crossing points that were associated with the seasonal fruiting of a particularly food source were identified.

As traffic loads increase, there will be increased pressure for bigger roads and the road-induced mortality on cassowaries will continue to increase. In addition, as tourism increases in the Wet Tropics region[6] there will be increased pressure for easy public access to parks and in particular to cassowaries. Given the considerable impact of public roads on cassowaries, managers now face the additional dilemma with respect to the development of roads in parks. While there is a benefit to the public from access provided by roads, the increased exposure of park interiors to road-related impacts may be considerable. Preliminary results from the U.S. National Parks (e.g., Schonewald-Cox & Buechner, 1992) indicate that many of these parks may be sacrificing their ability to protect sensitive species for the sake of visitor access. The results from this study suggest that as the remaining cassowary habitat areas become increasingly surrounded and fragmented by roads and human development, the accentuated mortality rates due to vehicle collisions will eliminate many subpopulations.

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[6] Some 4.77 million visits per year are made to the Wet Tropics region (WTMA, 1996).

9.4.4 Predators

Lace Monitors, *Varanus varius*, predate on cassowary eggs and hatchlings.

Direct evidence of predation on cassowary eggs and hatchlings by lace monitors, *Varanus varius*, was obtained in this study and from incidental observations made by Mark Geyle. Predation occurred at time of hatching (Geyle, M. pers. comm. April, 1997) and abandonment of unhatched egg (Chapter 7, Section 7.3.6.2). Because males do not leave the nest during incubation (Chapter 7, Section 7.3.4), predation of eggs is more likely to occur before and after incubation. However, predation during the laying period when eggs were left unattended was not observed in this study. New hatchlings are possibly most vulnerable to predation during hatching when lace monitors are likely to be attracted by strong odours present around the nest site, or within the few months post-hatching when chicks are most vocal (Major, 1991).

While lace monitors may be severe predators and may have a considerable impact on subpopulations, it is uncertain if they are linked to the decline of cassowaries. Nevertheless, changes in habitat can lead to natural predators adding to the troubles of endangered species (Caughley & Gunn, 1996). Habitat modification and fragmentation may have altered the density of this predator to the extent that its impact is increased considerably in certain areas and/or during certain years. In order to understand the scale and nature of this predation, the next stage would be to focus on obtaining larger sample sizes in other sites to confirm low reproductive success and to examine specifically the effects of this predator on this success.

The findings from this study do not support the assumption that feral pigs, *Sus scrofa*, are significant predators of cassowary eggs or hatchlings despite evidence of high pig presence in the Kennedy Bay National Park study site (detection rate = 0.43 pigs per hour, n = 1,272 hours; Chapter 7, Section 7.4.6.2). However, a method used to eradicate pigs, pig traps, has caused both death and severe injury to all age classes of cassowaries (Chapter 6, Table 6.5; Bentrupperbäumer, 1992). The types of injuries sustained include a broken neck and broken casque and beak (Appendix A.2.3, Plates 6.14 and 6.15). As well as death from these injuries, once caught in the pig trap cassowaries often die from exposure[7] and exhaustion. The real extent of mortality due to pig traps is unknown as both the public and management agencies are not reporting such findings. With the Wet Tropics Management Authority (WTMA) actively promoting pig

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[7] Many pig traps are located in open fields and can be left unchecked for up to 5 days.

eradication using traps (300 traps available, 150 in use in 1996/1997; WTMA, 1997), the design of which has not been standardised nor definitely proven to be cassowary proof (a variety of so-called cassowary-proof pig traps continue to catch cassowaries and cause death, pers obs), I am very concerned at the long term consequences of such a pig eradicating strategy.

Dog attack on cassowaries was the second most important known source of mortality.

Results from the cassowary monitoring program indicated that dog attack on cassowaries was the second most important recorded known source of mortality (15.1%, Chapter 6, Table 6.5; Bentrupperbäumer, 1992; Appendix A.2.3, Plates 6.10 and 6.11). These attacks occurred in the rural areas and along the edges of residential development. The age class most effected by such attacks was the subadults (Table 6.5). All attacks reported for the period 1990-1992 were by packs of 2, 3 and 5 dogs (total 18 dogs).

In rural and Wet Tropic World Heritage areas dogs are also used for pig hunting which often occurs at night, the most vulnerable time for cassowaries. Several recent reports have been made of cassowaries being killed by either pig-dogs or the pig-hunter as a result of mistaken identity. Again it is very difficult to establish the real impact of such activities because of the difficulty of obtaining the information. However, what is clear is that cassowaries are definitely dying as a result of a number of strategies now in place to eradicate pigs. The important questions for the management agencies are: (1) what is the cassowary mortality level due to pig eradication programs? (2) does the impact of feral pigs on the natural environment outweigh the impact of the pig eradication programs on the natural environment? and (3) is it possible to totally eradicate or even control populations of such a feral animal?

9.4.5 "Other" Threatening Agents

Other threatening agents operating on cassowaries in the Mission Beach region include shooting and disease (Chapter 6, Table 6.5). In both instances that shootings were recorded during the 1990/1992 period, the action appeared deliberate. Neither hunting for meat nor eliminating a 'nuisance' animal appeared as the motive. The fungal disease aspergillosis was recorded in a subadult that died (Reid, K. pers. comm., 1990). While not recorded in the Mission Beach region, fence wire tangled around the legs of a subadult caused the death of this bird (Storch, D. pers. comm. 1991; Appendix A.2.3, Plates 6.12 and 6.13). Wire was also found around the leg of an adult on Mt Whitfield (Storch, D. pers. comm. 1995).

An indirect threatening agent acting on cassowaries is hand feeding. This was most apparent following Cyclone Winifred. During this period there was the intentional effort to manipulate the abundance of food for the benefit of cassowaries using the public to provide the food. The most apparent detrimental side effect resulting from this management strategy was the high incidence of road kills (Section 9.4.3; Bentrupperbäumer, 1988), because motorists would hand feed these birds from their cars.

9.5 Research Considerations

9.5.1 Estimating Population Parameters

The success of any management strategy can only be measured by comparing longitudinal surveys of various demographic parameters such as numbers, density, survival rates, against firm baseline data (Colbert & Lebreton, 1991). However, it is extremely difficult to obtain accurate measurements of these parameters particularly with endangered species which occur in low numbers, are generally wary, and difficult to observe (Colbert & Lebreton, 1991). Estimating these parameters usually relies on sampling a population and applying appropriate statistical techniques (Colbert & Lebreton, 1991).

Methods of estimating population size, and thereby population density and presence-absence, are usually the first considerations of applied research. This is because it is this baseline information that managers generally use to assess the status of the species and its distribution. Furthermore, a major provision of the endangered species act is to list a species according to categories such as endangered, vulnerable, threatened, etc. (Clark, 1994). This listing is based primarily on population size and distribution, which provide objective, scientifically based assessments of extinction risks (Mace & Lande, 1991). The process of changing a species listing also depends on this information. In addition, management policy requires the estimation of population size not only to evaluate the number of individuals, but to follow their fluctuations through time and space to analyse the causes and consequences of these trends. Methods of censusing birds can be ranked by their ability to answer such questions.

Managers need methods of estimating population size of cassowaries that work well. Currently such methods are nonexistent. As well as maintaining statistical validity, techniques have to be developed that account for various biological and behavioural characteristics of the species. This study has identified a number of important considerations that must be taken into account when estimating population size and associated parameters.

Firstly, quick and easy methods will not be sufficient to establish population levels, the annual changes in these levels, and causes of these changes. Secondly, it is clear from this study that the use of scat counts to estimate population size or even presence-absence of cassowaries is inaccurate. The considerable variation in food availability at different times of the year (Dennis, 1997), the species of plants producing fruits (Appendices A.4.1, A.4.2 and A.4.3), and the movement patterns of cassowaries associated with this seasonality of food supply (Chapter 8, Figure 8.10), means that for the same number of individuals density of scats varies in any one area at different times of the year. The variable gut retention times (Chapter 8, Table 8.1) and detection rates of scats (Chapter 8, Figure 8.6) reflect this annual, monthly and area variation in food supply. In addition, while the direct and indirect indices considered for a cassowary being present can be sightings and vocalisations, and scats and footprints, the absence of these indices cannot definitely confirm that a cassowary is absent. Movement patterns associated with food supply can skew cassowary censuses such that very low numbers or total absence can be reported for forests when they are devoid of fruit. This approach, which places a heavy emphasis on simple tallies of the number of animals present or the inferred absence of a species on simple presence-absence data, has been criticised on the basis that it rarely accounts for movement patterns and variable use of different sections of the home range (see Harris & Silva-Lopez, 1992). Any census technique used must therefore consider these important behavioural and ecological factors.

The other important insight from this study that I consider has important implications to the census and management of cassowaries is the notion that degradation can be a slow transformation from optimal to unsuitable conditions. Under these circumstances it appears that the strategy of monitoring population sizes to gauge effects of habitat degradation, no matter how rigorous, is inadequate because “long lag times can exist between critical levels of habitat degradation and any detectable change in population size, even when monitoring data are excellent” (Doak, 1995, p.1378). Doak (1995) goes on to point out that management plans that rely exclusively on census data to measure the effects of human impacts are inadequate and suggests that “changes in population densities in particular habitat types or change in specific demographic rates may be more effective measures of population status than are overall population numbers.” Short-term one-off population census will not adequately account for long time-lags which may accompany population declines, annual variations in population levels due to seasonality of food, the inevitably of missing birds, and movement patterns.

9.5.2 Pragmatic Management Action

With no time to lose, research on the endangered cassowary must become tightly focused on issues proximate to pragmatic conservation and management action, for example, risk assessment, diagnosis of declines and evaluation of treatment of declines (Caughley & Gunn, 1996). Conservation research must also be based on analyses that consider not only the current status, but characteristics of the cassowary and its habitat that have led to its vulnerability. An understanding of the habitat and biology of the species will allow conservation scientists and managers to establish what must be done to save the species. Simply focusing exclusively on the numbers that would constitute an minimum viable population "would be at best an inefficient approach; at worst, extinction would ensue" (Simberloff, 1988, p.501).

Without understanding the connections between seasonality and abundance of food supply, movement patterns, habitat use, reproduction, survivorship, dispersal, etc., management of cassowaries will be severely handicapped. In short, research that focuses exclusively on estimating population parameters and neglects the many facets of behaviour will probably offer little to the development of conservation and management strategies. In addition, while most research focuses initially on biological characteristics of the adult population, there is the urgent need to address characteristics of subadult populations, such as survivorship, recruitment, dispersal, habitat use, etc., because it is on the survival of this age class that the future of the species depends. For example, while lack of connectivity between isolated habitats may not be a problem for territorial adults, dispersal and hence survivorship and recruitment of subadults may depend on it. And, while "critical" habitat may in part be designated on the basis of adult resource needs and habitat use, subadult habitat use may differ significantly given there is the possibility that they forage opportunistically. Clearly, managers need to know about human behaviour as well; about why the clear felling and habitat loss is taking place.

The urgent need of managers in the face of declining cassowary populations and increasing public concerns is to develop and implement recovery strategies that are well founded in both the biological (Clark et al., 1989; Dickman, 1996; Jarman & Brock, 1996) and social sciences (Burroughs & Clark, 1995; Clark et al., 1989; Maguire & Servheen, 1991). While management action can be delayed by insufficient knowledge

(Miller et al., 1994), there are many who caution against managers rushing in adopting any approach that promises relief in the face of the problems, ignoring limitations and assumptions (e.g., Caughley & Gunn, 1996; Dickman, 1996; Miller et al., 1994; Simberloff, 1988). Uncritical implementation of untested strategies which may be adopted quickly often result in detrimental consequences (Simberloff, 1988), a risk that cannot be taken with an endangered species. On the other hand, "postponing decisions can often be more damaging than making them with incomplete scientific information" (Burroughs & Clark, 1995). In the management of endangered species there obviously has to be an informed process.

Conservation and management of cassowaries will depend on the vigorous implementation of several strategies and not be accomplished on just one effort. No greater error could be made than to make decisions that have long-term repercussions based on short-term considerations (Mattson & Reid, 1991).

9.5.3 Additional Behavioural and Management Needs

There are many additional behavioural and management questions and considerations that could be discussed and explored. Three concentrated years of field work and a life time living and working in the study region provide a richness of data which this dissertation cannot do justice to. For example, behavioural considerations which have immediate relevance to the biology, sustainability, and management of the species include such considerations as stressors, adjustment/adaptation to stress, the differential salience and importance of particular sense modalities and types of stimuli (including auditory, visual, olfactory).

From a more social science perspective, or from the perspective of comparative psychology, a somewhat different set of questions and considerations emerge. These would address issues of "intelligence", nature and complexity of social behaviour, the maturity of the behavioural repertoire at birth and the implications of this for learning and adjustment, and the behavioural implications of the extended life span (e.g. with respect to a territorial bird which is living in an expanding semiurban, tourist destination).

It is clear that a number of these considerations are peculiarly "psychological". For example, few biologists would address issues of "intelligence" as they would frame such a consideration in a different language. Yet some understanding of how the species makes sense of its environment and its capacity for learning and coping with change, are clearly relevant to survival in conditions of rapid change. As well such considerations enable us to more clearly examine human-cassowary interaction.

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