Technical Memorandum 4

The Foraging Behaviour of Herons and Egrets on the Magela Creek Flood Plain, Northern Territory

H. F. Recher and R. T. Holmes

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SUMMARY

Recher, H.F. and Holmes, R.T. (1982). The foraging behaviour of herons and egrets on the Magela Creek flood plain, Northern Territory. Supervising Scientist for the Alligator Rivers Region, Tech. Mem. 4.

Five species of diurnal herons (Ardeinae) are common on the Magela Creek flood plain and forage along the edges of natural and artificial waterbodies both inside and outside the Ranger Uranium Project Area. Insects, frogs and fish are the most commonly taken prey. The species of heron differ in the kinds and sizes of prey they take, their foraging location, degree of sociality and foraging behaviour. The range of foraging behaviours is similar to that described for North American herons, but the Australian birds differ in ways that may be related to the generally drier conditions that prevail over the Australian continent.

Little Egret *Egretta garzetta* and Pied Heron *Ardea picata* were the most active hunters. The Great Egret *E. alba*, Plumed Egret *E. intermedia*, and White-necked Heron *A. pacifica* foraged predominantly by 'standing and waiting' or by 'walking slowly'. The Pied Heron foraged mostly on dry land and took small insects from low vegetation. The Plumed Egret and White-necked Heron foraged in shallow water where there was dense emergent vegetation. Mostly they took small fish, tadpoles and frogs. The Little Egret and Great Egret hunted in open water habitats. The Little Egret was restricted to shallow water in drying pools or edges along channels and took small fish and insects. The Great Egret hunted in deeper water where it took relatively large fish. All the herons congregated where prey were concentrated by the receding waters of the flood plain.

Because it takes relatively large fish, the Great Egret is most likely to be affected by any contamination of the aquatic environment by heavy metals or radionuclides. The Nankeen Night Heron *Nycticorax caledonicus* hunts at night and was not studied. However, it is also abundant on the Magela Creek flood plain and probably feeds on large fish and frogs. It would also be at risk from any contamination of the aquatic environment. The other herons take smaller or immature prey or hunt mostly in terrestrial habitats. They are therefore less likely to be affected by contamination of the aquatic environment.

Our observations were confined to a small part of the seasonal cycle and all species probably hunt in different ways and places and take different kinds and sizes of prey during the different times of the year. It is necessary to obtain information on foraging habits and diets throughout the year before the risk to all species of ardeids can be fully ascertained.

1 INTRODUCTION

Herons and egrets (Ardeidae) are particularly good subjects for studies of foraging ecology. They are large, abundant and take prey which is easily identified. Near Jabiru, Northern Territory, herons are common along the edges of natural waterbodies of the Magela Creek system and in the Ranger Uranium Project Area. As piscivores, ardeids may be affected by the introduction of heavy metals or other toxins into these aquatic environments (e.g. Hoffman and Curnow 1973). Detailed studies of the foraging ecology of herons at Jabiru are therefore necessary, as a knowledge of the prey taken by herons will allow prediction of their exposure to potential contamination resulting from mining activities. Studies of foraging behaviour permit wider powers of prediction about prey liable to be encountered through the seasonal cycle. In addition, observational study of foraging birds reduces the necessity to destroy them, and provides broader information about the utilisation of food resources than does stomach analysis.

Little work has been done on Australian herons. Hindwood (1933) described the habits of the mangrove heron *Butorides striatus* and the Rechers reported on the foraging ecology of the reef heron *Egretta sacra* (Recher and Recher 1968, 1972; Recher 1972). Other accounts are largely anecdotal. During April, 1981 we studied the foraging ecology of herons on the Magela Creek flood plain. Our objective was to describe the foraging behaviour of herons (using standard ornithological terminology) as a base for more intensive studies of ardeid foraging ecology.

Australian herons can be conveniently divided into three groups: the day herons (Ardeinae) with ten species; the night herons (Nycticorinae) with one species; and bitterns (Botaurinae) with three species. (Nomenclature and vernacular names follow Payne and Risley (1976) as the most authoritative review of the Ardeidae.) Thirteen of these species occur in the Northern Territory (Reader's Digest 1976; Pizzey 1980). The three groups are distinguished by morphological, behavioural and habitat differences. The day herons are mostly long-legged, long-billed and long-necked birds which forage primarily during the day although a number of species also hunt after dark (Kushlan 1978; Recher and Recher 1980). They are typical of open aquatic habitats, but are opportunistic and often forage on grasslands and pastures. Foraging on dry land, which appears especially prevalent among Australian herons, may reflect the limited extent of shallow water habitats and the erratic rainfall characterising most of the Australian continent. The Cattle Egret *Ardeola ibis* is usually found in upland habitats where it commonly associates with cattle (Hancock and Elliott 1978). Night herons and bitterns tend to be stout birds with relatively short bills, necks and legs. The night herons forage mostly at night. Bitterns are restricted to densely vegetated freshwater habitats, forested creeks, marshes and swamps. The Nankeen Night Heron *Nycticorax caledonicus* is widely distributed in estuarine and freshwater habitats.

It is difficult to study the foraging ecology of night herons and bitterns, and most studies of heron behaviour and foraging ecology have been restricted to the day herons. There is an extensive literature from North America (see Sprunt et al. 1978 for reviews) which provides detailed descriptions of heron foraging behaviour (Kushlan 1976) and ecology (Kushlan 1978; Recher and Recher 1980). In this report, we use the North American literature and particularly the terminology proposed by Kushlan (1976) as the basis for describing the ecology and behaviour of herons foraging in the Magela Creek system.

2 METHODS

Foraging behaviour of ardeids was studied at two places on the Magela Creek flood plain, West Plains Channel (132°8'E, 12°27'S) and Jabiluka Billabong (132°52'E, 12°28'S). Because foraging behaviour at the two sites was similar, the observations from West Plains and Jabiluka have been combined.

At both study sites, the flood plain supported dense macrophytic growth dominated by the grasses *Pseudoraphis spinescens* and *Hymenachne acutigluma* and a fleshy, thickly growing member of the family Onagraceae, *Ludwigia adscendens*. These plants generally provided total submergence cover and only where water was deeper than about one metre or was flowing rapidly (as at West Plains Channel) were there patches of substrate free of macrophytes.

April is the beginning of the dry season. During the time we were there, only light rain fell and water levels on the flood plain receded rapidly. The habitats available to herons therefore ranged from dry, upland areas through recently exposed but still moist sites and extensive shallow pools to the deeper waters of the channels and billabongs. The full range of habitats was available at each of the study sites.

We selected foraging birds for observation on the basis of availability. When a large number of individuals was present, each bird was studied in sequence. If only one or a few birds were visible, a maximum of five consecutive measurements was made on each. Because we returned to the same sites each day, it is likely that data were obtained on the same individuals on consecutive days. We made occasional counts of herons at our study areas (Table 1). Sample sizes are therefore presented as the total number of observations, the minimum number of individuals known to have been studied, and as the maximum number of individuals known to be present at the two sites throughout the study period. Observations were made at West Plains on 16-21 April, and at Jabiluka on 23 and 24 April.

Species with a low prey attack rate were observed for longer periods than those which made frequent attempts at prey capture. Foraging behaviour of individual Great Egrets, *E. alba*, was scored in time periods of 300 seconds, for White-necked Herons, *Ardea pacifica*, 150 seconds, and for Pied Herons, *A. picata*, Little Egrets, *E. garzetta* and Plumed Egrets *E. intermedia*, 60 seconds.

For each bird we counted the number of steps taken and flights made; we estimated the distance moved, timed the period the bird was stationary, and recorded attempts at prey capture and whether these were successful. If possible, prey were identified and their size estimated using the beak of the bird as a gauge of the length of prey. The habitat of each bird was described and, if the bird was in water, the depth of water was recorded as a function of its position on the heron's leg. The morphological measurements required to use these means of estimating prey size and water depth are given in Table 2. Most measurements were taken from study skins at the American Museum of Natural History (New York) and the Australian Museum (Sydney). The specimens came from various parts of Australia and were mostly collected at the turn of the century. Data available for specimens from the Magela flood plain suggest that ardeids from this region are similar in size to those from other parts of Australia (Table 2). Because few data are available at this time for Little Egrets, we have used measurements for the closely related (and similarly sized) Snowy Egret, *E. thula*, a North American species.

Four other ardeids were recorded on the Magela Creek system, but we were unable to obtain data on their foraging behaviour. One of these, the Black Bittern *Dupetor*

flavicollis, was uncommon on the flood plain and difficult to approach. Two other species, the Cattle Egret, and the White-faced Heron, *A. novaehollandiae*, were also uncommon and did not forage in the areas where we were able to work. The Nankeen Night Heron was abundant but nocturnal, and we obtained only limited notes on its foraging habits. All observations are presented in the separate sections on the species.

3 RESULTS

3.1 Great Egret

We recorded Great Egrets foraging along the edge of billabongs, at the edge of the flood plain, and at a riffle where water flowed from the plain across a rock ledge into a deep channel. They foraged mainly where there was some open water. There were no apparent differences in behaviour between birds foraging in any of these situations. Almost all Great Egrets hunted in water which was 150 to 200 mm deep (Table 3). Hunting was by standing still and waiting for prey ('stand and wait') or walking slowly ('walk slowly'). Great Egrets hunted from fully erect to partially crouched positions. In a fully erect position, the neck is extended its entire length and held perpendicular to the ground. In a crouched position, the neck is usually withdrawn and may be held back against the body. However, the birds at West Plains often crouched slightly and stretched their necks fully to the side, holding the head nearly horizontal to the water. Probably this was to reduce the effects of glare in bright sun.

Great Egrets averaged fewer than 5 steps per minute and moved 1.5 m per minute (Table 4). On a few occasions (<10% of observations), birds moved quickly ('walk quickly') or made short flights. This probably occurred after prey had been sighted at a distance. When walking, Great Egrets averaged 24 steps per minute (Table 4). They moved less than 25% of the time spent hunting and made relatively few attempts at prey capture. The foraging behaviour of Great Egrets on the Magela flood plain was essentially identical to that of the same species in southeastern Australia (Recher unpubl.) and in North America (Kushlan 1976, 1978; Recher and Recher, 1980).

Most prey taken by Great Egrets were relatively large fish, including *Strongylura kreffti*, *Neosilurus* spp., *Fluvialosa* sp., and ?*Hephaestus* sp. (names of fish follow Lake 1971). The largest of these were about 15 cm in length which is about the same size as the largest fish taken by Great Egrets in North America (Recher and Recher 1980; Schlorff 1978). Great Egrets found large prey (>12 cm) difficult to handle and required several minutes to kill and swallow a large fish. Catfish *Neosilurus* spp. were the most difficult. As a result, many of the largest fish and most catfish were pirated by Whistling Kites *Haliastur sphenurus* and White-breasted Sea-eagles *Haliaeetus leucogaster*.

About one in four prey attacks made by Great Egrets was successful (Table 4). Difficulties in coping with some prey, the small number of prey attacks, and the relatively low success rate, are typical of herons hunting large fish (Recher and Recher 1968, 1980). The largest fish were taken by egrets hunting at the riffle. Fish larger than those taken by Great Egrets (>15 cm) were abundant in the riffle and it is clear that the egrets selected a fairly narrow size range of prey from that available.

3.2 White-necked Heron

White-necked Herons were uncommon and we observed only six individuals. Two were single birds and the others appeared to be paired. Paired birds hunted relatively close together. Although these herons congregate where food is abundant and sometimes

hunt in small flocks, they mostly hunt as pairs or single birds (Recher unpubl.). In southeastern Australia, White-necked Herons are associated with densely growing vegetation and frequent the edges of shallow waterways, grassy swales and paddocks. At Jabiru, the majority of observations were of birds hunting in water less than 70 mm deep among sparse *P. spinescens* and *L. adscendens* (Table 3).

Like the Great Egret, the White-necked Heron uses mostly 'stand and wait' or 'walk slowly' methods when foraging. When hunting slowly through tall grass, the White-necked Heron appears to be stalking prey ('stalk'). Foraging birds seldom flew (<5% of observations) and rapid movements ('walk quickly') were associated with prey sighted at a distance. White-necked Herons took slightly more steps per minute than Great Egrets, but spent about the same proportion of time moving and moved about the same distance (Table 4). There are no differences between these observations and those made on birds foraging in southeastern Australia (Recher unpubl.).

Most prey taken by White-necked Herons were small (<3 cm) and could not be identified. The largest item taken and swallowed was a catfish 10 cm in length. A slightly larger catfish (>12.5 cm) was caught, but could not be swallowed. The herons averaged less than one prey attack per minute and had a success rate of 64% (Table 4). These data are similar to those recorded for Plumed Egrets hunting in the same places and taking many of the same sized prey (Table 4).

Birds hunted from upright and crouched positions. Birds hunting in an upright position appeared to be scanning for prey at relatively long distances. White-necked Herons seem to have short necks and 'peering' was common behaviour. Peering is not distinguished by Kushlan (1976, 1978) from other heron foraging behaviour, but was used consistently by White-necked Herons and Plumed Egrets in the Magela Creek area. A peering heron holds its body nearly horizontal, with the neck fully extended and held in line with the body. The head and bill are at a slight angle to the ground.

3.3 Plumed Egret

Plumed Egrets were the most abundant ardeids on the flood plain, with scores of birds foraging in loose aggregations at several locations. In contrast to both the Great and Little Egrets, which frequented open water, the Plumed Egret foraged almost exclusively in dense, emergent *P. spinescens*, *L. adscendens*, and *H. acutigluma*. The majority of our observations were of birds hunting in vegetation where the water was less than 80 mm deep (Table 3).

The Plumed Egret is a slow and methodical hunter. The birds we watched spent nearly 80% of their time motionless, and hunted mostly by 'standing and waiting' or 'walking slowly'. Individuals hunted from upright and crouched positions and often peered for prolonged periods. Most of the prey taken was small (<3 cm) and consisted of fish, frogs and insects. The largest item recorded was a fish between 8 and 10 cm in length. Plumed Egrets made fewer than one prey attack per minute and were successful in two out of three attempts (Table 4).

3.4 Little Egret

Little Egrets were moderately abundant on the flood plain and occurred with Great and Plumed Egrets (Table 1). As in the case of the Great Egret, Little Egrets hunted mostly in open water 100 to 150 mm in depth (Table 3) with little or no emergent vegetation. Often this was in drying pools, but individuals also hunted in the shallows at the edge of deeper water.

The foraging behaviour of the Little Egret has been described variously as 'wading and stalking in shallow water' (Voous 1960) and 'actively pursuing small fish in shallow water' (Payne and Risley 1976). The birds we observed used a wide range of foraging behaviours. On average Little Egrets spent 60% of their time standing still (Table 4), but it would be inaccurate to equate this entirely with 'stand and wait' behaviour. Some individuals did 'stand and wait' either in an upright or crouched position, but most often the birds paused between bouts of activity. Typically a bird would pause in an erect position with the neck fully extended and scan for prey. When prey was sighted the egret would either 'walk quickly' or run in pursuit. These behaviours are commonly reported for the Snowy Egret (Kushlan 1976). When moving, Little Egrets averaged nearly 50 steps per minute (Table 4) and when running exceeded 65 to 70 steps per minute, although we found it difficult to count accurately the steps of running birds. 'Wing flicking', which is a common foraging behaviour in Snowy Egrets (Recher pers. observ.), was seen only a few times. Compared with the conditions in which Snowy Egrets wing flick (large expanses of shallow water in bright sun), conditions on the Magela flood plain (small expanses of relatively shallow water broken by emergent vegetation) probably did not favour wing flicking. However, 'foot stirring' was used in about 30% of observations to disturb prey hiding in submerged vegetation or debris. Snowy Egrets use foot stirring in the same situations (Meyerriecks 1962; Recher pers. observ.).

In North America, Snowy Egrets often forage in association with other wading birds, cormorants or fish, which are pursuing schools of small fish at the edge of deeper water (Kushlan 1978; Recher pers. observ.). In these instances, the egrets exploit fish driven into the shallows and disoriented by the large number of predators. Little Egrets, which were foraging in the riffle at West Plains, followed foraging cormorants and took prey driven into the shallows by these birds. Similar behaviour has been reported for Little Egrets in southeastern Australia (Vestjens 1975; Morris 1978; Hobbs 1980) and Africa (Fraser 1974; Connor 1979).

Most prey taken by Little Egrets were small fish (<2.5 cm), but fish up to 8 cm in length were taken. At Jabiluka Billabong one egret caught several catfish between 10 and 15 cm in length, but had difficulty in handling these. Ultimately all were lost. Little Egrets averaged two prey attacks per minute and were successful 50% of the time (Table 4). This is similar to the attack and success rate of Snowy Egrets in North America (Recher and Recher 1980).

3.5 Pied Heron

Pied Herons were abundant at West Plains and Jabiluka Billabong, but more than 90% of the individuals were juveniles. As in the case of North American Little Blue Herons *E. caerulea* (Recher and Recher 1969, 1980), immature birds foraged in small groups or flocks, but adults tended to be solitary.

Most of our observations were of birds hunting on dry land or in very shallow water (Table 3). Pied Herons foraged mostly by 'walking quickly' and gleaning prey from low vegetation by rapid pecks (Table 4). The attack rate of Pied Herons was twice that of Little Egrets (Table 4). Nearly 90% of attacks were successful. Most prey were probably small insects (<1.5 cm). Walking birds frequently paused and either peered intently at nearby vegetation or assumed an upright posture and scanned a larger area. Occasionally a walking bird would see some food item at a distance and move forward quickly one or two metres. The few birds that hunted in deeper water foraged by 'standing and waiting' or 'walking slowly'. Individuals hunted from upright and crouched positions.

3.6 Other Species

Limited observations were made on Nankeen Night Heron, Cattle Egret, White-faced Heron and Black Bittern. Nankeen Night Herons probably forage from dusk to dawn. We recorded them feeding at two places; Jabiluka Billabong and where the Magela Creek crossed the Oenpelli Road. In both places the birds were using 'stand and wait' behaviour in either an erect or crouched posture. At Jabiluka Nankeen Night Herons hunted from the bank at the edge of deep water. The creek crossings were shallow with a substrate of gravel and small stones. Schools of small fish (<12.5 cm) were abundant and the birds probably fed on these. White-faced Herons were seen most often at the same crossings, but were diurnal. In southeastern Australia, White-faced Herons take mostly small prey (<2.5 cm) and hunt by 'walking slowly' or 'standing and waiting' (Recher unpubl.). This bird probably forages in more kinds of habitats than any other heron. Recher (unpubl.) has recorded it on coral reefs, open rocky coasts, estuaries, ponds, improved pasture, dry pasture and in forest near creeks. One Cattle Egret was recorded. The bird was foraging on dry land at West Plains and was probably taking insects. It hunted by 'walking slowly' or 'walking quickly' in a partially crouched posture. We did not observe Black Bitterns foraging. Bitterns were flushed from vegetation along the Magela Creek where they were probably roosting during the day. The bird is probably abundant along the Magela and occurs sporadically in thick vegetation near some of the flood plain billabongs (Morton pers. comm.).

4. FORAGING TERRITORIES AND AGONISTIC BEHAVIOUR

Herons commonly defend foraging territories (Kushlan 1978). Although we had insufficient time to make a precise determination of territorial behaviour, it appeared that some adult Pied Herons and some Little Egrets (probably adults, judging by plumage and bill colour) were defending a foraging territory against conspecifics. In our longest period of observation (four days at West Plains), a distinctively marked adult Pied Heron defended an area of shallow water which was about 50 m^2 in extent. An adult Little Egret was tolerated within the territory, but all Pied Herons were attacked. Little Egrets defended foraging areas at West Plains and Jabiluka for at least two days in succession.

Although not territorial, agonistic behaviour was common among egrets foraging in the riffle at West Plains. At times nearly 100 birds were congregated in a relatively small area (Table 1). Aggressive interactions were frequent throughout the day, and increased as the numbers of birds increased. During a 15 minute period when 55 Great Egrets and 20 Little Egrets were present, 23 interactions, from simple supplantations to prolonged fights, were recorded among Great Egrets and 15 among Little Egrets. Virtually all aggression was intra-specific, and it disrupted foraging.

5 DISCUSSION

5.1 Foraging Behaviour and Habitat

At the time of our study, herons were not particularly abundant on the Magela Creek system. Those that were present were concentrated in a few localities (e.g. West Plains, Jabiluka Billabong). Even at these places there were seldom more than a hundred birds (Table 4). This is in contrast to later in the dry season and early wet when the numbers of ardeids in the Magela are in the vicinity of ten thousand birds (S.R. Morton and K.G. Brennan unpubl.). At this time, the three species of *Egretta* are,

as a group, the third most common birds on the flood plain after Magpie Geese *Anseranas semipalmata* and Whistle Ducks *Dendrocygna* spp.

Presumably, as the dry season progresses and aquatic organisms are concentrated into increasingly small areas of water, herons move on to the flood plain from elsewhere in Australia. There is limited information on the long distance movements of Australian ardeids. Little and Great Egrets banded in Australia have been recovered in New Zealand and New Guinea (McClure 1974). Both species are known to migrate from nesting areas in northern Europe and Asia to wintering areas in Africa and southeast Asia (Voous, 1960; Hancock and Elliott 1978). Plumed Egrets from northern Australia probably migrate to New Guinea during the dry season (Hancock and Elliott 1978) and McClure (1974) reports that Japanese birds migrate to the Philippines. The longest movement recorded for a Japanese Plumed Egret was 3520 km. It is also probable that Pied Herons migrate from northern Australia to New Guinea during the winter dry season (Hancock and Elliott 1978). The White-necked Heron is an irruptive species (Hancock and Elliott 1978) with large numbers of birds appearing irregularly in southwestern Australia (Serventy and Whittell 1962), Tasmania (Sharland 1958), and southeastern Australia (Hindwood and McGill 1958; Recher pers. observ.). These movements appear to follow good breeding seasons in the interior of the continent. Crawford (1972) reports that the White-necked Heron is rare in the Darwin area from January to May, common June to August, and scarce September to December.

Although the information is limited, it is clear that Australian herons are capable of moving long distances and that some migration (e.g. movements of Plumed Egrets to New Guinea) may occur. The aggregation of thousands of birds on the flood plain of the Magela means that any contamination of the Magela Creek system from mining operations or changes in the hydrological system may affect birds over a large part of the Australian continent and birds which migrate to New Guinea.

Australian herons use the same range of foraging behaviours as recorded for North American birds (Table 5). 'Stand and wait', 'walk slowly' or 'walk quickly' are the most common ways to hunt. More active hunters, such as the Little Egret, tend to have a more diverse repertoire than less active herons such as the Great Egret.

Kushlan (1976, 1978) does not distinguish 'peering' as a foraging method for North American herons, but such behaviour is probably included under 'stand and wait'. 'Peering' is frequently used by Little Blue Herons when hunting in thick vegetation (submerged or emergent) and Cattle Egrets in tall grass, but is not seen regularly among other North American ardeids (Recher pers. observ.). The behaviour appears to be associated with thick or tall vegetation where birds are hunting prey which is close to the ground or in shallow water. In such habitats, it is obvious that such prey cannot be seen at a distance and birds are restricted to hunting at 'neck's length'. 'Peering' may be particularly common among Australian herons because of the large amount of foraging done on land or in tall emergent vegetation. There may also be a correlation between foraging in such habitats and the relatively short necks which characterise White-necked Herons and Plumed Egrets.

The eight species of heron observed on the Magela flood plain are distinguished by size, time of foraging, foraging behaviour and habitat. Differences in habitat include depth of water, and the kind, height and density of vegetation. Each species therefore encounters different kinds of prey or different parts of the same prey population (Recher and Recher 1980). Most of the prey taken by herons on the Magela flood plain during April was small (<2.5 cm) and included insects, amphibians and fish. Only the Great Egrets at West Plains Channel took significant numbers of large fish (up to 15 cm).

Of the five species of day herons studied, the Pied Heron hunted mostly on land at the edge of the flood plain. The other species foraged mostly in shallow water. The Great Egret and the Little Egret frequented places with little or no emergent vegetation and Plumed Egrets and White-necked Herons hunted mostly in dense emergent vegetation. The Plumed Egret in particular is associated with dense, emergent *Pseudoraphis* and *Hymenachne*.

The Plumed Egret has always been something of an enigma. Considering its abundance and wide distribution, there is little information about its habits. Most often it is portrayed as being intermediate in size between the Great and Little Egrets (which it associates with) and having similar habits (e.g. Reader's Digest 1976). In reality the Plumed Egret is quite different. Blaker (1969) compared the behaviour of Little and Plumed Egrets in Africa and found that the Plumed Egret foraged much more extensively in grassland than the Little Egret. This is similar to the differences which we recorded for Little and Plumed Egrets on the Magela Creek flood plain (Table 3). The three species of *Egretta* can therefore be distinguished by size, foraging behaviour and habitat. All may occur on the same wetlands, but each exploits a different array of resources.

5.2 Types of Prey Taken

A knowledge of heron foraging behaviour and the kind of habitats herons frequent enables us to predict the kinds of prey each species is likely to encounter. Prey size is largely determined by the size of the heron; large herons will, on average, take larger prey than small herons (Recher and Recher 1980). However, herons do not necessarily take every organism encountered (Recher and Recher 1968, 1980). As illustrated by the Great Egrets at West Plains Channel, ardeids are probably highly selective in the kinds and sizes of prey taken. Birds may choose particular prey because they are easy to capture or require minimal handling before swallowing. The risk of piracy by kites and eagles on the flood plain may force herons to avoid large fish or prey, such as catfish, which require prolonged manipulation. The risk of piracy to individual herons may decline as the number of ardeids on the flood plain increases during the late dry and early wet seasons. At such times, large fish may become an important part of the diet.

Although we did not concentrate on the identification of prey taken by ardeids on the flood plain, it would be possible to establish observation posts (i.e. hides) close to where birds were foraging and identify prey as it was captured. For birds hunting in emergent vegetation and taking small prey, which is hard to identify before it is swallowed, it is a simple matter to determine where in the vertical column of vegetation and water, prey were captured. Inspection of the sites where herons hunted would then enable likely prey to be identified. This, coupled with stomach analyses, would enable the diets of ardeids feeding on small prey (<1.5 cm) to be narrowly defined. These data are needed before we can specify which species of heron might be affected by possible contamination of the Magela Creek system from uranium mining and milling. The data presented in this report already enable us to make some preliminary predictions.

5.3 Effects of Contaminants on Heron Species

If contamination of the Magela Creek system by heavy metals or radionuclides from uranium mining and milling is biologically active and if contaminants are concentrated as they move through and up the food chain, then, as a general proposition, ardeids that feed on fish or frogs will be at greater risk than those that feed on insects or tadpoles. It can also be assumed that mature (adult) prey will be more likely to have accumulated heavy metals or radionuclides than immature (juveniles or larvae) prey. Therefore herons which take large prey are more likely to be affected than those which take small

prey. Allowing for the simplification inherent in the preceding assumptions, the following predictions can be made concerning the possible effects of uranium mining and milling on ardeids.

The species most likely to be affected are the Great Egret and Nankeen Night Heron. On the Magela Creek system both species probably feed largely on fish and frogs, and both are capable of taking fairly large prey (>12 cm). As evidenced by Great Egrets at West Plains Channel, large prey are probably preferred to small.

White-necked Herons, Plumed Egrets and Little Egrets probably forage mostly for aquatic organisms. They may take some large prey (certainly the White-necked Heron is capable of doing so), but mostly they feed on small organisms (<2.5 cm) which probably include insects, tadpoles and young fish. The White-faced Heron probably has similar habits. Because of these dietary habits, these four species are less likely to be affected by contamination of the Magela Creek system than Great Egrets or Nankeen Night Herons.

On the flood plain, Pied Herons and Cattle Egrets probably feed mostly on insects. Both species hunt largely on land and may therefore take large numbers of terrestrial insects, along with any aquatic organisms moving away from the water. In our estimation, these two species are least likely to be affected by uranium mining or milling, insofar as it relates to contamination by heavy metals or radionuclides.

There are two aspects of ardeid foraging ecology which require additional study: (i) the habits of herons during the late dry and early wet seasons when they are feeding on prey concentrated in dry pools or billabongs. At this time, even the smaller herons may feed on relatively large fish and thereby increase their risk of contamination; (ii) the diets of Great Egrets and Nankeen Night Herons. Once their prey is known, those species of fish and frogs can be monitored for contamination by heavy metals or radionuclides. Pre-milling levels in heron prey should be established.

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TABLE 1 NUMBERS OF DIFFERENT TYPES OF HERONS SIGHTED AT DIFFERENT TIMES OF DAY IN WEST PLAINS CHANNEL AND JABILUKA BILLABONG

West Plains Channel

	21 April, 1981						
Time	0845	0930	1020	1140	1240	1350	1500
Great Egret	0	5	14	35	51	60	55
White-necked Heron	0	0	0	0	0	0	0
Plumed Egret	2	4	4	5	21	10	10
Little Egret	10	17	23	25	21	21	18
Pied Heron	0	1	0	1	2	3	0
Cattle Egret	0	0	0	0	1	0	0
White-faced Heron	0	0	0	0	0	0	0

Jabiluka Billabong

	23 April, 1981				24 April, 1981			
Time	0740	0900	1100	1300	0645	0800	1010	1140
Great Egret	1	4	5	5	2	5	8	8
White-necked Heron	3	2	2	2	3	3	3	2
Plumed Egret	18	20	22	34	19	49	45	17
Little Egret	1	1	1	1	1	2	1	2
Pied Heron	1	11	7	11	0	19	8	16
Cattle Egret	0	0	0	0	0	0	0	0
White-faced Heron	0	0	0	0	0	1	0	0

TABLE 2 CULMEN, WING AND TARSUS MEASUREMENTS OF DIFFERENT SPECIES OF HERON [a]

Species	Number Measured	Culmen	Wing (mm)	Tarsus
Great Egret [b]	11	106.6 ± 3.0	nd	151.9 ± 4.0
Great Egret [c]	4	109.4	365	nd
White-necked Heron [d]	7	85.8 ± 1.1	402.4 ± 10.8	133.1 ± 1.6
Plumed Egret [d]	7	74.5 ± 1.2	275.7 ± 3.1	96.3 ± 2.0
Plumed Egret [c]	8	77.3 ± 2.4	288.1 ± 5.9	nd
Little Egret	0	nd	nd	nd
Snowy Egret [e]	21	83.6 ± 1.2	254 ± 2.4	105.1 ± 1.9
Pied Heron [b]	7	67.1 ± 1.0	228.4 ± 3.3	77.0 ± 1.0
Pied Heron [c]	1	59.0	240	nd

[a] Size = ($\bar{x}$ ± s.d.)

[b] The Australian Museum, Sydney

[c] Magela Creek flood plain

[d] American Museum of Natural History, New York

[e] North American species

nd = not determined

TABLE 3 FORAGING DEPTHS FOR DIFFERENT SPECIES OF HERON

Water Depth (mm)	Great Egret	White-necked Heron	Plumed Egret	Little Egret	Pied Heron
	Percentage of observations				
200-250	26.4	0	0	0	0
150-199	72.8	0	0	1.6	0
100-149	+	11.4	1.9	73.3	0
50-99	0	57.1	25.8	18.9	6.3
1.1-49	0	17.1	39.9	6.0	3.8
0-1	0	14.3	32.3	0	90.0
Number of observations	106	70	213	180	160

TABLE 4 RATE OF MOVEMENT AND FORAGING SUCCESS FOR DIFFERENT SPECIES OF HERON

	Great Egret	White-necked Heron	Plumed Egret	Little Egret	Pied Heron
Number of observations	107	70	214	117	160
Minimum number of individuals observed	30	6	30	15	25
Minimum number of birds present	70	6	100	40	60
Time moving (%)	22.4	26.4	21.2	40.2	58.7
Number of steps per minute ($\bar{x}$ ± s.e.)	4.8 ± 0.4	6.3 ± 0.6	4.6 ± 0.3	20.2 ± 1.4	28.1 ± 1.5
Steps per second of moving birds ($\bar{x}$ ± s.e.)	0.4 ± 0.02	0.4 ± 0.03	0.5 ± 0.02	0.8 ± 0.03	0.9 ± 0.03
Mean distance moved per minute (m)	1.5	1.6	1.3	2.4	4.3
Mean number of prey attacks per minute	0.2	0.6	0.7	2.2	5.0
Attack success rate (%)	23.6	64.4	67.5	54.5	87.9

TABLE 5 COMPARATIVE FORAGING BEHAVIOUR OF HERONS ON THE MAGELA FLOOD PLAIN

Foraging Behaviour[a]	Species							
	Great Egret	White-necked Heron	Plumed Egret	Little Egret	White-faced Heron	Cattle Egret	Nankeen Night Heron	Pied Heron
Stand and wait	X	X	X	X	X	-	X	X
Glean	-	X	-	-	-	X	-	X
Walk slowly (stalk)	X	X	X	X	X	X	X	X
Walk quickly	X	X	-	X	-	-	-	X
Run (dash)	-	-	-	X	-	-	-	-
Peer	-	X	X	-	-	-	-	X
Wing flick	-	-	-	X	-	-	-	-
Foot stir	-	-	X	X	-	-	-	X

[a] Terminology follows Kushlan (1976).