

Aspects of the breeding biology of the pied shag (*Phalacrocorax varius*) at Makara Beach, Wellington, New Zealand

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Abstract Breeding of pied shags (*Phalacrocorax varius*) at 2 colonies at Makara Beach, Wellington, was studied from Mar 1996, when breeding was 1st noted there, to May 2005. Pairs occupied and refurbished vacant nests rather than build new nests. The number of breeding attempts increased from 3 in 1996 to 46 in 2004, with 166 occurring during the study. New nests ($n = 14$) took about 3 weeks to build; most nests were used twice a year. Clutches were laid in all months, but there were 2 peaks: 61 nests (37%) in Feb–Mar and 53 nests (32%) in Aug–Sep. Overall, 76.6% were successful (fledged at least 1 nestling, $n = 154$ breeding attempts for which the outcomes were known), and the mean success was 1.4 fledglings nest⁻¹. The proportion of successful breeding attempts and the mean number of fledglings produced nest⁻¹ were similar for 1996–2000 (when the number of breeding attempts yr⁻¹ increased from 3 to 11) compared with the 2001–2005 period (when breeding attempts increased from 15 to 46 yr⁻¹). Of 14 breeding attempts for which clutch size was determined, mean clutch size was 3.4 (range 2–4 eggs), and mean brood size at fledging was 2.1 young (62% of eggs resulted in fledglings). The maximum number of shags counted at the colonies increased from 14 in 1996 to 68 in Dec 2003, after which numbers appeared to stabilize. However, since 2003, numbers of pied shags seen elsewhere in the Wellington region, particularly on Mana I and at Waikanae Estuary, have increased.

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INTRODUCTION

The pied shag (*Phalacrocorax varius*) is a large (♂ 2.2 kg, ♀ 1.7 kg), predominantly black-and-white shag (Nelson 2005). Two subspecies are recognised: the nominate *varius* inhabits (mainly coastal) waters about New Zealand, and *hypoleucos* has a disjunct distribution on the Australian coast particularly in the west and south (Marchant & Higgins 1990). In addition, both subspecies occur inland, foraging and breeding at freshwater wetlands, particularly in Australia (Marchant & Higgins 1990).

Pied shags can breed on the ground, on low shrubs, high up on tall trees, and on man-made structures, such as navigation platforms (Marchant & Higgins 1990). Nests can be substantial structures (45 cm deep; 45 cm dia.) made of sticks, foliage, and seaweed, with pieces of cultural rubbish,

such as plastic bags and strapping, incorporated occasionally. Clutch size ranges from 2–5 and eggs are laid at 48-h intervals. The incubation period decreases slightly with egg laying order. The 1st 3 eggs take 28–33 days to hatch, but 4th-laid eggs hatch after 25–28 days (Millener 1972). Both parents incubate, swapping at least 3× during the day (Marchant & Higgins 1990). Nestlings hatch naked and helpless, but grow and develop rapidly. By 14 days they are covered in short, dense, black down. By then they can squat on their tarsi, but they continue to be guarded by a parent even if they do not need brooding during warm weather. By c.20-days old, the chicks are reasonably well covered by contour feathers, are adept at moving about the nest, and are left unattended occasionally (Marchant & Higgins 1990). Although they fledge at c.53 days (range 47–60), fledglings remain at or near the colony, and are fed for up to a further 80

days (Millener 1972). Breeding success at Werribee, Victoria, Australia, was 26.2% (134 fledglings from 511 eggs in 2 breeding seasons; Norman 1974). Breeding success at Lake Pupuke, Auckland, New Zealand, was 43.3% (138 fledglings from 319 eggs in 3 breeding seasons; Millener 1972).

Throughout its range in New Zealand, the pied shag has been found breeding in all months at Auckland (Sibson *et al.* 1956; Millener 1972), Marlborough Sounds (Soper 1976), and Stewart Is (Lalas 1979). Usually colonies have most occupied nests in spring, with sometimes a secondary peak in autumn (Millener 1972; Lalas 1979). However, Nelson (2005) concluded that autumn egg-laying was favoured, presumably in Australia.

Despite its approachability when breeding, in comparison to black shags (*Phalacrocorax carbo*) and little shags (*P. melanoleucos*), which can abandon their nests (RGP *pers. obs.*), there have been only 2 detailed studies of pied shag breeding biology (Millener 1972; Norman 1974). Much remains to be learnt, including the consistency of breeding parameters at different latitudes.

In 1996, a pair of pied shags was found breeding at Makara Beach, Wellington, southern North I (Reese *et al.* 1996). This was the 1st reported breeding of the species in Wellington, and no other colony is known to have established in the region since. Observations at the 2 Makara Beach colonies continued until May 2005. The aim of the study was to monitor colony development, the seasonal occurrence of breeding, breeding success, and to add to the general knowledge of breeding of this species at a new geographic location.

STUDY AREA and METHODS

Pied shags nested in 2 colonies at Makara Beach, both on macrocarpa (*Cypressus macrocarpa*) trees overhanging Makara Stream (41°13'S, 174° 43'E). The 1st colony, referred to as 'Island', was situated on an island c.100 m up-stream from the stream mouth at Makara Beach (hereafter "Makara"), Ohariu Bay, on the Wellington west coast, while the 2nd, referred to as 'Road', was c.100 m further up-stream.

Observations began on 26 Mar 1996 and continued until 29 May 2005, by which time all breeding attempts that began (eggs laid) during summer 2004-2005 had either failed or the nestlings had fledged. From Mar 1996 to Dec 1999, visits to monitor breeding were made at 2-3 week intervals when the birds were breeding, but visits were made almost weekly from Jan 2000.

At Island colony, most observations were made by an observer who had climbed 1 of the nest trees, but observations of the Road colony were made from ground level. Observations were made using 10 × 40 binoculars, or 20× telescope, or both. The

identity (based on location) of each nest and the predominant activities of the occupants (courtship, nest-building, incubation, rearing nestlings) were recorded during each visit. The brood size in each nest was visible from the ground once nestlings were >4 weeks old and did not require brooding.

Although we were able to look down on only 4 nest sites while observing from 1 of the macrocarpa trees of Island colony, each site was occupied several times during our study. Even so, when shags at these nests were incubating or brooding chicks <2 weeks old, they rarely stood up or changed incubation shift during our observations. Therefore, determinations of clutch-size and brood-size were infrequent. The number of eggs seen in a nest was regarded as being the entire clutch when the same number was seen twice or was seen during the 3rd or 4th weeks of incubation. Brood-size could be determined accurately only when each brood was ≥ 4 weeks old, by which age the young were not brooded often and regularly begged to be fed when a parent was at the nest. Breeding success was based on the number of nestlings at the nest when the brood was 6-7 weeks of age, 1-2 weeks before fledging.

No adults or chicks were captured and banded. Irregular counts at dusk were made of the number of roosting pied shags (adults and juveniles combined) at the 2 colonies from Aug 2002 to Feb 2005.

The computer package SigmaStat® was used for statistical tests. All data are expressed as means ± SD.

RESULTS

Nest building

When breeding started during the peak periods, Feb-Mar and Aug-Sep (see later), vacant nests were initially occupied by males, and later by pairs, both showing bright nuptial colours (bare skin in front of the eye yellow, eye ring blue, iris green, gular pouch and base of bill pink). These nests were refurbished before each breeding attempt, mainly by addition of lining material of seaweed and fine grasses to form a nest cup. Only after all vacant nests had been occupied did males in nuptial colours occupy new sites on branches where nests were built later. Males called and displayed to attract a mate. They accumulated some sticks at their nest sites, but often some of this material was robbed by other nest-building males while the owner was away foraging. Nest-building began in earnest, and the nest formed, only after a male had attracted a mate. Then 1 bird guarded the nest while the other foraged. Nest material was gathered mainly while swimming in Makara Stream, or while at sea. The material was presented to the female at the nest site, accompanied by much calling by the male and displaying by both birds. The nest base

Table 1 Monthly success of pied shag (*Phalacrocorax varius*) breeding attempts at Makara Beach, Wellington, New Zealand, for 1996-2000, 2001-2005, and in total. The results for only breeding attempts for which the outcome was determined are presented ($n = 154$). A breeding attempt was deemed successful if at least 1 fully-feathered nestling was seen on or beside the nest.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1996 – 2000													
No. of nests	-	-	11	3	2	-	1	4	8	-	1	-	30
Proportion successful	-	-	72.7	33.3	100.0	-	0.0	100.0	75.0	-	100.0	-	73.3
Mean brood size	-	-	1.2	1.0	1.5	-	0.0	2.7	1.2	-	2.0	-	1.40
2001 – 2005													
No. of nests	4	31	19	5	3	2	8	10	23	12	4	3	124
Proportion successful	100.0	87.1	57.9	40.0	100.0	100.0	62.5	70.0	91.3	75.0	75.0	66.7	77.4
Mean brood size	2.5	1.9	1.3	0.6	2.0	2.5	0.9	1.4	1.4	1.1	0.7	1.7	1.46
1996 – 2005													
Proportion successful	100.0	87.1	63.3	37.5	100.0	100.0	55.6	78.6	87.1	75.0	80.0	66.7	76.6
Mean brood size	2.5	1.9	1.2	0.7	1.8	2.5	0.8	1.8	1.4	1.1	1.0	1.7	1.45

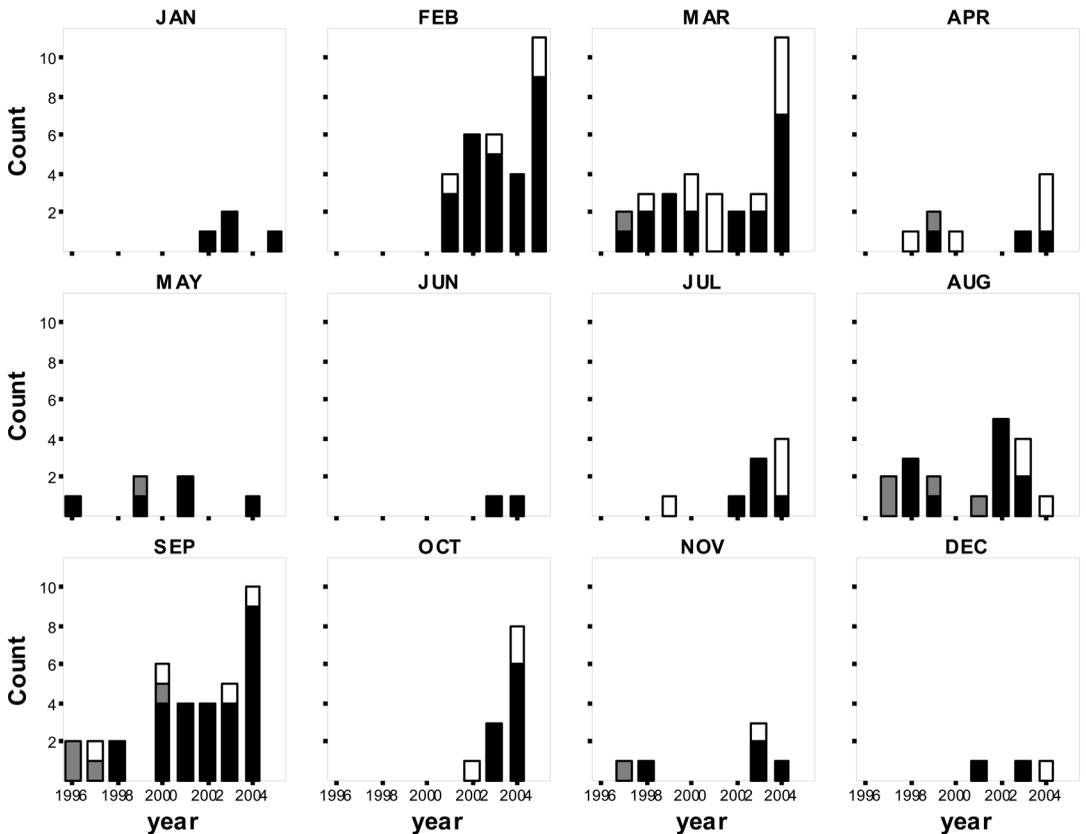


Fig. 1 Breeding effort month⁻¹ (number of nests in which clutches were laid) and success (proportion of breeding attempts resulting in at least 1 fledgling) each month of pied shags (*Phalacrocorax varius*) at Makara Beach, Wellington, May 1996 - Feb 2005. Black, successful breeding attempts; white, failed attempts; grey, attempts with unknown outcomes.

was composed mainly of sticks and seaweed, and then the nest cup was formed of seaweed and flexible, fibrous material (commonly flood debris such as dead grasses), as well as occasional pieces

of plastic. Building an entire nest took 2.8 ± 0.7 weeks ($n = 14$, range 2-4 weeks), although the 7-day interval between visits prevented our determining the precise duration.

From 2002 onwards, most nest sites and/or nests were used twice a year. Those nests used in Feb-Apr that had remained relatively intact were re-used following refurbishment after breeding attempts during Jul-Nov. A successful breeding cycle at the nest takes c.4 months (Millener 1972: nest-building 3 weeks; pre-laying 1-2 weeks; incubation 4 weeks; rearing 7 weeks), so some sites were in use for much of the year, especially if a failed attempt was followed promptly by a successful attempt. Even when all material was robbed from a site by shags building nearby, a nest was often built at the same site within a few months.

From Mar 1996 to Mar 1998, all breeding attempts were at the Island colony. However, during Aug- Nov 1998, all breeding attempts were at the Road colony. In 1999, birds nested at both colonies simultaneously. By 2000, both in autumn (Mar-May) and spring (Sep-Nov), all breeding was again at the Island colony. Thereafter, both colonies were occupied simultaneously during the peak breeding periods.

Number of clutches initiated annually

During 1996-2000, there was little growth in colony size. In 1996, we recorded 3 breeding attempts, followed by 7 in 1997 (Fig. 1). During 1998, 1999, and 2000, the number of breeding attempts yr⁻¹ was static at 10-11. Then during 2001-2004, the colony expanded annually, with 15, 20, 32, and 46 breeding attempts yr⁻¹, respectively. In total, 166 breeding attempts were monitored, of which the outcome of 154 was determined.

Number of clutches initiated monthly

Clutches were laid in all months, and there were 2 peaks in breeding: Feb (31 clutches, 18.7% of 166) to March (31, 18.7%), and Aug (19, 11.4%) to Sep (35, 21.1%) (Fig. 1, Table 1). However, it is notable that no clutches were laid in Feb during 1996- 2000 (Table 1). Fewest clutches were laid in Jun (2, 1.2%), Dec (3, 1.8%), and Jan (3, 1.8%). The greatest number of nests in which eggs were laid during a single month was 11 (Mar 2004, Feb 2005), and the greatest number of pairs involved in breeding during a visit was 17 on 25 Oct 2004.

Clutch size

Mean clutch size was 3.4 ± 0.6 eggs ($n = 14$, mode = 4, range = 2-4).

Monthly breeding success

Breeding success of pied shags at Makara, whether considered as the proportion of attempts that were successful (reared at least 1 fledgling) or mean brood size at fledging, varied from month to month, particularly in 1996-2000 when sample sizes were invariably < 10 (Table 1). Overall, breeding success in 1996- 2000 ($n = 30$, 73.3% successful, 1.4 fledglings brood⁻¹) was not significantly different to that in

2001-2005 ($n = 124$, 77.4% successful, 1.5 fledglings brood⁻¹), nor did the proportion of successful breeding attempts ($\chi^2 = 0.055$, $df = 1$, $P = 0.815$; with Yates' correction) or mean brood size (Mann-Whitney Rank Sum test, $P = 0.762$) vary significantly between the 2 periods. For 1996-2005, 76.6% of 154 breeding attempts of which the outcome was determined were successful, and mean brood size was 1.4 fledglings. The mean brood size of successful breeding attempts ($n = 118$) was 1.9 fledglings.

We did not see any harriers (*Circus approximans*) closely approach either colony nor see any evidence that mammalian predators had taken eggs or nestlings (egg shells with sign of having been broken open by predators, or partly eaten nestlings under either colony). The consistently high breeding success each month during the study (Table 1) also suggests that if predation did occur at the colonies, it was an unusual event.

Impact of a storm

During 14-20 Aug 2004, a protracted southerly storm affected the Wellington region. Several mature macrocarpa and many Monterey pine (*Pinus radiata*) trees were blown down in the Makara district. Although none of the colony trees was blown down during the storm, some nests were destroyed. Of 16 nests present before the storm, of which 4 were in use, 6 (none in use) were blown down, and 2 breeding attempts failed.

Proportion of eggs that resulted in fledglings

Sixty-two percent of eggs produced fledglings ($n = 14$ breeding attempts, 48 eggs). Mean brood-size at fledging was 2.1 ± 0.8 nestlings (mode = 2, range = 1-3). Even though the modal clutch-size was 4 for just 14 breeding attempts where it could be determined, at none of the 118 successful breeding attempts during this study did 4 nestlings fledge from a brood.

Population increase

During 1996, when breeding by pied shags was 1st observed at Makara, 5 to 14 shags were recorded roosting at the colonies (Reese *et al.* 1996). Subsequently, numbers roosting at the colonies at dusk increased to 45 and 46 in Aug and Nov 2002, respectively, and to 68 and 67 in Dec 2003 and Jan 2005, respectively.

As numbers increased at Makara, sightings and counts of the species increased in frequency and number in the Wellington region. In Wellington Harbour, no pied shags were seen during monthly shoreline counts in 1975-1977, and just 1 or 2 during some counts in 1986-1988 (Robertson 1992). In 1994-1995, a pied shag was seen roosting occasionally about the harbour by day, and up to 3 were seen roosting on macrocarpas on Somes/Matiu I in the evening (Reese *et al.* 1996). In Apr 2001, pied shags

were found roosting in willows (*Salix* sp.) on the riverbank of the Hutt River c.1.5 km upstream of the river mouth. Monthly counts of shags at this roost near dusk from Apr 2001 to Sep 2004 ranged from peaks of 5-6 in May-Aug, to none in Oct-Jan (A. Munro & J. Woon, *pers. comm.*). In addition, pied shags were found roosting overnight on Monterey pines near Point Halswell, Wellington Harbour. The greatest number seen there was 3 birds on 13 Feb 2006 (S. Keall, *pers. comm.*). No pied shags were seen during monthly counts of shags roosting in the Karori Wildlife Sanctuary, Wellington, from Jun 1994 to Feb 2000 (R. Empson, R. Powlesland & S. Sharp, *unpubl. data*). Since resuming these counts in Aug 2004, 1 pied shag was present in most months from Sep 2005 to Aug 2006.

Sightings of pied shags along the west coast from Pukerua Bay north to the Manawatu River estuary have also increased. Single pied shags were recorded at or near the Waikanae River estuary only on 13 Apr 1997 (Tennyson & Lock 1998) and in Oct 2003 (Parrish 2006). However, on 6 Sep and 17 Oct 2006, 6 and 10 pied shags, respectively, were roosting near the estuary (G. Suckling, *pers. comm.*). At the Manawatu River estuary, an adult was seen on 26 Jul and 16 Aug 1997 (Tennyson & Lock 2000), 1 or 2 immatures were seen regularly between Aug 1998 and Apr 1999 (Parrish 2000), 1 shag was seen from 25 Sep to 13 Nov 1999 (Parrish 2001), and 1 was seen on 14 Apr 2002 (Parrish 2003). On 7 and 8 Jun 2006, 10 pied shags were seen roosting in a macrocarpa tree on Mana I (C. Miskelly, *pers. comm.*), and Department of Conservation staff based on the island reported that the species had been roosting there for about a year, with up to 14 regularly seen at a time.

DISCUSSION

Nest building

In most respects the findings of this study with regard to nest building by pied shags at Makara were the same as those reported by Millener (1972) for the species at several colonies in the Auckland region, and were similar to such activities of other *Phalacrocorax* species (Nelson 2005). Although pied shags do not develop nuptial plumes at the start of the breeding cycle, as do many *Phalacrocorax* species (Johnsgard 1993; Nelson 2005), they do develop vivid skin coloration about the eyes and base of the beak, which gradually declines in intensity to that of the non-breeding status by part way through nestling rearing. Our observations confirmed this pattern at Makara.

For nest occupancy, Millener (1972) also found that early-formed pairs occupied and refurbished vacant nests, and that subsequent pairings then built entire nests. Presumably, refurbishing a nest

saves time and energy for pairs that do not need to build a complete nest. Likewise, nest-building pied shags at Makara invariably took material from unoccupied nests nearby, whether they were old nests from which nestlings had fledged or those briefly vacated by an unpaired male, rather than gathering material from further afield.

When collecting nest material, the shags at Makara gathered the most readily available material, either at sea after foraging or in the stream near the colonies. Generally, shags breeding in trees can obtain much of the material directly from the nesting trees, as Millener (1972) noted for pied shags nesting on pohutukawa (*Metrosideros excelsa*) trees. However, pied shags at Makara were rarely able to break off dead or live twigs from the macrocarpa trees, and had to gather their material from elsewhere. The nests of pied shags on dead trees at Werrabee consisted mainly of the annual herb *Atriplex hastata* (Norman 1974) because that was the only nest material available near the colony.

Pied shags at Makara took a mean of 2.8 weeks to build an entire nest, whereas those at Auckland took a mean of 3.6 weeks (Millener 1972). Given that our observations were at weekly intervals, and Millener's were daily, the difference in mean duration is probably due to differences in sampling methods.

Most nests at Makara were used 2-3 times a year, and survived from year to year. Similarly, Millener (1972) found that pied shag nests at Lake Pupuke were also used more than once each year, and noted that 1 particular nest was used 8 times in 2.5 years. Although each succeeding pair add material to a nest, Millener (1972) noted that the nests were never >80 cm in diameter or >50 cm deep because the rate of loss of old material from the base was similar to the rate at which new material was added at the top.

Pied shag nests at Werrabee survived poorly. For example, of 27 nests present in May 1972, 10 (37%) had been lost by the end of the breeding season, just 7 months later (Norman 1974). Some had been dislodged during strong winds, while others collapsed when supporting branches or the entire dead tree on which they were built disintegrated. The bases of these nests included few sticks, and were composed mainly of herbs, which may have contributed to their loss.

Breeding season

Over the 9 years of study at Makara, clutches were laid by pied shags in all months, with peaks in Feb-Mar and Aug-Sep. Likewise, Millener (1972) found that pied shags at 9 colonies in the Auckland region laid clutches in all months, with peaks in Feb-Apr and Aug-Oct. In contrast, at Werrabee clutches were laid from late May to late Oct only, with a peak in May-Jun followed by a broad lower peak from

late Jul to late Sep (Norman 1974). The ability of New Zealand's pied shag to produce clutches in all months in the temperate climate is unusual. In comparison, while shag species generally produce clutches over a protracted period in most parts of their range, or lay in all months, most species in cool-temperate regions have fairly compressed and annually-consistent laying periods (Nelson 2005). Of the other 11 shag species of the New Zealand region, only the Stewart Is shag (*Leucocarbo chalconotus*) produces clutches in all months (but not at any 1 colony), while the black shag, little shag, and spotted shag (*Stictocarbo punctatus*) have protracted laying seasons of 6-8 months (Marchant & Higgins 1990; Heather & Robertson 2005; Nelson 2005).

At Makara, although no clutches were laid in Dec-Feb during the 1st 5 years, 31 clutches were laid in Feb during 2001-2005, the greatest number laid in any month during that period. We speculate that this change in timing of egg-laying resulted from the maturation of the age structure of the population. Since breeding commenced at Makara in 1996, perhaps most shags breeding there during 1996-2000 were immigrants and their progeny with no or little breeding experience, and that by 2001-2005 a reasonable proportion of the breeders had a few years' experience. Some support for this suggestion comes from studies of seabirds other than the Phalacrocoracidae, in which new breeding sites are colonized by young birds, and seabirds with no or little breeding experience lay their clutches later than older, experienced breeders (Schreiber & Burger 2002; Nelson 2005).

Given that a successful breeding cycle from nest-building to independence of fledglings takes about 6 months (Millener 1972), it is possible that pied shags could rear 2 broods in a year. While the rearing of 2 broods in 1 year occurs occasionally in the bank cormorant (*Phalacrocorax neglectus*) (Ryan & Hunter 1985) and exceptionally in the European shag (*Phalacrocorax aristotelis*) (Wanless & Harris 1997), most species of the genus breed successfully only once a year (Nelson 2005). This may result from the nutrient and energy demands of the post-breeding moult. However, other than shags and cormorants having a complex form of primary moult, termed *Staffelmause*, whereby primary feathers of older adults are moulted in 2-4 waves concurrently, there seems to be little information about how long a complete moult takes or whether breeding interrupts the process (Ginn & Melville 1983; Nelson 2005). Another possible reason for completing just 1 successful breeding cycle per year is insufficient food to meet self-maintenance and breeding requirements at certain times of year, such as in winter when days are short. Individually marked birds would be needed to determine whether pied shags are able to breed twice in a year,

or to change from an autumn to spring breeder and vice versa.

Clutch size

Even though it was based on only 14 clutches, the mean clutch size of pied shags at Makara at 3.4 was much the same as that at an Auckland colony (mean = 3.3, $n = 186$, 1969-1971; Millener 1972) and at Werrabee (mean = 3.3, $n = 256$, 1971-1973; Norman 1974). The modal clutch size at each of the sites was 3 or 4, and there was a similar proportion of 3- and 4-egg clutches at each site: Makara 3-egg \times 6, 4-egg \times 7; Auckland 3-egg \times 86, 4-egg \times 77; Werrabee 3-egg \times 107, 4-egg \times 116. Likewise, the modal clutch-size of most *Phalacrocorax* species is 3 or 4 (Johnsgard 1993).

Breeding success

There was no significant difference in the breeding success of pied shags at Makara during 1996-2000 compared with that during 2001-2005 whether considered as the proportion of breeding attempts that were successful or mean brood size fledged. This result was unexpected because many of the breeders at the colonies during the 1st period were likely to have been inexperienced, and among Phalacrocoracidae (cormorants, shags), inexperienced females rear smaller broods than older females (Nelson 2005). Perhaps later in our study, competition for food became more of an issue, such that although most females were experienced breeders this advantage was cancelled out by poor prey availability.

Overall, 76.6% of 154 breeding attempts were successful, and a mean of 1.4 nestlings fledged nest⁻¹. Similarly, at the Lake Pupuke colony, Auckland, during 1969-1971, pied shags fledged a mean of 1.4 nestlings nest⁻¹ (Millener 1972). In contrast, the mean number of nestlings fledged nest⁻¹ was only 0.8 at Werrabee (Norman 1974), even though the mean clutch sizes at the 3 sites were similar (see above). The poor breeding success of pied shags at Werrabee did not result from predation, or poor parental nestling-rearing skills, but because several of the nests were dislodged or fell apart, or the dead branches or entire trees on which they were built fell down during breeding (Norman 1974).

The pied shag and the black shag are sympatric, coastal-breeding, species in the Wellington region. The breeding success of the black shag at Pencarrow, Wellington, during 1993-1998 (82.7% of breeding attempts were successful, mean of 1.4 fledglings nest⁻¹, and a mean of 1.7 fledglings successful nest⁻¹, $n = 185$; Powlesland & Reese 1999) was similar to that of the pied shag at Makara in 1996-2005 (76.6%, 1.4, and 1.9, respectively). The main difference between the breeding cycles of these 2 species was in the timing of egg-laying. Whereas the pied shag laid clutches in all months during the later years of our study, black shags laid only in Apr-Sep

(Powlesland & Reese 1999).

As a pair of black shags has bred with the pied shags at Makara, black shags nest at Pipinui Point, c.5.5 km north of Makara (Powlesland *et al.* 2007), and both species from these 2 colonies appear to forage entirely in coastal waters (RGP, *pers. obs.*), it is interesting that their breeding biology differs. The bill lengths of the 2 species are similar (*P. c. novaehollandiae*: ♂ 70 mm, female 62; *P. varius*: ♂ 73, ♀ 67), but the black shag has longer wings (*P. c. novaehollandiae*: ♂ 346 mm, ♀ 325; *P. varius*: ♂ 318, ♀ 300) and is heavier (*P. c. novaehollandiae*: ♂ 2508 g, ♀ 1941 g; *P. varius*: ♂ 2196 g, ♀ 1715 g) (Nelson 2005). Whether these size differences can be related to differences in diets of the 2 species is unknown. A detailed study of the 2 species' foraging habitats, diving regimes, and diets in the Wellington region may determine whether they compete for the same prey or not. The diet of pied shags in the Wellington region is not known, but McKinnon *et al.* (2004) described the diet of coastal foraging black shags at the Pencarrow colony during the breeding season.

As we noted for pied shag breeding at Makara, Millener (1972) also considered that no pied shag breeding attempts at the Lake Pupuke colony at Auckland failed as a result of predation. Likewise, Powlesland & Reese (1999) found no evidence of predation at the Pencarrow black shag colony during 6 breeding seasons of observations, even though brush-tailed possums (*Trichosurus vulpecula*), feral cats (*Felis catus*), and stoats (*Mustela erminea*) were seen in the area, and harriers occasionally flew very low over the colony. Although the harrier is known to prey on the eggs of the pied shag (Parkin 1950), it would seem to happen rarely. Presumably adult black shags and pied shags are large enough to deter the predatory mammals present in New Zealand from raiding their nests.

Population increase

Occasional counts of pied shags roosting at the Makara colonies indicated that numbers increased from c.14 in 1996 to c.70 shags by Dec 2003. Our few counts during 2004-2005 suggest that the population at the colonies stabilized during this period, even though the number of breeding attempts increased markedly in 2004 (Fig. 1). Perhaps this was because the number of shags that the coastal area within foraging range of the Makara colonies could support only c.70 birds, and so subsequent progeny were forced to disperse further afield to find sufficient prey. Some support for this suggestion is evident in the greater numbers of pied shags seen elsewhere in the Wellington region in the last few years, especially along the Wellington west coast (Mana I, and at the Waikanae River mouth). This result is also reflected in the species' more frequent presence in Wellington region coastal atlas squares during 1999-2004 than

during 1969-1979 (Bull *et al.* 1985; Robertson *et al.* 2007). As no other colonies have been found in the region, presumably the increase has been as a result of birds dispersing from the Makara colonies, immigration from outside the region (the closest colonies are in Marlborough, across Cook Strait), or both. In the South Is, pied shags have also spread along coastline around Banks Peninsula and south to Dunedin since 1979 (Bull *et al.* 1985; Robertson *et al.* 2007). This may indicate that the species is still recovering range lost in the past through human predation.

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