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Aspects of the Breeding Biology of the
Black shag (*Phalacrocorax carbo
novaehollandiae*) at Pencarrow,
Wellington, with special reference to
Diet.

Hilary Lorna McKinnon

October 2000

A thesis in partial fulfilment of the requirements for the degree of Masters of Science in Zoology at
Massey University, Palmerston North.



Frontispiece: (Top photo) Fledged bird Pencarrow colony. (Bottom Photo) Breeding pair at nest. Photos courtesy of Peter Reese.

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To Jeff

Acknowledgements

Many thanks are due to the following people for their unconditional support and assistance.

Associate Professor Dr Robin Fordham, my supervisor, for all of his guidance, support and ideas throughout this thesis. Ian Latta my co-supervisor who assisted with extracting otoliths.

Dr Ralph Powlesland who originally suggested the topic. Ralph never failed to offer support and assistance with field work and showed a keen interest in all aspects of the study.

Mr and Mrs Curtis for allowing access to they farm where the Pencarrow Black shag colony is located and for recovering some of my stolen gear.

To Gill McKinnon, my mother, who proof read drafts of my thesis and provided many editorial ideas.

To Jeff Dewhurst my partner for all his assistance with computer work especially with pictures. I would also like to thank him for putting up with my constant absence during the year when I was doing field work.

David Hargest and the Hutt City Council for the permit needed to gain access to Pencarrow Coast Road, and Scott of the Eastbourne Police for his concern for my safety throughout the study.

Dr Chris Lalas whose knowledge of Black shag diets and assistance on some measurements made the section on diet that much more significant, and Dr Chris Paulin, Te Papa, for his help with fish problems.

Members of the Wellington branch of the New Zealand Ornithological Society, especially Alan Munro and Dave Sim, for their assistance in locating fledged young in the Wellington region.

Peter Recse, Te Papa for providing a number of the photographs used in this thesis.

I would also like to thank Reg Cotter and Gail Abel of Wellington, Sharyn Garner, Jarn Godfrey, Paul Barrett, Sara Treadgold, Tracy Harris, Cathy Lake, Hayden Hewitt, Robin Fordham and all other Ecology Group staff and students who assisted with field work, especially banding chicks. Thanks also to Barbara Just who helped to keep my expenses on track.

To my family and friends who have been so supportive and encouraging during the past few years, who have made this task so much easier to accomplish. I would like to apologise sincerely to anyone I have overlooked as I found everyone's contribution to this thesis invaluable.

Abstract

Aspects of the breeding biology, diet and movements of Black shags (*Phalacrocorax carbo novaehollandiae*) were studied at Pencarrow Colony, Lake Kohangatera, Wellington.

The breeding behaviour of adult birds did not differ from that described in overseas research. Both parents were involved in all aspects of incubation and rearing young, but males collected material for the nest, and females remained at the nest site to build the nest, often with the assistance of the males. Agonistic behaviour was most often shown in the defense of the nest site and mostly involved warning than direct attack. Inter-bird competition within the colony most often involved the displacement of roosting birds by birds returning to the colony.

Eighteen pairs were successful in laying eggs and a total of 39 chicks hatched. For the broods that survived to fledge one had 1 chick, nine had 2, and one had three young. Breeding success, as measured by the number (2.1 ± 0.1) of fledged young per nest, was higher than that recorded (Powlesland & Reese 1999) between 1993-98. However the rate of nest failure was twice as high. The variation in breeding success observed at the Pencarrow colony also occurs in Black shag populations in other countries.

Black shags at Pencarrow colony are primarily marine foragers. Only one instance of freshwater foraging was identified in 1999. Half of the diet identified in regurgitated pellets comprised one fish species, Wrasse (spotty). Twenty-two different prey items were found in the 121 pellets recovered from the ground underneath the colony. Fish are the predominant prey with 17 different species confirmed. There was no significant difference ($p > 0.1$) in the number of prey items per pellet over the eight months they were collected.

Movements of adults and fledged young appear to be partially dispersive. The continued presence and return of birds banded since 1990 also suggests a sedentary core population at the colony. The daily presence of adults engaged in foraging

activities along the eastern side of Wellington harbour suggests that this area is the preferred foraging area during the breeding season. The number of adult Black shags seen throughout the year in marine areas was significantly higher than in freshwater areas. Young birds did not permanently disperse away from the colony immediately after fledging but returned to the colony to roost overnight. Their most preferred daytime roost in the first few months after fledging was the Mai Mai on Lake Kohangatera 1 km from the colony. The first fledged bird seen roosting overnight away from the colony was on 1 January 2000 (c. 7 months and 2 weeks old).

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Chapter 1

1.0 General Biology

1.1 Taxonomy

1.1.1 Origins

Shags/cormorants comprise a distinctive family of almost cosmopolitan birds that utilise marine, freshwater and terrestrial ecosystems. Fossils of the family *Phalacrocoracidae* have been identified as far back as the Eocene-Oligocene boundary (Johnsgard 1993). *Phalacrocoracids* belong to the order *Pelecaniformes* which is believed to have originated in Australasia (Van Tets 1976), and this region is the only area known to contain all five sub-genera identified in Van Tets' (1976) classification. According to Van Tets (1976) that there were more extant species of shags and cormorants in this region than in other zoogeographic regions (Johnsgard 1993).

1.1.2 Classification

Although there has been some controversy over the exact composition of the Order Pelecaniformes it has traditionally been considered the order of totipalmate birds: the cormorants, pelicans, gannets, boobies, frigatebirds, anhingas and tropicbirds (Sibley & Ahlquist 1990). However, traditional taxonomic classifications have recently been challenged by Sibley and associates (Sibley & Ahlquist 1990). Through biochemical work using DNA-DNA hybridization techniques, they suggested an alternative classification of the entire class Aves, including the Order Pelecaniformes.

The terms 'shag' and 'cormorant' are used fairly loosely within the family *Phalacrocoracidae*. According to Van Tets (1976) fishermen and New Zealanders prefer the term 'shag' whereas birdwatchers and North Americans prefer to use the name 'cormorant'. Van Tets (1976) attempted to zoogeographically classify the family into two genera using the two colloquial terms by referring to 'shags' as species with marine coastal distributions and 'cormorants' as species with marine and inland continental distributions. Within these two genera Van Tets recognized 34 extant species and five subgenera (Appendix: 1). Later Siegel-Causey (1988) offered another classification with 37 extant species of *Phalacrocoracidae* in two subfamilies and nine genera (Appendix: 1), (cited in Johnsgard 1993).

In New Zealand the precise taxonomic status of the Black shag is unclear and at least three sub-species have been identified (Heather & Robertson 1996). I will be following the nomenclature given in the Checklist of the birds of New Zealand (Turbott 1990), Johnsgard (1993) and Heather & Robertson (1996)(Table: 1.1). These authorities identify the New Zealand sub-species as *P.c. novaehollandiae* (Stephens 1826). The Checklist of the birds of New Zealand (Turbott 1990), uses a modified version of the proposed classification given by Siegel-Causey, (1988) for *Pelecaniformes*:

| ORDER | | Pelecaniformes | |
|-----------------|------------------------------------|---|----------------------------------|
| SUBORDER | Phaethontes | Pelecani | Fregatae |
| FAMILY | <i>Phaethontides</i> : Tropicbirds | <i>Pelecanidae</i> : Pelicans <i>Pelagornithidae</i> : Bony-toothed Pelicans <i>Sulidae</i> : Gannets & Boobies <i>Phalacrocoracidae</i> : Cormorants & Shags <i>Anhingidae</i> : Darters | <i>Fregatidae</i> : Frigatebirds |

Table 1.1: Taxonomic classification taken from the Checklist of the birds of New Zealand, (Turbott, 1990).

1.1.3 Distribution

The Black shag (*Phalacrocorax carbo*) is almost a cosmopolitan species, being widely distributed throughout Asia from southern China and Japan down to Indonesia, southeast Asia, and Australasia. It is found in southern and eastern Africa, and upper west coast of Africa, and also in Europe, Iceland, southwestern Greenland and eastern maritime Canada (Johnsgard 1993). The map (Figure: 1.1) shows the distribution and movements of *P.c. novaehollandiae* in Australasia.

Recorded sightings in New Zealand between September 1969 and December 1976 are taken from Bull *et al* (1979). The map (Appendix: 2) indicates that *P.c. novaehollandiae* is found throughout New Zealand both inland and along coastal regions (Bull *et al* 1979).



Figure: 1.1. Distribution and movement of Black shags in Australia and New Zealand according to Johsgard (1993).

□ – Shaded grey areas show wintering and non-breeding areas, and stippling and dark inked areas show breeding or residential areas.

1.2 Description of *Phalacrocorax carbo*

1.2.1 Measurements

Adult Black shags average 80-85cm in length with a wing span of 130-150cm, and weigh between 1200-3100 grams (Marchant & Higgins 1990). Variation between the sexes is not significant, but males are on average larger (Table: 1.2).

| | MALES | | FEMALES | |
|--------------------|--------------|--------------------|----------------|--------------------|
| | Range | Average (n) | Range | Average (n) |
| Wing length (mm) | 285-373 | 353mm (22) | 331-385 | 346mm (13) |
| Tail length (mm) | 141-174 | 152mm (22) | 140-180 | 153mm (13) |
| Culmen length (mm) | 56-73 | 66mm (22) | 54-70 | 60mm (13) |

Table 1.2: Measurements in millimetres of non-juvenile birds. (Johnsgard: 1993).

Serventy (1939) and Marchant & Higgins (1990) and recorded weights of live non-juvenile birds in New South Wales, Australia that show males are heavier than females (Table: 1.3).

| | | MALES | | FEMALES | |
|-------------------------|----------------|--------------|--------------------|----------------|--------------------|
| | | Range | Average (n) | Range | Average (n) |
| Serventy 1939 | Weight (grams) | 2253-2954 | 2508 (6) | 1545-2110 | 1941 (5) |
| Marchant & Higgins 1990 | Weight (grams) | 1600-3100 | 2400 (79) | 1200-1300 | 2000 (288) |

Table 1.3: Weights of non-juvenile birds in grams. (Johnsgard: 1993)

1.2.2 Breeding adult

(Plate: 1.1)

Breeding adult plumage is glossy black with a blue-green sheen. Long crest feathers extend from the top of the head down the back of the neck. The upper neck is covered with white nuptial plumes, which are longer and more numerous in older adults, hiding the dark plumage underneath (Johnsgard 1993). A distinctive small patch of white feathers also appears on each flank. Both neck and flank nuptial plumes disappear as the breeding season progresses. On the throat the feathers form a white, grey and buff patch extending upwards to the malar area and behind the eye (Marchant & Higgins 1990).

The gular pouch is black with yellow spots and is mostly bare of feathers. The iris is green and the orbital ring is black with light bluish purple and bead-like nodules (Johnsgard 1993). The lores are yellow to greenish black and the triangular patch above the gape is orange-red (Vestjen & Van Tets 1985, Johnsgard 1993). The bill is black-brown to a dark brown along the culmen, and the proximal mandible is dull white (Marchant & Higgins 1990).

On the body the upper scapulars and wing coverts are a dull bronze-brown, with individual feathers having a slight greenish gloss. The primary feathers are brownish black, also with a slight greenish gloss. Secondary feathers have a more significant greenish gloss with a blackish margin. The rectrices are black, and the skin of the legs and feet are black.

1.2.3 Post-breeding adults and immature shags

(Plate: 1.2)

Post-breeding adults resemble breeding adults except the white nuptial plumes on the neck and flank are absent. The gular pouch and triangular patch above the gape are yellow, the bill is paler, and general body plumage is less glossy (Marchant & Higgins 1990).



Plate: 1.1 Adult in full breeding plumage. Photo courtesy of Peter Reese.



Plate: 1.2 Plumage of post-breeding adults and immature Black shags. Photo courtesy of Peter Reese.

In the immature (pre-adult) bird the plumage on the throat is light brown, the head and neck is brown and dark brown with a slight greenish black sheen on the hind neck. The iris is yellow-brown, pale blue or greenish grey (Marchant & Higgins 1990) and turns green after the first year (Johnsgard 1993). The gular pouch and other bare parts of the face are greenish yellow. The mantle feathers are light grey-brown or brown, while the back and rump are glossy black with a blue-green sheen. The tail is black-brown and the upper tail coverts are a dull glossy black-green (Marchant & Higgins 1990). The breast area is white, with mottled dark brown-black feathers.

1.2.4 Juvenile

(Plate: 1.3)

The juvenile plumage on the head and neck is pale brown or brown, with narrow bluish black tips (Johnsgard 1993). The iris is greyish brown or brown, and the bill is basically dark brown with a very dark brown culmen but lighter undersides (Johnsgard 1993). The gular pouch and other bare parts of the face are greenish yellow, as with the immature bird. The scapulars and upper wing coverts are dull bronze, and the upper body feathers are brown with a glossy blue-black sheen (Marchant & Higgins 1990, Johnsgard 1993). The tail is black-brown and upper tail coverts a dull greenish-black. The basal edges of feathers on the breast are a dull white (Marchant & Higgins 1990), tipped with brown to sooty black (Johnsgard 1993). The legs and feet are black.

1.2.5 Nestlings

(Plate: 1.4)

The Nestlings are altricial, with slate blue skin (Vestjen & Van Tets 1985, Johnsgard 1993) and closed eyes, which open at four days of age (Marchant & Higgins 1990). Seven days after hatching sooty grey-black down covers the caudal region (Marchant & Higgins 1990). At fourteen days down covers most of the body except the face, neck and under wing area. By 21 days body down has thickened and covers the neck but is sparsely distributed on the face. Remiges and rectrices also begin to emerge from sheaths at this stage (Marchant & Higgins 1990). The gular pouch becomes pale pink-yellow, and the iris, initially bluish grey becomes greyish brown (Johnsgard 1993). Hatchlings have a pink bill which gradually turns dark grey as the chick ages. By 21 days the legs and feet are slate grey and the webs yellowish brown.



Plate: 1.3. Juvenile banded in 1995 (c. 12 to 18 months). Photo courtesy of Peter Reese.



Plate: 1.4. Nestlings (c. 6 days old).
Photo courtesy of Peter Reese.

1.3 Aims of study

1.3.1 Measurement of breeding output.

Marchant & Higgins (1990) and Johnsgard (1993) have summarised the reproductive biology of the black shag in countries other than New Zealand. In New Zealand Stead (1932) described Black shags and a recent publication by Powlesland & Reese (1999), gives the results of recent visits over six breeding seasons to the Pencarrow colony Wellington, New Zealand. The existing base of knowledge on the Pencarrow colony and the banding of chicks in 1990 and from 1992 to 96 by Powlesland & Reese (1999), makes it particularly suitable to carry out further study. Information gathered by the present research will improve comparisons of Black shag breeding biology in New Zealand and elsewhere.

According to Heather & Robertson (1996) the breeding season varies from one colony to the next, with most laying occurring from June to October, but some laying in April and May. At the Pencarrow colony the breeding season usually begins in mid-late March with courtship displays and territorial establishment through nest building activity by males. The season ends when the last of the late nesters have fledged their young in late September/October (Powlesland & Reese 1999).

The main objectives for assessing breeding output were:

- To identify and describe the behaviour of breeding pairs during the season.
- To record the ethology of significant events i.e. – the start and duration of courtship, nest building and refurbishment of existing nests, egg laying, incubation, hatching, chick rearing and fledging.
- To quantify the investment of parents in reproductive activities over the breeding season.
- To assess the effect of age of parent birds on breeding output (banded birds only).
- To follow the development and survival of fledglings and fledged young.

1.3.2 Diet

The diet of the Black Shag is well documented overseas, but less so in New Zealand. Most New Zealand studies have been done on the composition of the diet in freshwater systems, for example Falla & Stokell (1945) and Dickinson (1951) both concentrated on the central north island areas of Rotorua and Taupo. Lalas (1983)

investigated the feeding ecology of marine shags on the Otago coastline Stewart Island and Chatham Island.

This study investigates the diet of the coastal Pencarrow colony over the breeding season during which the objectives were.

- To identify the composition of the diet.
- To monitor dietary changes over the season.
- To identify differences between the diets of young and adults.
- To assess the relative significance of marine and freshwater systems in providing the diet.

1.3.3 Dispersal

The way in which young fledged Black shags disperse from colonies in New Zealand is little understood. Over the period 1976–89, 490 Black Shag nestlings were banded in the Wairarapa region. Sim & Powlesland (1995) reported that 41 (8.4%) of these birds were recovered by 1994. Of these recoveries 35 (85%) were found within 100km of the banding site, with the furthest being 2000km away on Lord Howe Island. This individual provided the first evidence of the species moving westward across the Tasman Sea to Australian waters.

The dispersal pattern of adult and independent young Black shags from the Pencarrow colony is unknown. Thus the objectives of this study were:

- To describe the area utilised and daily distances travelled from the colony by adult shags during the breeding season.
- To describe the daily pattern of dispersal of fledged young from the colony.
- To determine the destination of independent young when they finally leave the colony.

1.4 Thesis Layout

This thesis is presented in five primary chapters.

- Chapter 2 introduces the study site, giving maps and details of the area.

- Chapter 3 discusses breeding behaviour of adult breeding birds over the 1999 breeding season and quantifies aspects of their investment in rearing young. It also discusses aggression towards chicks by other adult birds, intra-colony aggression between adults and external threats to the colony.
- Chapter 4 discusses the breeding success at Pencarrow colony for the 1999 breeding season for comparison with previous research done at this site. Two significant development behaviours of fledgling chicks are discussed, as is the effect of gender on age at fledging. The effect of parent age on breeding output is examined.
- Chapter 5 identifies the diet of Black shags at Pencarrow colony over the 1999 breeding season and the significance of the seasons autumn, winter and spring on their diet. The frequency of species in the diet, the length and mass of fish prey taken are quantified and compared with overseas data, and differences between the diets of chicks and adults discussed.
- Chapter 6 discusses the population status of the colony throughout the season, and the daily movements and activities of adults and fledged young away from the Pencarrow colony. The dispersal of fledged young away from the colony at the end of the breeding season is mentioned.

A general conclusion for the thesis is provided in chapter 7.

Chapter 2

2.0 Study area

2.1 Location

Lake Kohangatera is located in lower Gollans valley, Fitzroy Bay, Wellington (Figure: 2.1, Plate: 2.1). The area mostly comprises sheep and beef farms with dense pockets of gorse and manuka scrub. It is set among steep hills rising to 224 m.a.s.l and low valleys that include watercourses, two lakes, and the Wainuiomata and Orongorongo rivers which have their sources in the Rimutaka Ranges. Few people live in the area, the nearest centres being Wainuiomata, and the Wellington suburb of Eastbourne.

A colony of Black shags – the “Pencarrow colony” – is located in a forested gully on the west face of Link ridge (41° 23'S, 174° 52'E) (Plate: 2.2) overlooking the northern swamp tributary that drains into the top of Lake Kohangatera (Figure: 2.2). The Black Shags roost and nest primarily in Karaka (*Corynocarpus laevigatus*) trees covering one side of the gully (Plate: 2.3) and also use small pockets of Karaka in the adjacent western gully as secondary roosting sites.

A swamp extends inland north of Lake Kohangatera towards the top of the valley (Plate: 2.4). The plant cover of the swamp is mainly raupo (*Typha orientalis*) with grass in areas where the swamp has dried out or rough pasture has encroached. Following heavy rain, and during wet winter months, the grassed areas and low valley areas become flooded.

North Island

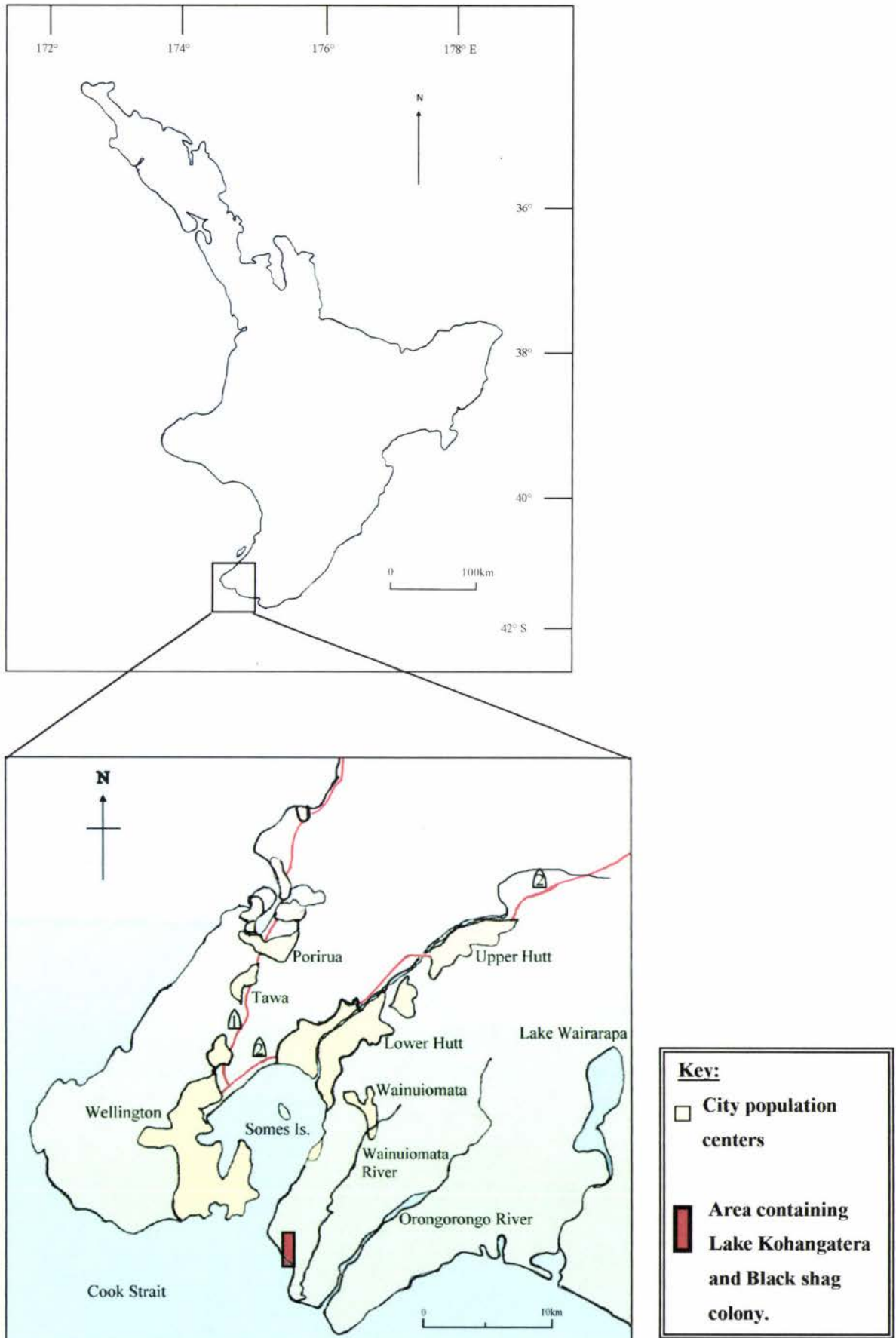


Figure: 2.1. North Island New Zealand.
 Insert: Wellington region containing study site.

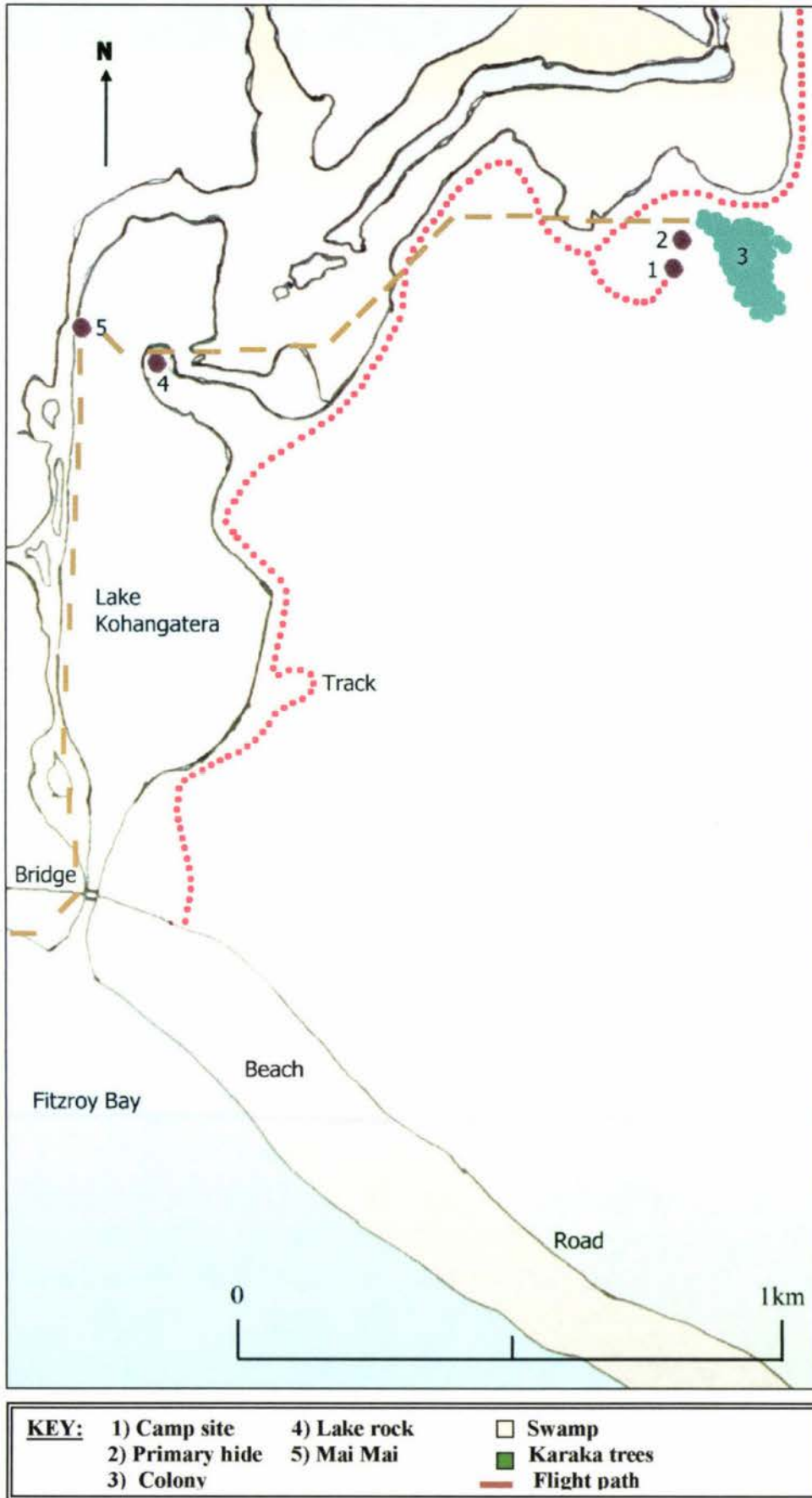


Figure: 2.2. Lake Kohangatera and Pencarrow Black shag colony.

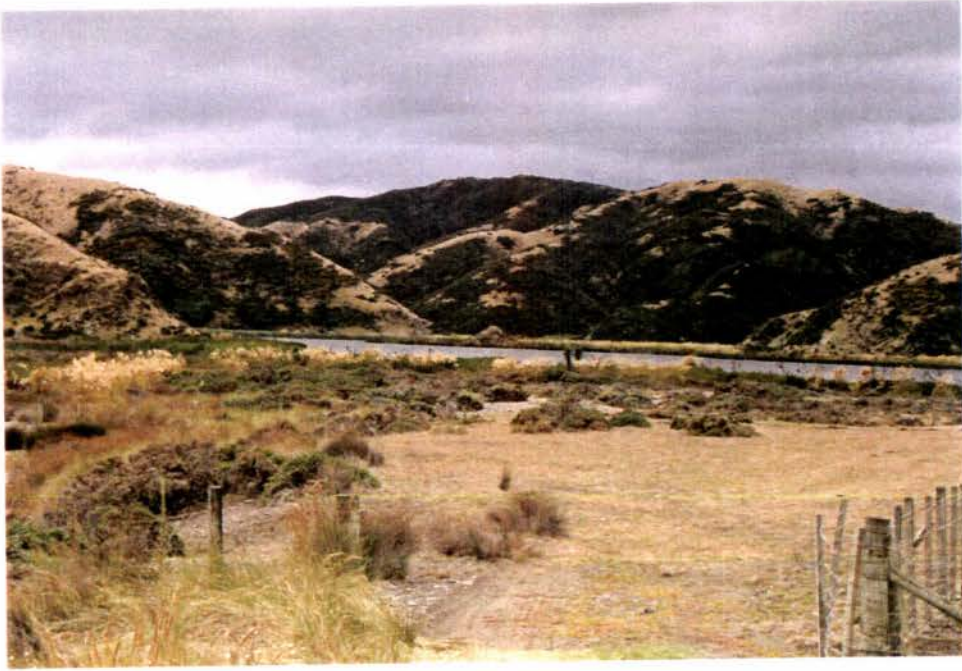


Plate: 2.1 Lake Kohangatera, looking north up Gollans valley from the coast of Fitzroy Bay.



Plate: 2.2 West face of Link ridge where the colony is located (patch of bright green trees in top center of photo). Photo courtesy of Robin Fordham.



Plate: 2.3 Main area of the Pencarrow Black shag colony in a stand of Karaka trees. Photo taken from the primary hide. Photo courtesy of Robin Fordham.

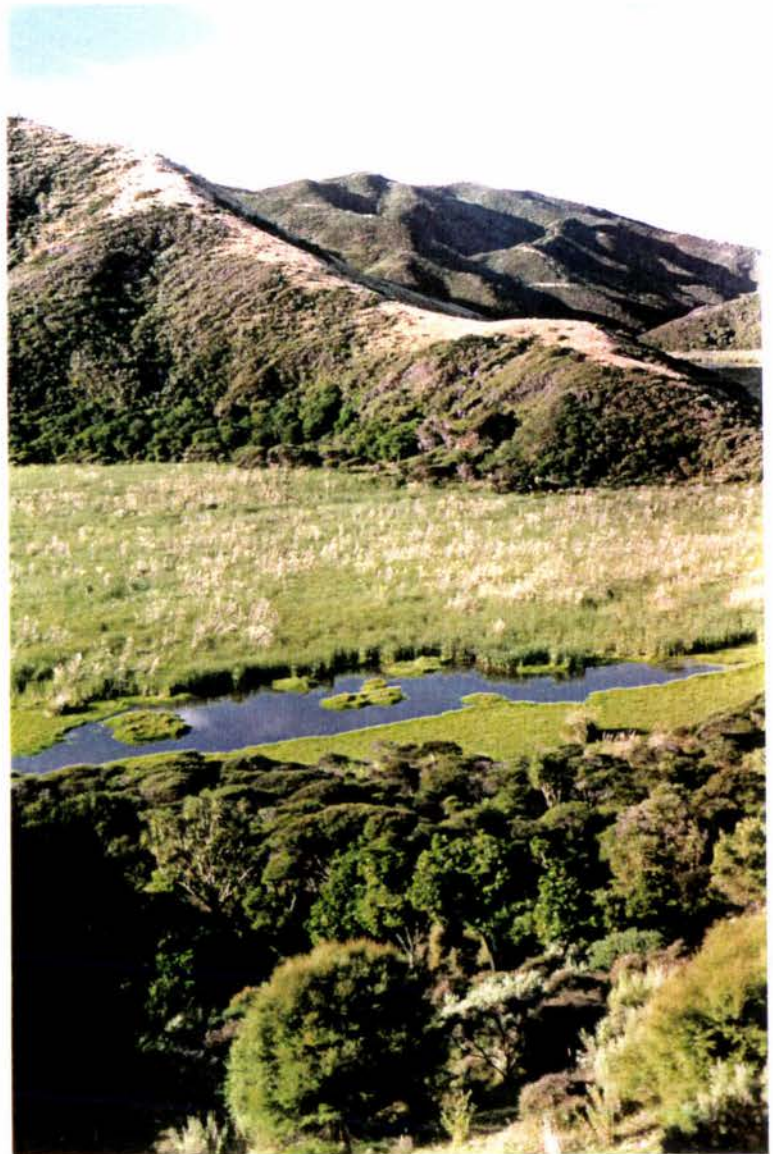


Plate: 2.4 Swamp area at northern end of Lake Kohangatera, looking up Gollans valley. Photo courtesy of Angus Fordham.

2.2 History of colony

The first published account of the Pencarrow colony is by R.H.D. Stidolph, who visited the colony in 28 June 1925 (Stidolph, 1971) when he recorded seeing young birds in beech (*Nothofagus* sp.) trees in Gollan's valley. Of four nests in one tree, two had chicks close to flying, one with three chicks and the other a single chick. The remaining two nests had one and three eggs respectively. A second tree held a nest with four pre-fledged young. A later visit on 2 August 1925 revealed two eggs in a nest that had previously held chicks. No Black Shags have been seen nesting in the beech (black beech – *Nothofagus solandri*) trees on the ridge next to the colony since at least 1988 (Powlesland & Reese, 1999).

Falla & Stokell, (1945) observed the Pencarrow colony periodically over 12 years from 1939. They counted 40 occupied nests, 20 in 1932, 12 in 1934 and none in 1942. Thus the colony decreased in size to the point where Falla & Stokell (1945) believed it had been abandoned. The reduction may have been caused by shooting; for instance Stead (1932) noted that the Black Shag had been persecuted by every Acclimatisation Society in New Zealand since trout were introduced in 1870, and up to 1911 a bounty of half-a-crown was paid for every Black Shag head by the North Canterbury Acclimatisation Society (Stead, 1932). However the Pencarrow colony began again and, by 1965, held 11 nests (P. Williams, quoted by Powlesland & Reese, 1999).

Since 1994 nest numbers have been counted (Powlesland & Reese, 1999) between April and May each year when the population of breeding pairs was at its highest. These counts showed there were 33 nests in 1994, 31 in 1995, 25 in 1996, 35 in 1997 and 30 in 1998 (Powlesland & Reese, 1999). The Pencarrow colony was therefore, relatively stable for the five years leading up to 1998.

2.3 Weather

Data collected from the New Zealand Climate Digest published by the National Institute of Water and Atmospheric Research LTD (NIWA), shows mean monthly air temperatures (C°), maximum wind speeds (m/s), and total rainfall (mm) patterns for the Wellington area over a ten year period (Appendix: 3). The weather period is taken from the beginning of March to the end of November 1990 to 1999. Meteorological

conditions were recorded at three different weather stations: Wellington airport 43 m a.s.l, Kelburn 125 m a.s.l, and Wainuiomata Coast Rd 82 m a.s.l. The first two stations are located in Wellington City and the third is the closest to the colony lying in the valley to the east. The data provided from Niwa, was a combination of three weather stations, due to missing data. Therefore it could not be provided from just one station for the entire ten-year period.

The average rainfall for 1999 was higher in March, May and November and lower in all other months when compared to the average of the previous nine years (Figure: 2.3). The average temperature was higher in every month from March to November 1999 than the average from the previous nine years (Figure: 2.4). Maximum wind speeds recorded were higher in 1999 in only three months May, July and November, compared with the average of the nine previous years (Figure: 2.5). Overall the 1999 breeding season experienced warmer temperatures reduced wind speeds and less rain than the previous nine years.

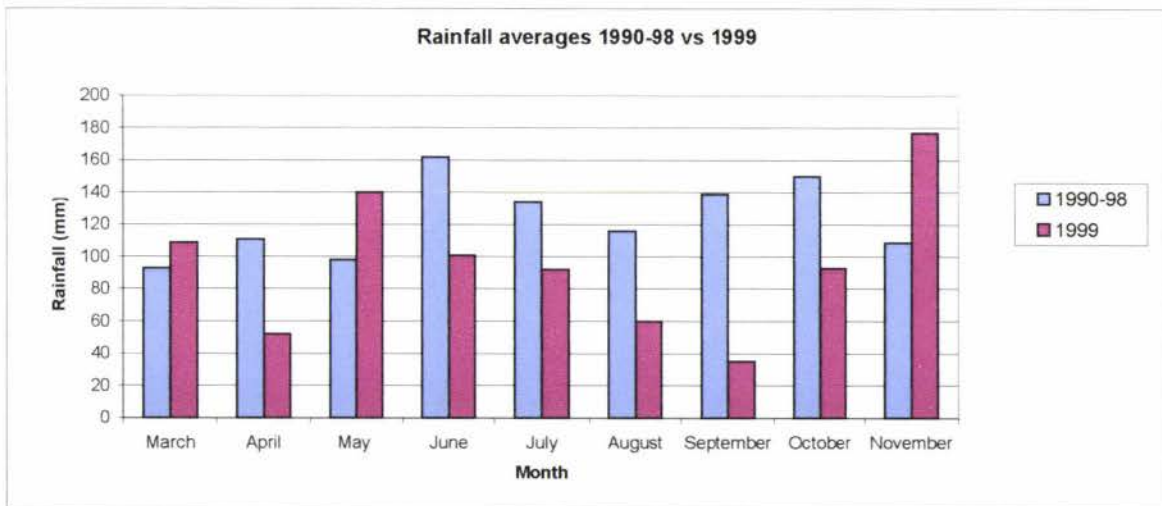


Figure: 2.3. Average rainfall for 1990-98 and 1999 from March – November in the Wellington area.

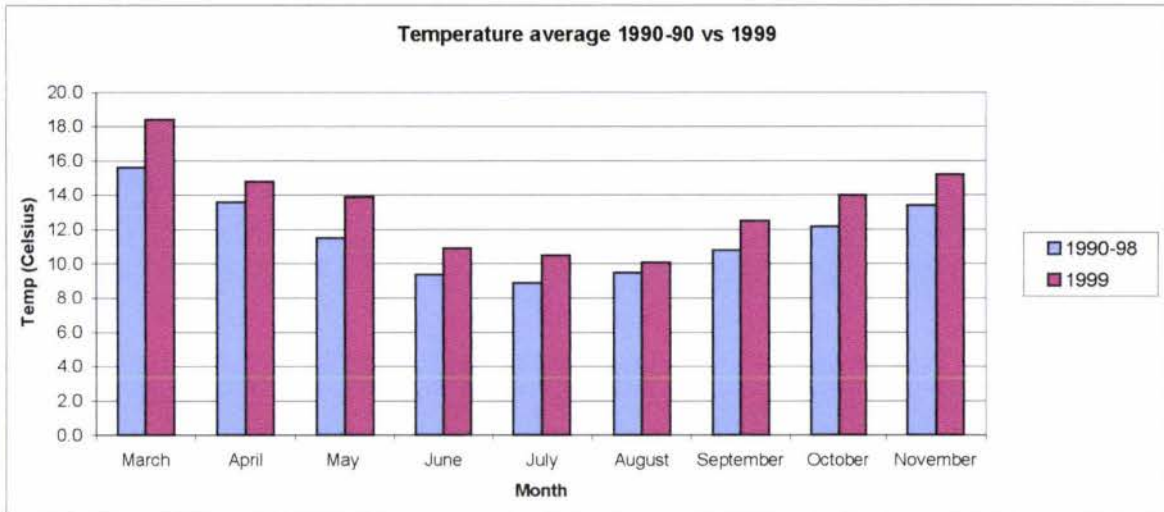


Figure: 2.5. Average temperature for 1990-98 and 1999 from March – November in the Wellington area.

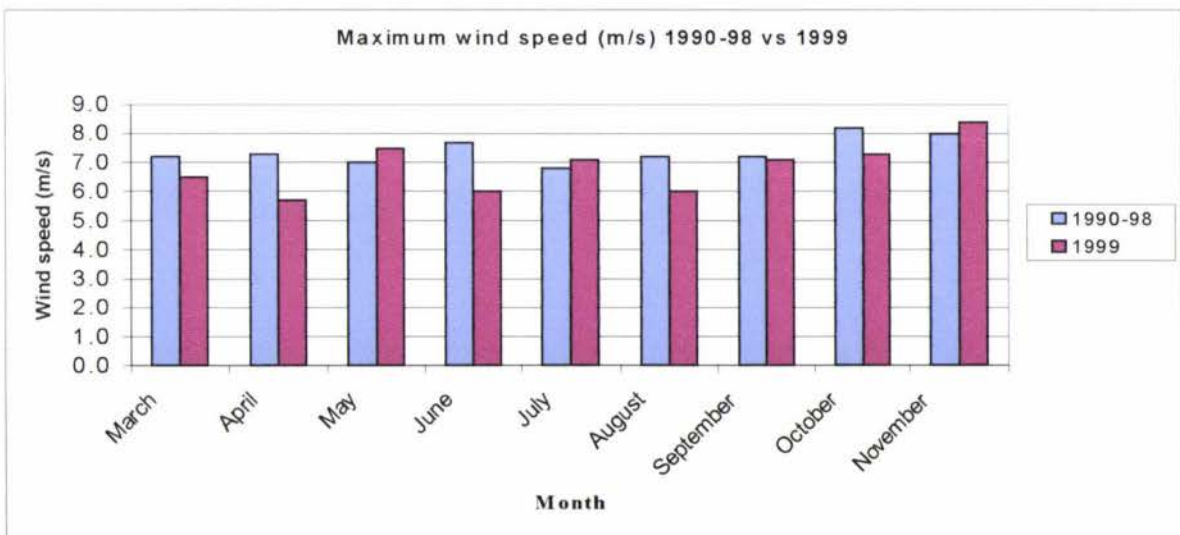


Figure: 2.6. Maximum wind speed (m/s) for 1990-98 and 1999 from March – November in the Wellington area.

Chapter 3

3.0 Breeding behaviour

3.1 Introduction

Johnsgard (1993), placed avian social behaviour in three groups: agonistic (behaviour dominated by attack or escape tendencies), cooperative (reciprocally beneficial as well as seemingly altruistic behaviour), and epigamic (sexual and parental behaviour). For this study I have categorised behaviour observed during the 1999 breeding season at Pencarrow colony under the following headings.

- Nest building behaviour
- Courtship behaviour
- Pair bonding behaviour
- Parental behaviour
 1. Incubation
 2. Brooding
 3. Chick rearing
 4. Fledged young rearing
- Territorial behaviour
 - Intra-colony aggression
 - Aggression towards chicks
 - External threats

Social behaviour in the Order *Pelecaniformes* has been well documented and is summarised and discussed by Palmer *et al* 1978, Cramp *et al* 1980, Marchant & Higgins 1990, Del Hoyo *et al* 1992 and Johnsgard 1993. General avian behaviour is treated by Dorst 1974, Nelson 1979 and specific behaviour such as nesting, extra-pair copulations and pair formation have been discussed by Collias & Collias (1984) Graves *et al* (1993) and Kortlandt (1995). Important contributions relating to social behaviour in *Pelecaniform* birds were made by van Tets (1965) and Schreiber (1977), discussed in Johnsgard (1993). Many *Phalacrocoracids* have similar courtship displays, with one of the major differences being the use of vocalisation (Johnsgard 1993). ‘Feather presentation’ (Cape shag) and ‘mutual neck swaying’ (Black shag) are examples of epigamic behaviour that appear to be unique to only one or two species (Johnsgard 1993).

This study will document and identify patterns of agonistic and epigamic behaviour in Black shags at Pencarrow colony, Wellington. The results will be compared with other breeding behaviour studies on Black shags in New Zealand and elsewhere.

3.2 Methods

Black Shags follow a strict diurnal schedule with activity at the colony beginning just before sunrise and ending just after sunset. In 1999 breeding activities in the colony began in late February - early March when adults developed nuptial plumes. By mid March males were actively defending nest sites and adjacent roosts, had started nest building, and begun displaying to attract females. From this period the colony was observed from one primary site, and several secondary locations with binoculars and a 27x telescope. The primary site was a hide located on the lower east side of the gully facing the colony (Plate: 3.1). Individual nests, not visible from the main hide, were also watched from sites protected only by plants above the colony on the upper east side of the gully. Observations began at dawn, except when low cloud and heavy rain made it difficult to see birds, and ended at sunset when it became too dark to observe any activity. After dark the general pattern of calling was noted. A description of the colony site is given in chapter 2.

3.3. Results

3.3.1 Nest building

The male starts nest building once he has acquired a nest site. The site is cleared of Karaka leaves and twigs, leaving the branches bare. The male starts to build the nest on his own, but after pairing with a mate they share the building. The female takes over building and shaping the nest while the male brings nest material. The female pushes and weaves the twigs or leaves he contributes into the nest, and also pulls leaves off the surrounding Karaka branches to line the bottom of the nest. Sometimes the male assists with working the nest material into place. After the nest is built both birds continue to maintain it throughout the season. Males frequently take nest material from abandoned nests and also from other occupied nests when the owners are absent. Early in the season both birds are often absent, which may indicate that a strong pair bond is still developing.



Plate: 3.1 Primary hide, the colony is behind the photographer. Photo courtesy of Robin Fordham.



Plate: 3.2 Adult feeding nestlings (c. 3 to 5 days old). Photo courtesy of Peter Reese.

3.3.2 Courtship

Males display to potential mates by wing waving with the head held vertical, the rump raised off the nest, and the tail held vertically and fanned out (Figure: 3.1). During wing waving the wings are partially unfolded and repeatedly raised and lowered causing the patch of white nuptial plumes on the flanks to be displayed as they are covered and uncovered. The completed cycle of wing movements is 1-2 beats/sec ending with the wings in the raised position, frequently increasing to 2 beats/sec when potential mates are nearby. There is no vocalisation during the display. Wing waving was first observed mid-March, reaching a peak in April (Figure: 3.2), and was last recorded in August. Males of bonded pairs, however, stopped mate-attraction displays once eggs were laid.

When a female lands in the colony the male responds by gargling (figure: 3.3). The wings are pulled down against the body, the tail is held vertically, and the head is swung back so it rests on the bird's back. The male swings his head back and forth in this manner while calling loudly. He also holds his head on his back and rolls it from side to side making the same loud call. When the male returns to the colony he calls loudly as he lands; the female will greet him with a softer gargle. Her outstretched head is pulled back only to the vertical and the tail is partially fanned and droops down. The pair recognition bond is strengthened by physical contact, by rubbing their necks, heads and beaks and bending their heads around each other. They were also observed biting each other's beaks, and the male biting the female's tail feathers, usually just before copulation. Neck rubbing was common during nest building, often after the male had assisted in placing nest material.

Copulation lasted 2-7 seconds with a mean of 4.8 (\pm 0.3) (n=36) seconds and no forced copulation were seen. The first copulation was observed on 3 April 1999 and the last on the 2 July 1999. Coition occurred while the male was pecking the back of the female's neck. It occurred in the nest on all occasions except one where two birds

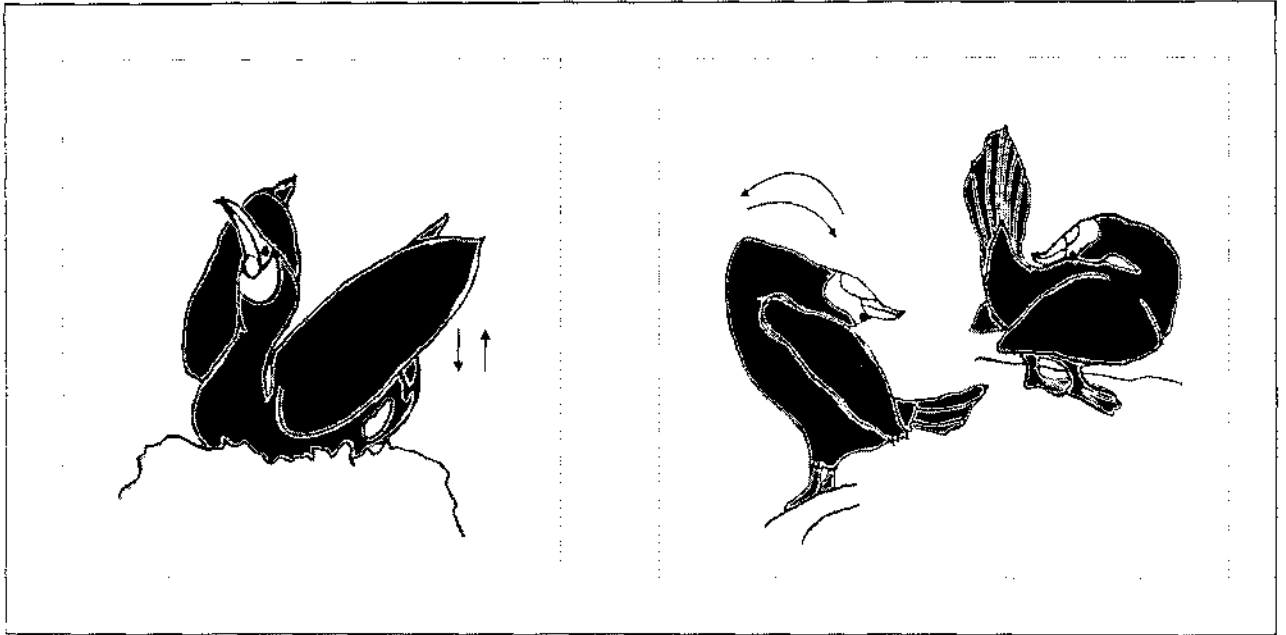


Figure: 3.1. Male wingwaving display
(Outlines derived from Johnsgard 1993)

Figure: 3.3. Two types of male gargling display
(Outlines derived from Johnsgard 1993)

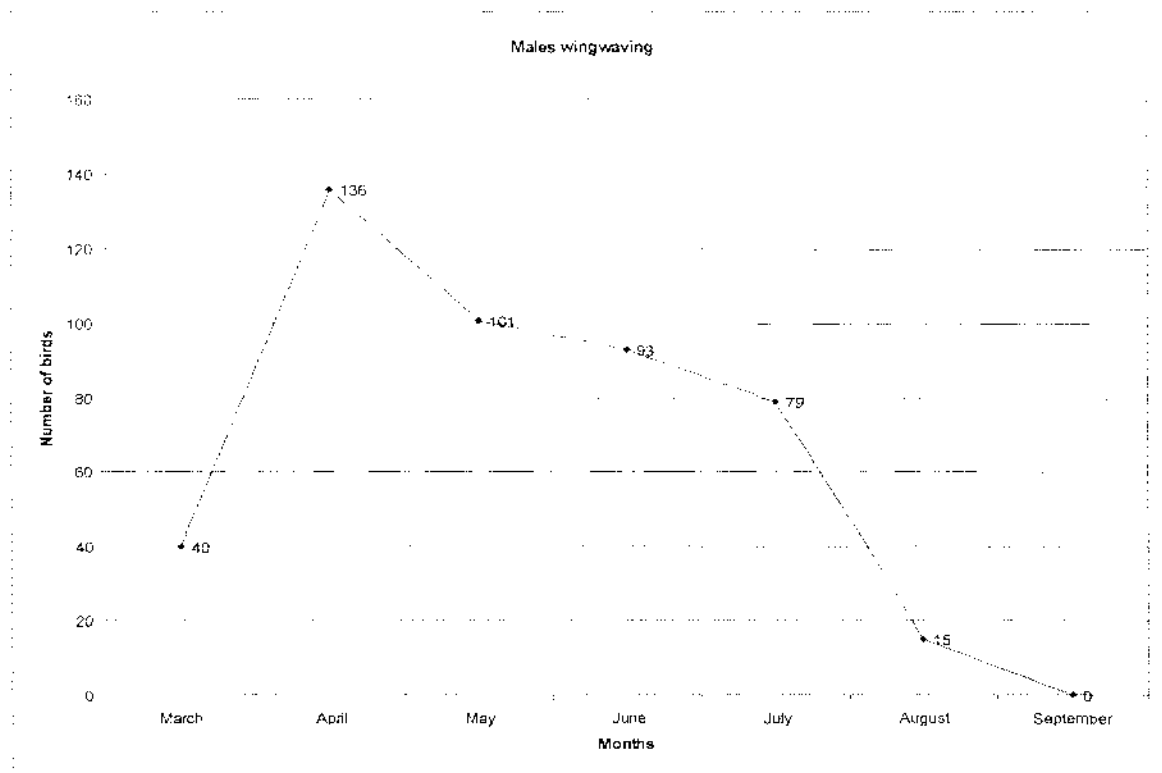


Figure: 3.2. Numbers of males displaying (mate attraction) from March – September at Pencarrow 1999.

attempted to mate in a dead tree above the colony but failed because they lost their balance. Although behaviour during copulation did not vary, there were some differences before and after mating.

Below is a typical example of mating behaviour:

The female returns to the nest. The male greets the female with a gargle, then takes-off, flies over the colony, and lands back on the nest. The female stretches her head and neck out horizontally in front of her. The male hops onto her back, and lowers and wraps his tail around her raised tail. He then bites the back of her neck for approximately 6 seconds during which coition occurs. He then hops off her back and stands beside her. The female shakes her tail after copulation, then raises her head and touches her beak to his, before they both begin preening.

Variation to the above situation include: (a) the male bites the female's tail feathers after he lands and before she stretches her head and neck horizontally, (b) after copulation, but not before it, the male leaves the nest, circles the colony and returns, and (c) no flying occurs.

Only one instance of an already paired male mating with another female was recorded. A banded 7 year old female (Red, Metal) was observed pair bonding and nest building with 3 – 4 males at different times throughout the breeding season. No eggs were evident from any of these possible pairings and all the nests were abandoned. In the 1993-1998 seasons Dr Ralph Powlesland (pers comm) observed similar behaviour from female Red Metal, which suggests that the bird may be infertile.

3.3.3 Incubation

Tree foliage obscured nests so it was not possible to see when eggs were present, and the use of a mirror on a pole was too obtrusive and disturbed incubating birds. There were no observable displays by females or males that could be clearly associated with egg laying, therefore the first sign of incubation was the continuous presence of at least one adult on the nest with its tail held at approximately at 45°. Both male and female shared incubation duties and continued nest building while sitting. Although the sex of the bird sitting at night was not determined, the female mostly incubated at

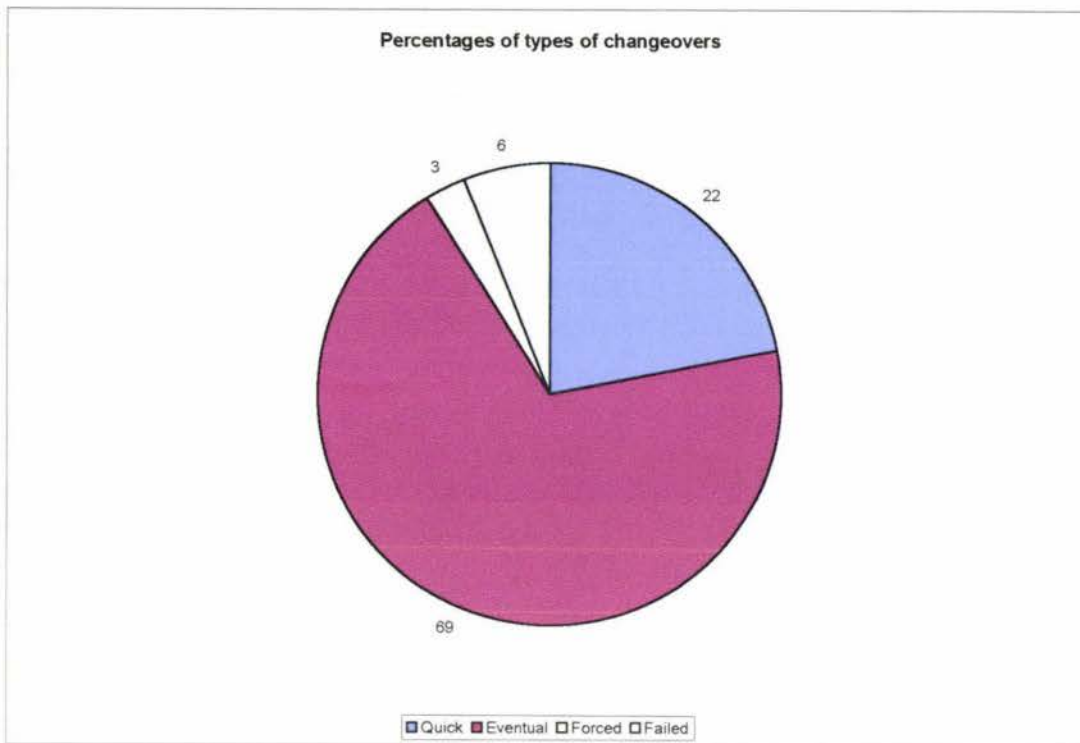


Figure: 3.4. Percentages of types of changeovers observed with incubating at Pencarrow 1999.

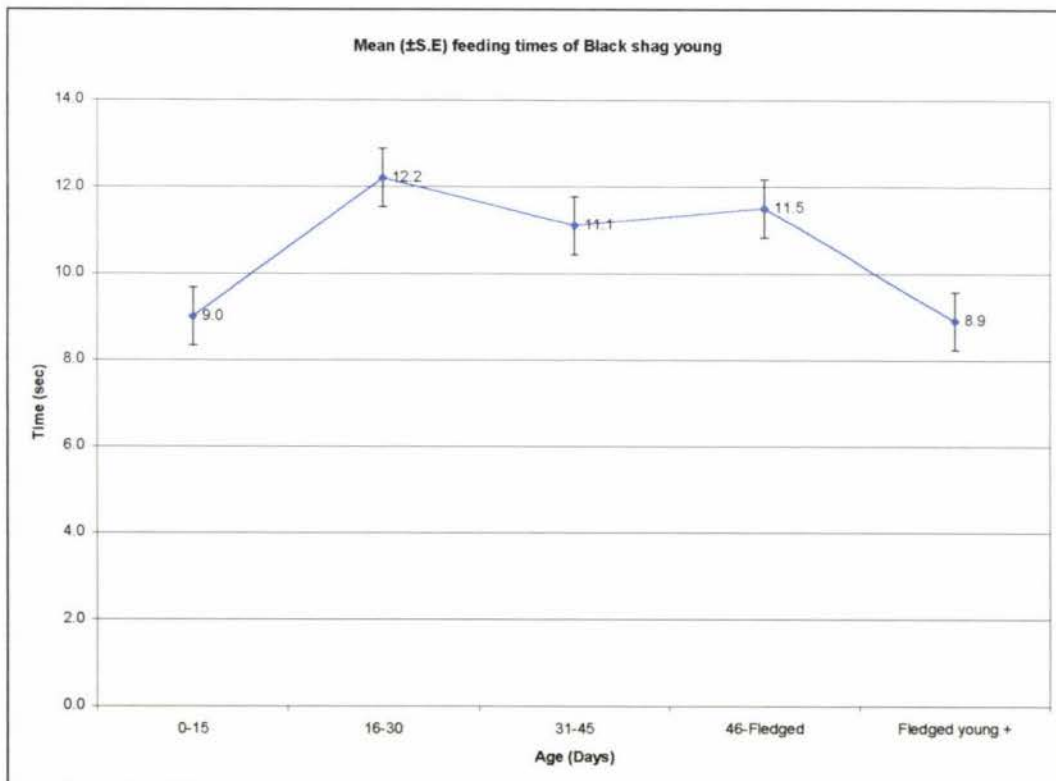


Figure: 3.5. Feeding times of Black shag nestlings and fledged young at Pencarrow 1999.

sunset, and often left the colony before sunrise. The male was most often seen in the nest in the first hour after sunrise until the female returned to the colony.

Four different behaviours were associated with changeovers during incubation

(Figure: 3.4):

1. Quick (n=8): The incoming bird landed at the nest and the sitting bird immediately moved out allowing the incoming bird to take-over. The outgoing bird then left the colony. This changeover took less than 10 seconds on average, and the total time from the female landing to the male leaving was c.30 seconds.
2. Eventual (n=25): The incoming bird landed on an adjacent perch but made no attempt to move onto nest. Eventually the incoming bird hopped onto the nest and the incubating bird moved out, but did not leave the colony immediately. In a variation of this sequence the outgoing bird left the colony as soon as it had been replaced at the nest.
3. Forced (n=1): The incoming bird hopped onto the nest and forcibly pushed the incubating bird off the eggs.
4. Failed (n=2): The incubating bird stepped off the eggs but the incoming bird did not take over; the sitting bird then returned to the nest bowl and recommenced incubating.

3.3.4 Chick rearing

There were no overt displays by incubating birds to indicate that young had hatched, and the first evidence of newly hatched chicks was either vocal or visual within 5 days of hatching. The young began emitting a high pitched call during the day or night directed towards the parent birds. Sometimes the head of the chick could be seen as it called, swaying just above the side of the nest. Chicks were believed to be between 3-5 days old by this time and starting to show grey-black down on their bodies.

The parents brooded small chicks until approximately 1 week of age and during that period at least one parent was always present at the nest. For the first few days parents offered food without any prompting from the chicks, but as they grew begging preceded every meal, and progressively lasted longer before the adult would respond. Begging did not always lead to feeding. Within five days the parents began to hold their heads high, forcing the young to reach up. The chicks would then tap their beaks

against the adult's beak to prompt opening. Once the adult opened its beak, the chick would push its own head inside to retrieve food (Plate: 3.2). At 7-10 days old chicks pushed their heads up into the parent's throat to retrieve food, and by 2-3 weeks of age the parent had to shake its head and neck to dislodge the feeding chick. Adults also gave water to chicks by lowering their head, opening the beak, and allowing the water to run down into the chick's open mouth.

There was a significant difference ($p < 0.001$) between the feeding times for the four age groups from hatching to fledging. The mean feeding time for chicks at 0-15 days of age was $9.0 (\pm 0.6)$ sec; at 16-30 days of age $12.2 (\pm 0.6)$ sec; at 31-45 days of age $11.1 (\pm 0.7)$ sec; and from 46 days of age until fledging it was $11.5 (\pm 0.9)$ sec (Table: 3.1) (Figure: 3.5). The longest feeding time for pre-fledged young was 20 seconds and the shortest 2 seconds.

| Age (days) | 0 - 15 | 16 - 30 | 31 - 45 | 46 - Fledged | Pre-fledged Total | Fledged young + | Combined |
|------------------------|--------|---------|---------|--------------|----------------------|-----------------|----------|
| Number of observations | 49 | 37 | 37 | 15 | 138 | 44 | 182 |
| Mean time | 9 | 12.2 | 11.1 | 11.5 | 10.7 | 8.9 | 10.3 |
| \pm S. E. | 0.6 | 0.6 | 0.7 | 0.9 | 0.3 | 0.4 | 0.3 |

Table: 3.1. Mean (\pm S.E.) feeding times of chicks and fledged young Black shags at Pencarrow 1999.

When the chicks were about six weeks old both parents began to leave them alone in the nest for short periods during the day. As the chicks grew they frequently solicited food from whichever parent was present, eventually driving the bird away from the nest. If the parent remained on the nest or perch and hid its head beneath a wing the chicks finally stopped soliciting, but began again if the adult turned toward the chicks, or removed its head from under its wing.

3.3.5 Fledged young

Each parent continued to routinely feed fledged young throughout the day, usually by offering at least two meals, to the same bird or to two siblings. On three occasions one parent offered three meals to the same fledged bird. There was a significant difference ($p < 0.0001$) between the feeding times of pre-fledged chicks and fledged young. The mean feeding time was $8.9 (\pm 0.4)$ sec (Figure: 3.5), with the longest feeding being 15 seconds and the shortest 3 seconds (Table: 3.1). The oldest fledged young fed in the colony by a parent was $127 (\pm 7)$ days.

Eventually the nest site was abandoned day and night by both the parents and young. Table: 3.2. shows seven of the ten nests where broods of chicks were successfully fledged, the mean age for young were 89.9 ± 4.7 (± 7) days old. At nest [1], for example, by the time the young were 73 (± 7) days old, another adult male had begun to establish himself on the site, wing waving and actively defending the nest.

| Nest | 1 | 2 | 3 | 4 | 5 | 8 | 14 | Mean (\pm S.E.) |
|------------|----|----|-----|----|-----|----|----|--------------------|
| Age (days) | 73 | 72 | 101 | 98 | 100 | 91 | 94 | 89.9 (4.7) |

Table: 3.2. Age of fledged young (± 7) days when nests were abandoned by both parents and young, Pencarrow 1999.

3.3.6 Territorial Behaviour

Throughout the season the most common form of inter-bird competition seen in the colony involved the displacement of roosting birds. When this occurred an incoming bird displaced the roosting bird and landed in its place, or used its own forward momentum to push the resident bird off the roost. Occasionally the roosting bird successfully fended off the incomer by biting it as it attempted to land.

Most territories comprised the nest and an adjoining perch. A mating pair defended their territory from any bird that flew over or landed too close to their nest. Defence often consisted of the defender stretching out its neck and biting at the intruder, who in turn backed off or flew away. Prolonged fighting with lunging, biting and wing flapping resulted when an intruding male landed at a recently established nest with the resident male in attendance. The intruder was driven off but tried repeatedly to land on the nest before eventually being discouraged. The occupant male successfully defended the nest during this dispute by gargling and swaying its head halfway down its back, then leaning forward and shaking a stick fixed in the nest (nest worrying), before letting go, and gargling again.

Disputes between neighbouring pairs occurred if the nests were built close together. For instance nest [2] was well established with two chicks by the time another nest was being built close by, and territorial disputes took place when the birds were coming and going from their respective nests. In these interactions the defending

birds made 'clucking' sounds and swayed their heads back behind them. Biting movements were common, however, the beak seldom touched the intruding bird.

3.3.7 Aggression towards chicks

Adult aggression towards chicks from other nests was observed five times and on four occasions the adult invaded the neighbouring territory. On three of these occasions the parent birds defended the chicks, on the fourth no parents were at the colony, and on the fifth occasion a chick moved too close to an adult and was chased off. In each case the chicks were between 38 – 41 days of age. In another instance the male adult was present but did not intervene, possibly because the birds were 52 days old and fledged.

3.3.8 External threats

Australasian Harriers (*Circus approximans*) were always present in Gollans Valley, and 13 sightings of Harriers were made near the colony from 4 April until 2 September 1999. On two occasions a Harrier landed in nests at the colony. One of these nests had been recently abandoned as a failed nest, and the other was a recently established nest site, in which eggs were laid about eight days after the Harrier's intrusion. On nine other occasions Harriers flew over the colony without physical confrontation with the Black shags. Each time the Harrier's presence caused a reaction expressed as alertness and calling by the shags. Adults with chicks leaned over young protectively, while adults with eggs or roosting adults would make 'clucking' sounds, with their heads raised towards the Harrier. A few shags took to the air, circling the colony until the Harrier flew off.

On two occasions Harriers attacked Black shags at the colony. In one instance the confrontation occurred in the air, with the Harrier driving off an adult and two fledged young. On the second occasion a Harrier swooped down and attacked a fledged bird roosting in the colony. The Harrier chased the shag away from the colony and then returned and attacked five adults roosting in trees above the colony, driving them off.

Only one other bird species was seen attacking a Black shag during the present study (1999). This occurred when an adult shag was chased by a Southern Black-backed seagull (*Larus dominicanus*) along the coastline going towards Lake Kohangatera.

3.4 Discussion

Most nest sites appeared to be rebuilt fresh from cleared former sites. There were instances where nests from the previous season were refurbished, with only a few nests being established in new sites. This agrees with published data by Marchant & Higgins (1990), Johnsgard (1993) and Powlesland & Reese (1999), that nests of Black Shags are substantial enough to last more than one season.

Both the male and female were involved in nest building activities at Pencarrow colony. All subspecies of *Phalacrocorax carbo* show this shared nest building behaviour (Johnsgard 1993), as do all other species within the Order *Pelecaniformes* (Collias & Collias 1984).

The method of mate attraction at Pencarrow appears to be the same as other researched *P. carbo* populations, although Marchant & Higgins (1990) and Johnsgard (1993) reported that when the male's wings are in the raised position they sometimes vibrate rapidly. This behaviour was not seen at Pencarrow, possibly because the primary observation hide was at least 100m away, and such movements may have been missed.

Copulatory behaviour and the length of coition recorded in the present study agree with Johnsgard (1993), who noted copulation lasted up to 7 seconds, with the male nibbling the female's neck feathers during treading.

Both parent birds are involved in all aspects of rearing their young and there was no evidence of juveniles or immature shags assisting parents in the care of nests or young. Changeovers between parent birds during incubation were recorded at least two to three times per day. This was also observed by Powlesland & Reese (1999) and discussed by Johnsgard (1993). Four types of changeovers were observed during the present study, whereas three types were noted by Powlesland & Reese (1999)

from 1993 – 1998. Powlesland & Reese (1999) did not discuss the fourth type, ‘Failed Changeover’; it may not have been observed.

The oldest fledged young observed being feed by an adult was 127 (± 7) days – over 18 weeks – of age which is similar to ages reported in previous years by Powlesland & Reese (1999).

Prolonged fighting was observed only once in the colony and did not appear to cause any injury to the two males involved. Johnsgard (1993) reported that fighting most often occurs between males fighting over nest sites and on occasion blood will be drawn. While studying the European shag on the Farne Islands Potts *et al* (1980) noted that nesting shags did not often react to the activities of other shags if they occurred more than four metres away.

The response of the adults to external threats to the colony varied. However they did have a fairly constant response to sudden loud noise such as grazing stock, motorbikes or chainsaws. Shags hearing such sudden noises became agitated and often took flight, circling above the colony before eventually settling again. Alarm behaviour to threats outside the colony is poorly developed in cormorants considering their preference to form colonies (Johnsgard 1993).

Mature Black shags do not appear to have any predators, but Black-backed gulls and Harriers harassed them in the air and at the colony. During the present study no predation of chicks in the nest was seen, but one egg was found on the ground below nest [11]. The contents were gone and a predator may have been responsible (Dr R Powlesland, pers comm). The nest the egg came from was abandoned and the status of the egg is unknown. No evidence of predation on chicks or eggs at the colony was noted by Powlesland & Reese (1999) and the Mammalian predators of tree-nesting birds seen in the area included *Rattus* spp., and the brushtail possums (*Trichosurus vulpecula*).

A.G. Hall (1962) reported seeing a Black shag forced down by Australian Magpies, and on occasions C.H. Parkin (1950) saw Pied shags (*Phalacrocorax varius*) chased

by a Harrier. C H Parkin (1950) also discovered broken eggshells from the Pied shag's nest on the ground with their contents missing on several occasions, and believed that Harriers were responsible.

3.5 Conclusion

The social displays of Black shags at Pencarrow colony appear to follow those described in overseas work summarised in Johnsgard (1993) and differ from descriptions by Powlesland and Reese (1999) only in the recognition of failed changeovers during incubation.

Adults continue to provide food for their young after they have fledged but may not offer protection from aggressive acts by other birds in the colony.

Territorial aggression appears to be more orientated towards warning than physical conflict and no fatalities occurred.

The constant presence of potential predators in the area suggests a threat to eggs and young in the colony, but there was no confirmed incidence of predation.

The Black shag reacted quickly to noises directly under the colony and from elsewhere in the valley, but quickly resettled.

Chapter 4

4.0 Breeding Success

4.1 Introduction

Breeding success can be defined as the percentage of young that fledge from eggs laid or chicks hatched (Powlesland & Reese 1999). In New Zealand only one previous study, carried out at the Pencarrow colony from 1993 – 1998 (Powlesland & Reese 1999), has quantified breeding success in Black shags. The present study, also carried out at Pencarrow, measured breeding success as the mean number of young per nest that fledged from eggs laid.

Overseas research on *P. carbo* breeding success is extensive, and is outlined in many publications including Palmer *et al* (1978), Cramp *et al* (1980), Marchant & Higgins (1990), Johnsgard (1993), and Debout & Sellers (1995). Other studies in which research has focused on the outcomes of breeding include Potts *et al* (1980) – population dynamics, Boudewijn & Dirksen (1995) – impacts of contaminants, Plattheeuw *et al* (1995) – growth in chicks, and Andrew & Day (1999) – relation to nest position in colony. Devout & Seller (1995), Daunt *et al* (1999), and Schjorring *et al* (1999) discussed the effects of age on breeding success.

Johnsgard (1993) has tabled the results of studies that show the average clutch sizes, and numbers of chicks and young fledged for some *Pelecaniformes*. The average clutch sizes for ‘shags’ and ‘cormorants’ were between 2.6 (Imperial shag) and 4.4 (Black shag). The percentage of surviving fledged young was between 22% (Imperial shag) and 95% (Double-crested shag). For Black shags the survival of fledged young was 65% (Quebec) and 69% (Natal) respectively in the two studies.

As stated by Elkins (1983) ‘it is generally accepted that for the majority of bird species the ultimate reason for breeding at a particular time is to ensure that the young are hatched when food is most abundant’. This can be best shown in Australia where the beginning of the breeding season can be associated with flooding – and therefore abundant fish stocks – for four species of shag including *P. carbo* (Hobbs 1956, 1961, Lamm 1965, Whyte 1981, Llewellyn 1983, Marchant & Higgins 1990). While most species in the Order *Pelecaniformes* appear to breed once a year, it has been suggested

that some breed twice in a year (Johnsgard, 1993), for example: the Pied cormorant on Stewart Island New Zealand, Great cormorant, Japan (*P. carbo*), and in the *Anhingidae* the African darter, the Australian darter and the Oriental darter.

All species in the Order *Pelecaniformes* have 'open nests' i.e. a cup, simple platform, or a scrape (Collias & Collias 1984). The nest sites used by species in this Order fall into three categories (Johnsgard 1993): Substrate nests on level ground, Elevated nests in shrubs and trees, and Cliff ledge nests. *P. carbo* breeds in all three of the types of nest sites listed, in New Zealand and in overseas colonies (Palmer 1978, Cramp *et al* 1980, Marchant & Higgins 1990, Johnsgard 1993). In the Wellington region coastal colonies of Black shags are located in trees at Pencarrow, and on cliff ledges at Makara. Inland colonies nest on cliff ledges in Hutt River gorges, and in Willows trees (*Salix* spp.) in the lower Wairarapa. Elsewhere other colonies are on sandspits, in Pines trees (*Pinus* spp.), pohutukawa (*Metrosideros* spp.), and Beech trees (*Nothofagus* spp.) (Stead 1932, Vestjen & Van tets 1985, Heather & Robertson 1996, Powlesland & Reese 1999).

Black shags nest in colonies (Palmer *et al* 1978, Cramp *et al* 1980, Marchant & Higgins 1990, Johnsgard 1993), and rarely in North America and Australia nest as single pairs (Palmer *et al* 1978, Marchant & Higgins 1990).

The breeding success of the Pencarrow colony in the 1999 season will be compared with earlier research there, particularly by Powlesland & Reese (1999), to help build an overall picture of *P.c. novaehollandiae* breeding in New Zealand and to compare it with overseas species.

4.2 Methods

The breeding success of the Pencarrow colony has been assessed by the number of fledged young surviving from eggs laid, and successful pairs as those that succeeded in laying eggs. Nests that were abandoned after losing eggs, or chicks, are termed failed nests. To assess the survival of young the season has been separated into three stages: Egg stage – the number of eggs laid; Chick stage – the number of eggs

hatched, and number of chicks surviving to banding; Fledged young stage– the number of chicks surviving to fledge.

4.2.1 Eggs and Chicks

Exact laying dates for eggs, and the final size of clutches can be only estimated because it was not possible to see directly into any nest without causing extensive disruption. The estimated dates on which clutches were completed were assessed by counting back from the day chicks were first observed in the nest, and by the presence of eggshells on the ground below the nests. The estimated age of chicks at first sighting, and the behaviour of the parents when incubation was believed to have started were also taken into account (± 7) days. The incubation length at Pencarrow colony (29 days) was determined by taking the median of the incubation range of *P. c. novaehollandiae* offered by Marchant & Higgins (1990) which was 27 – 31 days.

The size of each clutch was estimated from the number of eggs found on the ground beneath the nests, and the number of chicks seen after hatching. The laying interval was taken as 1-3 days (Marchant & Higgins 1990, Johnsgard 1993).

4.2.2 Banding

Nestlings were banded when 15 – 21 days old (Plate: 4.1). For young chicks the criterion used to carry out banding was whether the joint between the tarso-metatarsus and tibio-fibula was sufficiently grown to prevent the band from moving up onto the tibio-fibula. For older chicks the decision to band was based on an assessment during capture attempts of the likelihood of the bird jumping out of the nest, scrambling through the branches, and falling to the ground. This latter consideration was taken into account when deciding not to band the target chicks that were close to older chicks.

The metal bands used were 'O-size', and were accompanied by three coloured plastic bands. The colour bands were wrap-around-coloured plastic (Darvic PVC) 1mm thick with an exposed overlap, fastened with supa-glue. The plastic bands were made from strips 10mm x 130mm that were placed in hot water until pliable (usually 5 – 10 seconds) then rolled into a tight circle and placed in a metal ring approximately 20mm



Plate: 4.1 Preparing to weigh chick (14 – 21 days old). Photo courtesy of Sharyn Garner.



Plate: 4.2 Ralph Powlesland returning newly banded chick to nest (14 – 21 days old). Photo courtesy of Peter Reese.

in diameter. The metal ring and contents were removed and placed in cold water for 3 – 5 seconds until the plastic hardened. Band combinations were arranged so that each bird had an individual two-band combination on one leg, and on the other a standard single colour band identifying the year over the metal serial band. Green was the colour identifying the nestlings banded in 1999. To band the nestlings one person climbed the tree holding the nest, placed each nestling in a sugar sack and lowered it to the ground. Several people at the bottom then processed the chicks. One person collected the sack and weighted the nestling in the sack using 2.5kg spring scales. The nestling was then removed and the sack weighed. The nestling was held gently but firmly by hand, with the head out of the way under the person's upper arm. Weights were recorded. A feather sample, taken from each chick, was stored in 70% Ethanol and the sex of the birds determined by the Equine Blood Typing Unit at Massey University.

4.3 Results

4.3.1 Egg stage

Eighteen pairs of Black shags succeeded in laying eggs (showed signs of incubation, i.e. changeovers) including two pairs, both with single eggs, which failed to hatch and abandoned their nests (Figure: 4.1). In one nest [11] the egg was found on the ground below the nest, and in the other nest [7] the egg was seen in the bottom of the nest after it had been abandoned. Both nests were later re-used, but it was not possible to tell if they were the same pairs, as on each occasion they were unbanded. The pair at nest [7] succeeded in laying another egg that hatched. Nest [11] was re-used twice more but each time the nesting adults failed to lay eggs.

Of the 18 pairs that succeeded in laying a total of 41 eggs, three laid one egg, eight laid two eggs, six laid three eggs and one laid four eggs (Table: 4.1). The mean number of eggs per nest for the colony was 2.3 (± 0.2). The first eggs were laid on 12 April (± 7) days and the last on 17 July (± 7) days, a laying season of 91 (± 7) days (Table: 4.2). Eleven (61%) of the eighteen nests eggs were laid in May, and only one nest was laid in June. There were two late nests (11%) both laid in July. One was a second nesting attempt at the same site with the same male (banded), but an unbanded female. It was not possible to tell if it was the same female both times. The other nest

had two unbanded adults and, while no birds succeeded with a nest at that site, at least one male was seen displaying and actively defending the site early in the season.

| Lay dates (± 7) days | Nest | Eggs laid | Hatched | Banded | Fledged |
|----------------------------|------|-----------|------------|-----------|-----------|
| 12-Apr | 1 | 3 | 3 | 3 | 3 |
| 21-Apr | 2 | 2 | 2 | 2 | 2 |
| 26-Apr | 3 | 4 | 4 | 3 | 2 |
| 29-Apr | 4 | 3 | 3 | 2 | 2 |
| 01-May | 5 | 3 | 3 | 2 | 2 |
| 02-May | 6 | 3 | 3 | 0 | 0 |
| 03-May | 7 | 1 | 0 | 0 | 0 |
| 05-May | 8 | 2 | 2 | 2 | 2 |
| 09-May | 9 | 2 | 2 | 0 | 0 |
| 09-May | 10 | 3 | 3 | 0 | 0 |
| 10-May | 11 | 1 | 0 | 0 | 0 |
| 13-May | 12 | 2 | 2 | 0 | 0 |
| 14-May | 13 | 2 | 2 | 1 | 1 |
| 29-May | 14 | 2 | 2 | 2 | 2 |
| 30-May | 15 | 2 | 2 | 2 | 2 |
| 06-Jun | 16 | 3 | 3 | 3 | 2 |
| 12-Jul | 17 | 1 | 1 | 1 | 0 |
| 17-Jul | 18 | 2 | 2 | 2 | 2 |
| Total | - | 41 | 39 | 25 | 22 |
| Means | - | 2.3 | 2.4 | 2 | 2.1 |
| (S.E.) | - | 0.2 | 0.2 : pair | 0.2 | 0.1 |

Table: 4.1. Estimated laying dates of nests, numbers of eggs laid, and survival of young to fledging at Pencarrow colony 1999.

4.3.2 Chick stage

Hatching

A total of 39 chicks hatched with the largest clutch of four chicks at nest [3] (table: 4.1). The mean number of chicks that hatched per nest was 2.4 (± 0.2) from 16 clutches. The first nest hatched on 10 May (± 7) days and the last on 14 August (table: 4.2). Of the 39 chicks that hatched the sex of 23 (59%) was identified. Fourteen (61%) of the 23 were male and 9 (39%) were females (Table: 4.3). The T-test showed that there was no significant difference ($P > 0.3$) between the gender ratio of males and females hatched ($n = 23$). The mean number of males born was 1.2 (± 0.2) per nest and the mean number of females born was 0.9 (± 0.23) per nest.

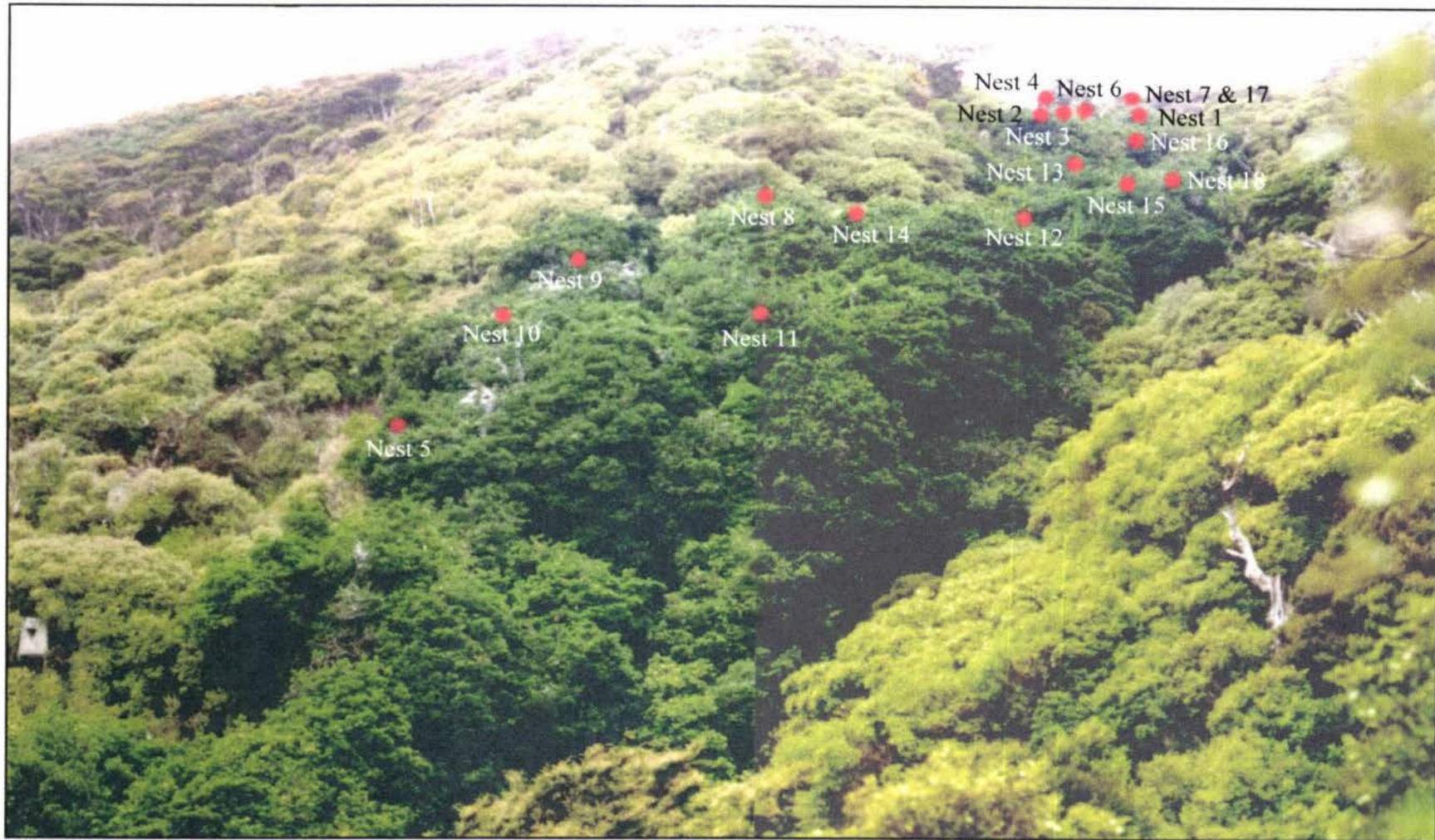


Figure: 4.1. Photo of upper colony showing nest sites that succeeded in laying eggs (showed signs of incubation).

| April | | May | | June | | July | | August | |
|-------|-------|-----|------------------------|------|--------------------|------|--------|--------|--------|
| 1 | | 1 | L (5) | 1 | | 1 | | 1 | |
| 2 | | 2 | L (6) | 2 | | 2 | | 2 | |
| 3 | | 3 | L (7) | 3 | H (8) | 3 | | 3 | |
| 4 | | 4 | | 4 | | 4 | H (16) | 4 | |
| 5 | | 5 | L (8) | 5 | | 5 | | 5 | |
| 6 | | 6 | | 6 | H (9) (10) L (16) | 6 | | 6 | |
| 7 | | 7 | | 7 | | 7 | | 7 | |
| 8 | | 8 | | 8 | C (6) (9) (10) (8) | 8 | C (16) | 8 | |
| 9 | | 9 | L (9) (10) | 9 | | 9 | | 9 | H (17) |
| 10 | | 10 | H (1) L (11) | 10 | H (12) | 10 | | 10 | |
| 11 | | 11 | | 11 | | 11 | | 11 | |
| 12 | L (1) | 12 | C (1) | 12 | H (13) | 12 | L (17) | 12 | C (17) |
| 13 | | 13 | L (12) | 13 | | 13 | | 13 | |
| 14 | | 14 | L (13) | 14 | | 14 | | 14 | H (18) |
| 15 | | 15 | | 15 | | 15 | | 15 | |
| 16 | | 16 | | 16 | | 16 | C (15) | 16 | |
| 17 | | 17 | | 17 | | 17 | L (18) | 17 | |
| 18 | | 18 | | 18 | | 18 | | 18 | |
| 19 | | 19 | H (2) | 19 | C (12) (13) | 19 | | 19 | C (18) |
| 20 | | 20 | C (2) | 20 | | 20 | | 20 | |
| 21 | L (2) | 21 | | 21 | | 21 | | 21 | |
| 22 | | 22 | | 22 | | 22 | | 22 | |
| 23 | | 23 | | 23 | | 23 | | 23 | |
| 24 | | 24 | H (3) | 24 | | 24 | | 24 | |
| 25 | | 25 | | 25 | | 25 | | 25 | |
| 26 | L (3) | 26 | | 26 | H (14) | 26 | | 26 | |
| 27 | | 27 | H (4) | 27 | | 27 | | 27 | |
| 28 | | 28 | | 28 | H (15) | 28 | | 28 | |
| 29 | L (4) | 29 | C (3) (4) H (5) L (14) | 29 | | 29 | | 29 | |
| 30 | | 30 | C (5) H (6) L (15) | 30 | C (14) | 30 | | 30 | |
| | | 31 | | | | 31 | | 31 | |

Table: 4.2. Calendar of dates (± 7) days for Laying = L, Hatching = H, chicks first seen in the nest = C, and nest = (), at Pencarrow colony 1999.

| <u>Banding date</u> | <u>Nest</u> | <u>Metal Id</u> | <u>Metal Leg</u> | <u>Colour Id</u> | <u>Sex</u> | <u>Weight (kg)</u> |
|---------------------|-------------|-----------------|------------------|------------------|------------|--------------------|
| 25-May | 1 | 32949 | right | orange/white | Male | no data |
| 25-May | 1 | 32950 | right | blue/orange | Female | no data |
| 25-May | 1 | 13611 | right | orange/black | Female | no data |
| 08-Jun | 2 | 43612 | right | blue/red | Female | 1.5 |
| 08-Jun | 2 | 13613 | right | white/red | Male | 2.01 |
| 08-Jun | 3 | 13614 | right | yellow/blue | Female | 1.05 |
| 08-Jun | 3 | 13615 | right | red/green | Female | 1.4 |
| 08-Jun | 3 | 13616 | right | white/green | Male | 1.45 |
| 08-Jun | * 3 | 0 | - | unbanded | unknown | 0.57 |
| 19-Jun | 5 | 13619 | left | red/black | Female | 1.6 |
| 19-Jun | 5 | 13620 | left | green/red | Male | 1.6 |
| 19-Jun | 8 | 13617 | right | yellow/white | unknown | 1.35 |
| 19-Jun | 8 | 13618 | left | orange/white | Female | 1.1 |
| 16-Jul | ** 13 | 20473 | right | red/white | unknown | 2.35 |
| 16-Jul | 14 | 20480 | left | green/blue | Female | 1.5 |
| 16-Jul | 14 | 20479 | left | white/yellow | Male | 1.575 |
| 16-Jul | 15 | 20475 | right | orange/yellow | Male | 1.44 |
| 16-Jul | 15 | 20474 | left | yellow/blue | Male | 1.52 |
| 16-Jul | 16 | 20478 | left | red/white | Female | 1.04 |
| 16-Jul | 16 | 20477 | left | orange/green | Male | 1.33 |
| 16-Jul | 16 | 20476 | right | green/orange | Male | 1.5 |
| 01-Sep | 17 | 20471 | left | white/orange | Male | no data |
| 01-Sep | 18 | 20472 | right | green/red | Male | no data |
| 01-Sep | 18 | 31101 | right | green/white | Male | no data |

Table: 4.3. Chick banding dates, identification, gender and weight at Pencarrow colony 1999.

* Chick too small to band, no data is available of gender.

** Chick kept jumping out of its nest and was removed to bird sanctuary, no data is available of gender.

Banding

All chicks were banded at 15 – 21 days of age with one exception (Table: 4.3). A single chick from nest 22 was banded at 35 (± 7) days and removed from the colony because it kept falling out of its nest. The mean age at banding was 17.8 ± 1.1 (± 7) days, excluding the late-banded chick from nest 22. A total of 25 chicks survived to banding age (mean = 2.0, ± 0.2 / pair) (Table: 4.1).

Weights at banding

The weights of chicks recorded at banding are given in table: 4.3. On average females weighed 1.3 (± 0.1) kg ($n=7$), less than males at 1.6 (± 0.1) kg ($n=8$), and there was a significant difference ($P < 0.05$). There was significant difference ($P < 0.01$) between the weights of individual chicks in broods of three and four young but when comparing the brood weights of individual chicks in broods of just two there was no significant difference ($P > 0.1$).

Survival to Fledging

In all 21 chicks survived to fledge at a mean age of 56.8 ± 1.1 (± 7) days (Table: 4.1). The mean number of fledged young per nest was 2.1 (± 0.1). One other chick survived to fledging but was removed from the colony and is excluded from these calculations.

In the seven broods of more than two chicks all chicks survived to fledging in only one nest (nest [1]). For other nests in this category the mean survival to fledging was 1.1 (± 0.4) and the maximum survival rate was 2 chicks per nest. There were 11 broods that survived to fledging, of these 82% ($n=9$) were broods of two chicks, 9% ($n=1$) was a brood of 3, and 9% ($n=1$) was a single chick, which had been earlier removed from the colony (Table: 4.4). Minimum overall losses for the 1999 breeding season are therefore 43.2% ($n=19$).

| Brood size | 1 | 2 | 3 | Total |
|------------------|---|----|---|-------|
| Number of broods | 1 | 9 | 1 | 11 |
| % of Total | 9 | 82 | 9 | 100 |

Table: 4.4. Brood size and percentage at fledging at Pencarrow colony 1999.

Development to fledging

Two distinctive behaviours observed in chicks after four weeks of age (± 7) days were hopping out of the nest and vigorous wing flapping. These behaviours appeared to occur at the same time, frequently being seen for the first time on the same day. As branches and leaves often obscured leg bands it was not possible to identify the individual chick engaged in the behaviour. Therefore age of chicks has been ascribed to brood and not to individual chicks. The mean age of broods when these behaviours were first observed was 41.1 ± 1.5 (± 7) days ($n=8$) (Table: 4.5).

| Nest | 1 | 2 | 3 | 4 | 5 | 14 | 15 | 16 | Mean | (S.E.) |
|---------------------|----|----|----|----|----|----|----|----|------|--------|
| Age of Brood | 40 | 42 | 42 | 34 | 39 | 47 | 46 | 39 | 41.1 | 1.5 |
| No of chicks / nest | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | - | - |

Table: 4.5. Age of brood (± 7) days when hopping out of nest and wing flapping first observed Pencarrow colony 1999.

4.3.3 Fledged Young stage

19 young from 9 broods fledged at a mean age of 56.3 ± 1.3 (± 7) days, with a range of 45 to 64 (± 7) days. 18 young were sexed and of those seven were female and 11 male. In broods with both female and male, 80% of females ($n = 4$) and 60% ($n = 3$) of males were seen flying before or on the same day as other members of their brood (Table: 4.6). There was no significant difference ($p > 0.05$) between genders within broods at age of first flight.

| Nest | Fledging Age | ID | Gender | * First seen flying |
|------|--------------|---------------|---------|---------------------|
| 1 | 51 | blue/orange | Female | Yes |
| | - | orange/black | Female | - |
| | - | orange/white | Male | Yes |
| 2 | 64 | blue/red | Female | - |
| | - | white/red | Male | Yes |
| 3 | 59 | red/green | Female | Yes |
| | - | white/green | Male | - |
| 4 | 57 | unbanded | Unknown | - |
| | - | unbanded | Unknown | - |
| 5 | 60 | red/black | Female | Yes |
| | - | green/red | Male | - |
| 8 | 50 | yellow/white | Unknown | - |
| | - | orange/white | Female | Yes |
| 14 | 60 | green/blue | Female | Yes |
| | - | white/yellow | Male | Yes |
| 15 | 60 | orange/yellow | Male | Yes |
| | - | yellow/blue | Male | Yes |
| 16 | 60 | orange/green | Male | Yes |
| | - | green/orange | Male | Yes |
| 18 | 50 | green/red | Male | - |
| | - | green/white | Male | Yes |

Table: 4.6. Age, identify and gender of fledged young, as well as young first observed flying, Pencarrow colony 1999. Chick removed from colony (nest 13) not included.

* First seen flying – per day.

Survival of Fledged young

Since the young Black shags fledged in 1999, three are known to have died. On 20 July 2000, there were no fledged young from 1999 at the colony. Minimum overall losses for the 1999 breeding season are therefore 53.7% ($n=22$). This calculation includes the survival of the fledged bird that was removed from the colony.

4.3.4 Effect of age on breeding output.

There were thirteen adults banded from previous years at Pencarrow colony in 1999 (Table: 4.7). There were insufficient banded adults to determine the effect of age on breeding output. Breeding pairs had a maximum of one banded bird so it was not possible to determine the age of both adults. The oldest adult at seven years of age 'Red Metal' attempted to pair at least three times without success. The youngest known breeding birds at three years of age did not succeed in hatching any chicks, although two of the three birds in this age group did acquire mates, copulate and were seen engaging in incubation behaviour, i.e. changeovers, sitting in the nest with the tail raised. The most successful age of adult banded birds was four years old where three pairs successfully raised chicks to fledge.

| Band Combination | | Year | | Male / Female | Pairing Fail or Succeeding | | |
|------------------|---------------|--------|-------------|---------------|----------------------------|-------------|-------------|
| Left (Leg) | Right (Leg) | Banded | Age (years) | | 1st Attempt | 2nd Attempt | 3rd Attempt |
| Metal | Red | 1992 | 7 | Female | Fail | Fail | Fail |
| Metal | Yellow | 1993 | 6 | Male | Success | - | - |
| Metal | Yellow | 1993 | 6 | Male | Fail | Fail | - |
| White/Metal | White/Yellow | 1995 | 4 | Male | Success | - | - |
| White/Metal | Red/Yellow | 1995 | 4 | Female | Fail | - | - |
| Green/Yellow | White/Metal | 1995 | 4 | Male | Fail | Success | - |
| Orange/Green | White/Metal | 1995 | 4 | Male | Fail | - | - |
| White/Metal | Green/Yellow | 1995 | 4 | Female | Success | - | - |
| Yellow/Red | White/Metal | 1995 | 4 | Male | Fail | - | - |
| Yellow/White | White/Metal | 1995 | 4 | Male | Fail | - | - |
| Yellow/Metal | Yellow/Orange | 1996 | 3 | Male | Fail | Fail | - |
| Yellow/Metal | White/Blue | 1996 | 3 | Male | Fail | - | - |
| Yellow/Metal | Yellow/Red | 1996 | 3 | Male | Fail | Fail | - |

Table: 4.7. Banded adults breeding success at Pencarrow colony, 1999, where success is defined as raising one or more chicks to fledge.

4.4 Discussion

Because clutch sizes could not be accurately determined by direct observation the numbers of eggs per nest have been estimated from the number of fledglings seen in nests, egg shells found on the ground, and dead chicks recovered. Between one and four eggs were laid by the 18 pairs that were successful in egg laying. Mean clutch size at Pencarrow colony was (2.3 ± 0.2) per nest from 18 clutches and is slightly lower than clutch sizes found in other populations of *P. carbo* around the world. From Johnsgard (1993), the mean clutch size for Southern Africa is 2.54 (n=472) (Brown *et al* 1982), Urban (1979) recorded a mean clutch size of 2.24 (n=96) from Ethiopia, and Debout (1988) took a sample over two years in Natal, with a mean

clutch size of 3.05 (n=60). In Northern Ireland Andrews & Day (1999) recorded mean clutch sizes of 3.76 (n=58) on Black Rock in 1993, and 3.71 (n=126) in 1993 and 3.4 (n=58) in 1994 at Bird Island. Clutches as large as high as six eggs have been recorded in Australia (Marchant & Higgins 1990) and in Quebec, Canada (Johnsgard 1993). Because of this there was a slightly higher mean of 4.1 (n=30) for Australia (Marchant & Higgins 1990), and 4.4 (n=112) for Quebec (Johnsgard 1993).

The number of young surviving at fledging determined the breeding success of the Pencarrow colony. In 1999 a mean of 2.1 (\pm 0.1) young fledged per nest, with 44.4% of nests failing (n=18). In comparison during the six previous years studied by Powlesland & Reese (1999) a mean of 1.44 young fledged per nest, with 17.3% of nests failing (n=32), with a range between years of 3% (n= 1, 1998) to 23.7% (n= 9, 1997). Of the 18 failed nests in 1999, 25% were lost during incubation and 75% during the nestling period. Between the years 1993-98 the failures were 65.5% during incubation and 34.4% during the nestling stage (Powlesland & Reese 1999). The range of mean young fledged per season from 1993-98 was 1.1 – 1.7 fledged young per nest (Powlesland & Reese 1999), which even in its highest year was 0.4 fledged young per nest lower than the current study. The brood sizes at fledging from 1993-98 were 37.9% one fledged bird, and 49.7% for two fledged birds. This is significantly different than the present study in which 81.8% of the broods had two fledged young.

The breeding success of *P. carbo* colonies in other parts of the world is fairly similar. For example the estimated fledging success of *P. carbo* in some coastal breeding populations in Europe ranges from 1.8 to 3.1 birds per nest (Debout *et al* 1995). Johnsgard (1993) cited fledged young survival rates for several studies: 1.25 per nest in the Netherlands (Kortlandt 1942), 1.2 in Nova Scotia Canada (Lock & Ross 1973) and 1.6 in Natal (Olver & Kuyper 1978).

The mortality of Black shags in their first year at Pencarrow colony is not known but unpublished data cited in Powlesland & Reese (1999) suggest that about 80% of banded fledged young disappear in their first year. There are no data for any other New Zealand colony. The last recorded death on 2 March 2000 was of a fledged bird aged 281 (\pm 7) days (about 9 months). Known mortality at the colony for the 1999

breeding season from eggs to fledged young is 53.7% (n=22). Kortlandt (1942) suggested that mortality of *P. carbo* in the Netherlands in their first year is similar for both males and females, with females recorded at 36% (cited in Cramp *et al* 1980). In Scotland Stuart (1948) reported losses of 70% for *P. carbo* in their first year (cited in Cramp *et al* 1980).

Male chicks were heavier than female chicks in the present study at Pencarrow colony, which is consistent with the differences between the sexes in adults (summarised in Johnsgard, 1993). It is difficult to compare chick weights because the chicks were not the same age when measurements were taken, and sample sizes were small. The significant difference in weights of individual chicks in broods of three and four can probably be attributed to the third and/or fourth chicks being significantly smaller than the other two chicks in the nests. This theory is supported by the result that the weights of individual chicks in broods of two are not significantly different. Within broods, Platteeuw *et al* (1995) found that growth rates were independent of brood size and age ranking within the nest. Food supplies and the ability of parents to provision their chicks may limit the growth and number of surviving chicks. Within two weeks of banding, two nests, with respectively three and four chicks, both had dropped to two chicks per nest following the deaths of the smaller birds in each nest. According to Platteeuw *et al* (1995) 'Parental fishing effort (expressed as the total amount of time spent on fishing trips) increased with brood size'. This suggests that the larger the brood the more energy and time is spent by parents feeding the young, and this would increase as the chicks aged and their energy needs grew.

Black shags reach sexual maturity at 4-5 years although it has been recorded at 3 years (Johnsgard 1993). At Pencarrow colony there were three, 3 year old banded birds that attempted to breed but were all unsuccessful, perhaps because of inexperience. Potts *et al* (1980) cited several papers in which poor breeding performance in young birds had been recorded and went on to say that in virtually every bird species that has been studied, the breeding performance of young birds had been relatively poor. Daunt *et al* (1999) concluded that environmental factors were not primarily responsible for the difference in breeding performance between older and younger shags. At Pencarrow colony, however the older banded birds did not

appear to perform any better than younger banded birds. One six year old male and his mate successfully reared three nestlings to fledge (nest [1]), but another six year old male failed to produce any chicks.

4.6 Conclusion

According to Snow (1960) 'loss of chicks in the first ten days after hatching is well known in shags', however there was no significant difference in the mean survival rate between the egg, chick, and fledged young stages studied at Pencarrow colony. Nests that failed due to total clutch loss, occurred more often in the egg stage and less in the chick stage during the present study, opposite to what Powlesland & Reese (1999) showed. This may have been due to extreme weather conditions during 1999 because, according to Elkins (1983), 'much mortality of young is due to either starvation, or to exposure to meteorological extremes'. Potts *et al* (1980) observed losses of whole nests swept away in storms on an island colony.

The mean number of fledged young per nest at Pencarrow colony in 1999 was higher than that achieved in the previous study from 1993-1998 by Powlesland & Reese (1999). But the rate of nests failing was twice as bad in the present study ($n=18$) than in the worst year ($n=9$) recorded by Powlesland & Reese (1999). The variation in breeding success of *P. carbo* shown at Pencarrow colony since 1993 can be seen in other colonies. For instance Debout *et al* (1995) reported fledging success in some coastal colonies in Europe that ranged from 1.8 to 3.1 birds per nest.

While age has proven to be a factor in breeding performance in overseas studies it has not been shown conclusively at Pencarrow colony. This is due to the lack of pairs in which both birds are banded.

Chicks between the age of 14 – 21 days appear to be at the optimum age for banding. By then the joint between the tarso-metatarsus and tibio-fibula is sufficiently grown to prevent the band from moving up onto the tibio-fibula. Also the chicks are less likely to jump out of the nest when they are approached. This escape reaction occurs more readily as they get older.

To acquire more accurate data on the length of incubation, exact dates of laying, and of hatching more accessible nests will be needed. Nests on the ground offer better opportunities for direct observation than nests in trees, by significantly improving the vantage point.

Chapter 5

5.0 Diet

5.1 Introduction

Seabirds have adapted to take advantage of many levels of the marine food chain (Nelson, 1979), with prey including phytoplankton, zooplankton, large crustacea, fish and squid. Most pelecaniforms have fish as their main prey and all eat fish (Nelson 1979, Schreiber & Clapp 1987, Johnsgard, 1993).

The diets of many shag species have been extensively studied, largely because of the belief that they compete for the same fish resources as humans (Schreiber & Clapp 1987). Indeed, the impact of shags foraging in fisheries and competing for commercial and recreational fish stocks in rivers and estuaries continues to be debated around the world (Schreiber & Clapp 1987, Barrett *et al* 1990, Suter 1995, Van Eerden & Gregersen 1995, Modde *et al* 1996, Bearhop *et al* 1999). Although shags have traditionally been considered a pest by fisherman worldwide their foraging abilities have long been, and still are, exploited for human benefit in China and Japan (Egremont & Rothschild 1980, Johnsgard 1993). Use of captive cormorants for fishing is a two thousand year old practice, the earliest record dating from 317 BC in China (Egremont & Rothschild 1980).

After trout were introduced into New Zealand rivers and lakes in 1870 the belief that shags were competing for commercial and recreational fish stocks saw the persecution of Black shags by every Acclimatisation Society (Stead 1932). Up to 1911 there was even a bounty of half-a-crown paid for every Black Shag head until 1911 by the North Canterbury Acclimatisation Society (Stead 1932).

The diet of New Zealand Black shags in both coastal and inland areas has been discussed by several authors. Falla & Stokell (1945) investigated the stomach contents of inland freshwater Black shags on Lakes Taupo and Rotorua, as did Dickinson in (1950), and Scott & Duncan (1967) recorded the occurrence of freshwater crayfish in Black shag stomachs from Lake Mahinerangi, Otago. Duncan (1968) later studied the general diet of Black shags on Lake Mahinerangi. Potts (1977) investigated the food of Little shags and Little black shags on Lakes Rotorua

and Rotoehu, while L alas (1983) carried out detailed comparative studies on the feeding ecology of marine shags along the Otago coast, Stewart Island and Chatham Island. The main prey species along the Otago coastline was yellow-eyed mullet which made up more than 50% of the diet, but on the Chatham Islands eels (*Anguilla* spp.) were the main prey, making up 25 – 50% of the diet (L alas 1983). Williams (1945) (cited in Duncan 1968) stated that the main diet in inland areas of Otago was brown trout (*Salmo trutta*), and in the same year Falla and Stokell (1945) found trout and eels to be the main diet of Black shags in five locations in the North Island. Dickinson (1950) concluded that native bully (*Gobiomorphus* spp.), carp (*Carassius* spp.) and crayfish were the most common prey in Lakes Taupo and Rotorua. Scott and Duncan (1967) also noted crayfish in the diet of Black shags in inland Otago.

Other aspects of shag foraging have not received much attention in New Zealand. The feeding behaviour and diving rhythms, but not the food, of Little shags, Pied shags, Spotted shags and Black shags was described by Stonehouse (1966).

Johnsgard (1993) summarised the results of several overseas studies on the prey taken by phalacrocoracids. The weight of fish prey for Black shags ranges between 6 and 500g in the Netherlands (Van Dobben 1952), and from less than 0.5 to 562g, with an average of 50g, in the Farne Islands (Pearson 1968). The Imperial shag of the South Shetland Islands showed a prey size range from 2.7 to 32g (Casaux *et al* 1997). Other studies have documented fish prey size, by length. Miller (1979) recorded fish prey lengths for Little black shags in Australia ranging from 2.5 to 18mm and for Little shags ranging from 2.3 to 16mm. L alas (1983) recorded fish prey lengths ranging from 90 to 230 mm for Black shags, 20 to 110mm for Little shags, 20 to 230 mm for Bronze shags, 30 to 250 mm for Chatham Island shags, 20 to 230 mm for Spotted shags, and 20 to 170 mm for Pitt Island shags.

Within the order *Pelecaniformes* the members have evolved different methods of foraging and undergone anatomical changes related to prey hunting. According to Nelson (1979) '*Feeding is the primary activity to which all else is geared. It determines basic anatomy and morphology (not the other way around), and distribution and breeding strategy*'. Nelson (1979) categorised six types of foraging methods by seabirds:

1. Picking food from the surface, whilst flying (e.g. Storm Petrels, Frigatebirds, Terns).
2. Exploiting the surface layer mainly whilst swimming (e.g. Shearwaters, Albatrosses, Pelicans).
3. Deep plunge diving – dropping from the sky (e.g. Gulls, Skuas).
4. Heavy plunge diving – diving to greater depths (e.g. Gannets, Boobies, Tropic birds).
5. Diving from the surface and collecting prey by extensive and deep swimming (e.g. Penguins, Cormorants, Auk).
6. Piracy (e.g. Skuas, Frigatebirds).
7. Scavenging and innovative feeding (e.g. Gannets, Gulls).

All of the above methods are utilised by *pelecaniform* birds. Shags and Darters forage by diving from the surface and engage in underwater pursuit, propelling themselves along with their feet. While plunge diving is not considered to be normal foraging behaviour for shags there have been some records of such activity e.g. the Socotra shag. Darters, on the other hand, have often been seen diving for prey from low perches over water (Johnsgard 1993).

New Zealand shags forage by diving from the surface of the water to catch their prey and, as with other shags around the world, utilise both freshwater and marine habitats. The foraging habitats for New Zealand shags are listed in table: 5.1. *Phalacrocorax* spp. forage in both marine and freshwater areas, but *Leucocarbo* spp. forage only in marine environments (Lalas 1983). Lalas (1983) used the terms 'pelagic' and 'demersal' to describe the feeding habitats of New Zealand marine shags. 'Pelagic' refers to animals living in the sea or ocean at middle or surface levels, and 'demersal' refers to animals living on or near the bottom of sea or lake (Lalas 1983, Allaby 1998). Of the shags that Lalas (1983) studied only Black shags regularly fed both in both pelagic and demersal regions.

| Species & sub-species | Common name | Habitat | Movement | Foraging behaviour |
|--|----------------------|---------------------|--|--|
| <i>Phalacrocorax (carbo) novaehollandiae</i> | Black shag | Marine & Freshwater | Prefer shallow water in Coastal and inland areas. | Typically solitary but group foraging has been observed. |
| <i>Phalacrocorax sulcirostris</i> | Little Black shag | Marine & Freshwater | Prefer shallow water in Coastal and inland areas. | Highly social. |
| <i>Phalacrocorax melanoleucos</i> | Little shag | Marine & Freshwater | Prefer shallow water in Coastal and inland areas. | Typically solitary. |
| <i>Phalacrocorax varius</i> | Pied shag | Marine & Freshwater | Prefer shallow water in Coastal and inland areas. | Typically solitary. |
| <i>Leucocarbo carunculatus</i> | King shag | Marine | Coastal feeding observed. | Unknown |
| <i>Leucocarbo (carunculatus) chalconotus</i> | Bronze shag | Marine | Up to 15km from shore. | Solitary. |
| <i>Leucocarbo (carunculatus) onslowi</i> | Chatham Island shag | Marine | Not well known foraging done within a few km of shore. | Unknown. |
| <i>Leucocarbo (carunculatus) colensoi</i> | Auckland Island shag | Marine | Coastal and sometimes well out to sea. | Unknown |
| <i>Leucocarbo punctatus</i> | Spotted shag | Marine | Deep water 2-16km off shore. | Solitary and group feeding. |
| <i>Leucocarbo campbelli</i> | Campbell Island shag | Marine | Coastal feeding observed. | Solitary and group. |
| <i>Leucocarbo (punctatus) featherstoni</i> | Pitt Island shag | Marine | Foraging done in coastal kelp beds. | Solitary. |
| <i>Leucocarbo (carunculatus) ranfurlyi</i> | Bounty Island shag | Marine | Coastal and out to sea. | Pairs too large group feeding. |

Table: 5.1. Foraging habitats of New Zealand shags (Lalas 1983, Marchant & Higgins 1990, Johnsgard 1993).

The depths at which shags hunt differs between species. Black shags and Little shags have been recorded hunting up to 9m below the surface (Cramp *et al* 1980, Johnsgard 1993), with an average depth of 1 to 3m (Cramp *et al* 1980). However in New Zealand Stonehouse (1967) stated that Black shags seldom forage in depths greater than 2 – 3m and remain close to shore. Pied shags, like black shags, feed close to the shore and have been recorded diving to depths of 10m, but most often to depths of 3 – 10m (Stonehouse 1967, Nelson 1979, Johnsgard 1993). Little black shags dive to depths of 1 – 2m and the Bronze shag to as much as 30m below the surface (Johnsgard 1993).

In Black shags the dives last between 15 – 60s (Cramp *et al* 1980), and up to 71s according to Palmer *et al* (1978). In New Zealand Stonehouse (1967) recorded mean diving times for four species of shag. The mean diving times for Pied shag and Spotted shag were longest at 31s and 30s respectively, Black shags were 21s and

Little shags 16s. Nelson (1979) stated that *phalacrocoracids* could remain under water for up to 3 to 4 minutes but usually remained submerged for around 40 seconds.

The principal aim of this chapter is to identify the diet of Black shags at Pencarrow colony over the 1999 breeding season and to identify any changes in their diet during this time. A secondary aim is to determine the frequency of species in the diet, the length and mass of fish prey taken, and any differences between the diets of chicks and adults.

5.2 Methods

Pellets

The ground below the colony and surrounding Karaka trees where the shags roosted were checked weekly for regurgitated pellets (Plate: 5.1, 5.2). As a pellet was found it was placed in a vial and the location and date recorded on the vial with a vivid marker. The pellets were preserved in 70% ethanol to preserve the contents until they were dissected and their contents separated and identified.

To determine the dry weights of the pellets, 105 were dried in an incubator oven for 46 ½ hours at 60 degrees Celsius. Sample pellets were taken from the oven and weighed at regular intervals to determine moisture content loss. When pellet weights stabilised, their dry weight was recorded in grams.

The pellets were broken up and identified bones and remains were separated and placed in numbered vials. These vials were then examined and, with the assistance of Dr Chris Lalas, families and species (where possible) of fish and invertebrates were identified and recorded. Dr Chris Paulin provided assistance in the composition of fish species present in Black shag foraging areas, Wellington Harbour and South Coast. Species were also identified using Paul (1986), Hopkins (1970) and presence in foraging areas Roberts (1996).

The otoliths were measured using venier calipers, with an error rate of (\pm 0.05)mm. As otoliths were often corroded the measurements taken could only be used as estimates of fish length and fish mass. Lengths (mm) are recorded with an accuracy

Plate: 5.1 Looking for regurgitated pellets under colony. Photo courtesy of Robin Fordham.



Plate: 5.2
Regurgitated pellet.



of $\sim \geq 10\%$, fish mass (grams) is recorded with an accuracy of $\sim \geq 20 - 30\%$ (Table: 5.2, Figure: 5.1). For two species Wrasse (spotty) and Jock Stewart, measurements were taken from the jawbones. Wrasse had five possible measurements, three from the upper jawbone and two from the lower pharyngeal tooth plate, Butterfish had one possible measurement from the lower pharyngeal tooth plate (Table: 5.3, Figure: 5.2). Dr Chris Lalas provided the equations used, but Triplefin spp. were too eroded for accurate measurements to be taken therefore fish lengths are presented as nominal total length.

| Family | Common name | Length range | Length (mm) | Mass (grams) |
|-----------------|--------------------|--------------|----------------------|----------------------------------|
| Clupeidae | Pilchard | FL | 48.31×1.047 | 0.885×3.397 |
| Moridae | Rock Cod | TL | 19.0×1.05 | $3.4 \times 10^{-4} \times 2.43$ |
| Moridae | Red Cod | TL | 8.35×1.534 | 0.004×4.752 |
| Trachichthyidae | Common ruffly | FL | 13.74×1.088 | 0.066×3.216 |
| Scorpaenidae | Jock stewart | TL | 18.91×1.101 | 0.073×3.542 |
| Carangidae | Mackerel | FL | 26.96×1.068 | 0.142×3.433 |
| Mugilidae | Yellow-eyed mullet | FL | 29.13×1.031 | 0.163×3.407 |
| Percophidae | Opalfish | FL | 35.85×1.252 | 0.428×3.148 |
| Soleidae | Sole | TL | 24.82×1.711 | 0.077×5.557 |
| *Tripterygiidae | Triple Fins | TL | 50 – 100 mm | Average of 5g |

* Otoliths too eroded for measurements to be taken, therefore they are presented as a nominal total length.

Table: 5.2. Equations of otolith measurements for mass and length of fish prey.

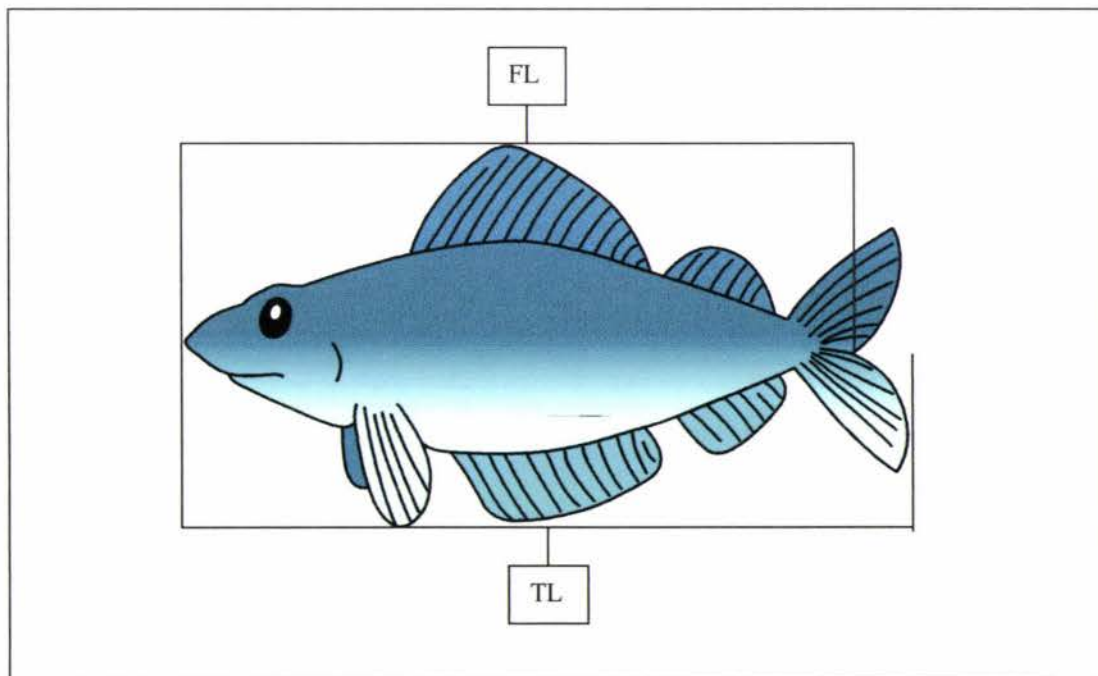


Figure: 5.1. Diagram of fish to show fish range. TL = Total length, from snout to end of tail. FL = Fork Length, from snout to fork in tail.

| Family | Common name | * Equation number | Length range | Length (mm) | Mass (grams) |
|----------|-----------------|-------------------|--------------|-------------------|-------------------------------|
| Labridae | Wrasse (spotty) | 1 | TL | $28.51 + 12.93 x$ | $9.6 \times 10^{-7} x^{3.51}$ |
| | | 2 | TL | $63.97 + 13.17 x$ | $9.6 \times 10^{-7} x^{3.51}$ |
| | | 3 | TL | $51.08 + 11.14 x$ | $9.6 \times 10^{-7} x^{3.51}$ |
| | | 4 | TL | $97.84 + 7.73 x$ | $9.6 \times 10^{-7} x^{3.51}$ |
| | | 5 | TL | $97.61 + 11.68 x$ | $9.6 \times 10^{-7} x^{3.51}$ |
| Odacidae | Butterfish | ** 5 | FL | $97.61 + 11.68 x$ | $3.8 \times 10^{-7} x^{3.60}$ |

* Equation number represents different measurements that are taken from dentition.

** Equation for Butterfish is taken from equation 5 of Wrasse dentition.

Table: 5.3. Equations of Wrasse and Butterfish dentition, measurements for mass and length of fish prey.

Wrasse dentition

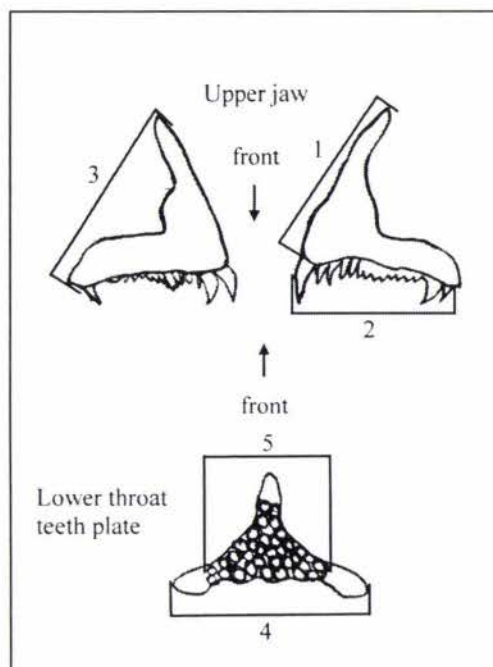


Figure: 5.2 Diagram of Wrasse dentition showing length measurements for 1 – 5 equations.

Stomachs from four dead chicks were dissected and the contents examined. Otoliths found in the contents were identified and measured (mm) and equations (Lalas 1983) applied to determine the mass and length of fish prey.

All statistical analysis was done using SAS analysis of variance (ANOVA) 6.12. The square root of the fish mass was used to add stability and therefore increase the normality of the distribution, when investigating comparisons between and within fish species.

5.3 Results

5.3.1 Composition of Diet

Only one prey item from a freshwater system was identified – a North Island freshwater crayfish (*Paranephrops planifrons*). All other items were marine (Table: 5.2). Dissection of regurgitated pellets revealed a total of 22 prey items, of which 19 were identified. Fish were overwhelmingly the primary prey type with 17 different species noted, of which 14 were identified. Remains of five types of invertebrates were also recovered from the pellets including numerous pieces of mollusc (Table: 5.4). Three nematodes, presumed to be gut parasites, were also associated with three pellets.

| Common Name | Family / Order | Species |
|----------------------|------------------|--------------------------------|
| Fish | | |
| Pilchard | Clupeidae | <i>Sardinops neopilchardus</i> |
| Rock Cod | Moridae | <i>Lotella phycis</i> |
| Red Cod | Moridae | <i>Pseudophycis</i> spp. |
| Common ruffly | Trachichthyidae | <i>Paratrachichthys traili</i> |
| Jock Stewart | Scorpaenidae | <i>Helicolenus percoides</i> |
| Gurnard | Triglidae | <i>Chelidonichthys kumu</i> |
| Mackerel | Carangidae | <i>Trachurus</i> spp |
| Wrasse (spotty) | Labridae | <i>Notolabrus celidotus</i> |
| Butterfish | Odacidae | <i>Odax pullus</i> |
| Yellow-eyed mullet | Mugilidae | <i>Aldrichetta forsteri</i> |
| Opalfish | Percophidae | <i>Hemerocoetes</i> spp. |
| Blue Cod | Pinguipedidae | <i>Parapercis colias</i> |
| Triple Fins | Tripterygiidae | - |
| Sole | Pleuronectiforms | - |
| Unidentified | - | 3 species |
| Invertebrates | | |
| Chiton | - | - |
| Parasitic isopod | - | - |
| Ostracod | - | - |
| Decapod crustacean | - | - |
| Freshwater crayfish | - | <i>Paranephrops planifrons</i> |

Table: 5.4. Prey of Black shags found in regurgitated pellets at Pencarrow colony 1999. Taxonomy following Paulin et al (1989) and Doret et al (1991).

From the stomach contents of four dead chicks aged between 10-11 days fish, invertebrates, molluscs, nematodes, seaweed, small stones, and small bits of wood were found (Table: 5.5).

| <u>Date found</u> | <u>Nest</u> | <u>Age (days)</u> | <u>Contents</u> |
|-------------------|-------------|-------------------|--|
| 8 June | 5 | 10 (\pm 7) | Nematodes (2), crab shell, stones, seaweed, wood. |
| 19 June | 8 | 11(\pm 7) | Fish eye & tooth, crab shell, seaweed, stones. |
| 19 June | 8 | 11 (\pm 7) | Nematodes (5), crab shell, seaweed, stones, Fish otoliths: yellow-eyed mullet (2 pairs), sole (1), unidentified (1). |
| 19 June | 8 | 11 (\pm 7) | Nematodes (8), crab shell seaweed, stones. |

Table: 5.5. Stomach contents of four chicks aged between 10 & 11(\pm 7) days. All chicks had been dead 1-2 days prior to being found.

Fresh vomit from two chicks aged 15 and 20 days respectively was collected when they were handled during banding. This material revealed only one otolith, from a sole.

The frequency of occurrence of prey items is given in table: 5.6. Spotty made up 50 % of the Black shags diet during the 1999 breeding season, rock cod 12.1 %, yellow-eyed mullet 7.4 %, sole 5.2 %, and red cod and mackerel had 3.6 %. The highest single occurrence of a species in a pellet were 15 yellow-eyed mullet. Invertebrates combined made up 7.2% with parasitic isopods and chitons the most frequent item.

| <u>Common name</u> | <u>Total No. of items</u> | <u>No. of pellets frequency (%)</u> | <u>Diet %</u> | <u>Items / pellet</u> |
|---------------------|---------------------------|-------------------------------------|---------------|-----------------------|
| Pilchard | 2 | 2 (1.7) | 0.5 | 1 |
| Rock Cod | 51 | 31 (25.6) | 12.1 | 1 – 3 |
| Red Cod | 15 | 11 (9.1) | 3.6 | 1 – 3 |
| Common Ruffly | 4 | 4 (3.3) | 1.0 | 1 |
| Jock Stewart | 1 | 1 (0.8) | 0.2 | 1 |
| Gurnard | 1 | 1 (0.8) | 0.2 | 1 |
| Mackerel | 15 | 11 (9.1) | 3.6 | 1 – 3 |
| Wrasse (spotty) | 210 | 89 (73.6) | 50.0 | 1 – 12 |
| Butterfish | 4 | 4 (3.3) | 1.0 | 1 |
| Yellow-eyed Mullet | 31 | 9 (7.4) | 7.3 | 1 – 15 |
| Opalfish | 3 | 3 (2.5) | 0.7 | 1 |
| Blue Cod | 2 | 2 (1.7) | 0.5 | 1 |
| Triple Fins | 1 | 1 (0.8) | 0.2 | 1 |
| Sole | 22 | 7 (5.8) | 5.2 | 1 – 11 |
| Unidentified | 28 | 13 (10.7) | 6.7 | 1 – 5 |
| Chiton | 10 | 9 (7.4) | 2.4 | 1 – 2 |
| Parasitic isopod | 10 | 8 (6.6) | 2.4 | 1 – 2 |
| Ostracod | 4 | 3 (2.5) | 1.0 | 1 – 2 |
| Decapod crustacean | 5 | 5 (4.1) | 1.2 | 1 |
| Freshwater crayfish | 1 | 1 (0.8) | 0.2 | 1 |
| Total | 420 | 121 - | 100 | = |

Table: 5.6. The frequency of prey in egested pellets, and diet composition at Pencarrow colony 1999.

5.3.2 Pellet Contents

Because adults, but not chicks, were seen regurgitating pellets, it is assumed that adult birds produced all pellets collected below the nest trees in the colony. The mean numbers of prey items per pellet each month is given in table: 5.7. Overall there were more items in July August and September, with July the highest at 4.6 (± 1.1) and April the lowest with 2.7 (± 0.5) but there was no significant difference ($p > 0.1$) in the number of prey items per pellet ($n=119$) during the eight months they were collected. The overall mean of prey per pellet was 3.4 (± 0.2). Table: 5.8, shows the frequency of occurrence of numbers of prey items found in 119 regurgitated pellets collected at Pencarrow colony 1999.

| Month | Feb | Apr | May | Jun | Jul | Aug | Sep | Oct |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
| Mean | 3.0 | 2.7 | 3.0 | 3.0 | 4.6 | 3.9 | 4.0 | 3.2 |
| S.E. | 0.4 | 0.5 | 0.7 | 0.4 | 1.1 | 1.1 | 0.5 | 0.3 |

Table: 5.7. Mean number of prey items per pellet February – October 1999.

| Number of prey per pellet | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 | 12 | 13 | 19 | Total |
|---------------------------|----|----|----|----|----|---|---|---|----|----|----|----|-------|
| Frequency of occurrence | 15 | 27 | 35 | 16 | 13 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 119 |

Table: 5.8. Frequency of number of prey found in 119 regurgitated pellets.

The frequency of prey items shows that many pellets contain few items and only 13 pellets (10.9%) holding six or more items. Close to half (52.1%) the pellets comprised two or three prey items, and the large majority (89.1%) had between one and five prey items. Several pellets contained numerous prey items for example: from one regurgitated pellet in August, 19 prey items were identified and of those 15 were yellow-eyed mullet. The approximate mass of these fish ranged from 2 –7g each. With a mean value of 3.4 ± 0.2 and a variance of 4.76, the data appear slightly clumped. Assuming however that a pellet is not produced when there is no prey material to regurgitate (i.e. a value of zero for pellet prey content), the data approximate a Poisson (random) distribution in which the mean and variance are equal.

For 105 pellets the mean dry weight was $5.3 (\pm 0.3)$ g. There was no significant difference ($p > 0.1$) in the dry weights of pellets over the eight months they were

collected (Table: 5.9). The heaviest pellets were in July, August and September, with the peak in September ($7.0 \pm 1.7\text{g}$, $n=6$) and the lightest pellets in April ($3.5 \pm 0.5\text{g}$, $n=11$).

| Month | Feb | Apr | May | Jun | Jul | Aug | Sep | Oct |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|
| Mean | 4.9 | 3.5 | 4.4 | 5.1 | 6.9 | 5.8 | 7.0 | 5.4 |
| S.E. | 1.0 | 0.5 | 0.5 | 0.9 | 1.2 | 0.7 | 1.7 | 0.5 |

Table: 5.9. Mean dry weights (g) of pellets February – October 1999.

5.3.3 Length and Mass of Prey

Eleven of the most frequent occurring fish species were used for measurements of length and mass. When comparing the sizes of the different fish species there was a significant difference ($p < 0.0001$) for both the length and mass. A Tukeys test to compare means of species with 95% confidence showed that Jock Stewart and Butterfish were not significantly different to any other species in length or mass. However Yellow eyed mullet and Rock cod were significantly different from six other species in length, and five other species in their mass. Mean length and mean mass of the species is given in table: 5.10. A comparison of mass against length for the two species with the highest number of otoliths recovered is given in Figure: 5.3.

The length of the fish eaten ranged from 105.8 (± 11.1) mm for yellow eyed mullet ($n = 28$) to 274.7 (± 6.1) mm for rock cod ($n=16$), and the mass ranged from 14.8 (± 2.9)g for Opal fish ($n=4$) to 356.0g for Jock Stewart ($n=1$).

| Species | Length (mm) | | Mass (g) | |
|--------------------|-------------|------|----------|-------|
| | Mean | S.E. | Mean | S.E. |
| Pilchard | 254.3 | 60.7 | 267.3 | 121.8 |
| Rock Cod | 274.7 | 6.1 | 297.7 | 16.0 |
| Red Cod | 211.1 | 22.9 | 141.1 | 37.8 |
| Common Ruffy | 135.8 | 16.8 | 112.8 | 27.4 |
| Jock Stewart | 255.0 | - | 356.0 | - |
| Mackerel | 239.1 | 9.0 | 168.7 | 20.3 |
| Spotty | 233.8 | 3.6 | 233.5 | 12.6 |
| Butterfish | 205.7 | 7.2 | 81.3 | 10.3 |
| Yellow-eyed Mullet | 105.8 | 11.1 | 30.1 | 11.1 |
| Opal fish | 143.8 | 11.7 | 14.8 | 2.9 |
| Sole | 155.7 | 13.4 | 47.3 | 11.6 |

Table: 5.10. Mean length (mm) and mass (g) of eleven frequently occurring fish prey at Pencarrow colony 1999.

The fish species identified from the chick stomachs and vomit were sole and yellow-eyed mullet. There was no significant difference ($p > 0.05$) between the length and

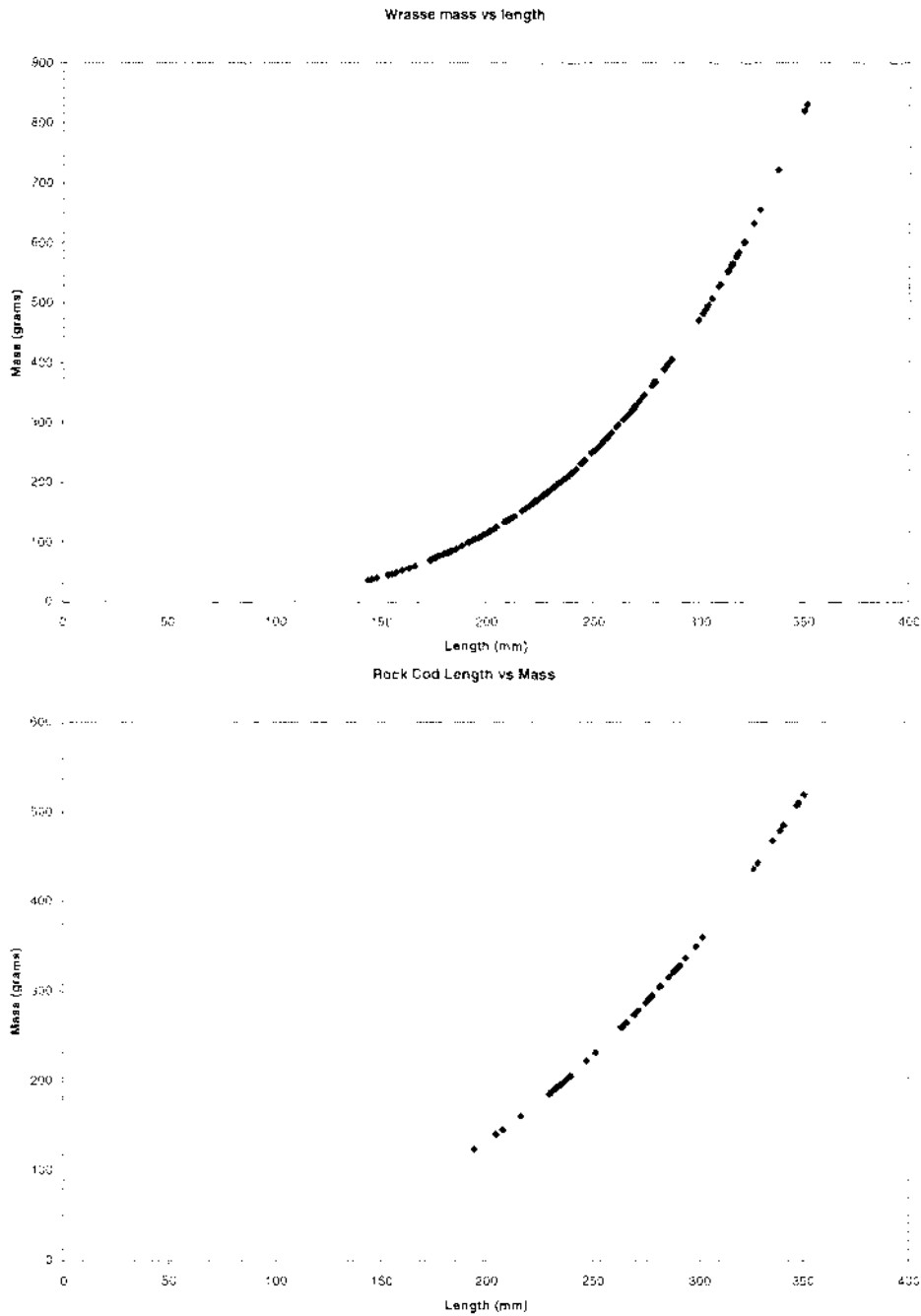


Figure 5.3. Comparisons of mass against length for Wrasse (spotty) and Rock cod, taken from equations in table 5.2.

mass of these fish when compared with the same species recovered from pellets regurgitated by adults. The means for length and mass for the two species are given

in table: 5.11. There were insufficient data to compare the diet of adults and chicks between months or seasons.

| <u>Species</u> | <u>Age</u> | <u>Length (mm)</u> | | <u>Mass (g)</u> | |
|---------------------------|------------------|--------------------|-------------|-----------------|-------------|
| | | <u>Mean</u> | <u>S.E.</u> | <u>Mean</u> | <u>S.E.</u> |
| <u>Yellow-eyed Mullet</u> | * <u>Chicks</u> | 190.5 | 5.5 | 80.5 | 7.5 |
| | ** <u>Adults</u> | 105.8 | 11.1 | 30.1 | 11.1 |
| <u>Sole</u> | * <u>Chicks</u> | 142.0 | 40.6 | 62.2 | 42.4 |
| | ** <u>Adults</u> | 155.7 | 13.4 | 47.3 | 11.6 |

* Prey taken from stomach contents and vomit, chicks aged between 10 – 20 (± 7) days.

** Prey taken from regurgitated pellets (only adults were seen regurgitating pellets, it is therefore assumed that all pellets come from adult birds).

Table: 5.11. Means of 'fish prey mass (grams) & length (mm)' collected from chicks and adults at the Pencarrow colony, 1999.

5.3.4 Change in adult diet over breeding season

The mean number of prey per pellet was highest in winter 3.8 (± 0.6) (n = 36), then spring with 3.4 (± 0.3) (n = 51) and the lowest autumn 3.0 (± 0.3) (n = 32), but there was no significant difference ($p > 0.2$) between the three seasons (Table: 5.12).

There was, however, a significant difference ($p < 0.05$), between the seasons in the mean dry weights of pellets. The heaviest pellets were in winter 5.9 (± 0.5)g (n = 35), then spring with 5.6 (± 0.5)g (n = 38) and the lightest in autumn at 4.3 (± 0.4)g (n = 32) (Table: 5.12).

| | <u>Seasons</u> | <u>No. of pellets</u> | <u>Mean</u> | <u>S.E.</u> | <u>Range</u> |
|-----------------------------|----------------|-----------------------|-------------|-------------|---|
| <u>Fish mass per pellet</u> | | | | | <u>Range of mean fish mass per pellet (g)</u> |
| | <u>Autumn</u> | 28 | 241.0 | 23.3 | 71.0 – 584.0 |
| | <u>Winter</u> | 32 | 143.9 | 12.5 | 3.0 – 336.5 |
| | <u>Spring</u> | 47 | 228.6 | 14.0 | 17.0 – 722.0 |
| <u>Prey per pellet</u> | | | | | <u>Range of prey per pellet</u> |
| | <u>Autumn</u> | 32 | 2.9 | 0.3 | 1 – 9 |
| | <u>Winter</u> | 36 | 3.8 | 0.6 | 1 – 19 |
| | <u>Spring</u> | 51 | 3.4 | 0.3 | 1 – 12 |
| <u>Dry weight</u> | | | | | <u>Range of weight of pellets (g)</u> |
| | <u>Autumn</u> | 32 | 4.3 | 0.4 | 1.8 – 13.9 |
| | <u>Winter</u> | 35 | 5.9 | 0.5 | 2.6 – 15.3 |
| | <u>Spring</u> | 38 | 5.6 | 0.5 | 1.2 – 14.2 |

Table: 5.12. Fish mass, Prey items per pellet and dry weight of pellets over autumn, winter and spring, Pencarrow colony, 1999.

The overall mean mass of fish per pellet at Pencarrow colony 1999 was 198.2 (± 9.2)g. There was no significant difference ($p > 0.4$) in mean fish mass per pellet

between the seasons. The heaviest mean mass per pellet was in autumn 241.0 (\pm 23.3)g (n = 28), then spring with 228.6 (\pm 14.0)g (n = 47), and the lightest in winter 143.9 (\pm 12.5)g (n = 32) (Table: 5.12). The mean mass of each fish species per season is given in table: 5.13.

Both length ($p < 0.05$) and mass ($p < 0.05$) varied significantly within fish species over the three seasons autumn, winter, spring. The means of length and mass for each of the eleven species during each season are given in Table: 5.13.

| <u>Species</u> | <u>Season</u> | <u>Length (mm)</u> | | <u>Mass (g)</u> | |
|---------------------------|---------------|--------------------|-------------|-----------------|-------------|
| | | <u>Mean</u> | <u>S.E.</u> | <u>Mean</u> | <u>S.E.</u> |
| <u>Pilchard</u> | <u>Autumn</u> | - | - | - | - |
| | <u>Winter</u> | 254.3 | 60.7 | 267.3 | 121.7 |
| | <u>Spring</u> | - | - | - | - |
| <u>Rock Cod</u> | <u>Autumn</u> | 310.6 | 18.3 | 400.3 | 51.9 |
| | <u>Winter</u> | 254.2 | 11.5 | 246.1 | 25.1 |
| | <u>Spring</u> | 273.7 | 6.7 | 292.0 | 17.4 |
| <u>Red Cod</u> | <u>Autumn</u> | 202.5 | 31.5 | 110.5 | 49.2 |
| | <u>Winter</u> | 219.0 | 76.7 | 217.8 | 121.8 |
| | <u>Spring</u> | 214.3 | 28.5 | 120.7 | 44.8 |
| <u>Common Ruff</u> | <u>Autumn</u> | - | - | - | - |
| | <u>Winter</u> | - | - | - | - |
| | <u>Spring</u> | 165.8 | 16.8 | 112.8 | 27.4 |
| <u>Jock Stewart</u> | <u>Autumn</u> | - | - | - | - |
| | <u>Winter</u> | - | - | - | - |
| | <u>Spring</u> | 265.0 | - | 356.0 | - |
| <u>Mackerel</u> | <u>Autumn</u> | 244.3 | 9.0 | 175.5 | 19.8 |
| | <u>Winter</u> | 187.0 | - | 71.0 | - |
| | <u>Spring</u> | 241.2 | 18.9 | 177.4 | 46.2 |
| <u>Wrasse (Spottv)</u> | <u>Autumn</u> | 242.4 | 7.9 | 263.3 | 31.5 |
| | <u>Winter</u> | 215.0 | 5.4 | 175.4 | 15.5 |
| | <u>Spring</u> | 248.0 | 5.3 | 276.1 | 20.6 |
| <u>Butterfish</u> | <u>Autumn</u> | 199.0 | - | 71.0 | - |
| | <u>Winter</u> | - | - | - | - |
| | <u>Spring</u> | 209.0 | 11.0 | 86.5 | 15.5 |
| <u>Yellow-eyed mullet</u> | <u>Autumn</u> | 122.0 | - | 18.0 | - |
| | <u>Winter</u> | 97.1 | 11.0 | 24.3 | 11.7 |
| | <u>Spring</u> | 169.3 | 44.3 | 80.3 | 38.3 |
| <u>Opal fish</u> | <u>Autumn</u> | 172.0 | - | 22.0 | - |
| | <u>Winter</u> | 124.5 | 0.5 | 10.0 | 0.0 |
| | <u>Spring</u> | 154.0 | - | 17.0 | - |
| <u>Sole</u> | <u>Autumn</u> | - | - | - | - |
| | <u>Winter</u> | 153.7 | 27.7 | 50.1 | 22.7 |
| | <u>Spring</u> | 156.7 | 15.4 | 45.9 | 13.9 |

Table: 5.13. Length and mass of eleven fish species in egested pellets over autumn, winter and spring, Pencarrow colony, 1999.

For all fish species combined there was a highly significant difference ($p < 0.0001$) between seasons in length and mass of fish taken as prey (Table: 5.14). A Tukeys test to compare means of length and mass with 95% confidence showed significant differences between winter and the two other seasons. For autumn the mean length difference was 52.3mm and mean mass 97.1g, for spring the mean length difference was 45.2mm and mean mass 84.7g (Table: 5.15).

| Season | Length (mm) | | Mass (grams) | |
|--------|-------------|------|--------------|------|
| | Mean | S.E. | Mean | S.E. |
| Autumn | 242.7 | 7.3 | 241.0 | 23.3 |
| Winter | 190.4 | 6.9 | 143.9 | 12.5 |
| Spring | 235.7 | 5.1 | 228.6 | 14.0 |

Table: 5.14. Means and standard errors of lengths and mass for all fish species for the three seasons autumn, winter and spring at Pencarrow colony, 1999.

| Length (mm) / Mass (g) | Autumn | Winter | Spring |
|------------------------|-----------|-----------|----------|
| Autumn | - | 97.1 (g) | 12.4 (g) |
| Winter | 52.3 (mm) | - | 84.7 (g) |
| Spring | 7.0 (mm) | 45.2 (mm) | - |

Table: 5.15. Differences between the means of mass and length for all fish species combined for the three season's autumn, winter and spring at Pencarrow colony, 1999.

5.4 Discussion

There are two common approaches to studying the diet of shags. These are investigating the contents stomachs and of regurgitated pellets for otoliths and other distinguishable prey remains. The collection and use of regurgitated pellets is a non-destructive and simple way of examining diet and also provides a large sample size (Suter 1997). However these methods will not give a complete record of the diet as the entire prey will pass through the digestive tract and the erosion and dissolution of otoliths and other distinguishable prey remains is well documented (Zijlstra & Van Eerden 1995, Suter 1997, Casaux *et al* 1998). Zijlstra & Van Eerden (1995) conducted trials on pellet production with captive Black shags, recovering 52% of otoliths for the larger fish prey examined, but only two of the five species used. It was also found that there were greater losses of otoliths 84% of Ruffe (*Gymnocephalus cernuus*) whose length was less than 10cm than 50% of otoliths from Ruffe that had a length greater than 20cm (Zijlstra & Van Eerden 1995). This suggests that while 50% of Black shag diet at the Pencarrow colony was identified as wrasse, it is likely that wrasse contributed even more significantly to the diet because their otoliths were undetected, and that there are other small fish prey that were unidentified. Wrasse (spotty) a subtidal species is extremely abundant in some areas (Paul 1986), is

abundant in Wellington harbour (Dr Chris Paulin pers. comm.), and is a very significant component of the Pencarrow Black shag diet. Lalas (1983) suggested that at least half of the diet by weight from any site of pelagic feeders was from one genus, usually one species of prey. Although Black shags are believed to be feeders of both pelagic and demersal regions Lalas (1983), they showed the characteristic of having a single predominant prey species in their diet in both Lalas' (1983) research and the present study at Pencarrow. This has also been documented in overseas research of Black shag diet. West *et al* (1974) in Ireland identified 60% of the diet weight could be attributed to wrasse (Cramp *et al* 1980). In North America Ross (1977) reported that 57.8% of Black shag diet studied at spring roosts were sculpin (*Myoxocephalus*) (cited in Johnsgard 1993).

Scott and Duncan (1967) noted crayfish in the diet of Black shags in inland Otago but only one freshwater crayfish was positively identified in the 119 regurgitated pellets taken from the Pencarrow colony. This and several sightings of Black shags diving on Lake Kohangatera were the only direct evidence that Black shags from the colony feed in surrounding freshwater systems. The Wainuiomata River east of the colony is a popular trout fishing area (Dr Chris Paulin pers. comm.), yet no trout otoliths were recovered from pellets, which suggests that if there is any feeding on the river it is infrequent.

Some items found in regurgitated pellets and stomach contents may not be primary prey of the Pencarrow colony Black shags but be secondarily derived from fish eaten by the birds. For instance, some of the small fish and invertebrates identified could have come from the stomach contents of the fish preyed upon by the shags. This phenomenon has been reported elsewhere (Lalas 1983, Barrett *et al* 1990, Casaux *et al* 1997), and Lalas (1983) noted that small items such as Chiton shells might have originated in fish guts as opposed to being direct prey of shags.

There was no significant difference in the number of prey items per pellet throughout the breeding season at Pencarrow colony, nor was the mean mass of the fish prey per pellet and dry weight of pellets significantly different. This suggests that the quantity of prey eaten did not vary significantly over the breeding season. However when comparing autumn, winter and spring some differences were noted in mean dry pellet

weights, with winter having the heaviest pellets. But there was no significant difference between the three seasons in the mean number of prey per pellet. The pellets weighed more during winter, but were composed of smaller fish; therefore the increase in weight could not be attributed to the taking of larger prey at the time. The most likely explanation is that non-food items, such as shell fragments, pebbles and other debris – in some cases secondarily derived from primary prey species (Lalas 1983, Barrett *et al* 1990, Casaux *et al* 1997) were responsible for the increase in weight.

The number of pellets produced per day was not investigated at Pencarrow colony but several studies on Black shags and other shags species have reported that at least one pellet is regurgitated per day. Zijlstra & Van Eerden (1995) concluded from trials on captive sub-adults Black shags that one pellet was produced per bird per day in winter (non-breeding season). Casaux *et al* (1997) reported a daily mean of 0.7 pellets per day and a mean mass of fish per pellet of 255g in Blue-eyed shags during the 1994 breeding season on the South Shetland Islands. In the following 1995 breeding season Casaux *et al* (1998) recorded Blue-eyed shag producing a mean of 0.6 pellets per day, and each pellet represented an estimated mean fish mass of 280.2 (± 185.1)g. The mean mass of fish per pellet at Pencarrow was 198.2 (± 9.16)g from pre-breeding season in February until the end of the breeding season in October.

There were significant differences in the mass and length of the eleven fish species most frequently encountered. This suggests that Black shags will take a wide range of prey. However, Winkler (1983) suggested that Black shags preferred fish approximately 130mm in length (Johnsgard 1983). The overall mean fish length at Pencarrow colony 1999 was 219.5 (± 3.9)mm, with a range from 105.8 (± 11.1)mm to 274.7 (± 6.1)mm and have a slightly larger range than given by Lalas (1983) who recorded mean lengths ranging from 110mm to 230mm for Black shags on the Otago coastline and 90mm to 180mm on Chatham Island. Eels, the main prey eaten by Black shags on the Chatham Islands had a mean length of 320mm (Lalas 1983). The overall mean fish mass at Pencarrow colony 1999 was 198.2 (± 9.2)mm, with a range from 14.8 (± 2.9)g to 356.0g. Van Dobben (1952) noted a range of prey mass from 6g to 500g, and Whitfield and Blaber (1979) recorded a range from 1 to 214g (cited in Johnsgard 1993). The ranges of length and mass of Pencarrow fish prey do not,

therefore, appear to be significantly different to that of other New Zealand and overseas studies on Black shag diet.

The length and mass of fish prey within species varied significantly over the three seasons with the smallest prey caught in winter and the largest in autumn. This may reflect a change in the size of prey that adults feed to chicks. As there were no chicks hatched at the colony until late autumn all food represented in pellets up to this time was adult diet, length 242.7 (± 7.3)mm, mass 241.0 (± 23.3)g. The difference in fish diet size between the autumn and winter was 52.3mm and 97.1g (Table: 5.15). By September (first month of spring) there was only one nest of chicks left at the colony and the length and mass of fish prey had increased to 235.6 (± 5.1)mm, mass 228.6 (± 14.0)g. The difference in fish diet size between the winter and spring was 45.2mm and 84.7g (Table: 5.15). However adults were still observed feeding fledged young in spring, and pellets that were recovered probably represented both adult and fledged young diet.

Otoliths recovered from the stomachs of the dead chicks in the present study at Pencarrow indicated that there was no significant difference in prey size or fish species between chick and the adults' diets. However, the stomach contents did not provide a large sample set and there were insufficient data to draw any strong conclusions. Lalas (1983) concluded that the range of fish prey size (i.e. yellow-eyed mullet and eels) was similar in adult and chick diet, and a decrease in the size of fish prey was not a 'necessary' part of chick diet. Casaux *et al* (1998) noted that most food brought back to nests was for chicks, and the pellets appeared to reflect both adult and chick diet. Casaux *et al* (1997) noted some differences in the diet of chicks and adults. They offered two possible reasons that might partially explain these differences. The first is that each pellet contained the remains of four to seven meals, and the second is the erosion and loss of otoliths as they pass through the gastrointestinal tract. Green and Williams (1997) suggested that differences in the diet of breeding and non-breeding Heard Island shags (*Phalacrocorax mivalis*) reflected the need of parents to feed chicks. This could help explain the decrease in prey size observed at Pencarrow during the chick rearing stage. As time was a constraint for

Black shag adults with chicks in the nest, the parents possibly cannot afford to be selective (i.e. take a wider size range of prey) when foraging for food.

5.5 Conclusion

Black shags at Pencarrow colony are primarily marine foragers, and only one instance of freshwater foraging (freshwater crayfish) was identified in the 1999 breeding season. The data suggests that Black shags diet is mainly fish and the otoliths of one species, wrasse was found more often than any other fish species. This high frequency of occurrence, 50% of diet, may be due to the high abundance of the species in the foraging areas of Pencarrow Black shag. The Pencarrow Black shags also appear to show the characteristics of pelagic feeders and have a single predominant prey species in their diet, a phenomenon documented in other Black shag communities that have been studied in New Zealand and overseas.

The size of fish prey decreases over winter and this may be associated with the time constraint of having chicks in the nest and adults not being able to be more selective in choosing their prey. The number of prey items per pellet showed that there were no significant increases in the number of prey caught while there were chicks in the nest, this may also be related to the time constraint of rearing young. Although there was a significant difference in pellet dry weight in winter compared to the other seasons. The range of fish length and mass was not dissimilar to other research in New Zealand or overseas, suggesting that variety in prey size is probably common for the entire species.

Using regurgitated pellets to identify and analyse shag diet is a simple and non-intrusive method that provides a large sample set of data, however it does not guarantee a complete composition of diet as otoliths and other identifiable materials can be dissolved and eroded in the digestive tract. Alternative methods to build on the information gathered from pellets, is to examine stomach contents either from dead shags or by adopting the 'shaking' method (not used in the present study) on birds returning to their nests from foraging trips used by Cooper (1985), Coria *et al* (1995) and (Casaux *et al* 1998). According to Coria *et al* (1995), the 'shaking' method was as effective as stomach flushing (cited in Casaux *et al* 1998).

Otoliths stored in 70% ethanol during the present study were subject to corrosion even though reports in a number of publications suggested that alcohol was an acceptable storage method. Keeping otoliths as dried samples, as suggested by Dr Chris Lalas was discovered to be a better method of storage.

Chapter 6

6.0 Daily Movements & Dispersal

6.1 Introduction

Movements of *Phalacrocorax carbo* in its range has been described as sedentary, dispersive, migratory, or nomadic (Johnsgard 1993). Definitions of these terms, given below, are taken from Allaby (1998) and Meagher (1991).

- “Sedentary” refers to birds that remain in one area.
- “Dispersive” refers to birds that move away from the breeding site to new habitats. Dispersal has been referred to as either “Natal dispersal” by fledged young from the birth site, or “Breeding dispersal” by adults from the breeding site. Rates of dispersal depend on interactions between the size and shape of the source area, the birds’ dispersal ability, and environmental factors such as rain.
- “Migratory” refers to individuals that move from one area to another, usually along well defined routes, particularly in response to seasonal changes in resources.
- “Nomadic” refers to individuals with no fixed habitat, moving from place to place according to food or habitat availability.

In New Zealand the post breeding dispersal of *P. c. novaehollandiae* has been discussed by Owen & Sell (1985) and Sims & Powlesland (1995). In a study of the “Birds of Waimea inlet” Owen & Sell (1985) indicated the variations in the Black shag population at the inlet during the year. There was no distinction made between adults and fledged young in relation to movements, and the pattern shown suggests that Black shags have a dispersal movement between the inlet and the breeding areas. Sim & Powlesland (1995) examined the movement of fledged young in the Wairarapa region away from their birth sites and a dispersive pattern was also noted.

Twelve species of shag breed on the New Zealand plateau (Table: 6.1). According to Johnsgard (1993) none of these migrates, although the movements of some species suggest that they are sedentary or dispersive. Of the documented species *Phalacrocorax melanoleucos* is considered dispersive, and *P. sulcirostris* partially dispersive. *Phalacrocorax varius* adults are sedentary while the juveniles are

dispersive. *Leucocarbo carunculatus* are sedentary and *P. punctatus* dispersive with a maximum range of banded birds being 500km (Johnsgard 1993).

| Species & sub-species | Common name | Movement |
|--|---------------------------|---|
| <i>Phalacrocorax (carbo) novaehollandiae</i> | Black shag | * Sedentary and partially dispersive. |
| <i>Phalacrocorax sulcirostris</i> | Little Black shag | Intermediate degree of dispersal, may be a general movement towards coastal areas in winter |
| <i>Phalacrocorax melanoleucos</i> | Little Pied (Little shag) | Dispersive more than migratory with some island populations believed to be fairly sedentary |
| <i>Phalacrocorax varius</i> | Pied shag | Sedentary species with most movements limited to dispersal in juveniles |
| <i>Leucocarbo carunculatus</i> | King shag | No evidence of seasonal movements and only a few records of birds occurring outside of their general breeding grounds in the Malborough sounds. |
| <i>Leucocarbo (carunculatus) chalconotus</i> | Bronze shag | No movements of note have been reported. |
| <i>Leucocarbo (carunculatus) onslowi</i> | Chatham Island shag | No movements of significance have been reported. |
| <i>Leucocarbo (carunculatus) colensoi</i> | Auckland Island shag | No significant movements are likely to occur in this species. |
| <i>Leucocarbo punctatus</i> | Spotted shag | Dispersive more than migratory max range of banded birds 500km. |
| <i>Leucocarbo (carunculatus) ranfurlyi</i> | Bounty Island shag | No documented movements away from the Bounty Islands. |
| <i>Leucocarbo (punctatus) featherstoni</i> | Pitt Island shag | Probably no movement except within Chatham Is group. |
| <i>Leucocarbo campbelli</i> | Campbeil Island shag | Apparently sedentary. |

Table: 6.1. Movements of New Zealand shags.

Movement description taken from Johnsgard (1993).

* Movement description taken from Owen & Sell (1985), Powlesland & Reese (1999).

Of the five shag species in Australia four, including *P. carbo*, concentrate in and around freshwater, and occasionally estuarine habitats (Llewellyn 1983). Their nomadic movement within Australia, movements around permanent bodies of water, and food supplies, are all significantly affected by water levels (Hobbs 1956, 1961, Lamm 1965, Whyte 1981, Llewellyn 1983, Marchant & Higgins 1990). Llewellyn (1983) states that flooding inland triggers successful breeding which in turns precedes wide spread dispersal. Serventy & Marshall (1957) conclude that for western Australian birds in general 'the response to rainfall is a physiological drought adaptation'. It is suggested that the environmental conditions following rainfall are probably critical stimuli to reproduction (Llewellyn 1983), because flooded regions can provide excellent foraging conditions. For instance, on one occasion in the southwest district of Deniliquin, New South Wales, a flock of over 10,000 black shags gathered in one corner of Yanga Lake to gorge on schools of carp (*Cyprinus* spp.) which had been herded against the weir by the shags (Hobbs 1961). Hobbs (1956) also noted flocks of Black shags feeding on fish, trapped in isolated pools as floodwaters subsided.

Dispersal of Black shags away from Australia occurs most often after there has been exceptionally good breeding inland; for instance, in 1974 Lake Eyre filled to capacity and two years of successful breeding followed (Marchant & Higgins 1990). Fish stocks in the lake increased and as many as 40 000 shags and 40 000 pelicans were reported (Llewellyn 1983). By 1977 many birds were deserting the area as the lake dried up, and the movement away from the area continued though to 1978 (Llewellyn 1983). This resulted in dispersal movement away from Australia to New Zealand in 1976-77 (Sagar 1977, Powlesland & Reese 1995) and up into the Torres Strait in 1977-78 (Draffan *et al* 1983).

In the Northern Hemisphere *P. carbo* is one of many bird species that migrate away from northern breeding grounds to warmer southern areas for the winter. For instance *P.c. sinensis* breeds across central and eastern Asia, but winters south in the Arabian Sea, Sri Lanka, the Malay Peninsula (MacKinnon & Phillips 1993), Sumatra, the Sundas and Taiwan (Johnsgard 1993). Birds from the north Caspian Sea and the Baltic, however, migrate overland to the Mediterranean basin (Johnsgard 1993, Cramp *et al* 1980), and distances of up to 2,400km from the Baltic region have been recorded (Cramp *et al* 1980). In western Europe *P. carbo* tends to migrate south and southwest for the winter, where as individuals from east Europe head south and south-southeast (Cramp *et al* 1980).

The movements of *P. carbo* from the Balkans, the Black Sea and Turkey are considered dispersive, as are those from the British Isles where the birds also show small-scale movements across the English Channel into Europe (Cramp *et al* 1980). In Africa *P. c. lucidus* is considered to be partially sedentary with some individuals dispersing up to a few hundred kilometres (Johnsgard 1993).

On the North American continent and in Greenland migrations by *P. carbo* tend to be short and variable, with some breeders remaining all year around the Gulf of St. Lawrence, not far from breeding areas (Palmer *et al* 1978). Younger birds, however, are more likely to move further afield and in all directions from their natal colonies (Palmer *et al* 1978).

The dispersal movements of shags thus vary considerably, and there is no single pattern for *P. carbo*. The object of this chapter, therefore, is to investigate the daily movements and activities of adults and fledged young away from the Pencarrow colony and to record activities particularly associated with the dispersal of fledged young. Also a census of the population was taken regularly throughout the day.

6.2 Methods

6.2.1 Eastbourne transect - Adults

An index of seasonal changes in the number of *P. carbo* in Wellington Harbour was obtained from counts along a road transect around the east coast of the Harbour. The transect extended from Seaview Wharf (Figure: 6.1) to Lake Kohangatera, and then to the Pencarrow Black shag colony. The transect was carried out to and from the colony between March and November 1999, and occasionally after that up to January 2000. The 19.6 km transect was travelled by bus to the start of Pencarrow Road (7.6km) and then on foot or by car to the colony (12km). The transect was divided into nine sections, each 2km in length except for one section that was 1.7km long (Table: 6.2). The final section covered the 2km portion from the coast, past Lake Kohangatera to the colony. The time taken to complete the transect was about three hours. All shags seen were identified by binoculars or telescope (27x magnification) and their locations noted. For Black shags, their activity and any bands were recorded.

Between October and December 1999, three other transects were carried out weekly to investigate the daily dispersal pattern of fledged young from the colony, although adults were also noted, as well as their activity. Each transect was travelled at the same time of day by car to provide consistent measures of movement.

Eastbourne Transect

| Transect Point Number | Discription |
|-----------------------|---|
| Marine | |
| 1 | Point Howard (Seaview wharf) to 1 st half York Bay |
| 2 | 2 nd half York bay to 1 st quarter Days Bay |
| 3 | 2 nd quarter Days Bay to Point Arthur (Bus stop) |
| 4 | Point Arthur (Bus stop) to sewer manhole [24] |
| 5 | Sewer manhole [24] to sewer manhole [14] |
| 6 | Sewer manhole [14] to sewer manhole [9] |
| 7 | Sewer manhole [9] to entrance of Lake Kohangapiripiri |
| 8 | Entrance of Lake Kohangapiripiri to entrance of Lake Kohangatera |
| Freshwater | |
| 9 | Lake enterance of Lake Kohangatera to colony |

Each section is 2km long, except [8] that is 1.7km.

Wellington transect

| Transect Point Number | Discription |
|-----------------------|---|
| 1 | Point Jerningham to Snapper Point |
| 2 | Snapper Point to Kupe canoe club, Evans Bay |
| 3 | Kupe canoe club to Kilbirnie/Airport roundabout |
| 4 | Kilbirnie/airport roundabout to ½ between Evans Bay wharfs & Shelly Bay |
| 5 | ½ between Evans Bay wharfs & Shelly Bay to far end point of Shelly Bay |
| 6 | Far end point of Shelly Bay to ½ Mahanga Bay |
| 7 | ½ Mahanga Bay to end Karaka Bay |
| 8 | End Karaka Bay to 2/3 Worser Bay |
| 9 | Last 1/3 Worser Bay to Breaker Bay (including Dorset Point) |
| 10 | Breaker Bay to Palmer Head |
| 11 | Palmer Head (Taraki Bay) to Lyall Bay (Breakwater) |
| 12 | Lyall Bay (Breakwater) to 2/3 Lyall Bay |
| 13 | Last 1/3 Lyall Bay to Te Raekaihua |
| 14 | Te Raekaihua to ½ Island Bay |
| 15 | Last ½ Island Bay to Owhiro Bay (End of Transect) |

Each section is 2km long, except [15] that is 2.2km

Table: 6.2. Descriptions of Eastbourne and Wellington transect points.

6.2.2 Wellington City transect

This transect started at Point Jerningham at 09.00hrs and ended at the Sirens rocks at 11.00hrs by following the coast around the west side of the Harbour (Figure: 6.1).

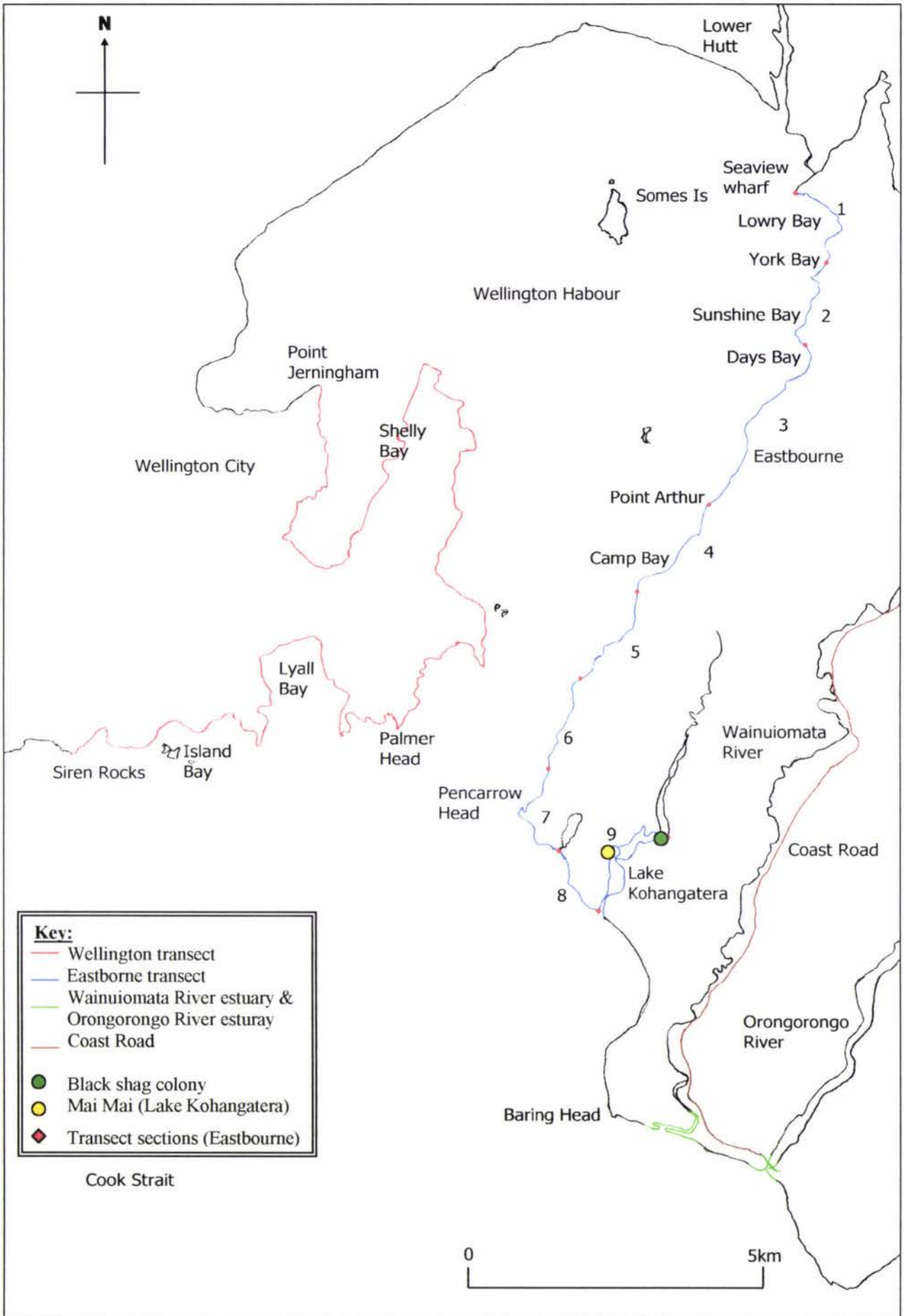


Figure: 6.1. Map of Wellington harbour and southern coastline, showing Wellington, Eastbourne, Wainuiomata River Estuary and Orongorongo River Estuary transects, highlighting transect points on Eastbourne transect.

The transect was 30.2km long and was divided into 15 sections, each 2km in length, except for one section that was 2.2km long (Table: 6.2)

6.2.3 Wainuiomata River Estuary & Orongorongo River Estuary transect

The Wainuiomata and Orongorongo river estuaries were accessed via the Coast road, Wainuiomata (Figure: 6.1). The estuaries were the main points of interest on the transect, however observations of shag activity were made for 14kms along the Wainuiomata river. The trip out to the river estuaries started at 11.45hrs at the summit of Wainuiomata Road, and covered 23kms. The total time for the round trip was approximately 1 hour.

6.2.4 Eastbourne transect – Fledged young

This transect was the same one used to monitor daily movements of adult shags throughout the season and was handled in the same way for both adults and fledged young. Monitoring began at Seaview Wharf at 13.00hrs and ended at the north end of Lake Kohangatera at 15.00hrs. This transect was carried out on the way in to the colony and again on the return journey from the colony.

6.3 Results

6.3.1 Daily movements of adults

The earliest pre-dawn departure of adults from the colony was 72 minutes before official sunrise, and the mean time 41 minutes before sunrise ($n=12$) (Appendix: 4). Exact numbers and the identity of individual birds leaving before dawn could not be determined in the poor light. After sunrise shags continued to leave and return to the colony throughout the day, but numbers in the colony were significantly higher in afternoons than in mornings (Figure: 6.2) ($p < 0.0001$) and overall were highest in April (55), May (55), June (56) and July (59). Because not all roost sites and nests were visible these were minimum counts. The highest counts were always recorded at sunset when most birds had returned to roost for the night. On 19 March 1999, there were no shags in the colony, but by late March shags were permanently present during

the day. On 28 September 1999, at the end of breeding, there were again no adults present in the colony during the day although four fledged young were present.

Data from the Eastbourne transect were compiled into two groups to compare the number of adults present at marine and freshwater areas in 2km sections (Table: 6.3). Figure: 6.3 shows that the percentage of adults seen along the coast was significantly higher ($p < 0.0012$) than Lake Kohangatera in every month. There was no difference between months in the counts ($p < 0.0979$) and the R^2 value is a good fit with 85% of the total variation being accounted for in the model. Nor was there any significant difference ($p < 0.3868$) in the comparisons between seasons (autumn: February/March – May; winter: June – August; and spring: September - November). The R^2 value is a good fit with 80% of the total variation being accounted for in the model.

| | Feb/Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Total | % of Total | Mean (SE) |
|--------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-------|------------|------------|
| Marine | 6 | 76 | 28 | 39 | 54 | 75 | 21 | 87 | 58 | 444 | 79 | 49.3 (9.2) |
| Fresh | 5 | 34 | 7 | 5 | 23 | 20 | 1 | 10 | 13 | 118 | 21 | 13.1 (3.6) |
| Totals | 11 | 110 | 35 | 44 | 77 | 95 | 22 | 97 | 71 | 562 | 100 | 31.2 (6.5) |

Table: 6.3. Counts of Black shags on the Eastbourne transect, 1999.

Transect points 1 – 8 are marine (Wellington Harbour coastline).

Transect point 9 is freshwater (Lake Kohangatera).

The average number of Black Shag adults and fledged young seen after the end of the breeding season on the Wellington and Eastbourne transects is shown in table: 6.4 below.

| Location (Transect) | October | November | Distance (km) |
|---------------------|---------|----------|---------------|
| Wellington | 2.9 | 1.9 | Over 30.2 km |
| Eastbourne | 15.3 | 7.3 | Over 19.6 km |

Table: 6.4. Average number of Adult and Fledged young every two kilometres on the 'Wellington City' and 'Eastbourne' transects, October & November, 1999.

* Wainuiomata River estuary and Orongorongo River estuary not included.

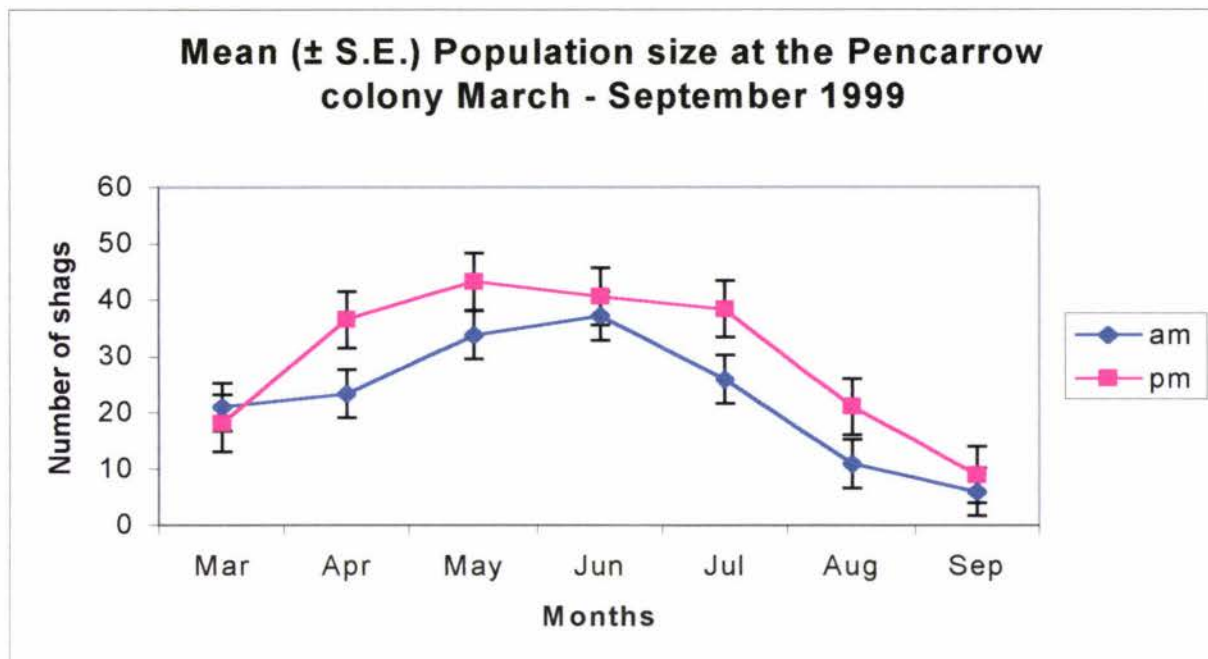


Figure: 6.2. Mean (\pm S.E.) morning and afternoon population size from March – September, Pencarrow 1999.

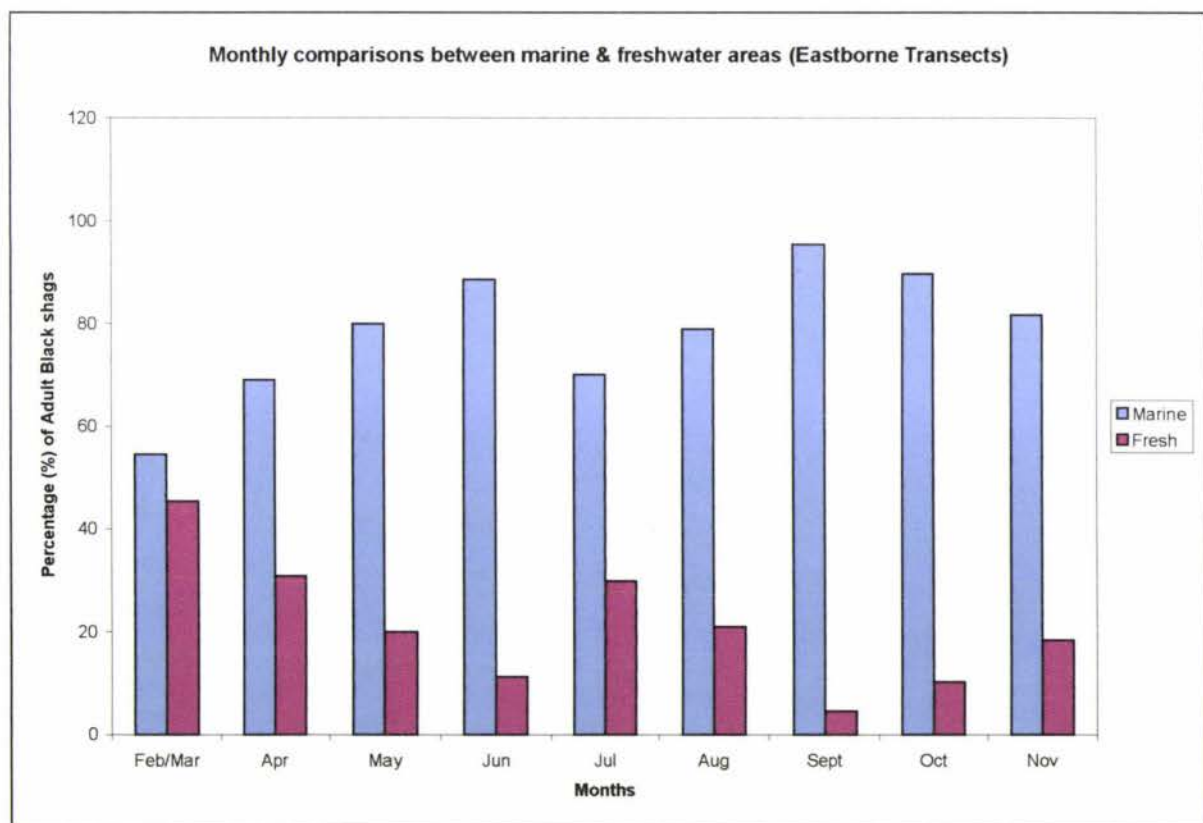


Figure: 6.3 Percentage of adult Black shags at daytime freshwater and marine roosts on Eastbourne transect from February to November 1999.

6.3.2 Activities

Activities of Black shags were categorized as flying, swimming, diving and stationary (including standing, preening and drying wings). In every month except May and July most shags were stationary, with an overall mean of 34.7 (\pm 8.5) (Table: 6.5). Flight was the next most frequent activity with a mean of 13.1 (\pm 5.1), and was the most common activity during May and July (Figure: 6.4). Shags were most stationary in September (95.2%), and least in July (33.3%). Little diving was seen, with an overall mean of 2.0 (\pm 0.4), and was not recorded at all in six of the ten months. Swimming was not seen March, June and September and had an overall mean of 5.0 (\pm 1.4).

| | <u>Feb</u> | <u>Mar</u> | <u>Apr</u> | <u>May</u> | <u>Jun</u> | <u>Jul</u> | <u>Aug</u> | <u>Sep</u> | <u>Oct</u> | <u>Nov</u> | <u>Total (n)</u> | <u>Mean (SE)</u> |
|-----------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------------|------------------|
| Flying (%) | 31.3 | 20 | 48.7 | 51.2 | 27.7 | 36.4 | 14.9 | 4.8 | 4.5 | 8.2 | 131 | 13.1 (5.1) |
| Stationary (%) | 37.5 | 80.0 | 49.6 | 43.9 | 72.3 | 33.3 | 72.3 | 95.2 | 80.9 | 88.5 | 137 | 34.7 (8.5) |
| Swimming (%) | 31.3 | 0.0 | 0.9 | 4.9 | 0.0 | 23.3 | 10.9 | 0.0 | 11.2 | 3.3 | 38 | 5.0 (1.4) |
| Diving (%) | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 6.7 | 2.0 | 0.0 | 3.4 | 0.0 | 8 | 2.0 (0.4) |
| Total (n) | 16 | 5 | 113 | 41 | 47 | 30 | 101 | 21 | 89 | 61 | 524 | - |

Table: 6.5. Activities (%) of adult Black shags with totals (n) and means (\pm SE) from February – November 1999.

The mean of adult activities observed on the Eastbourne transect from February to November 1999 is shown in Figure: 6.4.

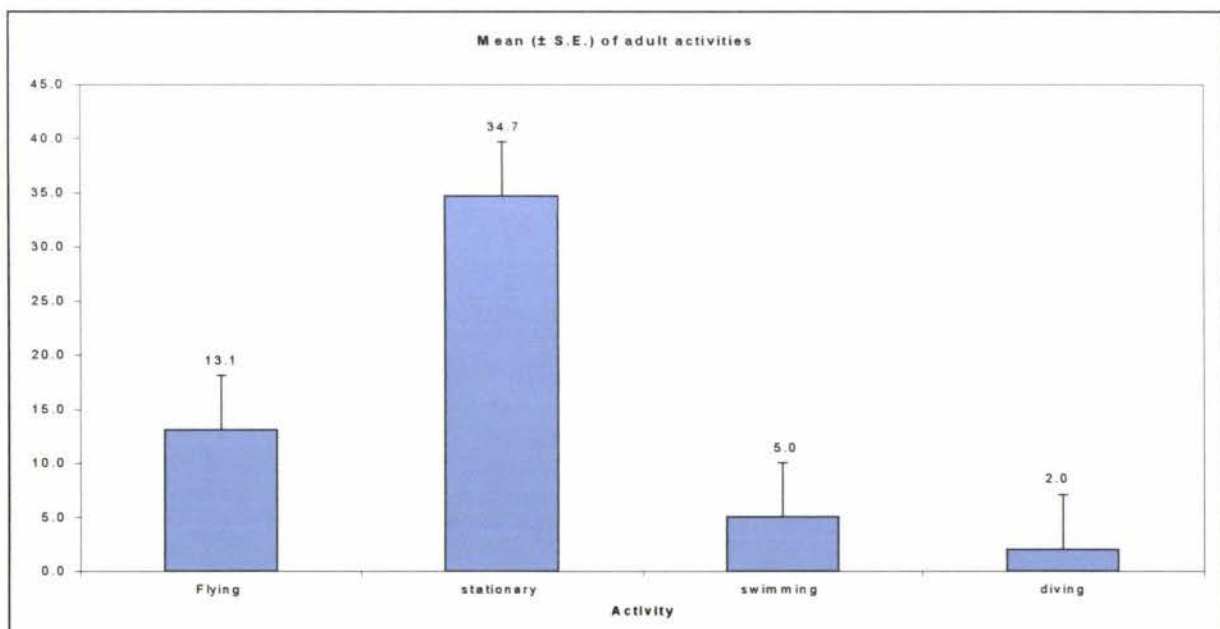


Figure: 6.4. Mean (\pm S.E.) adult Black shag activities on Eastbourne transect from February to November, 1999.

6.3.3 Interaction with other shag species

Four other shags species were associated with the Black shags: the Pied shag (*Phalacrocorax varius*), the Little black shag (*Phalacrocorax sulcirostris*), the Little shag (*Phalacrocorax melanoleucos*) and the Spotted shag (*Leucocarbo punctatus*). None of these species was seen at the Pencarrow colony, but Pied and Little shags were occasionally present at Lake Kohangatera.

Little black shags and Little shags were frequently seen in the company of Black shags throughout the transect, roosting, swimming and diving in close proximity to each other. The largest numbers of Little black shags and Little shags were seen on rocks out at sea in Lowry Bay, mean (9.3: \pm 1.9) and along Pencarrow Road at southern end of Camp Bay on beach rocks (mean 4.3: \pm 0.6) (Table: 6.6). Numbers of Little black shags and Little shags dropped after early September.

| Transect point | | Apr | May | Jun | Jul | Aug | Sep | Total |
|----------------|--------|-------|-------|-------|-------|-------|-------|-------|
| 1 | Mean | 30.0 | 15.6 | 10.2 | 7.0 | 8.4 | 4.7 | 9.3 |
| | (S.E.) | - | (8.1) | (7.5) | (2.0) | (3.6) | (2.2) | (1.9) |
| 2 | Mean | - | 1.2 | 1.0 | 1.4 | 1.8 | 1.6 | 1.4 |
| | (S.E.) | - | (0.2) | (0.0) | (0.4) | (0.3) | (0.2) | (0.1) |
| 3 | Mean | - | - | - | 1.3 | 1.3 | 3.3 | 2.0 |
| | (S.E.) | - | - | - | (0.3) | (0.3) | (1.9) | (0.7) |
| 4 | Mean | 3.6 | 4.0 | 5.8 | 4.6 | 5.0 | 2.4 | 4.3 |
| | (S.E.) | (0.7) | (1.1) | (2.4) | (1.2) | (1.6) | (0.8) | (0.6) |
| 5 | Mean | 1.1 | 2.0 | 1.3 | 1.9 | 2.5 | 2.0 | 1.8 |
| | (S.E.) | (0.1) | (1.0) | (0.3) | (0.5) | (0.6) | - | (0.3) |
| 6 | Mean | 1.2 | 1.0 | 1.0 | 1.6 | 1.5 | 2.0 | 1.3 |
| | (S.E.) | (0.2) | (0.0) | (0.0) | (0.6) | (0.2) | - | (0.1) |
| 7 | Mean | 1.6 | 1.0 | 3.2 | 2.4 | 2.3 | 2.0 | 2.3 |
| | (S.E.) | (0.6) | (0.0) | (1.7) | (0.8) | (1.3) | - | (0.5) |
| 8 | Mean | 1.3 | 4.0 | 1.0 | 2.5 | 4.4 | - | 2.7 |
| | (S.E.) | (0.3) | - | (0.0) | (0.7) | (2.2) | - | (0.8) |
| 9 | Mean | 1.0 | 1.0 | - | 4.0 | 1.5 | 2.0 | 1.6 |
| | (S.E.) | - | (0.0) | (0.0) | - | (0.5) | - | (0.4) |
| Total | Mean | 2.8 | 4.4 | 3.4 | 3.3 | 3.5 | 2.7 | 3.4 |
| | (S.E.) | (0.9) | (1.4) | (1.1) | (0.5) | (0.7) | (0.6) | (0.3) |

Table: 6.6. Counts of Little black shags and Little shags on the 'Eastbourne' transect, April – September 1999.

Spotted shags were first sighted on 19 June 1999, when three were seen roosting on rocks at southern end of Camp Bay, but they were seen rarely and were often in the company of other shags, particularly Little black shags and Little shags.

Pied shags were seen on five occasions. Twice single adults were seen roosting on rocks in York Bay, and a juvenile roosted twice on the Mai Mai, on 8 October and 12 November. On both occasions other shag species were present, including Black shag adults and fledged young. Another single adult Pied shag was seen with one adult Black shag and two Little shags at Sunshine Bay roosting on rocks.

6.3.4 Fledged Young - Daily movements

Young fledged Black shags were first seen outside the colony on 16 July 1999 when five birds were present at the Mai Mai (Figure: 6.1), 1km from the colony, and another was on Shag Rock on the coast 2.7km from the colony. In August, September and October the numbers of fledged young recorded away from the colony were 20, 26 and 31 respectively before falling to 13 in November. There was a clear pattern of progressive movement by the fledged young away from the colony (Figure: 6.5). All fledged young were seen first on the Mai Mai at a mean age of 63.3 (± 7) days before spreading out to the coast. An exception to this was a single bird that fledged from a late nest (September) and was seen on the Mai Mai at 45 (± 7) days of age. The Mai Mai had the highest number of fledged young sightings on the 'Eastbourne' transect - July (83.3%), August (90%), September (65.4%), October (48.4%) and November (41.7%) (Table: 6.7)

| Location | Jul | Aug | Sep | Oct | Nov | Total |
|----------------------------------|------|-----|------|------|------|-------|
| Mai Mai (n) | 5 | 18 | 17 | 15 | 5 | 60 |
| % at Mai Mai | 83.3 | 90 | 65.4 | 48.4 | 41.7 | 66.7 |
| Total no. of observations | 6 | 20 | 26 | 31 | 12 | 95 |

Table: 6.7. Sightings of fledged Black shags at the Mai Mai on the 'Eastbourne' transect, July – November 1999.

Sightings each month showed a gradual movement outward from the colony by the fledged young spreading along the coast and into Wellington harbour (Figure: 6.5).

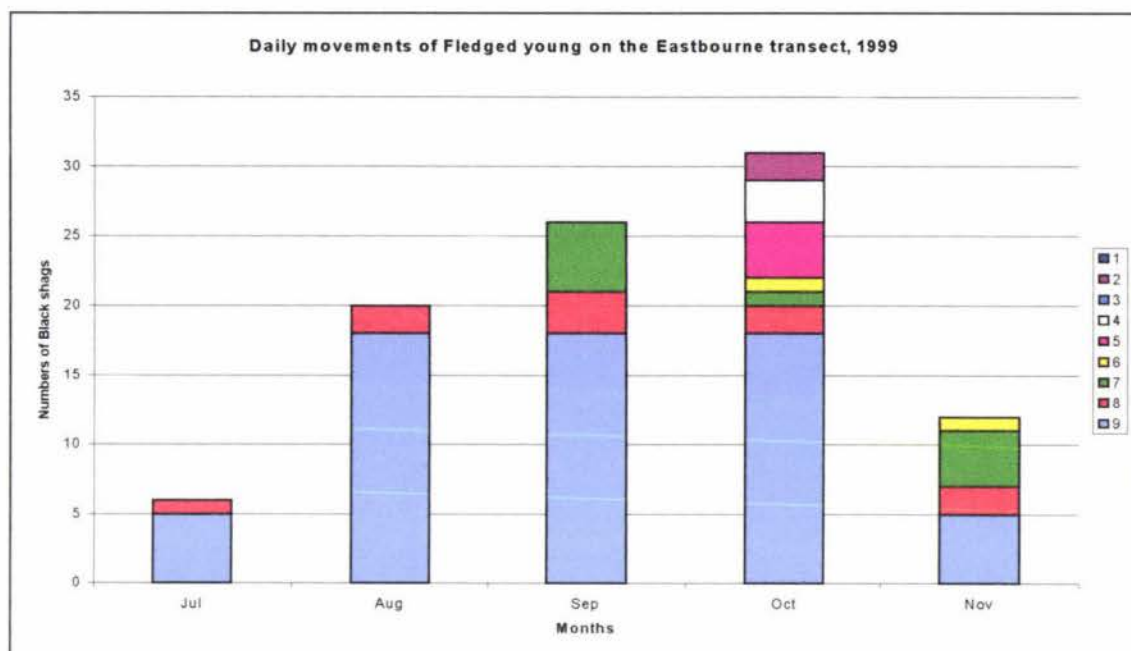


Figure: 6.5. Daily movements of Black shag fledged young along the Eastbourne transect from July to November 1999. Colours numbered 1 - 9 identify 2km transect sections along Eastbourne transect (Table: 6.2 and Figure: 6.1).

At Sunshine Bay (Figure: 6.1), 15.7km from the colony, two fledged young were observed in October standing on a rock with an adult. One of the fledged young 134 (± 7) days (c. four $\frac{1}{2}$ months) old was from an early nest and the other 55 (± 7) days old from a late nest. By October fledged young were seen on the west side of Wellington harbour at Lyall Bay, Island Bay, Shelly Bay and Palmer Head (Figure: 6.1). A single sighting of a fledged bird in the company of adult Black shags was made at both Wainuiomata and Orongorongo River estuaries (Figure: 6.1). This bird was 141 (± 7) days (c. four months and three weeks) old.

6.3.5 Flight path from the colony to Lake Kohangatera and the coast

Fledged young followed the same routes to the coast as adult birds (Figure: 6.6). After leaving the colony they flew west over the ridge and down the east side of Lake Kohangatera. They flew low and kept close to the hillside until they reached the large rock at the northern end of the Lake where they either landed, or continued on over the water to land at the Mai Mai. From there they flew down the west side of the Lake, still keeping close to the hillsides, and at the coast turned west along the shore

until they reached Shag Rock c. 1.7km from the Lake Rock and the Mai Mai. Fledged young flew up and down the coast keeping close to the land, usually flying less than 10m above the sea. Generally they followed the same route when returning to the Mai Mai and Lake Rock, but if flying directly to the colony they flew all the way up the east side of the Lake.

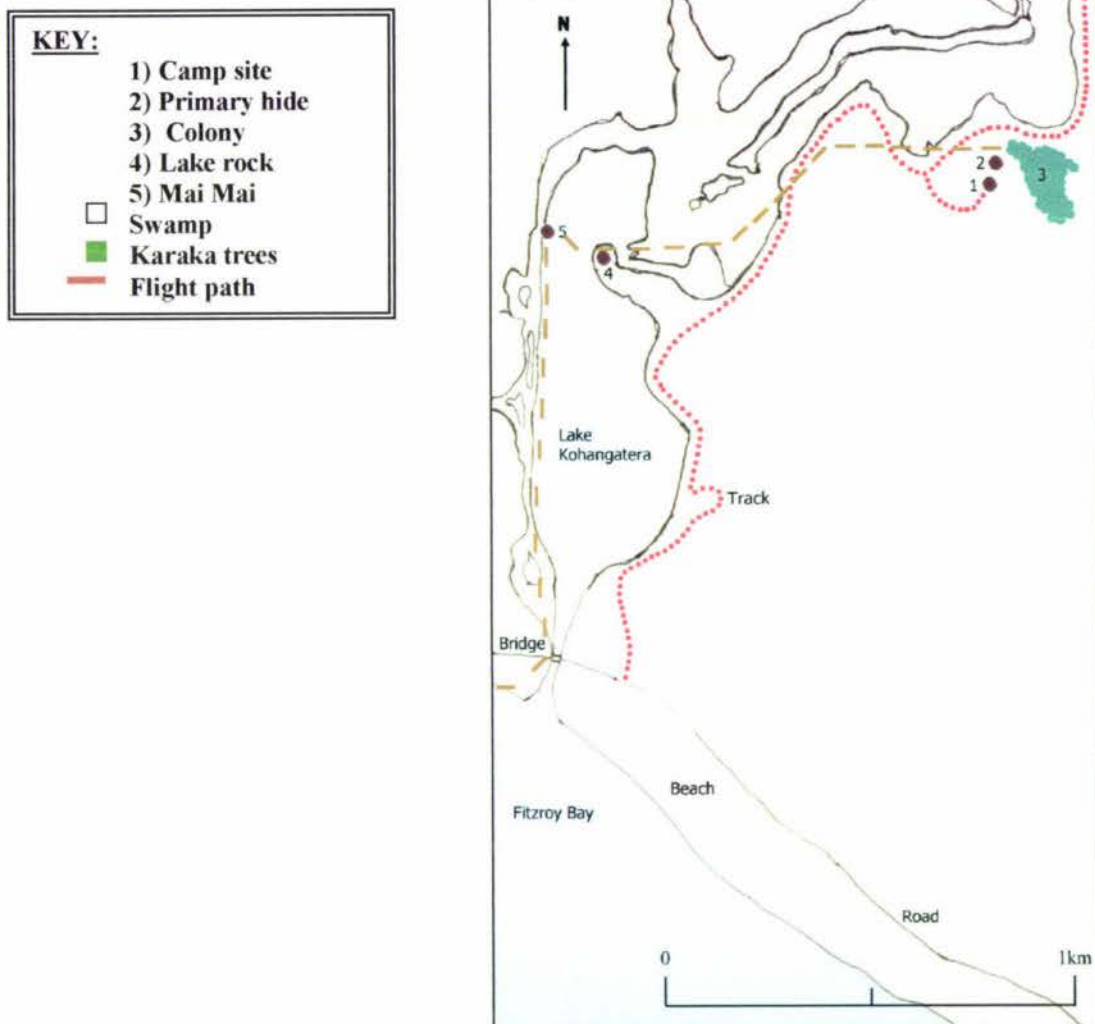


Figure: 6.6. Lake Kohangatera and Black shag colony, showing outgoing flightpath and most often the return flight path.

6.3.6 Activities

As for the adults, the activities of newly fledged Black shags were categorized as flying, swimming, diving and stationary. From July – October stationary activities were recorded more than 80% of the time, but fell to 67% in November. The overall mean occurrence for all transects was 36.5 (\pm 9.2) (Table: 6.8). Diving was recorded only in October (2.2%), mean occurrence 2.0 (\pm 0.6). In December 1999, January and

February 2000, all of the recorded activities were stationary, but over this three month period only five fledged young were seen and two of them were not on any of the transects. The mean of fledged young activities observed from July to February 2000 is shown in Figure: 6.7.

| | <u>Jul</u> | <u>Aug</u> | <u>Sep</u> | <u>Oct</u> | <u>Nov</u> | <u>Dec</u> | <u>Jan</u> | <u>Feb</u> | <u>Total (n)</u> | <u>Mean (SE)</u> |
|-----------------------|------------|-------------|-------------|-------------|-------------|------------|------------|------------|------------------|------------------|
| <u>Flying (%)</u> | 14.3 | 11.5 | 16.1 | 6.7 | 27.8 | 0.0 | 0.0 | 0.0 | <u>17</u> | 12.0 (4.7) |
| <u>Stationary (%)</u> | 85.7 | 84.6 | 80.7 | 88.9 | 66.7 | 100.0 | 100.0 | 100.0 | <u>110</u> | 36.5 (9.2) |
| <u>Swimming (%)</u> | 0.0 | 3.9 | 3.2 | 2.2 | 5.6 | 0.0 | 0.0 | 0.0 | <u>4</u> | 5.1 (1.5) |
| <u>Diving (%)</u> | 0.0 | 0.0 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | <u>1</u> | 2.0 (0.6) |
| <u>Total (n)</u> | <u>7.0</u> | <u>26.0</u> | <u>31.0</u> | <u>45.0</u> | <u>18.0</u> | <u>2.0</u> | <u>1.0</u> | <u>2.0</u> | <u>132</u> | - |

Table: 6.8. Activities (%) of newly fledged Black shags with totals (n) and means (\pm SE) from July 1999 – February 2000.

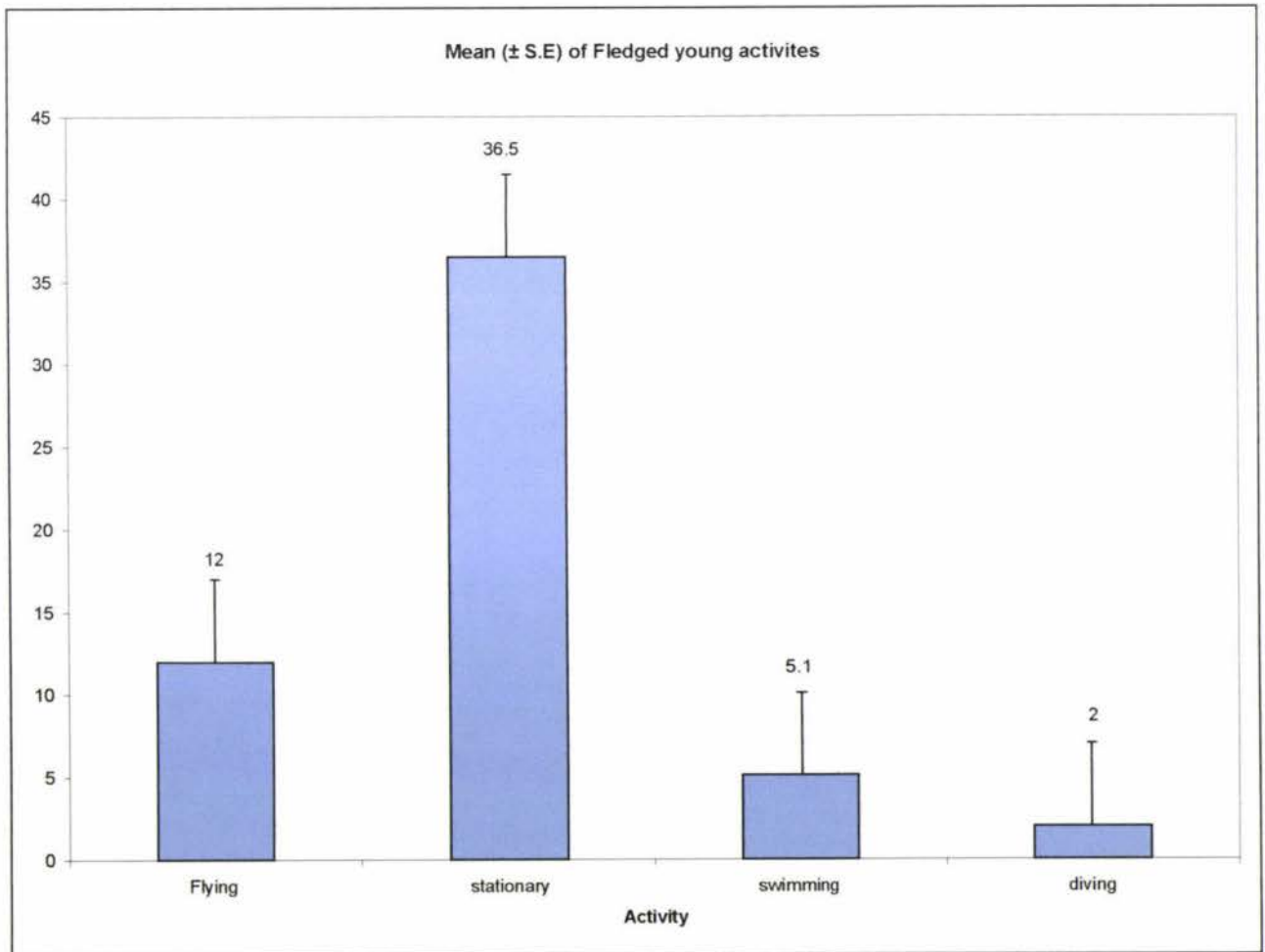


Figure: 6.7. Mean (\pm S.E) of newly fledged Black shag activities from July 1999 to February 2000.

6.3.7 Departure from the colony

Fledged young were first recorded roosting away from the colony over-night on 1 January 2000 (c. 7 months and 2 weeks old), when a bird roosted in a *Macrocarpa* tree (*Cupressus macrocarpa*) on the Hutt River near Melling (Figure: 6.8), 18km from the colony by direct flight, and 24km via the coast and Hutt River. Another fledged Black shag was recovered dead at Lake Wairarapa on 2 March 2000, c.42km from the colony, when the bird was $281 (\pm 7)$ days (c. 9 months and one week) old. Assuming this bird flew via the coast from Pencarrow colony to Lake Wairarapa, it travelled c. 70km. Another juvenile was seen at Lake Ferry on the Wairarapa Coastline on 14 February 2000 - 25km in direct line from the colony at $271 (\pm 7)$ days (c. nine months) old. Flying via the coast, from Pencarrow colony to Lake Ferry is c. 34km.

Several follow up trips were made to the colony in 2000. On 28 January there were three fledged young from 1999 present, but on 20 July there were none. This differs from 1999 when a maximum of three fledged young from the previous year were present at Pencarrow colony from March to November.

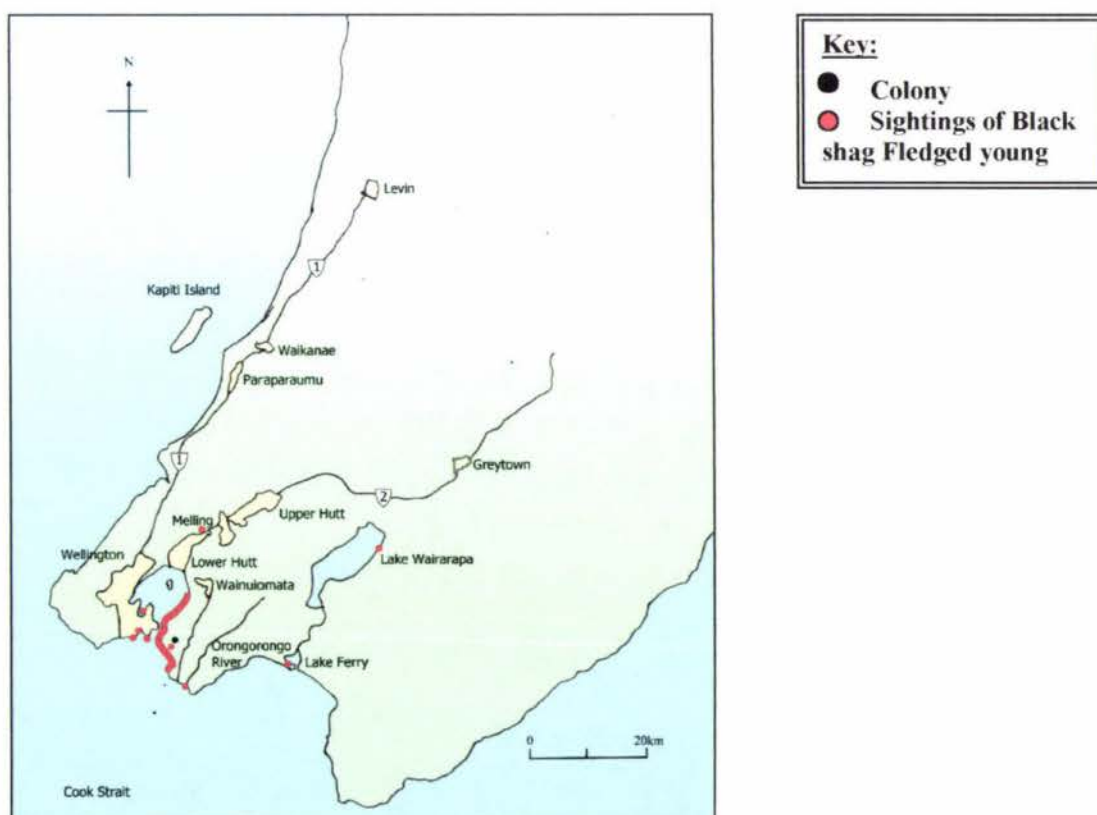


Figure: 6.8. Sightings of daily movements and dispersal of Black shag fledged young away from Pencarrow colony 1999.

6.4 Discussion

The average time of pre-dawn departure by adults from the colony was fairly similar to that described by Powlesland & Reese (1999), who recorded departures up to 30 minutes before sunrise, and noted that most birds left the colony before sunrise. In the present study, however, the earliest departure took place more than an hour before sunrise. In the 1999 season records of pre-dawn movement were made each month from March to October 1999, while noted them in June and July 1993 and May 1994. A possible explanation for the difference in earliest departure times from the colony may be because Powlesland & Reese (1999) were not staying overnight at the colony and may have missed earlier departures from the colony before they arrived to begin observations. Another possibility is that departure times were only recorded for three months over two years where as the present study recorded them over almost eight months. Unfortunately in the 1999 season frequent bad weather and low cloud in the early mornings made it difficult to hear or see activity on many occasions.

The numbers of adult shags in the colony build up from late February – early March to a peak in May and June, then declined between July and September. Powlesland & Reese (1999) tracked similar annual population trends between December 1993 and March 1996, but recorded peaks between August and October because they included fledged young. Powlesland and Reese (1999) recorded peak colony numbers of over one hundred (including fledged young) in August 1994 and 1995. In August 1999 with a minimum of 57 Black shags (44 adults and approximately 13 fledged young) were present. While adult numbers in the 1999 season were not the highest in August (reaching 59 in July), it is clear that the colony was significantly smaller than in the years described by Powlesland & Reese (1999).

Some Black shags roosted at Pencarrow colony all year, as noted by Powlesland & Reese (1999), who counted up to 40 – 60 birds over the summer months. The drop in the number of birds at the colony after breeding suggests partial dispersal by the adults. In previous years banded adults and juveniles have been seen at a several roosts around the Wellington region (Powlesland & Reese 1999). Chicks have been banded in the colony since 1990 (Powlesland & Reese 1999, present study), and the continued presence of these birds as juveniles and breeding adults suggests that the colony has a sedentary core of individuals. In the 1999 season 18 shags that had been

banded between 1992-96 were present at the colony. Two of these birds were seven years old being banded as chicks in 1992.

The transect counts clearly indicate that most shags frequent the coast rather than nearby Lake Kohangatera. This could reflect better food supplies or hunting conditions, along the coastline, and in Wellington Harbour, than at Lake Kohangatera. Prey communities in Marine and freshwater systems may respond differently to environmental changes and vary annually in the opportunities they present to foraging shags. More work on the distribution of the shags is needed, therefore, to test the consistency of the pattern observed in 1999. Dietary preferences of Pencarrow Black shag are discussed in Chapter (5).

Stationary activities were the ones most frequently seen in both adult and newly fledged Black shags, probably because of the high maintenance requirements, particularly preening and wing drying, associated with foraging. In shags the gaps between feather barbs are wider than in most other water birds (Burton 1985), allowing the plumage to become more easily waterlogged. With waterlogged feathers take-off from the water, and extended flight, becomes difficult (Nelson 1979, Burton 1985). Body insulation is also impaired when feathers are waterlogged (Burton 1985), and shags may sun bathe while they dry their feathers (Burton 1985, Johnsgard 1993). Predictably, flying was a frequent activity because parents constantly foraged for food for their young. Although the daily food requirements of young increased as they grew (Platteeuw *et al* 1995) there was no clear pattern of increased activity outside the colony as the season progressed. Rather, activity away from the colony was lowest during the months when most breeding pairs were incubating and rearing chicks. This may be explained by one parent remaining at the nest when the other is away foraging, until the chicks are approximately six weeks old. The steady increase in activity away from the colony in August coincided with a corresponding drop in adults at the colony during the day and may have been because many nests held chicks old enough to be left by both parents. Few data were available for September, but adult activity at the coast remained high during October and November. Monthly counts in Wellington Harbour from 1975-77 and repeated again from 1986-88 showed that the numbers of Black shags did not change significantly over the course of the

year apart from a small influx in numbers during the autumn months (Robertson 1992).

All fledged young dispersed from the colony to the Mai Mai – a highly preferred site - soon after fledging, but there appeared to be a difference in the age of first departure of early and late fledged young. Fledged young from early nests were 10 (\pm 7) days older than those from late nests when they first flew to the Mai Mai on Lake Kohangatera, 1km from the colony. A marked example of this was noted in October 1999 at Sunshine Bay 15.7km from the colony via the coastline. There, two fledged young respectively from early and late nests were seen together when there was a 79 (\pm 7) days age difference between the birds. Unfortunately there are too few observations of this kind to draw any conclusion, and more work is needed.

Once fledged, young of the year stepped up their daily movements away from the colony, but did not disperse permanently very quickly. The first sighting of fledged young roosting away from the colony over night was made at Melling, on the Hutt River, on 1 January 2000. This was a known roost site where, in previous years, fledged young have roosted over night and during the day. Only two other fledged birds were seen outside the immediate Wellington area.

Detailed information in the dispersal pattern of newly fledged Black shags in New Zealand is limited. Of 490 Black shag nestlings banded in the Wairarapa at Matthews and Boggy Pond Wildlife Reserves, and Te Hopai Lagoon between 1976-89 (Sim & Powlesland 1995), 41 (8.4%) were recovered dead by 1994. Of these recoveries 35 (85%) were within 100km of the banding site, and 9 (22%) were within 5km of the natal colonies. The furthest recovery was made 2000km to the west on Lord Howe Island, and suggests that at least some individuals may cross the Tasman Sea against prevailing westerly winds to Australian waters. The youngest bird recovered was 10 weeks old after drowning in a nest, and the oldest was shot at 4.5 years of age. Sim & Powlesland (1995) did not discuss the progression of distance from the colony in relation to the age of individuals recovered.

Direct observation of Black shags dispersing from the Pencarrow colony indicates that most fly close to the coast and along one side of Lake Kohangatera, as opposed to

flying over open water or hills to the ocean, which would have provided a faster route. This is consistent with the view that dispersal of *P. carbo* in Britain and North America is orientated along coastlines (Lewis 1937 cited in Llewellyn 1983), and that the birds generally avoid large expanses of open water (Coulson & Brazendale 1968 cited in Cramp *et al* 1980). Ford (1963) has also identified this pattern of movement in Pied shags dispersing from natal colonies in Western Australia (cited in Llewellyn 1983). These shags disperse randomly along coastlines and up estuaries, more than 300km from where they hatched (Llewellyn 1983).

During both two-year surveys of Black shag numbers in the Wellington Harbour Robertson (1992) noted that Little Black shag and Little shag numbers dropped significantly from August/September as they moved between inland breeding areas and the coast. Black shags are known to breed in trees near the Melling Bridge on the Hutt River (Gibb 2000), and both Black shags and Little Black shags have been seen moving up and down the Hutt River (Bull 1959, cited in Gibb 2000) with both Black and Little black shag numbers peaking in May.

The other two shag species that interact with Black shags both have colonies in the Wellington region. A small population of Pied shags nest at Makara on the south-west coast (Reese *et al* 1996) and the Spotted Shag is a breeding resident on Somes Island in the harbour, and has an small but increasing general population (Robertson 1992, Johnsgard 1993).

6.5 Conclusion

There were fewer Black shags at the Pencarrow colony – 1999 than in previous years 1993-98 (Powlesland & Reese 1999).

Higher counts of shags along the coast compared with inland Lake Kohangatera suggest the possibility of greater food availability in the sea. Because a significant proportion of the parent birds' time is assigned to foraging, and because coastal feeding grounds are significantly further from the colony than Lake Kohangatera, prey availability might influence decisions on which foraging sites are visited.

During October and November significantly more adults and fledged young utilise the east side of the Harbour as opposed to the west side, suggesting that the east side is the preferred feeding area after breeding. No observations of the west side of the Harbour (Wellington transect) were made before October, but the numbers of Black shags seen throughout the season on the east side (Eastbourne transect) were consistent with the total population at Pencarrow colony. This supports the view that the east side is the preferred feeding area for the colony throughout the year. The numbers of adult Black shags seen on the Eastbourne transect were low from May to July, when half of all brooding adults were engaged in pair bonding or sitting on nests.

Movements of Black shags in New Zealand appear to be both sedentary and partially dispersive. Results from the Wairarapa (Sim & Powlesland 1995) and the present study indicate that there is movement by fledged young away from natal areas to new locations. On 20 July 2000 there were no young from the previous 1999-breeding season present at Pencarrow colony, but during the 1999-breeding season several young from the 1998 breeding season were present throughout the year. Banding of chicks in previous years (Powlesland & Reese 1999) shows that at least some birds remain in, or return, to Pencarrow colony to breed. The oldest banded birds at Pencarrow in the 1999-breeding season were banded in 1992, making them seven years old.

Chapter 7

7.0 General conclusion

The breeding behaviour of Black shag adults at the Pencarrow colony appears similar to that described for Black shags elsewhere. In New Zealand the only difference with descriptions given by Powlesland and Reese (1999) is recognition of failed changeovers between parent birds during incubation. Two mammalian predators (rats and possums) of tree-nesting birds were present around the colony but only one (unconfirmed) instance of egg predation was noted. Breeding shags responded consistently to sudden noise around the colony, by becoming agitated, and often taking flight.

The population of adult Black shags at Pencarrow colony in 1999 was significantly less than in the previous six seasons. The reason for this reduction is unclear. The smaller number of birds may have influenced the higher mean number $2.1 (\pm 0.1)$ of surviving fledged young per nest in the present study, compared to the years 1993-98 (Powlesland & Reese 1999) when the mean survival rate was 1.75 ($n=153$) fledged young per nest. Lower adult numbers in 1999 could have reduced competition for prey in foraging areas, allowing parents to feed young in the nest more readily and increasing their chances of survival.

The high proportion of sightings of Black shags along the eastern coastline of Wellington Harbour suggests that this their main foraging area. Freshwater areas such as Lake Kohangatera, close to the Pencarrow colony, was relatively less used. Analysis of regurgitated pellets – a non-intrusive method of diet investigation – from the colony showed conclusively that the Pencarrow Black shags took few prey from freshwater. Instead the birds show the characteristics of pelagic feeders, with one prey species making up the bulk of their diet. This trait has also been documented in Black shags in the South Island of New Zealand by Lalas (1983) and in overseas research. Wrasse, the main prey constituting (50%) of Pencarrow Black shag diet, is a subtidal species, and is abundant in Wellington Harbour. The size of fish prey decreased in winter, which may be explained by the demands on adults to feed chicks in the nest, when time constraints could influence a less wide selection of prey.

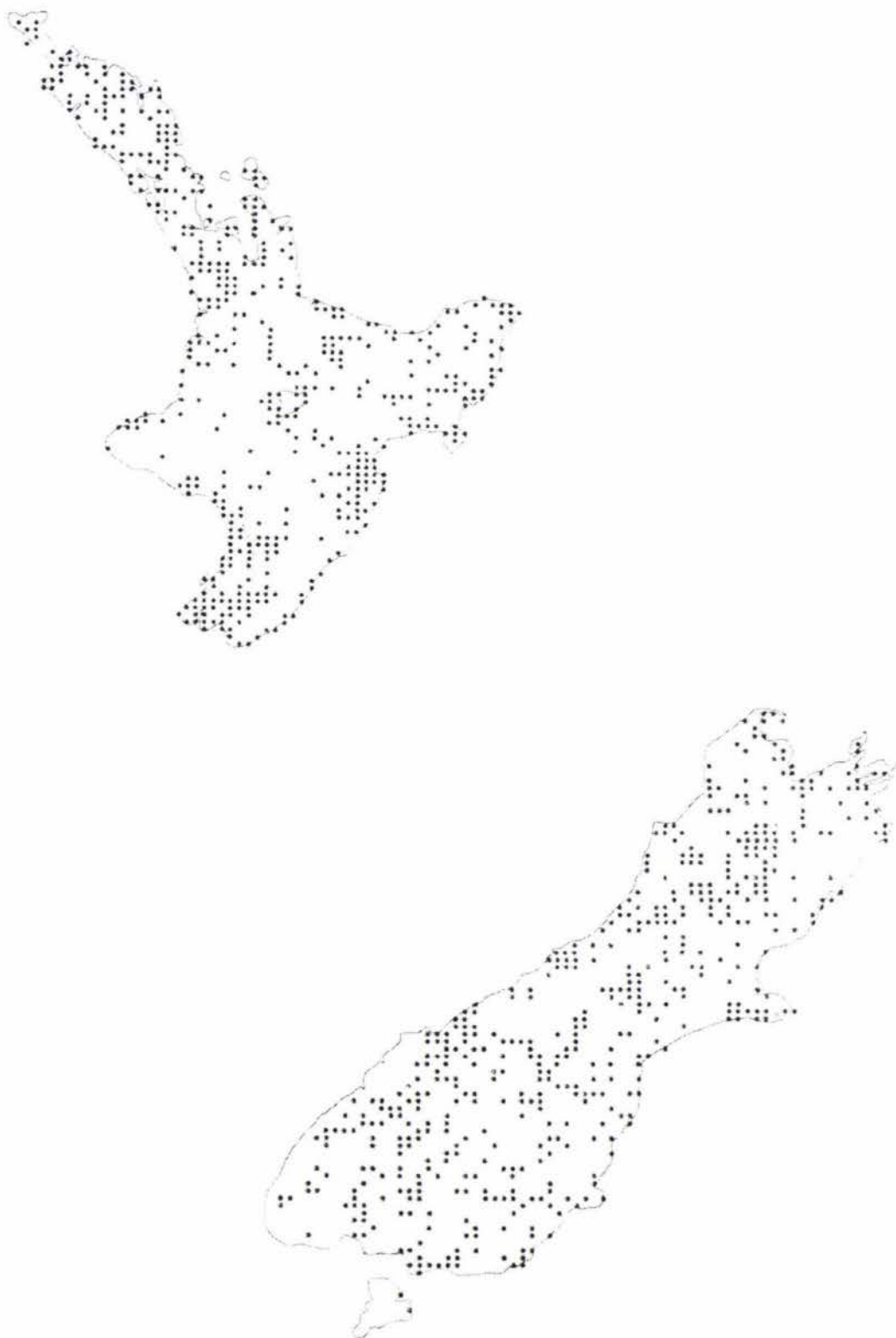
When comparing data from the present study with previous work from 1993-98, a continuous presence of banded birds was seen at Pencarrow colony. This suggests a sedentary core population of breeding and immature birds. Sightings of fledged young outside the colony during 2000, and observations of banded adults and juveniles at roosts around the Wellington region (Powlesland & Reese 1999) also suggest that there is a partially dispersive movement in Black shags from Pencarrow colony.

Appendix: 1. Taxonomy

Taxonomies of Family *Phalacrocoracidae* (Johnsgard, 1993).

| Van Tets (1976) | Siegel-Causey (1988) |
|-------------------------------|------------------------------|
| Leucocarbo | Subfamily. Phalacrocoracinae |
| Subgenus <i>Leucocarbo</i> | Genus <i>Microcarbo</i> |
| <i>L. (L.) bougainvillii</i> | <i>M. africanus</i> |
| <i>L. (L.) atriceps</i> | <i>M. coronatus</i> |
| <i>L. (L.) albiventer</i> | <i>M. pygmaeus</i> |
| <i>L. (L.) carunculatus</i> | <i>M. niger</i> |
| <i>L. (L.) chalconotus</i> | <i>M. melanoleucos</i> |
| <i>L. (L.) onslowi</i> | Genus <i>Compsohalieus</i> |
| <i>L. (L.) ranfurlyi</i> | <i>C. perspicillatus</i> |
| <i>L. (L.) colensoi</i> | <i>C. penicillatus</i> |
| <i>L. (L.) campbelli</i> | <i>C. harrisi</i> |
| <i>L. (L.) verrucosus</i> | <i>C. neglectus</i> |
| <i>L. (L.) fuscescens</i> | <i>C. fuscescens</i> |
| <i>L. (L.) capensis</i> | Genus <i>Hypoleucus</i> |
| <i>L. (L.) neglectus</i> | <i>H. olivaceus</i> |
| <i>L. (L.) nigrogularis</i> | <i>H. auritus</i> |
| <i>L. (L.) penicillatus</i> | <i>H. fuscicollis</i> |
| <i>L. (L.) harrisi</i> | <i>H. varius</i> |
| Subgenus <i>Strictocarbo</i> | <i>H. sulcirostris</i> |
| <i>L. (S.) punctatus</i> | Genus <i>Phalacrocorax</i> |
| <i>L. (S.) featherstoni</i> | <i>P. carbo</i> |
| <i>L. (S.) aristotelis</i> | <i>P. capillatus</i> |
| <i>L. (S.) urile</i> | Subfamily Leucocarboninae |
| <i>L. (S.) pelagicus</i> | Genus <i>Leucocarbo</i> |
| <i>L. (S.) gaimardi</i> | <i>L. nigrogularis</i> |
| <i>L. (S.) magellanicus</i> | <i>L. capensis</i> |
| <i>Phalacrocorax</i> | <i>L. bougainvillii</i> |
| Subgenus <i>Phalacrocorax</i> | Genus <i>Notocarbo</i> |
| <i>P. (P.) carbo</i> | <i>N. verrucosus</i> |
| <i>P. (P.) capillatus</i> | <i>N. atriceps</i> |
| Subgenus <i>Hypoleucus</i> | <i>N. bransfieldensis</i> |
| <i>P. (H.) varius</i> | <i>N. georgianus</i> |
| <i>P. (H.) auritus</i> | Genus <i>Nesocarbo</i> |
| <i>P. (H.) olivaceus</i> | <i>N. campbelli</i> |
| <i>P. (H.) fuscicollis</i> | Genus <i>Euleucocarbo</i> |
| <i>P. (H.) sulcirostris</i> | <i>E. carunculatus</i> |
| Subgenus <i>Microcarbo</i> | <i>E. chalconotus</i> |
| <i>P. (M.) melanoleucos</i> | <i>E. onslowi</i> |
| <i>P. (M.) niger</i> | <i>E. colensoi</i> |
| <i>P. (M.) pygmaeus</i> | <i>E. ranfurlyi</i> |
| <i>P. (M.) africanus</i> | Genus <i>Stictocarbo</i> |
| | <i>S. magellanicus</i> |
| | <i>S. pelagicus</i> |
| | <i>S. urile</i> |
| | <i>S. aristotelis</i> |
| | <i>S. gaimardi</i> |
| | <i>S. punctatus</i> |
| | <i>S. featherstoni</i> |

Appendix: 2. New Zealand Distribution



Recorded sighting of *P. carbo* from September 1969 to December 1976 (Bull *et al* 1979).

Appendix: 3. Weather

| Date | Wellington | | Air Temp | Rainfall | | * Wind | ** Sun |
|----------------|--------------------|----------------------|--------------|------------|------------------------|----------------------|--------------------|
| Year/ Month | Weather Station | Height of station | Mean Temp | Total Rain | Number of rain days | Mximum wind speed | Bright sunshine |
| | | m.s.l. | Celsius | mm | | m/s | hrs |
| March-90 | Wainui Coast Rd | 82 | 16.3 | 193 | 12 | 8.1 | 211.6 |
| April | Wainui Coast Rd | 82 | 13.3 | 99 | 15 | 8.3 | 132.2 |
| May | Wainui Coast Rd | 82 | 11.5 | 117 | 12 | 9 | 166.7 |
| June | Wainui Coast Rd | 82 | 9.2 | 296 | 21 | 9.5 | 79.6 |
| July | Wainui Coast Rd | 82 | 8.3 | 96 | 17 | 7.5 | 125.8 |
| August | Wainui Coast Rd | 82 | 9.2 | 216 | 22 | 7.5 | 125.8 |
| September | Wainui Coast Rd | 82 | 9.5 | 114 | 15 | 8.6 | 173.8 |
| October | Wainui Coast Rd | 82 | 12.4 | 115 | 11 | 8.9 | 187.5 |
| November | Wainui Coast Rd | 82 | 13.7 | 147 | 16 | 9.7 | 181.1 |
| March-91 | Wainui Coast Rd | 82 | 14.8 | 55 | 7 | 5.3 | 221.2 |
| April | Wainui Coast Rd | 82 | 12.4 | 278 | 17 | 9.3 | 126.1 |
| May | Wainui Coast Rd | 82 | 10.2 | 42 | 11 | 6.5 | 154.1 |
| June | Wainui Coast Rd | 82 | 7.9 | 261 | 22 | 9.9 | 93.2 |
| July | Wainui Coast Rd | 82 | 7.2 | 85 | 18 | 7.2 | 129.1 |
| August | Wainui Coast Rd | 82 | 9.8 | 136 | 15 | 8.5 | 138.3 |
| September | Wainui Coast Rd | 82 | 11.4 | 111 | 16 | 8 | 158.5 |
| October | Wainui Coast Rd | 82 | 11.3 | 94 | 13 | 10.3 | 208.6 |
| November | Wainui Coast Rd | 82 | 11.9 | 213 | 15 | 8.9 | 215.4 |
| March-92 | Wainui Coast Rd | 82 | 13.7 | 67 | 10 | 9.4 | 201.1 |
| April | Wainui Coast Rd | 82 | 10.4 | 117 | 12 | 8.4 | 135.9 |
| May | Wainui Coast Rd | 82 | 8.2 | 183 | 16 | 8 | 107.6 |
| June | Wainui Coast Rd | 82 | 8.4 | 72 | 16 | 8.4 | 104.9 |
| July | Wainui Coast Rd | 82 | 8.4 | 294 | 19 | 8 | 93.8 |
| August | Wainui Coast Rd | 82 | 7.8 | 189 | 18 | 8.7 | 128.2 |
| September | Wainui Coast Rd | 82 | 8.8 | 243 | 23 | 6.5 | 127.7 |
| October | Wainui Coast Rd | 82 | 10.4 | 482 | 17 | 8.6 | 140.4 |
| November | Wainui Coast Rd | 82 | 13.6 | 105 | 15 | 7.8 | 145.9 |
| March-93 | Wainui Coast Rd | 82 | 13.8 | 126 | 13 | 7.1 | 194.6 |
| April | Wainui Coast Rd | 82 | 11.8 | 141 | 16 | 7.7 | 136.4 |
| May | Wainui Coast Rd | 82 | 11 | 187 | 11 | 7.5 | 128.8 |
| June | Wainui Coast Rd | 82 | 10 | 179 | 20 | 8.6 | 101.5 |
| July | Wainui Coast Rd | 82 | No data | 42 | 11 | 7.3 | 92.7 |
| August | Wainui Coast Rd | 82 | No data | 55 | 13 | 6.1 | 187.4 |
| September | Wainui Coast Rd | 82 | No data | 274 | 18 | 8.1 | 144.1 |
| October | Wainui Coast Rd | 82 | 11.8 | 60 | 9 | 8.5 | 227 |
| November | Wainui Coast Rd | 82 | 11.8 | 142 | 16 | 7.6 | 186.3 |
| March-94 | Kelburn | 125 | 15.2 | 103 | 16 | 8 | 210.1 |
| April | Kelburn | 125 | 14.5 | 34 | 10 | 7.6 | 192.8 |
| May | Kelburn | 125 | 12.1 | 68 | 16 | 7.5 | 135.6 |
| June | Kelburn | 125 | 8.9 | 143 | 23 | 7.6 | 91.9 |
| July | Kelburn | 125 | 8.7 | 96 | 19 | 6.6 | 115.9 |
| August | Kelburn | 125 | 10.1 | 88 | 11 | 6.8 | 158.5 |
| September | Kelburn | 125 | 10.2 | 132 | 13 | 6.7 | 171.2 |
| October | Kelburn | 125 | 11.3 | 86 | 19 | 6.5 | 231.3 |

| | | | | | | | |
|-----------|---------|-----|------|-----|----|-----|-------|
| November | Kelburn | 125 | 13.1 | 173 | 13 | 8.8 | 188.6 |
| March-95 | Airport | 43 | 17 | 45 | 12 | 7 | 232.9 |
| April | Airport | 43 | 15.3 | 146 | 17 | 5.6 | 123.3 |
| May | Airport | 43 | 12.3 | 91 | 11 | 6.4 | 133.3 |
| June | Airport | 43 | 9.8 | 190 | 19 | 6.2 | 99.2 |
| July | Airport | 43 | 8.8 | 88 | 17 | 5.7 | 158.5 |
| August | Airport | 43 | 9.6 | 46 | 14 | 6.3 | 148.8 |
| September | Airport | 43 | 11.1 | 90 | 12 | 7.6 | 146.5 |
| October | Airport | 43 | 12.4 | 116 | 15 | 7.2 | 165.9 |
| November | Airport | 43 | 13.4 | 62 | 13 | 7.2 | 206.7 |
| March-96 | Airport | 43 | 15.9 | 93 | 12 | 6.7 | 196.7 |
| April | Airport | 43 | 15.4 | 62 | 19 | 6.2 | 132.8 |
| May | Airport | 43 | 12.2 | 82 | 11 | 6.2 | 158.9 |
| June | Airport | 43 | 9.8 | 43 | 16 | 6.2 | 105.3 |
| July | Airport | 43 | 9.2 | 193 | 22 | 6.3 | 87.7 |
| August | Airport | 43 | 9.3 | 84 | 16 | 6.3 | 156 |
| September | Airport | 43 | 13.1 | 80 | 14 | 6.8 | 168.3 |
| October | Airport | 43 | 13.4 | 89 | 10 | 7.8 | 193.1 |
| November | Airport | 43 | 13.7 | 72 | 14 | 6.9 | 219.8 |
| March-97 | Airport | 43 | 15.5 | 129 | 11 | 6.3 | 176.4 |
| April | Airport | 43 | 13.7 | 90 | 13 | 7.1 | 178.1 |
| May | Airport | 43 | 13.1 | 21 | 13 | 5.3 | 123.4 |
| June | Airport | 43 | 10.1 | 120 | 16 | 6.4 | 116.1 |
| July | Airport | 43 | 8.7 | 115 | 12 | 6.1 | 151.9 |
| August | Airport | 43 | 9.8 | 139 | 19 | 7.9 | 135.9 |
| September | Airport | 43 | 9.8 | 139 | 15 | 5.7 | 134.8 |
| October | Airport | 43 | 12.9 | 86 | 9 | 7.7 | 207.7 |
| November | Airport | 43 | 14.9 | 10 | 8 | 8.7 | 232.2 |
| March-98 | Airport | 43 | 18.5 | 23 | 7 | 6.9 | 211.5 |
| April | Airport | 43 | 15.3 | 34 | 11 | 5.8 | 173.1 |
| May | Airport | 43 | 12.9 | 93 | 9 | 6.7 | 122.5 |
| June | Airport | 43 | 10.3 | 158 | 19 | 6.3 | 82.9 |
| July | Airport | 43 | 11.6 | 197 | 16 | 6.7 | 96.9 |
| August | Airport | 43 | 10 | 95 | 20 | 6.5 | 141 |
| September | Airport | 43 | 12.3 | 72 | 12 | 7.1 | 196.8 |
| October | Airport | 43 | 14.1 | 225 | 18 | 7.9 | 174.8 |
| November | Airport | 43 | 14.5 | 61 | 9 | 6.1 | 249.8 |
| March-99 | Airport | 43 | 18.4 | 109 | 12 | 6.5 | 177.7 |
| April | Airport | 43 | 14.8 | 52 | 12 | 5.7 | 190.3 |
| May | Airport | 43 | 13.9 | 140 | 12 | 7.5 | 128.3 |
| June | Airport | 43 | 10.9 | 101 | 16 | 6 | 125.8 |
| July | Airport | 43 | 10.5 | 92 | 15 | 7.1 | 123.7 |
| August | Airport | 43 | 10.1 | 60 | 17 | 6 | 151.8 |
| September | Airport | 43 | 12.5 | 35 | 13 | 7.1 | 188 |
| October | Airport | 43 | 14 | 93 | 16 | 7.3 | 172.7 |
| November | Airport | 43 | 15.2 | 177 | 18 | 8.4 | 155.9 |

* Wind data is taken from Airport weather station

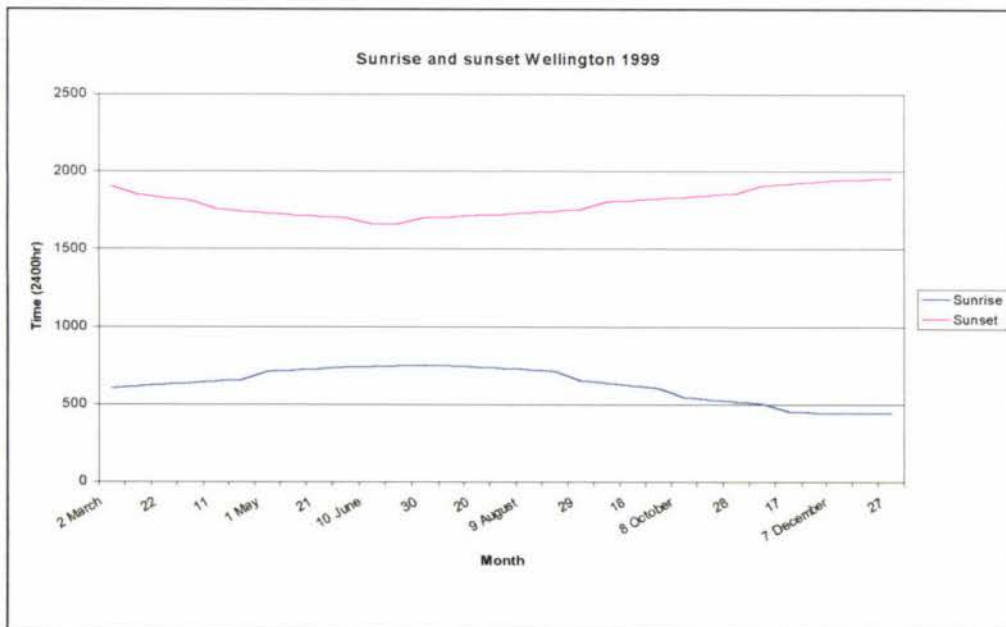
** Bright sunshine hours are taken from Kelburn weather station

Appendix: 4. Sunrise and sunset

Sunrise and Sunset for Wellington area March – December 1999.

| | | | | | | | |
|---------------------|------------------|------|------|------|-----------------|------|------|
| Month | March | | | | April | | |
| Day | 2 | 12 | 22 | | 1 | 11 | 21 |
| Sunrise (am) | 602 | 614 | 625 | | 636 | 646 | 657 |
| Sunset (pm) | 1904 | 1848 | 1831 | | 1814 | 1758 | 1742 |
| Month | May | | | | June | | |
| Day | 1 | 11 | 21 | 31 | 10 | 20 | 30 |
| Sunrise (am) | 707 | 717 | 727 | 736 | 742 | 746 | 748 |
| Sunset (pm) | 1729 | 1717 | 1708 | 1701 | 1658 | 1658 | 1701 |
| Month | July | | | | August | | |
| Day | 10 | 20 | 30 | | 9 | 19 | 29 |
| Sunrise (am) | 746 | 740 | 732 | | 721 | 707 | 652 |
| Sunset (pm) | 1707 | 1715 | 1723 | | 1733 | 1743 | 1753 |
| Month | September | | | | October | | |
| Day | 8 | 18 | 28 | | 8 | 18 | 28 |
| Sunrise (am) | 636 | 619 | 602 | | 545 | 529 | 514 |
| Sunset (pm) | 1803 | 1813 | 1823 | | 1833 | 1845 | 1856 |
| Month | November | | | | December | | |
| Day | 7 | 17 | 27 | | 7 | 17 | 27 |
| Sunrise (am) | 502 | 451 | 445 | | 441 | 442 | 447 |
| Sunset (pm) | 1908 | 1921 | 1933 | | 1943 | 1951 | 1956 |

Times listed are in NZ standard time (NZST), add 1 hour when NZ daylight time (NZDT) is in force.



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