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THE BREEDING BIOLOGY OF THE OSPREY *Pandion haliaetus* ON THE NORTH COAST OF NEW SOUTH WALES

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Observations were made at nine nests of the Osprey *Pandion haliaetus* in the Clarence Valley, north-east New South Wales, from 1991 to 1996 for a total of 213 hours over 172 nest visits. Details of the breeding behaviour (nest sites, nest construction, courtship, display, mating, egg-laying and incubation, brood size, nest defence, fledging, breeding success, post-fledging) are presented. Breeding occurred in winter with most nestlings fledging in spring and occasionally early summer. Nests were defended against potential predators of eggs and chicks such as the White-bellied Sea-Eagle *Haliaeetus leucogaster* and Torresian Crow *Corvus orru*. Over 30 per cent of diurnal incubation was carried out by the male, despite him being the sole food provider during the incubation and early nestling stages.

INTRODUCTION

The Osprey *Pandion haliaetus* is a rare to uncommon breeding species in New South Wales. The species is cosmopolitan but the subspecies *cristatus* is confined to Indonesia, New Guinea, Solomon Is, New Caledonia and Australia (Condon 1975; Prevost 1981; Poole 1989; Ferguson-Lees and Christie 2001). This subspecies has also been referred to as *leucocephalus* (Marchant and Higgins 1993), however, *P. h. cristatus* Vieillot 1816 takes priority over *P. h. leucocephalus* Gould 1838, and the latter is a junior synonym.

Between 1973 and 1979 only two active Osprey nests were documented in New South Wales. Surveys in 1980 and 1981 found fifteen active nests between Forster and the Queensland border (Clancy 1980, 1981, 1989). The species bred as far south as Lake Macquarie before 1912 with an unconfirmed report of breeding at St Georges Basin (North 1912). The only other historical data on the pre-1970 status of the species in New South Wales concern a pair fishing between the Tweed River and Cook Island (North 1912). Despite this paucity of information the Osprey is generally presumed to have declined in Australia since European settlement (Morris *et al.* 1981; Olsen 1995). It is no longer found near the centres of population in southern Australia but was probably never common there (Hollands 1984).

The Osprey was listed on Schedule 12 of the New South Wales *National Parks and Wildlife Act 1974* as 'vulnerable and rare fauna' as the Scientific Committee considered its "population critical, but suspected to be stable; poor recovery potential; threatening processes severe." The Osprey was later placed on Schedule 2 of the New South Wales *Threatened Species Conservation Act 1995* as a 'vulnerable species'. Nationally, the Osprey is considered 'secure' but it is listed among the 'taxa of special concern' by Garnett (1993). The main threats to Ospreys in New South Wales are believed to be the loss of traditional nest trees, disturbance at the nest site, reduction in quality and quantity of food, degradation of estuarine systems, effects of pesticides, egg collecting, shooting and collision with powerlines (Clancy 1991).

Since the late 1970s active management of the species, in the form of monitoring, protection of nest trees, public education and the erection of artificial nest poles, has allowed a small but continued population increase. The estimate of the state's population at the time of this study, based on more intensive monitoring by National Parks and Wildlife Service district staff, volunteers and the author, was approximately 100 breeding pairs. A smaller number of non-breeding birds also occur. The nine nests studied during this project constituted approximately ten per cent of the presently known state breeding population. Between 1997–1999 there were at least 40 breeding pairs between Taree and Scotts Head alone (Bischoff 2001). The limited information on the breeding biology of Ospreys in northern New South Wales consists of two papers (Rose 2000; Bischoff 2001) and a number of reports prepared for the National Parks and Wildlife Service (Clancy 1980, 1981, 1989, 1991).

The breeding biology of the Osprey has been extensively studied in the Northern Hemisphere, particularly in the United States and Scotland (Poole 1989). Most studies in Australia have been brief or limited, e.g. Clancy (1980,

1981, 1989, 1993), Cupper and Cupper 1981, Dennis (1987), Holsworth (1965) and Marr (1987). Marchant and Higgins (1993) summarized the existing knowledge of the breeding biology of the Australian subspecies and identified gaps in our knowledge. Clutch size, which is two to three (rarely four), is well known but other facets of the breeding cycle are not. The main deficiencies are the timing and details of breeding events, such as nest construction, courtship display, mating, incubation, young in nest, nest defence, and fledging, although some information on these aspects has been published in recent years (Rose 2000; Bischoff 2001).

This study was carried out in north-east New South Wales to establish the timing and nature of the main breeding events and to document breeding behaviour, allowing a comparison to be made with other populations, particularly those in the Northern Hemisphere.

METHODS

Nine Osprey nests were observed in north-eastern New South Wales between 7 July 1991 and 12 December 1996 (Table 1). These nests were located in the Clarence and adjacent Wooli Wooli River systems of north-east New South Wales, ranging from Iluka in the north to Wooli in the south, and west to Lawrence. These observations covered all stages of the breeding cycle from pair formation to fledging. The stage of breeding (nest construction, courtship, display, mating, egg-laying and incubation, fledging, post-fledging.) was recorded at each visit. Activity was observed through binoculars or a spotting scope and the commencement and cessation times of each activity were noted to the nearest minute. Observations were made from, or adjacent to, a stationary vehicle parked 50 to 150 metres from the nest. The distance depended on the site characteristics and response of the birds to observers.

A total of 213 hours was spent observing the nine nests over six breeding seasons, which involved 172 nest visits. These visits ranged in duration from 30 minutes to 11 hours. In addition, a number of brief visits, of ten minutes or less, were made to nests opportunistically to determine the stage of breeding. The number of hours of nest watches and the number of visits per year from 1991 to 1996 are shown in Table 2. A limitation of the survey methodology was the variability in the time and duration of nest watches.

RESULTS

Nest sites

Nests were constructed in dead trees (four each in 1991, 1992 and 1993, three in 1994, one in 1995 and two in 1996), on power poles (two in 1991 and 1992, one in 1993), on a light pole (one in 1991 and 1992) and a modified crane derrick in 1995 and 1996 — a total of ten nest locations at nine sites (Table 1). Nests sites were mainly on agricultural land used for cattle grazing, although one nest was close to a residence in sugar cane farmland, one on a light pole at a sportsfield in a coastal town, one in disturbed swamp open forest near a sportsfield, and one was at a former mineral sand-mining site.

Osprey nests are sometimes commandeered locally by other species, in particular the Black-necked Stork *Ephippiorhynchus asiaticus*. The Munros Lane pair, observed during this study, apparently built their nest during or before the 1995 breeding season. The nest was used in 1996, first by a pair of Black-necked Storks, and then by the Osprey pair following the loss of the Storks' young. The Storks used the nest in 1997, causing the Osprey pair to construct a new nest on a steel electricity

TABLE 1

Details of Osprey nest sites in the Clarence Valley, 1991 to 1996.

Nest	Latitude/Longitude	Site	Estimated nest height (m)	Number years observed	Years of observation (year nest first found)	Habitat	Water body
Iluka	29°23'S, 153°21'E	dead tree	24	1	1991–1992 (1989)	former sand mining site	ocean/estuary
Serpentine	29°24'S, 153°15'E	power pole	16	1	1991–1992 (1990)	agricultural	river
Yamba Oval	29°26'S, 153°26'E	light pole	20	1	1991–1992 (1990)	sportsfield/urban	estuary
Woodford Is.	29°27'S, 153°08'E	dead tree	10–20	4	1991–1994 (1989)		
		crane derrick pole	8	2	1995–1996 (1995)	agricultural	river
Kings Creek	29°27'S, 153°07'E	partly dead tree	25	3	1993–1994 (1993)	agricultural	river
Munros Lane	29°31'S, 153°07'E	dead tree	25	1	1996 (1996)	agricultural	river
Lawrence	29°31'S, 153°05'E	dead tree	24	6	1991–1996 (1987)	agricultural	river
Swan Creek	29°40'S, 153°00'E	dead tree	20	3	1991–1993 (1991)	agricultural	river
Wooli	29°51'S, 153°15'E	power pole	16	3	1991–1993 (1989)	disturbed swamp open forest	ocean/estuary

TABLE 2

Number and duration of visits to Osprey nests in Clarence Valley, 1991–1996.

Year	Total Hours	Number of visits	Number of visits per nest
1991	21.8	9	Iluka (1), Serpentine (1), Yamba (1), Woodford Is. (2), Lawrence (2), Swan Crk (1), Wooli (1).
1992	28.5	6	Serpentine (1), Woodford Is. (1), Lawrence (2), Swan Crk (1), Wooli (1).
1993	42.2	55	Woodford Is. (15), Kings Crk (9), Lawrence (18), Swan Crk (7), Wooli (6).
1994	17.6	26	Woodford Is. (8), Kings Crk (8), Lawrence (9), Swan Crk (1).
1995	35.5	16	Woodford Is. (8), Kings Crk (1), Lawrence (7), Swan Crk (1).
1996	67.4	60	Woodford Is. (23), Munros Lane (22), Lawrence (15), Swan Crk (1).
Totals	213	172	Iluka (2), Serpentine (2), Yamba (1), Woodford Is. (57), Kings Crk (18), Munro's Lane (22), Lawrence (53), Swan Crk (9), Wooli (8).

tower 2.5 kilometres to the north. In 1989 a pair of Storks took over an Osprey nest at Corindi, north of Coffs Harbour, causing the Ospreys to build in another, nearby tree (pers. obs.). A nest in the process of being constructed by Ospreys, at South Boambee in 1983, was occupied by an adult Black-necked Stork on 26 June 1983. The nest was subsequently abandoned by both species (pers. obs.).

Breeding season

Details of the activity at Osprey nests during visits are presented (Table 3). The date of egg laying and hatching could only be estimated from the observation and recording of other events and the behaviour of the parents. Although I could not be certain, I believed that breeding birds using a particular nest site over consecutive years were the same individuals, unless there was evidence to the contrary. In two cases males at separate nests were found to be different birds from those present during earlier visits. In one case a male was colour-banded and in the other it possessed distinctive head markings.

There were unsubstantiated reports from local residents of two pairs double brooding in the Clarence Valley but I found no evidence to confirm this. These observations were casual and did not involve the systematic recording of dates, activity etc.

In this study Ospreys started to construct or repair nests in April, with the last young fledging in December, although most had fledged by November (Table 3).

Nest building and material

Ospreys constructed or repaired nests from April to August (Table 3) but collected and delivered sticks, cane trash and grass to nests throughout the nesting period. Sticks below four active nests came from the Grey Mangrove *Avicennia marina* var. *australasica* (one site), River Oak *Casuarina cunninghamiana* ssp. *cunninghamiana* (one site), Swamp Oak *Casuarina glauca* (one site), Blueberry Ash *Elaeocarpus reticulatus* (one site), Pink Bloodwood *Corymbia intermedia* (one site), Forest Red Gum *Eucalyptus tereticornis* (three sites), *Eucalyptus* sp. (one site), Paperbark *Melaleuca* sp. (one site), Sugar Cane (one site), driftwood (two sites), unidentified plant species (two sites). These sticks varied in length from 124 millimetres to 1 160 millimetres (mean 480.4 mm, n = 36) and in diameter at the broadest end from 8 millimetres to 27.8 millimetres.

The few observations made of Ospreys collecting sticks involved their procurement from standing trees, usually dead branches on living specimens, which were grabbed by the feet as the bird flew at them. Sometimes the bird had to pull at the branch/stick until it snapped off. Not all attempts were successful. Other objects found under a nest at Yamba in July 1991 included a 205 millimetres long sprig of foliage of the Norfolk Island Pine *Araucaria heterophylla*, a piece of polystyrene (28 mm × 13 mm), a section of plywood (295 mm × 37 mm × 14 mm) and a broken piece of timber (242 mm × 23 mm × 23 mm). A small piece of polystyrene (35 mm × 20 mm) was also found under the Lawrence nest on 11 December 1993. Ospreys may not have been responsible for the deposition of this material but it is noted here for future reference. On 25 October 1996, the adult female Osprey, from the Munros Lane site, collected a green sprig of foliage from a Forest Red Gum, in the vicinity of the nest. She delivered this to the nest, which contained two small nestlings, and began to chew at the stem, running her bill along much of its length.

Courtship, display and mating

Six observations were made of Ospreys displaying. Single male birds were observed performing an undulating display and calling high over the nest sites at Wooli on 25 July 1991 and 4 September 1992, at Bonville (south of the study area) on 30 May 1995 and at Lawrence on 10 October 1995. On 9 August 1996 a pair of Ospreys engaged in a synchronous flight display high above the Woodford Island nest. The male followed the female at an estimated height of 800 metres, then displayed to her by flying towards her and banking. Both birds called during the display. Shortly afterwards two birds (presumably the displaying pair) landed on the nest and the male displayed to the female by drooping, then shaking and shivering his wings.

On 18 July 1996 a pair of Ospreys perched at the Munros Lane nest took off. The male flew at the female and they both circled around the nest area flying in synchrony, and rose to about 700 to 800 metres. The male again flew at the female. She rolled and presented her talons, and both flew out of sight.

Mating was observed on 13 occasions at four nests, over the six breeding seasons; the earliest date being 19 May and the latest 25 October. One mating event occurred in

TABLE 3

Activity during visits to Osprey nests in breeding season.

Activity	Mar (5)	Apr (8)	May (15)	Jun (14)	Jul (19)	Aug (17)	Sep (14)	Oct (13)	Nov (9)	Dec (5)
Birds absent	1	3	4	2	1	1	0	0	2	1
Birds present	4	5	11	12	18	16	14	13	7	4
Nest building	0	1	2	3	1	1	0	0	0	0
Display	0	0	0	1	1	1	0	2	0	0
Mating	0	0	1	2	2	2	1	1	0	0
Incubating	0	0	0	0	6	7	5	1	0	0
Nestlings present	0	0	0	0	1	2	5	6	3	1
Fledglings/juveniles present	0	0	0	0	0	0	0	2	2	3

NB: Numbers refer to the number of visits during which each activity was recorded at 9 nests over 6 years. Numbers in parentheses refer to the number of visits per month.

May, four in June, two in July, three in August, two in September and one in October. None were observed during periods of incubation or nestling care.

Egg-laying and incubation

Egg-laying dates were calculated by observing incubating adults and counting back from subsequent dates of fledging of the young, using an incubation period for the species of 36–39 days (Holsworth 1965; Poole 1989). Incubation was mostly observed from July to September (Table 3) so laying was assumed to have occurred from June to August. In the only case of incubation in October, it was believed that a new male had mated with the female in August.

Incubation of eggs (which possibly included brooding of newly hatched chicks) was observed for 42.2 hours during daylight hours. Females spent longer incubating than males: 29.4 hours (69.7% of time) vs. 12.8 hours (30.3% of time) (Mann-Whitney test W = 337, p = 0.0002). A total of 56 incubating events was noted with 38 (68%) involving females and 18 (32%) involving males. Eggs or young chicks were never left unattended, except when the sole parent at the nest chased off a potential predator. This was always for a short duration, never more than five minutes.

Brood size

The number of eggs laid in nests was not determined because it was difficult to reach or see them due to the height of nests, but the number of nestlings and fledglings was recorded for most nests. Four (28.6%) nests had a brood of one, eight (57.1%) had two and two (14.3%) had three young.

Nest defence

Breeding Ospreys of both sexes defended their nests from eleven bird species, including a conspecific (Table 4). Most were other raptors or corvids. The most frequently expelled birds were White-bellied Sea-Eagles *Haliaeetus leucogaster* and Torresian Crows *Corvus orru*. Aggression occurred at a similar frequency (interactions per hour of observation) through the breeding cycle up to fledging (Table 4).

Fledging and breeding success

Fledging occurred between late October and early December, although specific dates are known for only a few nests. Nine out of 15 nesting attempts were successful with a mean of 1.1 young per nest or 1.9 per successful nest (Table 5). The Woodford Island nest was the most productive, with a total of ten young fledged over five years. The pair did not breed in 1994 as the nest tree had deteriorated and could not hold a nest. The birds moved to a converted derrick pole in 1995. The Lawrence pair was successful in the first two years but produced no young from 1994 to 1996. The Kings Creek nest was present for two years but failed to produce any young, while the Munros Lane pair produced two young in the first year of observation, which was apparently their second year of nesting.

Four successful breeding attempts observed during the study involved two fledglings, three fledged one young each and two produced three young.

TABLE 4

Aggressive interactions by Ospreys during the breeding season.

Species	Pre-laying	Eggs	Nestlings	Fledgling	Totals
Osprey *Pandion haliaetus*	1				1
Black-shouldered Kite *Elanus axillaris*	1				1
Whistling Kite *Haliastur sphenurus*	1	1			2
Brahminy Kite *Haliastur indus*	1				1
White-bellied Sea-Eagle *Haliaeetus leucogaster*	2	5	4		11
Wedge-tailed Eagle *Aquila audax*			2	2	4
Brown Falcon *Falco berigora*		1			1
Galah *Cacatua roseicapilla*	1	2			3
Eastern Rosella *Platycercus eximius*	1				1
Australian Magpie *Gymnorhina tibicen*			1		1
Torresian Crow *Corvus orru*	3		7		10
Totals	11	9	14	2	36
Total hours	87.3	49.7	59.7	14.3	211
Interactions/hr of observation	0.13	0.2	0.2	0.14	0.17

TABLE 5

Number of young Ospreys produced per nest — 1992 to 1996.

Nest	1992	1993	1994	1995	1996	Total
Woodford Is.	3	2	0	2	3	10
Kings Crk.	*	0	0	*	*	0
Munros Lane	*	*	*	na	2	2
Lawrence	2	1	0	0	0	3
Wooli	1	1	na	na	na	2
Totals	6	4	0	2	5	17
Average	2	1	0	1	1.6	1.1

* = nest not present, na = data not available. The average refers to nests with a known outcome only.

At the Woodford Island nest late fledging may have also been due to the loss of the male early in the season, as a new male appeared later in the season, which successfully bred with the resident female. No young fledged from the Lawrence nest in 1994, 1995 or 1996. This was apparently due to the male's reluctance to feed the female at the nest. The male appeared, from its heavily marked breast band and head markings, to be a young bird. It apparently first arrived in the area in 1995 and was found injured on the roadside, near the nest, in May 1995. It recovered and was banded, and colour banded, and released shortly after being found. The colour bands enabled the bird to be identified as the resident male at the Lawrence nest during 1995, 1996 and early 1997. The lack of success at the nest may be due to the male's immaturity, rather than any incapacity from his injuries, as he carried out all other behaviours, such as hunting and mating, normally. Another possibility is that the female may have been sterile. The resident female, presumably this bird, produced two young in 1992 but only one in 1993 and since then has not produced any offspring.

Subsequent to this survey, on seven occasions, a single dead nestling was found in or under six different nests where one or two well-advanced young were present in the nest (pers. obs.), indicating that clutch size is often larger than the number of young that ultimately fledge.

Post-fledging

Post fledging dispersal of Clarence Valley birds is variable. Some remain within the natal area at least until the next breeding season while others disperse early. A nestling colour-banded near Maclean was observed at Narrabeen Lake, Sydney less than two years after banding, 504 kilometres to the SSW (Australian Bird and Bat Banding Scheme). This bird was also observed at Lake Tabourie on the New South Wales coast, 714 kilometres from the banding sight on April 17, 2006. Other locally banded birds have remained within the Valley and some are now breeding at local nests, although not at their natal nests (pers. obs.).

DISCUSSION

Breeding season

The breeding season of the Osprey varies between different sites in Australia and in the Northern Hemisphere. The results for the study were similar to those previously recorded for New South Wales; laying and fledging dates fell between those for lower and higher latitudes elsewhere in Australia (Holsworth 1965; Morris *et al.* 1981; Clancy 1989; Marchant and Higgins 1993; Rose 2000).

Adult Ospreys on the New South Wales north coast are present throughout the year. Some use nests as feeding platforms during the non-breeding season, while others appear to forage over wide areas adjacent to their breeding territories. Others may move up nearby rivers (Marchant and Higgins 1993; pers. obs.). The breeding season in the Northern Hemisphere is influenced by the migratory nature of most populations. Migratory Ospreys lay in spring, following their return to their nesting sites from wintering grounds, whereas resident populations, nesting at lower latitudes, are winter breeders (Poole 1989).

Holsworth (1965) found that Ospreys at Rottnest Island, Western Australia, usually fledged during December. In 1991 nestlings fledged from two separate nests at Pelsaert Island, Western Australia, in late October and late November to early December, respectively (Surman 1994). At Cairns, in North Queensland, J. Wren (RAOU Australian Nest Record Scheme) observed fledging during early August in 1979. This is consistent with Marchant and Higgins (1993), who stated that breeding is earlier in northern compared with southern Australia.

The late fledging dates in 1996, during this study, are probably due to flooding of the Clarence River in June, a critical period in the Osprey's breeding cycle. The capture of fish from the flooded Clarence River would have been hindered by the high turbidity of the water. The diet of the birds during, and immediately after the flood, included a greater variety of fish species than usual and the scavenging of at least one dead fish is suspected (Clancy 2005).

Nest sites

As well as the nest locations observed during this study, Osprey nests on the New South Wales north coast are also placed in living trees, on steel electricity towers and on artificial platforms on poles (pers. obs.; Bischoff 2001). Ospreys often use dead branches in living trees for nesting. The tops of isolated trees, often dead ones, are preferred nesting spots throughout the world. If the nest tree is alive it is generally flat topped, making nest building easier (Poole 1989).

Avian predators are the most likely threat to eggs and young and these are aggressively repelled from nest sites. Osprey reaction to human disturbance varies considerably between pairs (Dennis 2004) but was generally not a factor in the breeding success of pairs in this study as disturbance was minimal. Although nests are exposed to the sun, their height and exposure allows wind to reduce thermal loads and provides increased visibility to adults (Edwards and Collopy 1988). However, very strong winds are likely to inhibit breeding success.

Throughout the world Ospreys construct their own nests and there are no published records of Ospreys using nests constructed by other species. However, two nests in the Tweed Valley, in the early 1980s, were reported by a local resident to have been used, and possibly constructed by Brahminy Kites *Haliastur indus*. The ability of displaced Ospreys to find other nearby, suitable nest sites and the absence of observations of resident Osprey pairs that fail to nest, indicates that, at the time of the study, nest sites are unlikely to be a limiting factor to Osprey breeding success locally. The loss of dead nest trees was noted in a study on the mid-north coast of New South Wales, however most pairs were able to rebuild at the same or new sites (Bischoff 2001).

Nest materials

I found that, as elsewhere, Ospreys build nests mostly of dead sticks taken from trees (Beruldsen 1980; Cupper and Cupper 1981; Clancy 1989; Poole 1989; Rose 2000). Driftwood is also collected from beaches (Cupper and

Cupper 1981), though I have not observed this. Nest lining in the form of grass, seaweed and cane trash is usually picked up from the ground (pers. obs.).

My observations support the view (Clancy 1989; Poole 1989) that the sticks for nest construction and the lining materials vary depending upon locally available materials. The dimensions of the sticks used in nest construction were similar at the four nests sampled. A detailed assessment of the nesting material from one nest has been published elsewhere (Bischoff 2001). I once observed an adult female Osprey delivering fresh foliage to a nest, though this behaviour is rarely recorded in Australian Ospreys (Olsen 1995).

Courtship, display and mating

The display behaviours observed in this study were as previously described (Poole 1989; Marchant and Higgins 1993; Rose 2000), except for the undulating hover ('yo-yo'), which was not observed. The fish display (Marchant and Higgins 1993; Rose 2000) was also not recorded.

No mating attempts were observed in the incubation or nestling stages during this study, the late mating events were at a nest where breeding was unsuccessful. Mating while young have been present in the nest, which has previously been recorded in New South Wales (Clancy 1989), was not observed during this study.

None of these mating events was immediately preceded by courtship feeding. However, one female bird had been fed by the male 30 minutes earlier. Only 63 of 385 copulation attempts, during a study in British Columbia, were associated with feeds and these attempts were no more likely to be successful than those not associated with feeds (Green and Krebs 1995). It has been argued that courtship feeding may function primarily to ensure mate fidelity (Poole 1985), but the general wisdom is that courtship feeding brings female raptors into breeding condition (Olsen 1995).

Egg-laying, Clutch and Brood Size

Although no clutches were seen in this study, six nests examined in north-east New South Wales, before this study, contained three eggs (Clancy 1989; Marchant and Higgins 1993; pers. obs.). Throughout its range the Osprey has a clutch of two or three, rarely four eggs (Beruldsen 1980; Cupper and Cupper 1981; Olsen and Marples 1993). Three has been the most common clutch recorded for the species world-wide (Poole 1989).

The most common brood size in this study was two, which may have resulted from the death of the smallest nestling, or, from the failure of one egg to hatch. When a clutch of three occurs, it is common for one egg to fail to hatch (Cupper and Cupper 1981; P. Olsen, pers. comm.). The smallest and last hatched chick, in species with asynchronous hatching, often succumbs to the effects of low food supply in any but the most productive seasons (Olsen 1995). Holsworth (1965) found that only once did more than two young fledge at Rottnest Island, Western Australia despite three eggs being laid at all nests. It is likely that the fate of the third nestling is dependant on food supply.

At a nest at Rottnest Island in 1962, all three nestlings died, apparently from food shortage, the smallest died first, the second smallest six days later and the largest the following day (Holsworth 1965). A study at Chesapeake Bay, USA found that the sex of the hatchlings and hatching asynchrony appear important in facilitating aggression and brood reduction due to size disparity (McLean 1991). Forbes (1991) stated that nearly all aggression among nestlings occurred during meals and took two forms: physical abuse and threat displays.

Breeding performance hardly differed in British Columbia between two locations despite differences in food quality (Steeger *et al.* 1992). Therefore, modest fluctuations in food supply do not appear to influence clutch or brood size in Ospreys. However, clutch size, brood size and the number of fledglings all declined with progression of the breeding season in British Columbia (Steeger and Ydenberg 1993).

In 1984, a female at Forster, New South Wales, successfully reared one nestling after her mate disappeared when the nestling was about one week old (Rose 2000).

Incubation

My results from nest watches show that, although males generally assume the role of food provider for the female, and later the young, they do take considerable responsibility for incubating the eggs and (probably) brooding the chicks. In this study 30.3 per cent of diurnal incubating was done by males. At three separate Northern Hemisphere sites between 13 per cent and 66 per cent of diurnal incubating was performed by males (Poole 1989). The male takes his share of incubating during daytime (Marchant and Higgins 1993), but the female always incubates at night (Poole 1989).

Double-brooding

Double-brooding is virtually unknown in Ospreys, with no reference to it by Poole (1989). However, at least one pair of Ospreys near Brisbane double-brooded during the mid 1980s to early 1990s (G. Czechura, pers. comm.; Marchant and Higgins 1993).

Nest defence

Ospreys defend their nests throughout the breeding season. Most aggression involved species, such as raptors or corvids, that pose a threat to the Ospreys' eggs or nestlings. However, Eastern Rosellas *Platycercus eximius* and Galahs *Cacatua roseicapilla*, which were nesting in the nest trees were also sometimes attacked.

Various species of bird (including Galahs and Eastern Rosellas) occupy the hollows and branches of Osprey nest trees, frequently with no response from the Ospreys. A pair of House Sparrows *Passer domesticus* regularly nests in the sticks of the Osprey nest at Woodford Island (pers. obs.). Many other birds, including honeyeaters, fantails, and herons nest in trees and shrubs close to Osprey nests (pers. obs.). This may provide some protection from nest predators or may be due to many bird species being forced to congregate in small remnants of natural vegetation within cleared agricultural land.

The White-bellied Sea-Eagle and Torresian Crow, which were the most frequently expelled species, potentially pose a threat to the nestlings (Marchant and Higgins 1993), and, in the case of the crow, the eggs of the Osprey. Wedge-tailed Eagles *Aquila audax* were attacked while nestlings or fledglings were present. Nestling birds feature commonly in the diet of the Wedge-tailed Eagle and White-bellied Sea-Eagle (Marchant and Higgins 1993). The disappearance of two well advanced Black-necked Stork nestlings in 1995, from the nest subsequently used by Ospreys at Munros Lane, may have been due to predation by Wedge-tailed Eagles.

Eggs and small nestlings are vulnerable to crows; Hagan and Walters (1990) suspected that Fish Crows *Corvus ossifragus* had taken Osprey eggs from nests in North Carolina. Evans (1982) identified gulls as possibly causing the loss of eggs or small young, although they were usually repelled from the nest. Ospreys defend their nest sites (and territories?) against conspecifics, though I only saw this once. However, two male Ospreys were found dead under powerlines at South Ballina, in August 1995. A female was perched nearby. An autopsy (NSW Agriculture, Regional Veterinary Laboratory, Wollongbar) revealed that the birds had apparently died from an impact sustained during a fight, contrary to initial impressions that they may have been electrocuted. This indicates that, at least occasionally, intraspecific fighting can be aggressive and may lead to the death of one or both combatants. Intraspecific aggression may be due to competition for a nest site or mate. Attempted predation of eggs or young seems unlikely, as the species is virtually exclusively piscivorous in New South Wales (Clancy 2005).

Intraspecific aggression was frequent in Ospreys in North Carolina and often resulted in brief encounters on the nest platform, possibly because the species is colonial there. Egg loss could result from intense interactions rather than predation in colonies, given the tenacious nest attendance by females during incubation (Hagan and Walters 1990).

All nests in this study were placed high enough to be inaccessible to mammalian predators, with the possible exception of the Common Brushtail Possum *Trichosurus vulpecula* and Black Rat *Rattus rattus*, which are known to eat birds' eggs (Pedler 2004). However, Lace Monitors *Varanus varius* could climb to nests but would find the eggs or young difficult to reach. There are no records of possums, rats or Lace Monitors attempting to rob Osprey nests.

Human predation was not recorded during this survey, but egg collecting has been identified as a threat to the species in the past (Parslow 1969; Clancy 1989).

Fledging and breeding success

Ospreys at Rottnest Island fledged at about 50 days (Holsworth 1965). Insufficient information was gathered during this study to determine age at fledging of local birds although one brood was in the nest for at least 50 days. Two nestlings at Ballina, New South Wales fledged at 71 and 76 days respectively (Maciejewski 1993).

Northern Hemisphere Ospreys fledge when 50–55 days old for migratory populations or 52–76 (average 63) days old for non-migratory populations (Poole 1989).

In the United States, Henny and Wright (1969) concluded that a population of nesting Ospreys should fledge 0.95–1.30 young per breeding pair per year to maintain a stable population. The results for this study indicate that sufficient young are produced per nest (1.2), if mortality rates are similar in north-east New South Wales to those in the USA.

The increase in the size of the Osprey population in New South Wales in recent years indicates that sufficient young are being produced to, not only maintain existing population levels, but allow for an increase. Band recoveries indicate that at least some of the additional birds observed in recent years have fledged in north-eastern New South Wales (pers. obs.).

Post-fledging

Some young Ospreys in this study remained in the natal area at least until the next breeding season while others dispersed early. Some are now resident breeders at nests within a few kilometres of their natal area. Holsworth (1965) found that young birds disperse widely, both north and south, of Rottnest Island. One juvenile moved 240 miles (386.4 km) in 4.5 months; others moved shorter distances (7 miles–11.27 km) within their first twelve months. At Forster, New South Wales, young birds remained in the nest area for four to five weeks (Rose 2000).

In Scotland, the post-fledging dependence period lasted an average of 30.4 days (n = 35). The adult male continued to provide fish to the nest while the fledglings were in the area and did not promote fledgling independence by stopping fish delivery to the nest, however there was a significant final decrease in the rate that fish were delivered to the nest during the last five days of the post-fledging period (Bustamante 1995).

CONCLUSIONS

Breeding behaviour of Ospreys in north-eastern New South Wales is similar to that elsewhere in Australia and, indeed, the Northern Hemisphere. The main differences between regions are the season of breeding, the colonial nesting of some northern populations and the utilization of inland lakes as foraging and nesting sites.

Northern Hemisphere birds lay their eggs in the spring (Poole 1989), which is similar to tropical Australia whereas subtropical and temperate Australian birds lay in the winter. Most Northern Hemisphere populations are coastal and migratory. However, some (particularly in Europe) nest near inland lakes or rivers, unlike Australian birds, which are restricted to coastal, or near coastal sites. Australia has a shortage of clear freshwater lakes and rivers and much of the interior of the continent is arid. It is, therefore, not surprising that Australian birds do not breed very far inland. Australian birds are mostly sedentary (Marchant and Higgins 1993; pers. obs.), unlike most Northern Hemisphere populations, and this would account for some of the differences identified. Extremely low winter temperatures and use of freshwater (i.e. lakes get frozen) account for both migration and spring breeding in the cooler parts of the Northern Hemisphere. Australian birds experience mild winters and do not need to migrate to survive.

This study provided no evidence to suggest that breeding success at the nests surveyed was atypically low or that a shortage of nest sites occurred. Therefore, it is unlikely that edge-of-range effects (where habitat may be marginal) or organochloride or other pesticide pollution are significantly influencing breeding Ospreys in north-east New South Wales. There was also no effect of DDT on the thickness of Osprey eggshells in Australia (Olsen *et al.* 1993).

The information gathered for this study on incubation patterns, copulation, and egg laying and fledging dates are based on limited data and should be considered as indicative only but are strongly supported by Rose (2000).

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