CHAPTER EIGHT

SILVER GULL EGG OILING TRIAL

8.1 Introduction

Human activities have allowed populations of many avian species to become over-abundant throughout coastal and urban areas of the world. This has been attributed to these species ability to adapt to anthropogenically created habitats and food sources (Belant, 1997) and include sites such as landfill, rooftops, airfields, golf courses, agricultural fields (Blackwell *et al.,* 2000), fisheries discards (Garthe *et al*., 1996; Oro *et al*., 1996) and aquaculture farms (Price & Nickum, 1995; Glahn *et al*., 1999). Avian species involved include both native and introduced species of gulls, waterbirds and terrestrial birds (Smith, 1995; Christens *et al.,* 1995; Belant, 1997; DAFF, 1997; Glahn *et al.,* 1999; Martin & Dawes, 2005).

These avian populations sometimes conflict with human activities and have engendered a range of problems which include bird strikes to aircraft, transmission of disease to both humans and animals, detrimental ecological impacts (to other species, changing vegetation etc.), economic costs to agriculture, aquaculture and building owners, and general nuisance issues (See Chapter 1 for a full discussion).

Like many coastal towns and cities in Australia, the population of Silver Gulls in Port Lincoln has increased substantially from 3,500 nesting pairs in 1999 (Farlam, unpublished data) to as high as 27,800 in 2005. These gulls breed on offshore islands amongst the low to medium level vegetation (See Chapter 2.4.1 for a full description of the breeding colonies) with the main colony usually found on Rabbit Island. This population has caused economic, ecological and nuisance problems, however, unlike most situations where inflated populations of gulls rely heavily on human refuse, this population is reliant on the Southern Bluefin Tuna Industry as a major food source for a majority of the year.

Several tools are available for management of pest populations of gulls, however, few are effective in the long term as many species can modify their behaviour to adapt to anthropogenic factors. As Silver Gulls are opportunistic breeders and have become accustomed to human disturbance, they can readily rebuild nests, re-lay eggs and recruit to new colonies if need be (Smith, 1995).

Past management practices for over-abundant bird species have included culling chicks or adult birds (Caithness, 1968; Baxter, 2003), modifying habitat to prevent hatching (Skira & Wapstra, 1990), nest and egg disturbance and/or removal (Skira & Wapstra, 1990; Ickes *et al*., 1998), relocation of pest birds (Temby, 2004), fecundity control through the use of hormone (Bomford, 1990), and egg addling (shaking, pricking and oiling) (Smith & Carlile, 1993; Christens *et al*., 1995; Shaw, 1999). Previous control measures for Silver Gull populations in Australia have included culling of adults using alpha chloralose (a central nervous system depressant), such as at Lake Eyre in 2000 (Baxter, 2003), and in Tasmania (Skira & Wapstra, 1990). In the correct dosage, alpha chloralose induces hypothermia and death in birds (Caithness, 1968; Baxter, 2003). It is best distributed through laced butter which is placed on bread and fed to incubating birds just before sunset as this poison works best at extremes of temperature (Baxter, 2003). Approximately 100mg of alpha chloralose is sufficient to kill a single adult Silver Gull (Baxter, 2003). As Silver Gulls are aggressive scavengers they have been shown to eat the bread before any other species get the chance to (Baxter, 2003). However, care must be taken when aggressive species such as ravens, crows and Pacific Gulls are around as they will compete with the Silver Gulls for the bread and could be poisoned. Egg pricking has also been used as a control measure and was trialled in Port Lincoln in 1999 (Farlam, unpublished data). This method involves pricking a hole through the end of the egg with a heavy gauge needle and placing it back in the nest (Smith & Carlile, 1993). This method has been shown to reduce survival of eggs to "approximately zero", however, it is not an effective means of extending the incubation period of sitting adults (Smith & Carlile, 1993).

For the Port Lincoln gulls, culling of adult birds during the breeding season was not deemed to be ethical as they were possibly leaving behind chicks that would starve to death. As the birds breed for nearly 10 months of the year, egg pricking was not an option as Silver Gulls have been shown to roll pricked eggs out of the nest seven days after treatment (Smith & Carlile, 1993; Shaw, 1999), they are capable of replacing a lost clutch within 12 days (Smith, 1995) and can lay up to four replacement clutches per season (Higgins & Davies, 1996).

Egg oiling, which involves the application of various oils (mineral and vegetable) to eggs during nesting, has been used successfully to significantly decrease hatching success (Pochop *et al.,* 1998[a]; Johnson *et al.,* 2000; Martin & Dawes, 2005; Martin *et al.,* 2007). The oil blocks the pores in the egg shell, preventing gas exchange and the embryo asphyxiates (Blokpeal & Hamilton, 1989). It is relatively cheap and is less labour intensive than nest destruction and egg shaking (Christens *et al.,* 1995). In addition, as the egg is not handled or damaged in anyway, the contents do not generally leak out as occurs in egg pricking (Smith & Carlile, 1993) and the parents cannot tell the egg is unviable and continue to incubate (Christens *et al.,* 1995; Martin *et al.,* 2007). This method has been used successfully on a number of species both overseas and in Australia. It is not only effective in reducing hatching success in problem birds, but it also has the added advantage of encouraging further incubation of unviable eggs. It is for these reasons that this method was chosen to be used on the Port Lincoln Silver Gulls.

Success has been observed in laboratory experiments using mineral oils (Christens *et al.,* 1995; Pochop *et al.,* 1998[a]), food grade vegetable oils such as corn oil (Pochop *et al.,* 1998[a]; Johnson *et al.,* 2000; Martin & Dawes, 2005) and canola oil (Martin & Dawes, 2005; Martin *et al.,* 2007) as well as dormant oil (an insecticide) and sodium silicate on chicken eggs (Morris & Siderius, 1990). However due to the toxicity of dormant oil and the increased preening behaviour caused by sodium silicate, they should not be used in field studies (Morris & Siderius, 1990).

When chicken eggs were wiped with white mineral oil during incubation, hatchability was reduced to 52.1% when oiled in early incubation (4 days) and reduced down to 4.4% when oiled in late incubation (17 days) (Blokpeal & Hamilton, 1989). However, when the oil was sprayed on it became more effective and reduced hatchability to 0%, with the timing of oiling having no effect (Morris & Siderius, 1990). Corn oil was tested with several other vegetable oils and was 100% effective whilst being the most cost effective treatment (Pochop *et al.,* 1998[a]).

Egg oiling field studies have also been undertaken on Herring Gulls (Blackwell *et* *al.,* 2000), Ring-billed Gulls (Blokpeal & Hamilton, 1989; Morris & Siderius, 1990; Pochop *et al.,* 1998[b]), Canada Geese (Christens *et al.,* 1995), Double-breasted Cormorants (Johnson *et al.,* 2000) and Australian White Ibis (Martin & Dawes, 2005; Martin *et al.,* 2007) where the oil was sprayed onto the eggs at different times of incubation. White mineral oil was used on Ring-billed Gulls (Blokpeal & Hamilton, 1989; Morris & Siderius, 1990) and Canada Geese (Christens *et al.,* 1995) with 100% effectiveness no matter whether done early or late in incubation. Morris and Siderius (1990), treated some eggs twice (7-14 days apart), but effectiveness was the same. When white mineral oil was compared to corn oil in another study on Ring-billed Gulls, it was 96% effective compared to the corn oil which was 99% effective (Pochop *et al.,* 1998[b]). However, both oiling treatments were more effective if done later in incubation. Corn oil has been shown to be effective in preventing hatching in Herring Gulls, but was more effective when done later in incubation (80% early incubation to 99% late incubation) (Blackwell *et al.,* 2000). It has also been shown to be 100% effective for Double-breasted Cormorants (Johnson *et al.,* 2000) with the eggs treated 3 times. Both corn and canola oil (separately) have been tested on the eggs of Australian White Ibis, with one study suggesting they were 100% effective in preventing hatching when sprayed weekly (approximately 3 times) (Martin & Dawes, 2005), whilst another found that canola oil was 100% effective in laboratory studies and more than 98% effective in field studies when applied weekly or once at any stage of incubation (Martin *et al.,* 2007). A Wildlife Service Technical Note (APHIS, 2001) on the use of corn oil in America suggests that the oil be sprayed with a pressurized back pack sprayer, and about 2ml/egg of oil applied to gull eggs (7ml/egg for goose eggs), between the fifth day after laying and at least five days before EHD. Colonial nesting species such as gulls may have to be treated at 10 day intervals to assure complete coverage of all eggs as laying may not be synchronous within the colony.

As oiling is non destructive it encourages further incubation of unviable eggs however, oiling has contributed to early clutch loss in a few studies including Canada Geese where around 45% of nests were abandoned before estimated hatching date (EHD) (with less and more abandonment in early and late oiling treatments respectively) (Christens *et al.,* 1995), and 29-38% (early and late) abandonment in Herring Gulls (Blackwell *et al.,* 2000). However, in both of these studies over 50% of the oiled nests were incubated 1-40 days beyond EHD, with an average of 13.7 days after EHD for the Canada Geese (Christens *et al.,* 1995) and 14.1 days after EHD in the Herring Gull (Blackwell *et al.,* 2000). Some nest abandonment also occurred in Australian White Ibis, although 30% of nests were incubated on average 13 days beyond EHD, with some up to 54 days longer (Martin *et al.,* 2007). Egg oiling has been shown to alter the behaviour of nesting gulls with a higher rate of preening, changing of incubation partner and adjusting nesting material when compared to non oiled nests (Blackwell *et al.,* 2000), which may contribute to early detection and abandonment. In addition, some oils may take longer to dry than others which may influence detection by parent birds (Pochop *et al.,* 1998[a]; Blackwell *et al.,* 2000). In contrast, other studies have reported that oiling eggs does not cause early abandonment, with nearly all birds of oiled nests incubating beyond EHD, up to 50% longer in some cases (Martin & Dawes, 2005), and in all the literature cited in these cases, no re-nesting was observed. This is important for this research as Silver Gulls may re-lay within one of two time periods: either shortly after clutch loss (two weeks) or up to 76 days after the initial attempt (Dunlop, 1986). Therefore, the longer the gulls can be made to incubate, the less chance there is of re-laying, which also reduces recruitment as the nesting territory remains occupied. Additionally, the longer they incubate, the more chance there is of the testes and ovaries undergoing recrudescence (Smith & Carlile, 1993; Smith 1995).

The primary aim of this chapter was to document and investigate the efficacy of egg oiling as a potential control measure for this Port Lincoln Silver Gull population. While egg oiling does not deal directly with the problem birds, it can reduce the numbers for the next generation. Although Silver Gulls are recognized as a pest species almost Australia wide, this is the first formal documented trial of this kind to use egg oiling on this species.

Aims

The aims of this trial were to answer the following questions.

- Does egg oiling reduce hatchability of Silver Gull eggs?
- Does egg oiling encourage incubation of clutches beyond estimated hatching date (EHD)?
- What is the fate of oiled eggs?
- Do the parents of oiled clutches re-lay (within 2 weeks)?
- Is there any difference any of the above measures for clutches treated once and clutches treated twice?

Hypotheses

H0: Egg oiling will have no impact on the hatching success of Silver Gull eggs.

HA: Egg oiling will change the hatching success of Silver Gull eggs.

H0: Treating the eggs once or twice with oil will produce the same results.

HA: Treating the eggs once or twice with oil will produce the different results.

H0: Egg oiling will have no impact on early clutch loss or relaying rate.

HA: There will be a change in early clutch loss and relaying rate for treatment (oiled) eggs in comparison to those that had eggs assigned the control treatment (no treatment).

H0: Egg oiling will not alter the period parent gulls incubate eggs.

HA: There will be a change in incubation period for treatment vs. control eggs.

Declaration: The work reported in this chapter was carried out in collaboration with DEH, TBOASA and SBT Industry members under a DEH scientific permit. All parties took part in identifying nests and spraying of oil. All of the results reported were gathered and analysed by myself.

8.2 Methods

8.2.1 Study Area

The egg oiling trial was undertaken on Louth Island and Rabbit Island (Figure 8.1) during the 2006 breeding season. Refer to Chapter 2.4.1 for a description of Louth and Rabbit Island. Silver Gulls have been breeding on Rabbit Island since about 1982 (Farlam, unpublished data) and on Louth Island since 1997 (Schoder, pers. comm.). However, abundance of nesting has increased substantially since the initial breeding seasons. Silver Gulls breed on these islands from approximately January to October and the trial was commenced in July 2006. The trial was undertaken with 103 nests between 19 July and 11 September 2006 on Rabbit Island and with 91 nests on Louth Island between 18 July and 11 September 2006. The nests were checked approximately weekly, depending on weather conditions.

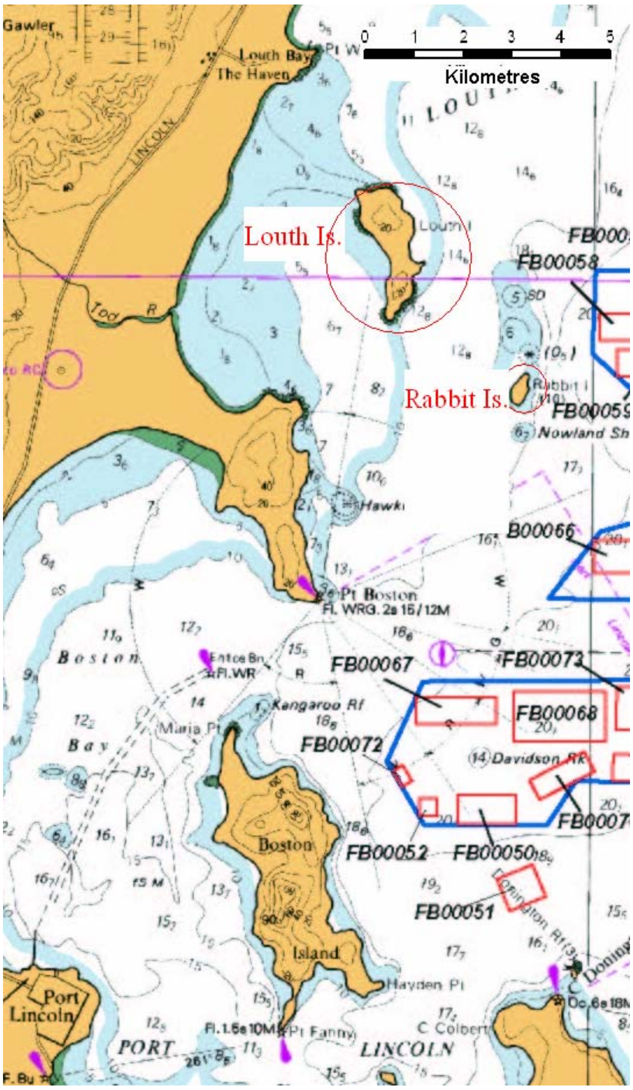

Figure 8.1: A map showing Louth Island and Rabbit Island in relation to Port Lincoln. The red rectangles are tuna leases (2003 chart) (map obtained from PIRSA Aquaculture).

8.2.2 Treatment of Eggs

There were two treatments and a control assigned in this trial. The control nests (C) were untreated and used to assess natural hatching success for each island, and to determine estimated hatching date (EHD). Treatment 1 (T1) eggs were sprayed once while the treatment 2 (T2) eggs were sprayed twice with a week between sprayings. New eggs found in treatment nests on subsequent visits were also treated. Eggs were sprayed with sunflower oil using a 15 litre back pack sprayer which was adjusted to deliver approximately three millilitres of oil per second. Calibration was carried out by spraying the oil into a container that was placed on electronic measuring scales and weighing the amount of oil dispensed in 1-5 second bursts. Each egg in a treatment nest was sprayed for approximately one to two seconds which equated to 3-6 ml of oil per egg. The spray wand tip delivered oil in a fan pattern and was held five to 10 cm away from the egg. The tip was moved so that the oil was distributed over the entire upper surface of the egg. There was no need to move or turn the eggs, as this amount of oil is adequate to completely cover the entire egg through capillary action. After oiling, the eggs had a visibly oily surface or sheen, and the base of the nest also exhibited an oily sheen.

Figure 8.2: Using the back pack sprayer to oil Silver Gull eggs.

8.2.3 Experimental Design

Nest Selection

On the initial visit to Louth Island we started at the south eastern most point of the breeding colony and worked northwards through the colony. Every nest on the island was used in the trial following a sequence of assigning control nest, T1 nest, T2 nest. Each nest was marked with a nest marker which had nest number, treatment and date of initial treatment. New nests found on a second visit were assigned mostly T1 with a few controls as the island owner wanted all nests oiled and inclement weather made us unsure as to whether we could return to the island in exactly a week to oil again as for T2. There were 24 control nests, 45 T1 nests and 22 T2 nests.

On the initial visit to Rabbit Island a section of the breeding colony was randomly chosen by walking through the colony and picking an area. Forty-eight nests were marked and treated in the sequence described above. Inclement weather meant we had to leave the island early, so more nests were assigned in a different area in the same sequence on subsequent visits. There were three sections of the breeding colony used in the trial on Rabbit Island (Figure 8.3) with a total of 26 control nests, 46 T1 nests and 31 T2 nests.

Although new nests were selected on subsequent visits, these nests were still classed as being laid in the same part of the season, as they were laid within one month of each other. Therefore, the results are comparable in terms of timing of breeding attempt.

Any nests that were found containing pipping or hatching eggs were not treated with oil and were excluded from the trial.

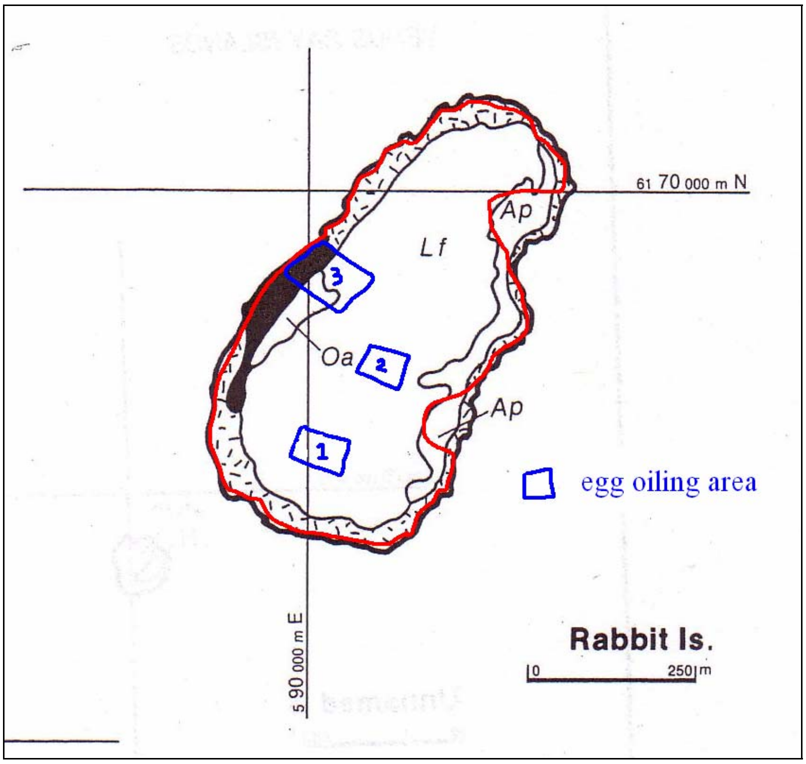

Figure 8.3: The areas used in the egg oiling trial on Rabbit Island (blue rectangles (not to scale)) within the Silver Gull breeding colony (red line outlines the entire colony) (Refer to Table 2.3 for vegetation type (lettering)). (Map from Robinson *et al.,* 1996).

8.2.4 Data Collection

All eggs used in this trial were weighed prior to treatment and their length and width obtained with vernier calipers (Refer to Chapter 2.4.2). Each egg was inscribed with the nest number and egg number which was simply the order in which the egg was selected. Any hatched chicks were weighed with the same scales and banded (as described in Chapter 2.4 and 2.5).

Apart from recording clutch size, egg weight, length and width, each egg/nest used in this experiment also had hatching success, fate of the egg and incubation period and relaying attempts recorded (§Chapter 2.4.2). Nests were assessed weekly. The gulls were assumed to be incubating the eggs if the eggs were still warm and the nest appeared intact. The incubation period for Silver Gulls ranges between 19 to 29 days, with reported means of 24 days (Wheeler & Watson, 1963) and 26.8 days (Smith, 1995). The estimated hatching date was predicted by adding 24 days to the laying of the last egg (if known) or comparing it to other control nests which were close by. Egg laying is highly synchronous within colonies (Wooller & Dunlop, 1979), so we could assume that eggs in surrounding nests would be laid/hatched within 1-2 weeks of each other (personal observation). As most nests had a full clutch when they were first marked, a combination of the two methods was used.

The nests and eggs were monitored for four possible fates:

1. Hatched.
2. Predated. The eggs had holes in them or pieces of egg shell were found in or near the nest.
3. Abandoned. The eggs were abandoned in the nest or removed from the nest by the parent gull. These eggs were identified by being intact but cold and the nests were flattened out and unkempt.
4. Missing. These eggs were probably predated. They were assumed not to have hatched as they did not fit in with the estimated hatching date and based on nearby control nests.

Treatment nests were monitored for two weeks after clutch loss to determine if the gulls re-layed.

8.2.5 Statistical Analysis

Data from both islands were combined for analysis and presentation. See the Appendix for data from individual islands.

Incubation period was expressed in weeks as nests were monitored weekly. They were not monitored frequently enough to obtain exact days for length of incubation.

All data analysis was performed per nest (eggs nested within nest), as per egg would mean that eggs in the same clutch were more likely to have a similar hatching success.

Fishers Exact Tests (2-tailed) were used to

- analyse hatching success for the egg oiling treatment as a whole (no statistical analysis test was necessary to compare hatching success between T1 and T2 as the results were so clear)
- for the comparison of hatching success each treatment (the data were analysed per nest using three categories of hatching success (for eggs within the nest): none hatched, some hatched and all hatched).
- to compare the fate of nests for each treatment.
- to compare the re-laying rate of nests between treatments.

A one sample Chi Square Test was used to analyse the differences in timing of clutch loss for each treatment. Two treatments were compared at a time using this test and so a Bonferroni Adjustment was used on the p-value. Therefore a significant p-value for these tests was $p < 0.017$ (0.05/3).

Although the above analyses do not specifically take into account time intervals between visits to the colony, the colonies were visited frequently enough to determine hatching success of eggs. In addition, the timing of clutch loss and state of the egg (eg. visually predated) also made it possible to determine if an egg/clutch successfully hatched. Therefore, there was no need to run a probability of survival model such as in Program MARK.

8.3 Results

8.3.1 Behaviour of Parent Gulls

Silver Gulls did not seem to be adversely affected by the presence of the researchers. Gulls left their nests as they were approached and soon returned and continued incubation upon our withdrawal.

8.3.2 Hatching Success of Treatment Nests

The hatching success of the control nests (mean = 84.7%) was significantly higher than those in either T1 or T2 (mean = 0%) (Fishers Exact: $p<0.0001$) (Table 8.1). Both treatments were successful in reducing hatching success by 100% as no chicks were hatched from oiled eggs.

Table 8.1: A comparison of hatching success for the three treatments used in the egg oiling trial.

Hatching Success (%) per nest	**Control**	**T1**	**T2**
Mean	84.7%	0%	0%
Standard Deviation	33%	0%	0%
N	49	90	52

As hatching success was 0% for both T1 and T2, no statistical analysis was necessary to compare the two. There was no difference in hatchability of eggs between the two treatments as both were equally successful in eliminating hatching in Silver Gull eggs.

8.3.3 Fate of Unhatched, Oiled Eggs

There was a significant difference in frequency of each fate category for treated eggs (T1 and T2 data combined) (Chi Square: $\chi^2_2 = 57.73$, $p< 0.0001$).

There were significantly more missing/non hatched eggs (80 nests out of 135) than predated eggs (47 nests out of 135) and abandoned eggs (8 nests out of 135) and also significantly more predated eggs than abandoned eggs.

The ratio between predated, missing and abandoned nests was found to be similar for both T1 and T2 nests for the trial (Fishers Exact: p=0.414) (Table 8.2).

Table 8.2: A comparison of the fate of oiled nests for both treatment types.

Fate of Nest for Each Treatment		**Predated**	**Missing** (not hatched)	**Abandoned**
T1 (N=83)	Mean	31.3%	63.9%	4.8%
	N	26	53	4
T2 (N=52)	Mean	40.4%	51.9%	7.7%
	N	21	27	4

8.3.4 Incubation Period and Timing of Clutch Loss

The average incubation period for gulls within each treatment group was very similar (Table 8.3). The majority of control nests were incubated to EHD (4 weeks), however, this pattern was not observed for both treatment groups (Figure 8.4), with more nests lost before EHD and incubated beyond EHD.

Table 8.3: A comparison of the incubation period (weeks) for each treatment.

Incubation Period (weeks)	**Control**	**T1**	**T2**
Mean	4.1	4.3	4.6
Median	4	5	5
Mode	4	5	5
Standard Deviation	0.4	1.4	1.1
Min-Max	3.5-6	2-8	2-7
N	48	91	43

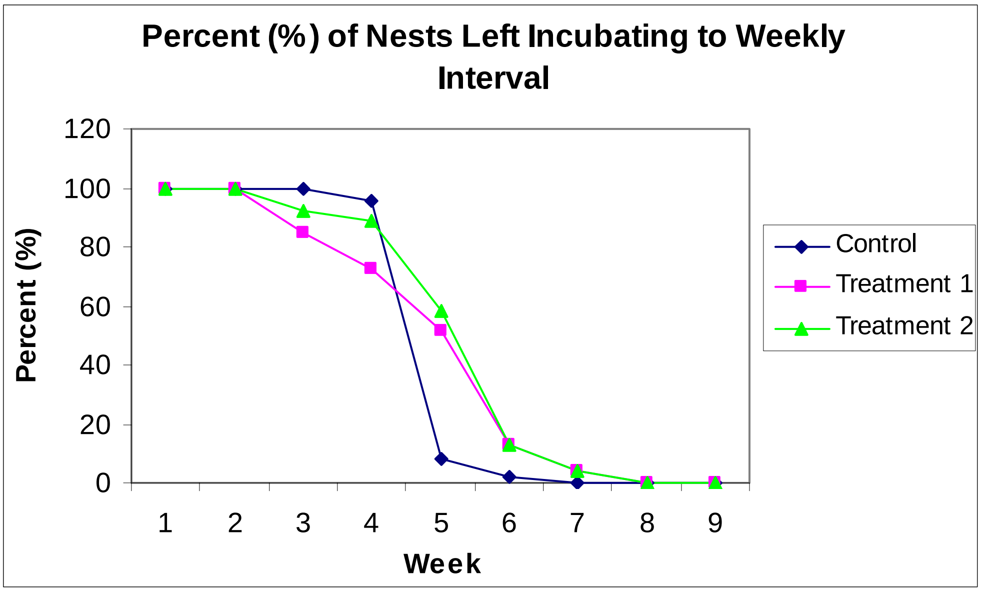

Figure 8.4: Percent of nests incubated to each weekly interval.

There was a significant difference in the proportion of early clutch loss in nests incubated to EHD and eggs incubated beyond EHD for the 3 treatments in this trial (Chi Square: $\chi^2_4 = 56.95$, $p<0.0001$) (Table 8.4).

Table 8.4: The frequency of nests from each treatment that were lost before EHD, incubated to EHD (only), and incubated beyond EHD.

	Nests lost before EHD		**Nest incubated to EHD (4 weeks)**		**Nests incubated beyond EHD**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Control	2 (48)	4.2	39 (48)	81.2	7 (48)	14.6
T1	25 (91)	27.5	19 (91)	20.9	47 (91)	51.6
T2	6 (53)	11.3	15 (53)	28.3	32 (53)	60.4

There was significantly more early clutch loss in the treated nests than the control nests with 27.5% of the T1 nests lost before EHD (Chi Square: $\chi^2_2 = 47.35$, $p<0.0001$) and 11.3% of the T2 nests lost before EHD (Chi Square: $\chi^2_2 = 28.52$, $p<0.0001$). There was no significant difference between the frequency of early clutch loss in T1 and T2 nests (Chi Square: $\chi^2_2 = 5.31$, $p=0.07$) (Table 8.4 and Figure 8.5).

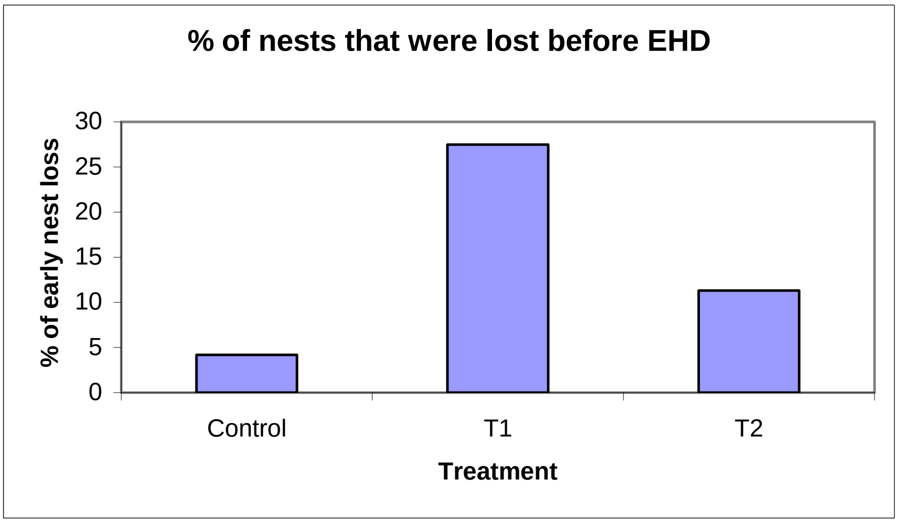

Figure 8.5: Percentage of nests in each treatment that were lost before the estimated hatching date (EHD).

The majority of control nests were incubated to EHD (81.2%), while significantly fewer T1 nests (20.9%) were incubated to EHD only (Chi Square: $\chi^2_2 = 47.35$, $p<0.0001$). There were also significantly fewer T2 nests (28.3%) incubated to EHD than control nests (χ^2 (2) = 28.52, $p<0.0001$). However, there was no significant difference between the frequency of nests incubated to EHD only for T1 and T2 nests ($\chi^2_2 = 5.31$, p=0.07) (Table 8.4 and Figure 8.6).

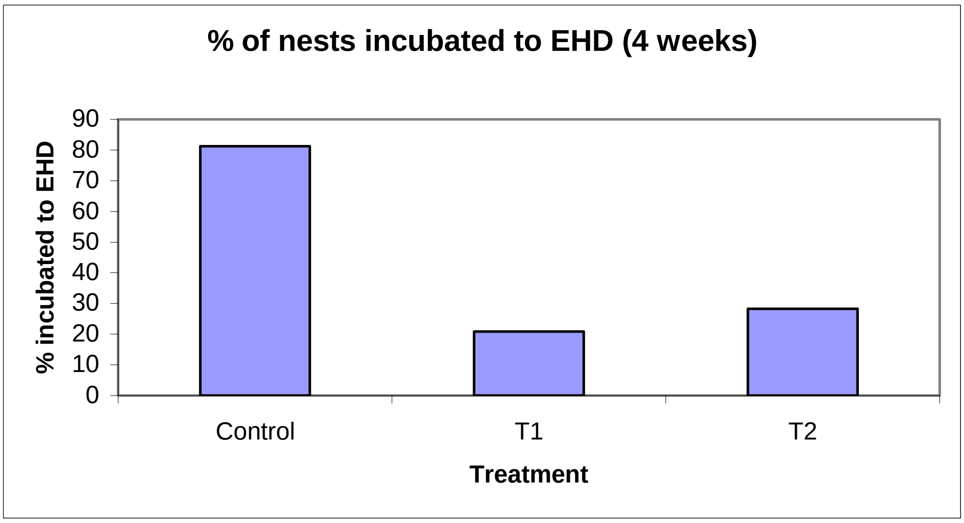

Figure 8.6: Percentage of nests in each treatment that were incubated to the estimated hatching date (EHD) – no longer.

Only 14.6% of nests were incubated beyond EHD, with significantly more T1 nests (51.6%) (Chi Square: $\chi^2_2 = 47.35$, $p<0.0001$) and T2 nests (60.4%) (Chi Square: $\chi^2_2 = 28.52$, $p<0.0001$) incubated beyond EHD than the control nests. However, there was no significant difference between the frequency of nests incubated beyond EHD for the T1 and T2 nests (Chi Square: $\chi^2_2 = 5.31$, $p=0.07$) (Table 8.4 and Figure 8.7).

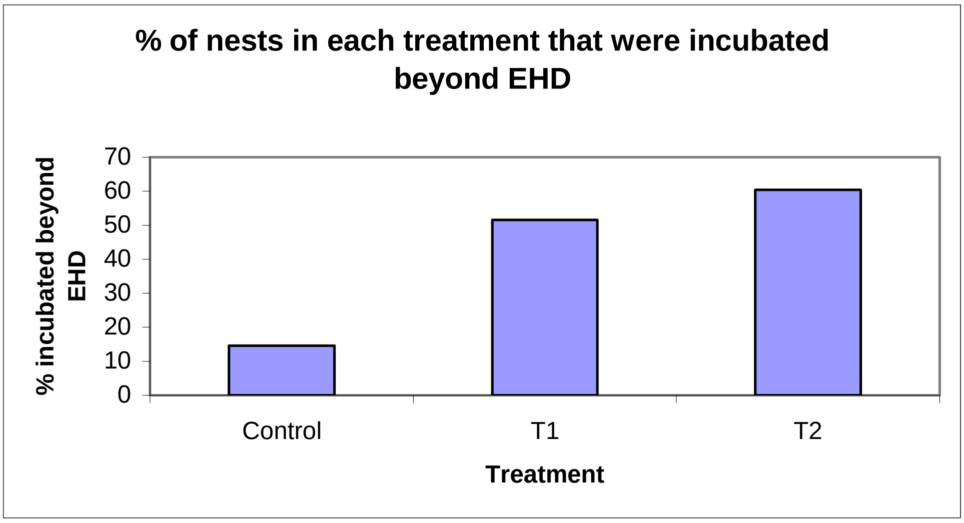

Figure 8.7: Percentage of nests in each treatment that were incubated beyond the estimated hatching date (EHD).

8.3.5 Re-laying Rate

T2 nests seemed to have a slightly higher frequency of re-laying (mean = 9.62%) than T1 nests (mean = 2.41%) although the difference was not significant (p=0.107).

Table 8.5: A comparison of re-laying rate % for gulls with treated nests.

Relaying Rate (%)	**T1**	**T2**
Mean	2.41	9.62
N	(2) 83	(5) 52

8.4 Discussion

The results of this egg oiling trial show that the hatching success of oiled Silver Gull eggs can be reduced to zero. These findings reflect results displayed from much of the literature where egg oiling has been shown to be very successful in reducing hatching success of the eggs. However, these results are far better than some cases which have shown only 80% (Blackwell *et al.,* 2000) and 90% (Blokpeal & Hamilton, 1989; Morris & Siderius, 1990) effectiveness. However, many cases have shown similar success with 96% (Pochop *et al.,* 1998[b]), 98% (Martin *et al.,* 2007), 99% (Blackwell *et al.,* 2000) and the majority of cases exhibiting 100% effectiveness (Christens *et al.,* 1995; Pochop *et al.,* 1998[b]; Johnson *et al.,* 2000; Martin & Dawes, 2005) in reducing hatching success of eggs. These differences in efficacy may be due to some oils being more resistant to weathering than others with factors such as higher viscosity and therefore less gaseous exchange or slightly longer drying times which would mean a longer period of reduced or no gas exchange.

The results also show that the majority of the nesting gulls on treated eggs will incubate the eggs to at least the EHD. Indeed 51.6% of the T1 nests and 60.4% of the T2 nests were incubated beyond the EHD with some nests incubated for up to 8 weeks. These findings are similar to those found for Canada Geese (Christens *et al.,* 1995), Australian White Ibis (Martin & Dawes, 2005; Martin *et al.,* 2007) and Herring Gull (Morris & Siderius, 1990; Blackwell *et al.,* 2000) where these birds incubated an average 13-14 days longer than EHD. Although more than half of the treated nests were incubated beyond EHD, early clutch loss was higher in the treated nests than the control nests with 27.5% for T1 and 11.3% for T2 (4.2% for control). These are better findings than results from oiling trials on Herring Gulls with 29-38%

early clutch loss (Blackwell *et al.,* 2000) and 45% early clutch loss in Canada Geese (Christens *et al.,* 1995). Importantly though, the oiling treatment did not seem to deter the gulls from returning to the nest to incubate. Most observed gulls behaved similarly to those which had nests used in reproductive output data collection in previous years. Although no formal observations were undertaken on the affect of the oil on the behaviour of these gulls, other studies have found that it does cause a slightly higher rate of preening, change of incubation partner and adjusting nesting material when compared to non-oiled nests (Morris & Siderius, 1990; Blackwell *et al.,* 2000). This could possibly have induced the early clutch loss as some parents may be more sensitive to oil than others.

The majority of the clutch loss from treated nests was from missing or predated eggs. Most missing eggs were probably predated, but as the trial was undertaken in late winter and the site was only attended weekly, signs of predation may have been covered by vegetation or sand, or blown or washed away by strong winds or heavy downpours. However, it is known that the missing eggs from treated nests where the clutch was lost early (before EHD) did not hatch any chicks as clutch loss occurred too early for the eggs to have hatched. Those clutches from treated nests that went missing about EHD (20.9% for T1 and 28.3% for T2) were assumed not to have hatched as there were no hatched chicks or any signs of hatched chicks which is unlike what was found for the control nests at this time. Some treated nests had crumpled eggs within them that did look similar to hatched eggs. However, these types of eggs were also found in treated nests with clutches lost before and after EHD. These eggs also did not have the blood membrane on the inside of the shell that successful eggs which hatch chicks exhibit. The inside of the shell was either clean or had rotten yolk attached to it, indicating that the eggs were unviable. Therefore, it can be assumed that the crumpled eggs found in treated nests around EHD did not hatch chicks as the eggs were unviable and no chicks were found which was in contrast to the control nests. There were very few nests that were abandoned. Most eggs were probably predated, however, it is not clear whether this was by the parent birds, neighbours or other predators. There were two control nests on Rabbit Island that had the eggs predated, presumably not by parent birds. There were also nests observed outside of the trial area that had predated eggs within them (personal observation). Therefore, neighbouring Silver Gulls may have been responsible for clutch predation on Rabbit Island as there are no rats, large lizards or snakes on the island. However, some predation could have been due to Pacific Gulls, sea eagles or Ospreys, although their numbers were low on the island and the birds of prey usually predate the adult birds. Predation on Louth Island was also probably due to neighbouring gulls, although Pacific Gulls may have caused some predation, as may have rats as the island is inhabited by humans. Although there are snakes and lizards on Louth Island, they were unlikely to have caused clutch loss as the trial was during winter. Most clutch loss during other egg oiling trials have been due to abandonment or predation (Blokpeal & Hamilton, 1989; Christens & Blokpeal, 1991; Blackwell *et al.,* 2000; Martin *et al.,* 2007). Some predation was due to unknown predators (Blokpeal & Hamilton, 1989; Christens & Blokpeal, 1991), while Blackwell *et al.,* (2000) named crows, raccoons, snakes and snapping turtles as possible predators.

The frequency of re-laying was very low with no re-laying observed in control nests and an average of 2.41% for the T1 nests and 9.62% for the T2 nests (difference not significant). At the cessation of the egg oiling trial on Louth Island, the gulls had completely abandoned their nests, and only a few parents were present on the island with the small proportion of chicks that hatched from control nests and probably a few nests that were missed. Therefore, it is unlikely that any new nests were made on Louth Island after the trial. However, Rabbit Island is a much bigger colony, and on the last day of data collection there were still nests with newly hatched chicks and fledgling stage chicks with their parents on the island. Most of the birds from treated nests did not re-lay within the two week re-laying time period indicated by Dunlop (1986), which was the period of nest observation after clutch loss. However, they may have re-layed after the observations concluded, in the second re-laying period after clutch loss which is up to 76 days (Dunlop, 1986). However, this is unlikely as the breeding season of these gulls ceases in about October. If these gulls did re-lay, it would be unlikely that the chicks would be successfully reared as these gulls would be relying on a lesser quality feed source such as garbage, or having to work harder to forage for fish. It is also known that birds that breed in the latter stages of the breeding season are not as successful as those that breed earlier as they are usually the younger, less experienced breeders (Mills, 1973).

There was no statistically significant difference in efficacy of the two oiling treatments in terms of hatching success, fate of nests, relaying rate, average incubation period, early clutch loss and clutches incubated beyond the EHD. Thus, these results suggest that a single oiling treatment is enough to prevent hatching in Silver Gulls eggs as has been found for Australian White Ibis (Martin *et al.,* 2007), which is contrary to some of the literature (Johnson *et al.,* 2000; Martin & Dawes, 2005). This is an excellent result which suggests that costs and man hours can be reduced. However, these gulls breed for 10 months of the year with three nesting peaks, and eggs present outside of these nesting peaks. Therefore, one treatment would not be adequate to cover all nests or eggs within nests. Therefore, an effective oiling regime would include initiating oiling at the first nesting peak, oiling sections of a colony at regular intervals and only oiling the number of nests necessary for the desired population reduction. Regularly, oiling all eggs present within a nest in a section of the colony would ensure all new nests were sprayed, all eggs in a clutch were oiled and any re-layed eggs were treated. However, due to the sheer number of nests and the large size of the main breeding colony on Rabbit Island it may be necessary to mark nests that have been oiled to prevent re-spraying and to lower costs. However, unless clutch size was recorded for each nest, it would be unclear whether the entire clutch had been oiled as the oil dries within 24-48 hours. Spray paint could be used to spray next to nests that have been oiled, or a dye could be placed in the oil to highlight eggs and nests that have been oiled, although the latter has never been trialled in this context. However, picric acid and methyl blue have been used in gull research to facilitate field recognition of birds (Morris & Siderius, 1990) with the marked plumage being lost after the gulls moult. However, as the population is large and the method is quick and cheap, oiling all eggs sighted every 10 days would be the most effective method.

This treatment could be used to the desired effect so that if a 100% reduction in chick output was required, an attempt could be made to oil all eggs over the whole season (obviously some would be missed) otherwise, a regime that continuously treated the proportion of the population that is required to be reduced could be used. As the gulls continue to incubate unviable eggs, the likelihood of recruitment to the colony is also reduced. However, the effects of this treatment on population size would not be evident until that cohort was to return to the natal colony to breed at around 3 years of age. Therefore, this treatment could take anywhere from 3-10 years to have any noticeable impact on breeding population size, depending on the dynamics of that population (i.e. age, breeding regime). Although, how Silver Gulls would react to a long term egg oiling program is unknown and they may abandon the colony and move further offshore.

This egg oiling method will deal with the next generation of gulls and the problems they would have caused in the future, however, it needs to be undertaken long term and it does not deal with the current over-abundant population, consequently it is not the quick fix that some stakeholders would like. As these gulls are causing problems in the town of Port Lincoln in the off season and causing problems to the tuna industry in the tuna farming season as well and potentially impacting on other bird species, it may be necessary to cull a proportion of the adult population.

The results from this egg oiling trial have indicated that this method could be a highly effective population control measure for regulators, being cheap, quick (to undertake) and ethically palatable. Although the prognosis for a long term solution for this population will include continuing to reduce the availability of anthropogenic feed through the establishment of disturbance regimes at these food sources (tuna farms, dump, fish factories), phasing out SBT feeding regimes that allow the feed to be available to the gulls (and/or only feeding out fish that are too large for the gulls to eat) as well as public education and deterring the pastime of 'feeding the seagulls', the use of this population control measure will ensure the Silver Gull population in Port Lincoln does not continue to rise at the rate it has been.