Habitat selection and breeding ecology of the endangered Chatham Island oystercatcher (*Haematopus chathamensis*)

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CONTENTS

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ABSTRACT

The Chatham Island oystercatcher (*Haematopus chathamensis*) is an endangered shorebird endemic to the Chatham Islands, New Zealand. In the late 1980s the population was estimated at less than 110 individuals and was feared to be declining. The objectives of this study were to collect information on breeding ecology and to determine habitat selection at the general and territorial scales to assist conservation management. Research on Chatham Island oystercatcher (CIO) breeding biology and habitat use was conducted for three seasons between 1994 and 1997 on Chatham Island. Breeding effort was high, with 98% of pairs attempting to breed (n = 42 pair-seasons). Productivity averaged 0.44 fledglings/pair/season. Flooding was the main cause of egg loss (48%). Offspring were evicted (or dispersed) from their natal territories about 33 days after fledging. Over-winter habitat is probably not a critically limiting factor based on the high survivorship rates of first-year CIOs. Chatham Island oystercatchers used coastline, rather than the lagoon shoreline, almost exclusively. Intertidal rock platforms and wide sandy beaches were selected in much greater proportions than available. Paddocks were used extensively for foraging by some pairs.

Key words: breeding biology, Chatham Islands, Chatham Island oystercatcher, *Haematopus chathamensis*, endangered species, habitat selection, New Zealand.

1. Introduction

One of three New Zealand oystercatcher species, the Chatham Island oystercatcher (*Haematopus chathamensis*) occurs only on the Chatham Is, 860 km east of New Zealand. The other two species are widespread on the mainland of New Zealand.

The Chatham Island oystercatcher (CIO) breeds along the coastlines of Chatham, Pitt, Rangatira and Mangere Is (Baker 1973; Davis 1988; Hockey 1996) (Fig. 1). The birds defend territories during the breeding season, although individuals may move to other areas to feed (Davis 1988). Non-breeding and immature birds do not defend territories, moving from area to area, occasionally forming small flocks of up to a dozen birds (Davis 1988; Schmechel 2001). CIOs feed along the coast, mainly on molluscs and marine worms supplemented with other small invertebrates, on both rocky shores and sandy beaches. They also fossick among washed-up kelp and organic matter. Unlike South Island Pied oystercatcher (*Haematopus ostralegus finschi*), CIOs are non-migratory.

In 1987 the population of CIOs was estimated at about 100–110 individuals. Based on past productivity information it was feared to be declining and at risk of extinction within 50–70 years (Davis 1988).

Vegetation, predators, and disturbance factors have changed significantly on the Chatham Is since humans arrived. Many predators have been introduced to Chatham and Pitt Is, including cats (*Felis domesticus*), weka (*Gallirallus australis*), possum (*Trichosurus vulpecula*), hedgehog (*Erinaceus europaeus*), rats (*Rattus norvegicus, R. rattus*), and dogs (*Canus familiaris*). Except for rats, all are known predators of CIO nests, chicks, or adults (Moore et al. 2000). Habitat changes and human activities have probably resulted in higher densities of aerial predators such as black-backed gulls (*Larus dominicanus*) and Australasian harriers (*Circus approximans*), and the establishment of spur-winged plover (*Vanellus miles*)—a potential predator.

In dune areas, grazing by stock and competition with marram grass (*Ammophila arenaria*) has largely eliminated the original, more open dune community of pingao (*Desmoschoenus spiralis*) and endemic herbs (Atkinson 1996). Marram reduces the availability of habitat for CIOs by causing steeper dunes and creating thicker vegetative cover (Heyligers 1985; Best 1987; Park 1994). Marram-covered dunes also provide foraging, nesting, and hiding habitat for predators such as weka and feral cats (Schmechel 2001).

In addition to predators and habitat changes, other factors potentially affecting CIO populations include livestock use of coastal areas and disturbance associated with vehicles, dogs, and humans. These impacts are frequent and widespread along portions of the coastline of the two main islands (Schmechel 2001).

The New Zealand Department of Conservation (DOC) began managing the CIO in order to increase numbers in the late 1980s. The draft recovery plan identified research into CIO's habitat requirements and breeding biology as high priority (Davis 1988; Grant 1993). The aims of this study were to investigate basic breeding biology of the CIO and determine habitat selection at the general and territorial scale.
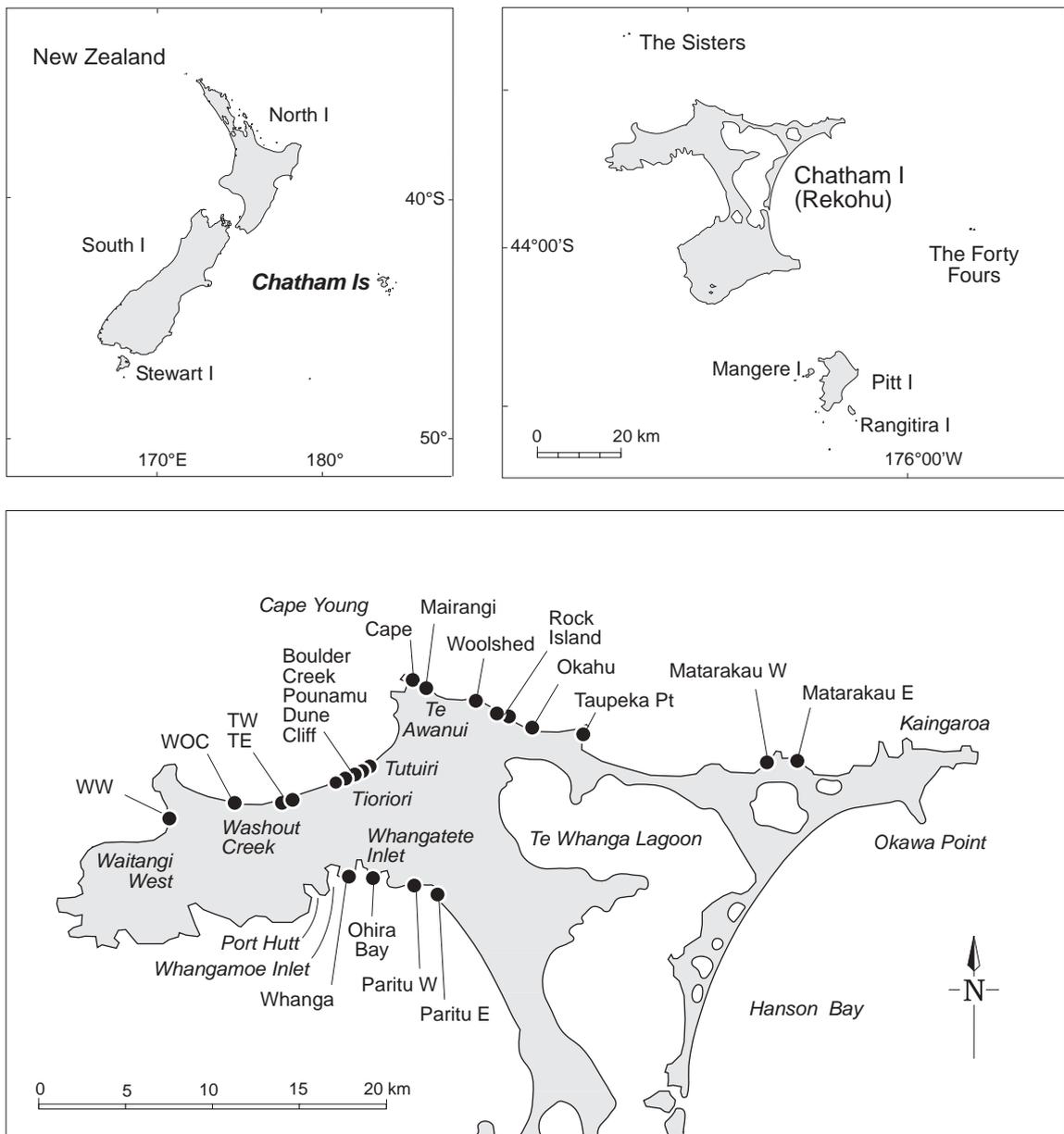
Figure 1.   Map of the Chatham Islands showing the north coast, Chatham Island with locations of study pairs.
WW = Waitangi West, WOC = Washout Creek, TW = Takihanga West, TE = Takihanga East.

The term 'season' or 'year' refers to the CIO breeding season, which begins in October and ends in the following calendar year. Seasons are given as the year in which breeding begins (e.g. 1994 indicates the 1994/95 breeding season).

2.   Breeding biology

2.1   INTRODUCTION

Information on CIO breeding across the whole of their range was collected in conjunction with a survey of CIO during the 1987 and 1988 seasons (Davis 1987; Davis 1988), and in conjunction with management on the north coast of

Chatham I. in the early 1990s (Sawyer 1993; Sawyer 1994). More detailed breeding data was collected incidentally on Rangatira and Mangere Is from the 1970s (Merton & Bell 1975).

The primary source of published information on CIO breeding is Marchant & Higgins (1993) and Heather & Robertson (2000). Additional data had been published in early accounts of the species of the Chathams (Travers & Travers 1872; Fleming 1939) and by Baker (1975, 1973) as part of a review of the oystercatchers of New Zealand.

However, there has been no systematic, long-term data collected on the breeding biology of the CIO to confirm predicted population trends or major factors affecting productivity. The aim of this study was to monitor breeding success, establish causes of egg and chick loss, confirm timing of the breeding season, and determine over-winter survival of first-year birds. Management intervention (e.g. predator control, nest moving, etc.) was minimal during the course of this study, providing a baseline from which to compare future efforts (DOC 1995).

2.2 LOCATION

The study area was located on the northern half of Chatham I., between Waitangi West and Te Awanui I., and between Whangamoe and Whangatete Inlets (Fig. 1) and is hereafter referred to as the 'north coast study area'. Territories outside the study area along the northern coastline of Chatham I. were also monitored for breeding success but less intensively and not in all years. Four of the breeding territories at Tioriori were within a site fenced-off to protect CIO nests from livestock; however, stock incursions occurred several times each breeding season.

2.3 METHODS

From 1994 to 1996, territories of 13–15 pairs of CIOs in the study area were intensively monitored for breeding activity over most of the breeding season (October or November until late March or early April). From 14 to 23 visits were made per pair per season. Pairs with fewer than eight visits in a season were excluded from some breeding calculations because of the higher likelihood of nests being missed.

Breeding success was analysed in terms of clutches. Clutch success was categorised into 'hatching success' (percentage of nests that hatched at least one egg) and 'overall success' (percentage of nests that fledged at least one chick).

When a range of dates, rather than the exact date, was known for clutch initiation, hatching, and fledging, the midpoint was normally used for estimating various parameters. If the intervals were at the beginning or end of the season, or simply too large (greater than 20 days), these data were excluded or noted in the appropriate section. Occasionally, if additional information (such as minimum re-nesting intervals) was available to narrow the possible range, this was also incorporated.

The following assumptions were used in calculations (based on parameters from this study's data where it was complete, and from other reported values for various oystercatcher species including CIO): 29-day incubation period from clutch completion to completion of hatching, a 48-hour period between each egg laid with incubation commencing when the last egg was laid, and a minimum 10-day re-nesting period from loss of clutch to initiation of the next replacement clutch (Baker 1969; Davis 1988; Marchant & Higgins 1993; Heather & Robertson 2000). If an egg had not begun pipping when checked, it was assumed the earliest probable hatch date for this egg was a minimum of two days later. Incubation was defined as the time from clutch completion to hatching completion.

The period of nesting was divided into 'early', 'mid', and 'late' season based on breeding patterns of CIOs in the study area, specifically when second and third clutches were initiated. 'Early season' nests were those initiated before 29 November, 'mid-season' nests were those initiated between 29 November and 3 January, and 'late season' nests were those initiated after 3 January.

Clutch data were compared using a repeated measures ANOVA and one-way ANOVA to determine if there were differences between mean sizes of first, second, and third clutches. Fisher's LSD test was then used to make pairwise comparisons between clutches.

The cause of failed nests was recorded when possible. Notes were made if large swells had passed over the nest area, or if predator, livestock, or tyre tracks were visible in the area around the nest-site. The causes of egg loss were categorised as: 'known' where there was a high degree of confidence in the cause of loss, 'suspected' when the evidence was less conclusive, and 'unknown'.

The presence of chicks was determined by sight. If chicks were suspected of being present, but not sighted, a recording of the behaviour of the parents was made. A fledgling was defined as any juvenile capable of flight. Fledglings were regarded as being independent once they left their natal territory and did not return for several days, or if their parents showed repeated aggressive behaviour to them and drove them away from their territories.

During most of this study, adult CIOs were not individually recognisable. Some birds had metal bands, but a method for drawing the birds in close enough to read the bands was not discovered until the third season (1996). One colour-banded bird was present in the study area during the beginning of the first season (1994). Some adults had coloured jesses during the final season, but were not individually identifiable due to the limited number of colours and combinations available. Some chicks were colour-banded with experimental powder-coated metal bands during the first two seasons of the study and so were individually recognisable for one to two years later before the colour faded.

2.4 RESULTS

2.4.1 Clutches

Clutch size varied between one and three eggs with a mean size of 2.20 (n = 61). Over 95% of the clutches contained two or three eggs, with two-egg clutches the most common (70%). Average clutch size tended to decrease with both advancement of the breeding season and number of replacement clutches.

There was a significant relationship between clutch size and order ($F_{2,60} = 4.60$, $P = 0.014$). Third clutches were significantly smaller ($P < 0.05$) than first and second clutches (Fisher's pairwise comparison). There was no significant difference in average clutch size between years.

Earlier clutches tended to be more successful than clutches initiated later in the season (27% versus 18% respectively, n = 61 clutches). A much larger proportion of two-egg clutches were successful (28%) than three- or one-egg clutches (7% and 0% respectively).

Pairs frequently re-nested after losing clutches and, in one case, after losing a 3 to 7-day-old chick. Almost all first clutches were replaced if there were no damaged eggs left in the nest scrape. A minimum of 90% of first clutches were replaced (n = 21). Of second clutches, 31% were replaced after loss (n = 16). No third clutches were replaced. If damaged eggs were left in a nest, replacement was precluded or delayed. Of eight first clutches with damaged eggs, only one was replaced late in the season (19 January).

2.4.2 Laying, incubation, and replacement intervals

Only one clutch yielded data on laying intervals. The first egg of the clutch was present for 2 days before another egg was laid, suggesting a 24–48-h laying interval. The clutch was eventually complete at three eggs.

For the two clutches where clutch completion and hatching dates were known to within a day, incubation periods of 27–29 days and 28–30 days were recorded. One successful clutch had a minimum incubation period of 30 days. Another clutch had a minimum incubation period of 37 days; however, the chick died while hatching.

The mean time for a pair to re-nest after losing a clutch was 15 days (range 8–24 days, SD = 4.5, n = 23). First clutches were replaced on average more quickly than second clutches. Midpoint estimates for first clutch replacements averaged 14 days (range 8–22 days, SD = 4.4, n = 18), and 18 days for second replacement clutches, (range 15–24 days, SD = 3.76, n = 5).

2.4.3 Hatching, fledging, and dispersal

Hatching was asynchronous by up to one day in some clutches and occurred over at least two days.

The mean time for chicks to fledge was 41 days after hatching (SD = 5.9, n = 15). One-chick broods fledged more quickly than two-chick broods. Midpoint estimates averaged 39 days for one-chick broods (range 30–47 days, SD = 4.8, n = 10) and 44 days for two-chick broods (range 36–54 days, SD = 6.9, n = 5).

All fledglings able to be monitored for at least six weeks were evicted from (or left) their natal territories (n = 8). Mean eviction / dispersal time was 36 days after fledging (n = 6, range 25–48 days, SD = 9.2).

2.4.4 Success rates and causes of loss

Within the north coast study area, 20% of clutches produced at least one independent fledgling over the three seasons, but success rates varied considerably between years, ranging from 9% to 38% (Fig. 2). Of 60 clutches, 41% hatched at least one egg (Table 1). Of those clutches which hatched at least

Figure 2.   Total number of clutches laid and of clutches that were successful (black bars) by season.
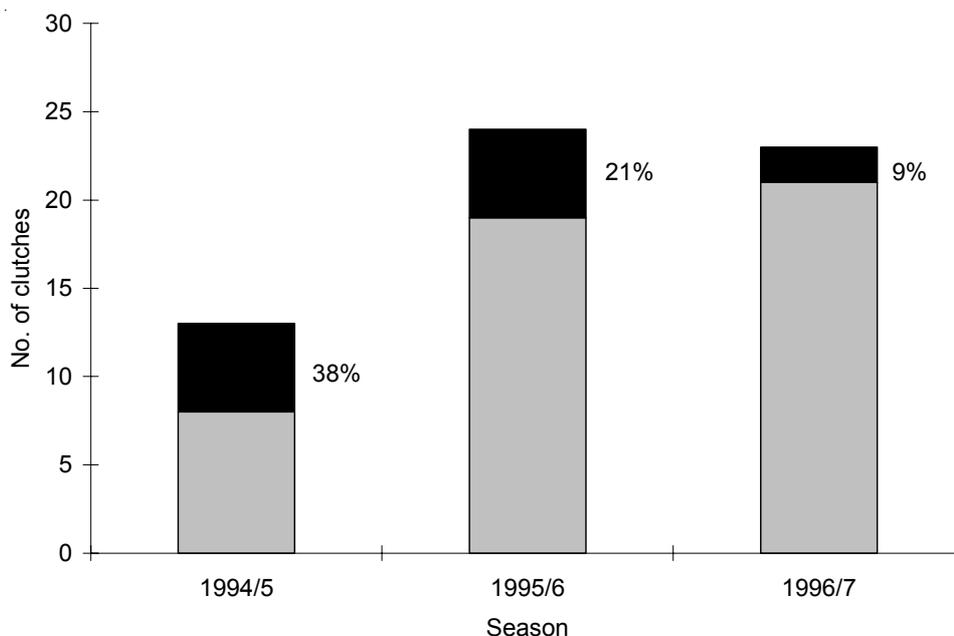
TABLE 1.   BREEDING SUCCESS BY CLUTCH OF CHATHAM ISLAND OYSTERCATCHERS 1994-1996.

| | YEAR | | | 1994-96 |
	1994	1995	1996	
Pairs	11	14	14	39
Clutches	13	24	23	60
Hatching success*	62%	42%	28%	41%
Fledging success†	63%	60%	43%	56%
Overall success‡/clutch	38%	21%	9%	20%
Chicks fledged/pair	0.73	0.50	0.14	0.44
Chicks fledged/successful pair§	1.60	1.17	1.00	1.31

*   Hatching success = percentage of clutches that hatched at least one egg.

†   Fledging success = percentage hatched that fledged at least one chick.

‡   Overall success = percentage of clutches that fledged at least one chick.

§   Raised at least one chick to fledging.

one egg, 56% fledged one or more chicks. The number of fledglings produced per year in both the north coast study area and some additional pairs visited less often is shown in Appendix 1.

The main cause of egg loss (known or suspected) over the three seasons was flooding (48%), especially in the 1995 and 1996 seasons (Fig. 3). In 1996, two major storms occurred just before many nests were due to hatch. Only one clutch was thought to be infertile. Crushing due to vehicles (once) or livestock caused several losses of clutches. There was suspected predation by weka and, possibly, spur-winged plover. One chick died during hatching.

Three nests were flooded by storm tides but incubation continued, with the eggs either in a new location, remaining in the nest, or being recovered by the pair. One of these tidally-flooded nests hatched a single chick and two were unsuccessful. Pairs recovered eggs dislodged from the nest by rolling them back into the nest.

Figure 3. Causes of egg
loss, including suspected
losses, 1994–1996.
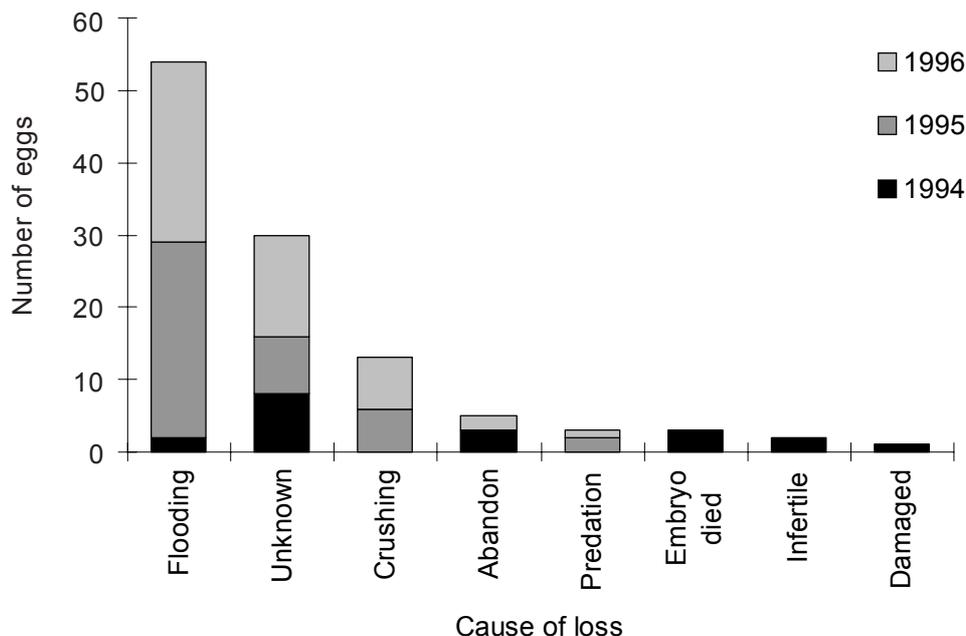
If eggs were damaged but substantially intact (e.g. shell cracked, or small hole in shell), pairs would often continue to incubate them for extended periods rather than re-nest. Of nine clutches with damaged eggs left in the nest, only one was replaced. Five pairs incubated non-viable eggs for as long as 40–55 days.

The highest risk of loss from any cause for eggs or chicks was during the 7 days before and after hatching (Fig. 4). About 60% of losses occurred during those two weeks.

Figure 4. Loss of eggs or chicks by week after clutch completion (%).
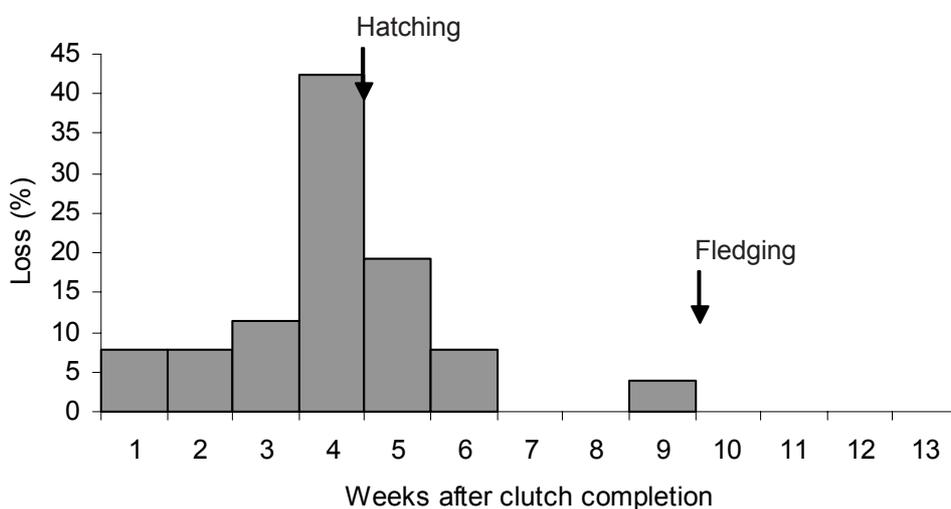
Most chicks that died before fledging (n = 8) disappeared without a trace (n = 7); the majority (n = 6) disappeared while still less than 11 days old. Over the three monitoring seasons, there were 45 eggs where it was not known whether loss occurred before or after hatching. If any chicks had hatched from these eggs, they must have died at less than 14 days old (based on when the territories were checked).

Some events led to the loss of a clutch, which was usually replaced. In contrast, other events led to the loss of an entire breeding season for a pair. Damaged

eggs left in nests either shortened or ended the breeding season for seven pairs (17% of unsuccessful outcomes). Pair turnover, due to divorce or death of one of the members of the pair, was implicated in three instances (7% of unsuccessful seasons). Loss of chicks and incubation of infertile clutches were minor causes (2% each).

2.4.5 Breeding effort and timing of the breeding season

Breeding effort during this study was high. Only one pair (2%) apparently did not attempt to breed out of a total of 42 pair-seasons.

The entire breeding period, from egg-laying to dispersal of fledglings, extended over at least 6 months from mid-October to April and, probably, into May. The estimated initiation date for the earliest clutches was between 9 and 13 October. The start of egg laying varied by 4–6 weeks in 1995 (the only year with complete data), with earliest pairs nesting in mid-October, and later pairs commencing first clutches in mid-November or early December.

Eggs began hatching in mid-November. The latest eggs hatched in mid-February. Numbers of chicks were highest from the first week in December until the last week in February (90% of observations). Nesting and chick periods peaked from November through February (Fig. 5).

Figure 5. Abundance of clutches, chicks and fledglings in north coast Chatham Island oystercatcher territories 1994–1996.
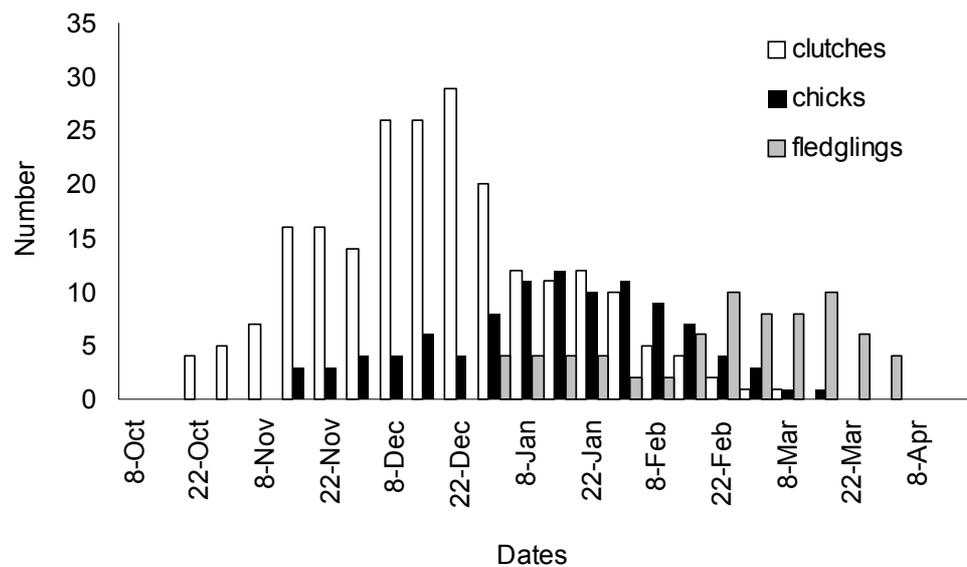
The earliest recorded fledgling was on 6 January (but the actual dates of fledging were probably earlier—sometime between 23 December and 6 January). The earliest dispersal or eviction of fledglings was the third week of January and continued into April and beyond. Some fledglings were still present in their natal areas when observations ceased in the first week of April (1995 and 1997).

2.4.6 Over-winter survival of first-year birds

Over-winter survival rates were high for the two years data were available. Of the 1994 season fledglings, 5 of 6 were seen the next season (83% survival rate), and of the 1995 season fledglings, 5 of 7 were seen the following season (71% survival rate).

2.5 DISCUSSION

2.5.1 Laying, incubation and hatching

The incubation times of 27–30 days are longer than those previously reported (Davis 1988; Marchant & Higgins 1993). However, they are similar to those recorded for CIO eggs kept in incubators which began hatching on day 26 (26.75 ± 0.89, n = 8), with chicks taking from 48 to 72 hrs to hatch, giving a total incubation time of 28–29 days (Sawyer 1993).

The extended incubation periods of two clutches (30 and 37 days) may have been due to disturbance or other factors that led to adults being off the nest for extended periods during cooler weather. There is evidence that chilling of eggs during incubation can retard hatching and extend the incubation period (Nysewander 1977; Webb 1987; Nol & Humphrey 1994).

Chatham Island oystercatchers continued to incubate eggs after flooding by the tide, and some later hatched. Andres (1995) reported that of 31 eggs of American black oystercatcher (*Haematopus bachmani*) submerged 1–4 times in Glacier Bay, Alaska, 17 survived to hatch.

2.5.2 Re-nesting

Re-nesting patterns observed in this study were similar to those reported by Davis (1988), with the exception of pairs on Rangatira I., which are reported to have laid up to a total of four clutches in one season. Up to three replacement clutches have also been reported for the Eurasian oystercatcher (*Haematopus ostralegus*) (Heg 1999).

The mean re-nesting interval of 15 days for the north coast study area was shorter than the minimum 21 days previously reported (Davis 1988; Marchant & Higgins 1993). This shorter period was similar to re-nesting intervals reported for Eurasian and American oystercatchers (*Haematopus palliatus*) (11–19 and 14 days respectively) (Mercer 1968; Nethersole-Thompson 1986; Nol & Humphrey 1994).

2.5.3 Chick rearing, fledging, and dispersal of fledglings

The mean time to fledging of 41 days in this study was less than that reported by Davis (1988) for Rangatira I (47.8 ± 1.5 days). Kersten & Brenninkmeijer (1995) reported fledging times ranging from 27 to 52 days in Eurasian oystercatcher. These differences could be because of differences in chick growth due to food availability (Groves 1984; Hatzlitt 1999).

Two-chick broods grow significantly more slowly than one-chick broods in American black oystercatcher (Groves 1984). This pattern also appeared in CIOs, with two-chick broods always taking longer to fledge than one-chick broods. The size of broods on Rangatira was not reported but, on average, they took longer to fledge than all but the slowest-growing two-chick broods in the north coast study area. These data suggest that chicks on Rangatira grew slowly relative to north coast chicks, due either to poor years when the data were collected, or poorer-quality territories, rather than differences in brood size.

The average time to eviction or dispersal of CIO fledglings on the north coast is similar to that of variable oystercatcher not in isolated territories (Marchant & Higgins 1993), but much shorter than that of variable oystercatcher from isolated territories, fledglings on Rangatira I., and for many other oystercatcher species, which remain with parents from 2 to 6 or more months (Davis 1988; Marchant & Higgins 1993; Nol & Humphrey 1994; Andres & Falxa 1995).

2.5.4 Breeding success

The average productivity of north coast pairs during this study was similar to the average for pairs monitored on Rangatira between 1974 and 1986 (Davis 1988), but much higher than in 1987 for the whole of the Chathams, which is the only productivity estimate for the whole of the CIO range (Table 2).

Breeding success reported by Davis (1988) should probably be considered a minimum, as eviction / dispersal times of juveniles were not known. Breeding was assumed unsuccessful if no chicks or fledglings were found in territories during a single check in mid to late March; however, this may have underestimated breeding success, since fledglings could already have left their natal territories by then.

TABLE 2. AVERAGE HATCHING AND FLEDGING SUCCESS OF CHATHAM ISLAND OYSTERCATCHERS BREEDING AT VARIOUS LOCATIONS AND DATES. RANGE OVER MONITORING YEARS IN PARENTHESES.

LOCATION	YEARS	PAIRS	FLEDGE/PR/y	SOURCE
North coast, Chatham I.	1994–96	13 (11–14)	0.44 (0.14–0.73)	Schmechel (2001)
Chathams group	1987	30	0.27	Davis (1988)
Rangatira I.	1974–86	10 (8–11)	0.48 (0.22–0.85)	Davis (1988)

2.5.5 Causes and timing of nest and chick loss

Causes of loss were often difficult to determine because eggs disappeared with few traces. This was due, in part, to frequent strong winds and rain which obscured any tracks or signs, and the CIO habit of removing shells if eggs are crushed or after hatching (Schmechel 2001). Virtually all chicks disappeared without trace.

The incidence of tidal flooding of CIO nests (and even chicks) along sandy beaches may have increased with the introduction of marram grass (Best 1987). In attempting to determine the relative causes of nest loss, flooding as a source of nest failure is the easiest to identify and may be over-represented relative to other causes.

Many of the 'unknown' cases of mortality noted in this study might have been caused by predation, which would have been more difficult to detect than flooding or some of the other causes. Predation is a significant factor affecting breeding success for several species of oystercatcher (Nysewander 1977; Campbell et al. 1990; Vermeer et al. 1992).

Disturbance and trampling by vehicles or livestock were also potential causes of breeding failure. Some coastal areas were frequently used for activities such as travelling, fishing, launching fishing boats, and mustering sheep. The use was

sometimes prolonged (several hours) and often associated with dogs and vehicles (Schmechel 2001). There are many examples of disturbance affecting oystercatcher species around the world, leading to nest abandonment, lowering breeding success, limiting population growth, and causing breeding pairs to avoid otherwise suitable habitat (Ainley & Lewis 1974; Nysewander 1977; Warheit et al. 1984; Jeffery 1987; Andres & Falxa 1995). Dogs amplify the disturbance to shorebirds by running after them, and also by causing them to leave their nests much sooner than they would when humans approach alone (Retallick & Bolitho 1993; Lord 1996).

The period of highest risk for CIO eggs and chicks was the week either side of the estimated hatch date. Some of this variation was due to uncertainty in hatching dates. Higher chick mortality during the first two weeks after hatching has been reported for several oystercatcher species (Heppleston 1972; Hockey 1983; Groves 1984; Kersten & Brenninkmeijer 1995). In African black oystercatchers (*Haematopus moquini*), 87% of chick mortality occurred during the first week after hatching (Hockey 1983).

2.5.6   Breeding effort

Breeding effort was much higher during this study than that reported by Davis (1988) who found in 1987 that 27% of pairs did not breed and 21% could not be confirmed. Davis' (1988) definition of pairs included those that were sexually immature, which accounted for some, but not all, of the non-breeding effort.

Frequent monitoring is needed throughout the nesting season to confirm lack of breeding effort, as oystercatcher clutches can be laid and lost quickly (Ens et al. 1996). Differences in monitoring and / or breeding effort between studies could account for the differences reported.

2.5.7   Seasons and limiting factors

If over-winter habitat was a significant limiting factor for the population, survival of first-year birds would be predicted to be low, as they are the portion of the population most vulnerable to starvation if food is limited, because of their low dominance rank, and inexperience (Goss-Custard et al. 1994; Ens & Cayford 1996; Goss-Custard et al. 1996; Durell et al. 2000). However, survival of first-year birds was high (71–83%), suggesting that at current densities the main factors limiting the population are probably operating during the breeding season through either low productivity and / or high mortality of breeding birds.

2.6   SUMMARY

- Flooding was the main cause of nest losses, but pairs re-nested up to three times, which compensated for some of this loss in less stormy years. A large proportion of nest losses were from unknown causes.

- Habitat modification on the Chathams, especially the establishment of marram grass, probably increased losses of nests to tidal flooding and may also have provided suitable habitat for predators.

- CIOs incubated damaged eggs rather than re-nesting. Pair turnover also ended attempts to re-nest within a breeding season. Therefore, these types

of losses had more impact on overall productivity than the loss of a clutch where all eggs disappeared from the nest, or were clearly damaged so that the pair re-nested.

- The highest risk times for non-flooding losses appear to be around hatching. The laying period may also be high risk, as has been shown for some other oystercatcher species.

- Causes of chick mortality were particularly difficult to establish since most chicks disappeared without trace; however, predation was probably a significant factor, based on the high number of predators present.

- In this study, if chicks survived the first two weeks after hatching, survival rates were very good. Only one chick older than 12 days old (n = 16) disappeared during the three breeding seasons monitored.

- Many CIO fledglings along the Chatham Island north coast appear to be evicted, or disperse, within four to six weeks of fledging.

- Survival of first-year birds was high, suggesting that the main limiting factors for the population of CIOs on the Chatham Is operate primarily during the breeding season.

3. Habitat use

3.1 INTRODUCTION

The recovery plan for the CIO identified research into habitat requirements as high priority to determine if management intervention which increased productivity would increase the breeding population, and how breeding habitat could be improved or increased (Davis 1988; Grant 1993).

Chatham Island oystercatchers have been reported to occur primarily in association with rocky shoreline (Best 1987; Davis 1988) although, historically, the species was reported to use both rocky shoreline and sandy beaches (Travers & Travers 1872; Fleming 1939). Best (1987) searched areas where birds had been in the previous few years in one of the first systematic attempts to determine total numbers of CIOs. All sightings of CIOs from this survey were on tidal rocky platforms (volcanic or sandstone) or beaches immediately adjacent. No CIOs were seen probing for food on beaches.

Davis (1988), in a survey of the coastline of the four main Chatham Is, concluded that wide wave-cut volcanic rock platforms were optimal habitat, but CIOs were also found to use sandy beaches associated with rock platforms and around stream mouths. Historically, CIOs had also been reported using schist and sedimentary rock platform areas (Davis 1988).

The aims of this study were to determine patterns of habitat use by CIOs at the broad-scale and territory level during the breeding season; habitat characteristics within breeding territories along the north coast, Chatham I.; and use of micro-habitat types within territories.

3.1.1 Definitions

Territory: Defended area with exclusive use (Maher & Lott 1995). In this study a territory was defined as an area used by a breeding pair of CIOs for feeding and breeding (nesting and chick-rearing) and defended from other CIOs.

Habitat preference: When a resource is used disproportionately relative to its availability in the environment.

Floater: Non-territorial, non-breeding CIOs.

3.2 METHODS

3.2.1 Coastline survey

To determine general habitat use by CIOs at a broad scale, the coastline of Chatham, Pitt, and Rangatira Is, and the Te Whanga lagoon shoreline were mapped by walking the areas and marking habitat types on 1:50 000 maps (Chatham Is, NZMS 260 series, 1&2). Distances were estimated by extrapolation from marked sections using an ipsometer (map wheel). Mangere I. and about 26 km of the southern-most cliff coastlines of Chatham I. were excluded due to inaccessibility.

Habitat types were divided into three zones: intertidal, storm-tide, and terrestrial. Within each zone, habitat categories were delineated at a minimum of 250 m in length for mapping purposes. The storm-tide sections were defined as those not inundated daily, but washed by ocean tides during storms (normally at intervals of > 30 days during the breeding season). The upper reaches of these areas were discernible (based on the lack of vegetation); the lower reaches by the fresh debris or wrack line. In sections where two or more habitat types were intermixed (e.g. cliff and rock platform, or sand and shell), classifications were made using the following criteria:

- by predominance of the habitat types (e.g. if a beach was 60% shell, 40% sand it would be classified as shell)
- if the mix was fairly even, by habitats known to be used by CIO (e.g. if a 250-m section of intertidal area was about half rock platform and half cliff it would be classified as rock platform).

3.2.2 Habitat selection calculations

To determine whether CIOs selected habitat with respect to availability, the proportions of available habitat types were compared with 'use' (proportion of sightings) of CIO found on these same substrates (habitat use / habitat availability = selection). To avoid overestimating selection, habitat availability categories were combined so that no single category comprised a total of < 5%. Chi-squared tests were used to compare observed and expected values of habitat use relative to availability.

Habitat use was recorded in conjunction with habitat mapping (1995 and 1996 seasons), and again during the December 1998 census (Schmechel 1999). The mean of the two use datasets was used to calculate selection ratios. A small section of coastline (8.5 km) not surveyed during the 1998 census was excluded from the calculations as only one set of use data was available for that section.

Birds were classified as pairs (including known breeders, territory holders, and pairs of unknown breeding status) and non-breeders. Because CIOs rarely used the lagoon shoreline, this category was excluded from some habitat selection calculations.

To determine if special features within general habitat types were used selectively, they were classified into the following categories: creeks, bays, areas with large amounts of kelp and wrack, and 'corners' (areas where sandy beaches meet rock outcrops). The proportion of areas that contained bays, kelp / wrack, and corners were too infrequent to analyse individually, so these were combined.

3.2.3 Habitat composition and use within territories

Habitat use within territories was investigated by detailed studies of 15 breeding territories within the north coast study area. This 28-km section of coastline is characterised by a mix of volcanic (or volcanic derived) intertidal rock platform, schist rock, sandy beaches, and small sections of shell or boulder beaches. Terrestrial areas along the coastline included long sections of marram dunes, paddock, forest patches, rough vegetation, and cliffs.

Territory boundaries were determined by a combination of watching birds defend boundaries, observations of general use, and by using cardboard decoys which resident birds would often attack if placed within their territory boundaries.

3.2.4 Observations

Habitat use within these 15 territories was studied during three successive breeding seasons (1994–1996). During observations, the habitat type used and associated behaviours were noted at 5-min intervals for at least 30 min per observation. Behaviours were classified into six categories (Table 3). Walking was often associated with either foraging or territory defence, but was noted as 'other'. Micro-habitats within territories used during timed observations of CIOs were classified into six categories: sand, rock platform, paddock, boulder / rock, freshwater, schist, and shell. If a mix of habitat types were present (e.g. shell and sand), the predominant habitat type used was recorded. For some calculations, the sandy beach and freshwater categories were combined because all freshwater areas had sandy substrates.

TABLE 3.   CHATHAM ISLAND OYSTERCATCHER BEHAVIOURAL DEFINITIONS.

BEHAVIOUR NAME	DEFINITION
Foraging	Searching for food including probing and eating
Resting	Standing, sitting, guarding behaviour and brooding chicks
Incubating	Sitting on eggs in a nest
Territory defence	Any of the behaviours associated with defending territories including moving aggressively towards intruders (carpel flex, direct approach, head lowered), piping displays, object-tossing, head-bobbing, body-rocking, or bill-tucking
Preening	Included bathing as well as feather cleaning with bill
Other	Any behaviours not included above including flying and walking

For incubating pairs, the non-incubating bird was the focus of observations. When beginning a round of observations, a pair was chosen at random for the initial observation and all pairs then observed over several days. A new pair was randomly chosen for the next round and the process repeated. Observations were conducted only during daylight hours and no attempt was made to time observations for a particular tide cycle or time of day. Pairs were observed with 10× Pentax binoculars from a distance (usually ≥ 30 m, depending on the topography) using hides or natural cover from vegetation and topography. If it appeared the pair was becoming overly influenced by the observer (e.g. alarm behaviours, false brooding, etc.), observations were discontinued and a new location for observations sought with a period of time (a minimum of 20 min) out of sight of the birds to allow them to resume normal activities. If individuals moved out of sight during the observations, this was noted and included as part of the calculations.

3.3   RESULTS

3.3.1   Coastline surveys

All of the Te Whanga Lagoon shoreline (93 km) and 92% of coastline on Chatham, Pitt, and Rangatira Is (277 km) were mapped. A total of 351 sections of coastal and lagoon shoreline habitat types were delineated (Appendix 2). During the mapping survey, a total of 115 CIOs were recorded (Table 4). During the 1998 census (Schmechel 1999), 136 (of 142 total) CIOs were recorded in the mapped areas.

TABLE 4.   NUMBERS OF CHATHAM ISLAND OYSTERCATCHER PAIRS (p) AND FLOATERS (f) ALONG THE COASTLINE AND LAGOON SHORELINE FROM MAPPING AND CENSUS DATA FOR THE CHATHAMS COASTLINE (CHATHAM, PITT, RANGATIRA AND MANGERE ISLANDS) AND TE WHANGA LAGOON EDGE.

	COASTLINE			LAGOON			TOTAL		
	p	f	TOTAL	p	f	TOTAL	p	f	TOTAL
Mapping survey	41	31	113	0	2	2	41	33	115
1998 census	51	32	134	0	2	2	51	34	136
mean	46	31.5	123.5	0	2	2	46	33.5	125.5

Along the lagoon shoreline, only two CIOs, both non-territorial non-breeders (floaters), were seen in each survey. Selection ratios (by linear km) were 1.32 for coastline, in contrast with the lagoon shoreline which had selection ratios of only 0.08.

Chatham Island oystercatchers were found around the entire coastline of all three islands, but only in low densities along coastline that had no storm-tide zone, or had narrow rock or shell in the storm-tide zone, or cliff / boulder / shell in the intertidal zone (Table 5). Sandy beaches and areas with intertidal rock platform were used two to four times more often than would be expected based on availability. The differences in use of habitat types within zones were significant, except for floaters in the terrestrial zone (Table 6).

TABLE 5. PROPORTIONS OF USE AND AVAILABILITY OF HABITAT TYPES FOR CHATHAM ISLAND OYSTERCATCHER PAIRS AND FLOATERS ALONG COASTLINE OF CHATHAM, PITT, AND RANGATIRA ISLANDS, (LAGOON EXCLUDED). RATIOS GREATER THAN 1.00 INDICATE USE OF HABITAT TYPES BY BIRDS IN HIGHER PROPORTIONS THAN AVAILABLE.

HABITAT TYPES BY ZONE	AVAILABILITY	FLOATERS		PAIRS	
		USE	RATIOS	USE	RATIOS
Terrestrial					
cliff / boulder	0.17	0.13	0.73	0.12	0.70
paddock	0.26	0.32	1.24	0.11	0.43
vegetation	0.57	0.56	0.98	0.77	1.35
Storm-tide					
cliff / boulder	0.13	0.10	0.72	0.09	0.66
no storm zone	0.06	0.02	0.28	0.01	0.19
sand narrow	0.22	0.08	0.37	0.16	0.76
rock / shell	0.28	0.41	1.47	0.29	1.02
rock/shell narrow	0.13	0.05	0.35	0.03	0.24
sand / mix	0.18	0.35	1.97	0.42	2.35
Intertidal					
cliff / boulder / shell	0.10	0.02	0.16	0.01	0.11
rock / mix	0.17	0.24	1.41	0.15	0.91
rock platform	0.13	0.33	2.57	0.54	4.14
sand	0.36	0.21	0.57	0.20	0.55
schist	0.24	0.21	0.86	0.10	0.41

TABLE 6. CHI-SQUARED VALUES FOR HABITAT USE BY ZONE FOR CHATHAM ISLAND OYSTERCATCHER PAIRS AND FLOATERS ALONG THE COASTLINE OF CHATHAM, PITT, AND RANGATIRA ISLANDS.

ZONE	FLOATERS				PAIRS			
	χ^2	df	p		χ^2	df	p	
Terrestrial	4.90	2	0.086	ns	7.77	2	0.021	*
Storm-tide	13.27	5	0.021	*	21.20	5	< 0.001	***
Intertidal	14.95	4	0.005	**	69.27	4	< 0.001	***

When storm-tide zones associated with intertidal habitat were classified as 'narrow' or 'wide', CIOs selected wide over narrow in every case except one. This preference was especially notable for rock platform habitats where selection ratios were 5.58 for breeding pairs (Table 7).

Special features such as creeks, areas with kelp and wrack, bays, and corners had selection ratios of 1.58 for breeding pairs. Creeks alone were not used more than available (selection ratio = 1.00 breeding pairs). However, if the creeks or streams were in areas with other special features (e.g. bays, areas with kelp / wrack, or corners), these areas were used almost four times as often as would be expected according to their availability (selection ratio = 3.84). Creeks were frequently used for foraging and bathing; kelp and wrack for foraging.

3.3.2 Breeding territories

From Washout Creek to Tutuiri Creek (including Tioriori), the density of breeding pairs was 1.2 breeding pairs/km. This section includes long stretches

TABLE 7. PROPORTIONS OF USE AND AVAILABILITY OF NARROW (n) OR WIDE (w) STORM-TIDE ZONES. RATIOS OVER 1.00 INDICATE USE IN GREATER PROPORTION THAN IS AVAILABLE.

INTERTIDAL	USE		AVAILABLE		RATIOS	
HABITAT TYPE	n	w	n	w	n	w
Pairs						
boulder / cliff / shell	0.01	0.00	0.08	0.02	0.14	0.00
rock / mix	0.03	0.12	0.06	0.11	0.59	1.07
rock platform	0.23	0.31	0.07	0.06	3.09	5.58
sand	0.01	0.19	0.23	0.13	0.05	1.42
schist	0.01	0.09	0.10	0.14	0.11	0.63
Floaters						
boulder / cliff / shell	0.02	0.00	0.08	0.02	0.20	0.00
rock / mix	0.05	0.19	0.06	0.11	0.85	1.68
rock platform	0.14	0.19	0.07	0.06	1.91	3.45
sand	0.02	0.19	0.23	0.13	0.07	1.45
schist	0.02	0.19	0.10	0.14	0.16	1.37

of sandy beach and stream mouths backed by extensive marram dunes and some paddocks. Within this section, the highest densities of breeding territories (3.0 pairs/km) were at Tioriori. This section of coastline was characterised by its extensive rock platform, backed by marram dunes and paddock.

Wharekauri also had a high density of pairs. Between Cape Young and Okahu Point there was 0.9 breeding pairs/km of coastline. This area was a mix of sandy beaches and rocky platforms, or outcrops of rock and boulders backed by either paddock or marram dunes.

The other northern area with high densities of CIO territories was around Whangamoe (1.7 pairs/km). The Whangamoe area was characterised by a mix of schist rock interspersed with sand and shell beaches, with a small volcanic rock area. The storm-tide zone was backed by paddock and rough vegetation.

Breeding territories within the north coast study area varied from 70 m to 1540 m long and 1 m to 70 m wide (Appendix 3). The territories tended to be either predominantly sandy beach and contain a large creek (n = 5), or be adjacent to rock platform (n = 8). The majority had paddock within the territory boundaries (10 of 15); an additional three had paddocks within short flying distances.

3.3.3 Habitat use within breeding territories

The 15 breeding pairs in the north coast study area were observed for a total of 83 h over three seasons and 1992 individual behavioural and habitat use records were noted. Pairs used anywhere from two to six different habitat types; most (80%) used between two and four different habitat types. For all activities (e.g. resting, incubating, foraging), sandy beach was used far more than any other habitat type (present in all territories, mean use = 67%, range 10–96%), followed by rocky platform (present in 8 territories, mean use = 30%, range 14–55%). Shell and schist were used very little (present in 2 and 1 territory respectively, mean use = 15% and 38% respectively).

For foraging, all pairs used rock platform if it was available within their territories, some quite extensively (up to 60%); in territories composed primarily of sandy beach, it was used almost exclusively for foraging (Appendix 4). Seven pairs foraged in paddocks from 4% to 22% of the time. Schist rock platform habitat and shell beaches were used in only one territory.

3.4 DISCUSSION

3.4.1 General habitat use

Broad-scale habitat selection by CIOs is probably influenced by a combination of the geology of the islands and wind patterns. The southern half of Chatham I. and portions of Pitt and Rangatira Is are composed of volcanic rock with steep cliff areas and little storm-tide zone, with prevailing southerly or south-westerly winds and limited nesting areas for CIOs.

Along the coastline, the preference for rock platforms was similar to that reported by Davis (1988), but the extensive selection of sandy beaches was either previously under-detected or is a recent development. Sandy beaches provided foraging habitat even when rock platforms are covered by the tides, and were often used for nesting.

The low use of narrow sections of coast, even those with suitable foraging habitat in the intertidal zone, was probably because these sections provided little in the way of high tide foraging or nesting sites. This is supported by the fact that all of the intertidal areas, except cliff / boulder, were used more if backed by wide storm-tide zones that provided good foraging substrates.

Although pairs had historically been reported using wide schist platforms, use of schist was thought to have decreased in the late 1980s (Davis 1988). In recent counts, CIOs were found using these areas (Schmechel & O'Connor 1999; Moore et al. 2000). Schist topography varies considerably on the Chathams; some sections are flat and wide with pools and good foraging areas, others are more narrow or uplifted, with less substrate for marine vertebrates (Davis 1988; Schmechel 2001). Schist use may vary with the total population of CIOs, decreasing when numbers are lower. Lower numbers may also reflect the fact that much of the schist coastline is difficult to survey, making CIO detection rates lower than along sandy beaches.

Although not a preferred habitat at the broad scale (across the entire coastline), paddocks were often used by CIO pairs for foraging along the north coast. Much of the paddock area (70%) was along sections of coastline with intertidal habitat types—such as boulder / cliff, narrow sand or schist—generally avoided by CIOs. Use of paddocks probably varied depending on the season and the wetness of the paddocks.

Differences in habitat use by floaters and breeding pairs may reflect different habitat requirements. Breeding pairs need areas with nest-sites adjacent to foraging and chick-rearing habitat and are better able to defend these territories than single birds (Heg 1999; Ens 1992).

The infrequent use of Te Whanga lagoon may be due to a lack of foraging habitat. Alternatively, non-habitat factors such as predator pressure,

disturbance, or social factors (such as prospecting for mates and territories) may affect use. Food supplies appeared (from limited observations, and based on feeding success rates for molluscs), to be good for CIOs. However, Murray & Sanders (2000) found molluscs occurred only rarely and in low numbers in the five sites they sampled; however, amphipods, oligochaete worms and fly larvae—all potential food for CIO—were present (Baker 1969; Davis 1988). Winds and the water levels within the lagoon may change food availability significantly from day to day, potentially rendering the lagoon shoreline unsuitable for chick-rearing because of variable food availability. Wind-driven fluctuations in water levels often dramatically change the amount of mudflat exposed along the northern lagoon edges over short periods of time (Murray & Sanders 2000). Moreover, the lagoon blocks and unblocks irregularly, meaning that food supplies over years are likely to be unreliable because of changing salinities and water levels.

3.4.2 Breeding territories

Although the CIO has been considered to be one of only two pied-coloured oystercatcher species to specialise on rocky shore habitat (Hockey 1996), CIOs also foraged extensively on sandy beaches, and 5 of the 15 north coast study area breeding territories were predominantly sandy beach. These territories had several common features: all but one had a large stream running through it (the one exception had a small creek); all had wide sections that were not inundated by daily tides; and all had regular deposits of kelp and other wrack along the tide-line, which were regularly used for foraging. Many of the differences in habitat use reported by Davis (1988) and this study may be because these were newly established territories.

The highest concentrations of CIO breeding pairs (4.0 pairs/km) was much higher than the average of 0.4 on Chatham I., 0.6 on Pit and Mangere Is, and 1.2 on Rangatira I. (Schmechel & O'Connor 1999). However, it was less than half that reported for Australian pied (*H. longirostris*) and sooty (*H. fuliginous*) oystercatchers on their most preferred habitats on Big Green I. in the Furneaux Is (Australia). There, the number of Australian pied oystercatcher breeding pairs at sandy, mixed beach, rock beach and overall was 4.8, 8.8, 1.4 and 3.1 per km respectively (Lauro & Nol 1995). This suggests that CIO breeding pair densities could increase significantly, depending on habitat suitability and behavioural constraints.

In contrast to past studies, in this study paddocks were used for foraging between 4% and 22% of the time by about half the CIO pairs. Davis (1988) reported only one instance of CIOs foraging in paddocks. Reasons for these differences could relate to changes in paddock availability or quality, changing behaviour by CIOs as they learn to use paddocks for foraging, or differences in observation methods. Extensive use of paddocks has been a relatively recent adaptation by some other oystercatcher species (reviewed in Hockey 1986).

3.4.3 Limitations to methodology

Areas with good habitat for CIO may be unoccupied due to non-habitat factors such as social cues, predator pressure, or disturbance (Stamps 1987; Stamps 1988; Smith & Peacock 1990; Reed & Dobson 1993; Baptista & Gaunt 1997;

Newton 1998). For example, takahe (*Notornis mantelli*) had been thought to prefer high-altitude tussock grassland, but are probably found only in these areas because of predator pressures elsewhere in their more preferred habitats (Newton 1998). Similarly, waders are absent from suitable or preferred habitat due to human disturbance (Pienkowski 1993; Liley 1998; Schulz & Stock 1993).

Observations of foraging behaviour by CIOs were only made during the day. Night foraging is very widespread in waders and in other oystercatcher species (Evans 1976; Dugan 1981; Zwarts et al. 1990; McNeil et al. 1992; Kersten & Visser 1996; Rohweder & Baverstock 1996), and almost certainly occurs in CIOs. In Eurasian oystercatchers breeding near tidal areas, radio-tracking indicated similar ranges and food intake rates day and night (Exo 1998).

The potential to over- or under-estimate habitat use and selection was minimised as much as possible, but some habitats were more difficult to observe CIOs in, e.g. broken boulders and rocky areas. These habitat types may, therefore, be slightly under-represented in the use figures. Pairs with chicks were more difficult to observe as they were very alert, and changed behaviours at a greater distance when approached than pairs without chicks.

Although the observations of habitat use within territories were from a significant percentage of the total population (about a third), they were not from a random sample of territories, as they included only north coast territories, and the results may not, therefore, be representative of other areas.

Some habitat types may seem to be preferred because they are often associated with another habitat type. For example, marram dunes (classified as 'vegetation') were almost always associated with wide sandy beaches. In the analysis, it appears that CIOs prefer vegetation in the terrestrial zone when, in fact, it was the wide sandy beaches they were selecting.

3.5   SUMMARY

- At the broad scale, CIOs preferred coastline containing rock platform, mixed sand / rock, and wide schist platform. They sometimes selected sandy beaches as well, especially if wide or near streams.
- Breeding pairs preferred areas which included rock platform and wide sandy beaches; floaters used habitats in somewhat different proportions to breeders.
- Use of the Te Whanga lagoon was low and restricted to floaters, possibly because food supplies are unpredictable because of fluctuating water and salinity levels.
- Paddocks were used extensively for foraging by north coast breeding pairs (up to 22%). Across the islands, paddock habitats were selected by floaters more than would be indicated by availability; however, outside the north coast area, paddocks were used less than expected by breeding pairs. This may be because paddocks were often associated with intertidal habitats avoided by CIOs, such as cliffs.

- The highest density of territories (4.0 pairs/km) across the three islands was at Tioriori, along the north coast, Chatham I. This is an area of wide intertidal rock platform backed by wide sandy beaches, open dunes, and paddocks.

- Although considered to be rocky shore specialists, most pairs along the north coast used sandy beaches extensively, and several pairs used sandy beaches almost exclusively for foraging and other activities. The extensive use of sandy beaches was either previously under-detected, or is a recent development. Sandy beaches provided foraging habitat even when rock platforms were covered by the tides, and were often used for nesting.

4. Management and research recommendations

4.1 MANAGEMENT

- Remove damaged eggs to encouraging re-nesting.

- Undertake intense predator control along the north coast of Chatham I. in areas of CIO breeding.

- Remove marram grass and continue the restoration of native dune communities to provide better nesting habitat and more options for nesting above storm tides.

- Consider focusing management efforts around the highest quality habitats as there are likely to be more gains per unit effort in these areas. (Pairs can raise more chicks per season if food supplies are high and there is potential for more pairs/km.)

- Consider colour banding some CIOs to provide information on adult and fledgling survival, movements, fidelity, population structure, fecundity, and management effectiveness (e.g. adult survival).

4.2 MONITORING

- CIO territories should be checked at least every nine weeks between mid-December and mid-March. If chicks are found, a follow-up visit within four weeks to determine if the chicks survived to fledging must be made to accurately determine fledging success.

- Use the behaviour of pairs when young are present as a surrogate to determine breeding activity for infrequently monitored territories in addition to sightings of chicks, as observers may not always detect chicks (Davis 1988; Sawyer 1993; Schmechel pers. obs.).

- Monitor and record the number of chicks fledged in specific areas, in addition to productivity per pair, as productivity per pair may decrease with increasing pair densities.

- Monitor mortality and turnover of breeding pairs in different areas, and under different management regimes, as populations are typically most sensitive to loss of breeding adults.

- Confirm eviction / dispersal periods for fledglings.

- Estimate fledging success for various areas over several years to provide the information essential for predicting population trends over time, and for determining levels of productivity needed to achieve population recovery goals.

- Determine the role of stormy weather in past productivity by comparing storm patterns with productivity by territory type. This information could help with predictions of fluctuations in productivity not attributable to the influence of management.

5.   Acknowledgments

6.   References

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Appendix 1

NUMBER OF CHICKS KNOWN TO HAVE FLEDGED 1994–96

Number of Chatham Island oystercatcher chicks known to have fledged, northern Chatham Island 1994-96. Numbers only for territories where pairs were territorial, resident, or suspected to have bred.

TERRITORY NAME	NO. OF FLEDGLINGS			NOTES
	1994	1995	1996	
Study area				
Waitangi W.	2	1	1	also known as WW
Washout Creek	2	1	0	also known as WOC
Takihanga W.	2	1	0	also known as TW
Takihanga E.	0	1	0	also known as TE
Boulder	0	0	0	also known as 'OTF or Over the Fence'
Creek	0	0	0	possible pair turnover
Pounamu	0	0	0	pair member disappeared 1994 season
Dune	0	0	0	1994—territorial pair, but no known breeding attempt
Cliff	0	0	0	
Cape	0	0	0	
Mairangi	–	1	1	1994—no known breeding attempt, pair not consistently in residence
Woolshed	1	0	0	
Rock	1	0	0	suspect pair turnover 1996
Island	2	2	0	
Whanga	0	1	0	
Other				
Paritu E.			0	
Paritu W.			0	1996—new pair, territorial, unknown if attempted to breed
Ohira Bay		1	0	
Okahu	–	0	0	1994—pair not consistently in residence
Taupeka		–	0	1995—no known pair, 1996-suspected nesting
Matarakau W.		0	0	1995 and 1996-pair of unknown status
Matarakau E.		1	0	1996—pair of unknown status, alternate name for this area is Rangatai Pt.
Totals				
Fledglings	10	10	2	
Pairs	14	19	22	
Fledglings/pair	0.71	0.53	0.09	

Appendix 2

HABITAT CATEGORIES ON CHATHAM, PITT AND RANGATIRA ISLANDS BY ZONE

Habitat categories on Chatham, Pitt and Rangatira islands by zone. Categories defined as 'wide' or 'narrow' (e.g. rock platform) were those sections greater or less than 30 m wide respectively.

ZONE	HABITAT CATEGORIES WITHIN EACH ZONE	TOTAL (km)	TOTAL NO. OF SECTIONS
Terrestrial	cliff	46.50	69
	paddock	68.75	76
	vegetation	152.25	151
Storm-tide	boulder / cliff	35.50	64
	no storm zone	15.25	16
	rock / shell	75.25	96
	rock / shell narrow	36.00	41
	sand	47.50	54
	sand narrow	58.00	25
Intertidal	boulder / cliff / shell	26.75	38
	rock / mix	45.25	70
	rock platform	34.75	69
	sand	96.25	50
	schist	64.50	69

Appendix 3

FEATURES OF CHATHAM ISLAND OYSTERCATER BREEDING TERRITORIES

Features of Chatham Island oystercater breeding territories. × indicates the presence of the feature. Items in parenthesis indicate feature is outside territory boundaries but nearby.

TERRITORY	COASTLINE		PADDOCK	ROCK PLATFORM	BOULDER / ROCK / SAND MIX	STREAM
	LENGTH (m)	WIDTHS (m)				
Whanga	350	10–30	×	×		
Waitangi W.	1000	13–67				×
Washout Ck.	990	3–28	×			×
Takehanga W.	700	4–25	×			×
Takehanga E.	1310	30–64	×		×	×
Boulder	1540	10–16	×		×	
Creek	180	15–37	×	×		×
Pounamu	170	4–8	×	×		
Dune	200	6–15	×	×		
Cliff	200	18–24	×	×		
Cape	450	1–9	(×)*	×		
Mairangi	490	5–15	×		×	×
Woolshed	700	5–70			×	(×)†
Rock	560	1–3	(×)	×		
Island	360	2–4	(×)	×		(×)
Mean / count	610		10	8	4	8

* paddock use nearby and suspected use

† minor creeks, rather than larger streams

Appendix 4

Habitats used for foraging by Chatham Island oystercatchers (by territory). SB = sandy beach, RP = rock platform, B = boulder, PAD = paddock, FW = fresh water, SHL = shell, T = schist rock platform. N = the number of observation sets. Total = the total number of habitat types used. In order by geographic distribution from southwest to northeast.

TERRITORY	SB	PAD	RP	T	B	FW	SHL	(N)
Whanga	15%	22%		48%			14%	6
WW	92%					8%		8
WoC	84%					16%		13
TW	85%	4%				11%		11
TE	76%	8%			11%	5%		11
OTF	58%				42%			9
Creek	75%		18%		2%	5%		10
Pounamu	71%	8%	21%					9
Dune	31%	10%	48%		12%			10
Cliff	31%	7%	60%		1%			9
Cape	48%		52%					5
Mairangi	63%	10%	12%		15%			10
Woolshed	95%				5%			7
Rock	36%		57%		7%			7
Island	71%		29%					5
Mean	64%	10%	37%	48%	12%	9%	14%	130