Spraying corn oil on Mute Swan *Cygnus olor* eggs to prevent hatching

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Abstract

During the 1980s and 1990s, non-native Mute Swans *Cygnus olor* increased dramatically in the Maryland (USA) portion of the Chesapeake Bay. As a method to slow further population growth, we tested the effectiveness of coating eggs in incubation with 100% food-grade corn oil to prevent hatching. During April to June 1996 and 1997, hatching success and nest abandonment was monitored in 26 control and 28 treatment nests. Whereas all full-term control nests hatched at least one egg, with an overall hatching success of 82.8% (111/134 eggs in 22 nests), no eggs in treated nests (0/118 eggs in 19 nests) hatched. Abandonment of oiled nests did not differ from that of controls, nor did abandonment among treated nests differ from controls between those treated early (first half of incubation) or late (last half of incubation). Treated nests carried full term were incubated on average an additional 16 ± 2.63 days (mean ± s.e.) beyond estimated hatching date. These experimental results were applied to a large-scale, integrated control programme initiated by the Maryland Department of Natural Resources (MDNR) aimed at reducing Mute Swan numbers in Maryland. In 2002, a fact sheet about the deleterious effects of Mute Swans and the agency's plan to treat nests was mailed to > 4,000 shoreline property owners who had previously licensed offshore waterfowl hunting blinds. Property owners who had known Mute Swan nests on their lands were contacted to seek multiple year permission to access their property to oil swan eggs. Over a 13-year period (2002–2003, 2005–2014), 1,689 Mute Swan nests containing 9,438 eggs were treated. Egg treatment was especially effective in reducing the number of swans that required culling by preventing an estimated additional *c.* 6,200 Mute Swans from entering the non-breeding population. Egg treatment was combined with the culling of adult swans (2005–2013) as part of the MDNR control programme that resulted in a reduction of the non-native Mute Swan population from *c.* 3,995 in 1999 to *c.* 41 in 2014. Corn oil provides resource managers with an effective, nontoxic method of reducing Mute Swan hatching success. While egg oiling can reduce the production of cygnets, however, merely treating eggs does little to reduce the swan population. If managers desire to reduce a

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Mute Swan population quickly (< 5–10 years), an integrated strategy of treating swan nests and culling swans (*i.e.* reducing annual survival) by humane lethal means should be considered.

Key words: *Cygnus olor*, hatching success, invasive species, oiling, swan control.

A breeding population of Mute Swans *Cygnus olor* originating from the escape of two captive pairs in 1962 increased to > 4,000 birds in the Maryland portion of Chesapeake Bay by 2002 (Reese 1975, 1996; Hindman & Harvey 2004). Population growth and range expansion of this non-native species increased the number of swan-related problems. One of the most serious occurred in the early 1990s when a large moulting flock (*c.* 600) of Mute Swans disrupted nesting by Least Terns *Sterna antillarum* and Black Skimmers *Rynchops niger*, both state-threatened species, on shell bars and beaches in Tar Bay, Dorchester County (Therres & Brinker 2004). Mute Swans also sometimes injure or kill young waterfowl in the Bay (Hindman & Harvey 2004; Therres & Brinker 2004). Because of their foraging upon submerged aquatic vegetation (SAV) like Widgeon Grass *Ruppia maritima* and Eelgrass *Zostera marina* (Perry *et al.* 2004), Mute Swans reduce the availability of SAV to native wildlife (Reese 1996; Allin & Husband 2004; Naylor 2004; Tatu *et al.* 2007). Some breeding Mute Swans are aggressive and will threaten and even attack people and pets that come too close to their nest or young. Although the potential for injury is low, their territorial behaviour sometimes renders riparian waters inaccessible to people during the nesting season (Hindman & Harvey 2004).

In the absence of aggressive population control, the number of Mute Swans in Maryland was expected to continue growing rapidly and eventually could have become established throughout most of the Chesapeake Bay region (MDNR 2003). The MDNR's 2003 plan for managing the State's population of Mute Swans included an objective to reduce recruitment of young by > 60% and reduce the population size to < 500 birds (*i.e.* to mid-1970s levels) (MDNR 2003). In 2011, the MDNR modified its Mute Swan population objective to reduce the population to as few birds as possible to protect Chesapeake Bay living resources (*i.e.* submerged aquatic vegetation, native waterfowl and colonial waterbirds) (MDNR 2011). Thus, effective techniques were needed to reduce Mute Swan hatching success that could be applied in combination with the culling of adult birds to achieve the agency's management objective.

Several oils, including liquid paraffin (Baker *et al.* 1993), vegetable oil and mineral oil are effective at reducing hatching success of bird eggs (Pochop *et al.* 1998). Of these, only corn oil is considered non-toxic to the environment and thus is exempt from U.S. Environmental Protection Agency (EPA) regulations and is the only oil that may be used to treat eggs of free-ranging waterfowl without a Federal Experimental Use Permit. Guidelines for oiling eggs of over-abundant or injurious avian species such as temperate breeding Canada Geese *Branta canadensis*

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(Smith *et al.* 1999) and Double-crested Cormorants *Phalacrocorax auritus* (Johnson *et al.* 2000; U.S. Department of Agriculture 2001) have recommended the use of corn oil.

A critical assumption of any egg-treatment programme is that the treatment technique does not cause incubating females to abandon the nest and provide opportunity for re-nesting. This assumption has been tested for temperate-breeding Canada Geese (Baker *et al.* 1993), but has not been established for Mute Swans, a species that will re-nest (Reese 1975, 1996) and for which widespread control, including egg treatment, has been advocated (Atlantic Flyway Council 2003; Mississippi Flyway Council 2012). Mute Swan eggs are larger with a thicker shell and possibly a different shell conductance and pore structure than the eggs of Canada Geese and other birds that have been used to test hatching success after treating with oils. In this study we therefore tested the effectiveness of spraying corn oil on Mute Swan eggs to reduce hatching success and monitor the rate of nest abandonment for free-ranging Mute Swans in Chesapeake Bay. The findings were applied to a large-scale control programme, which from 2005–2014 included a combination of reducing swan hatching success (treating eggs with oil) and adult survival (culling adult swans) to reduce the Mute Swan population in the Maryland portion of Chesapeake Bay.

Methods

This study was conducted in the brackish estuarine wetlands of Kent, Queen Annes, Talbot and Dorchester counties along the eastern shore of Chesapeake Bay, Maryland, USA (between 39°N and 38°N, 76°W). The study area supported about 70% of the State's Mute Swans that were distributed as large non-breeding flocks, located generally wherever SAV is abundant, and as breeding pairs within nesting territories. Mute Swan nests occurred in estuarine bay marshes dominated by Smooth Cordgrass *Spartina alternaflora* and Saltmeadow Cordgrass *S. patens* marshes and Common Reed *Phragmites australis* stands about 0.5 m above the high tide mark. Salinity was high (> 15 ppm) and tidal amplitude ranged from 21–24 cm.

This study was conducted over two breeding seasons from 29 April to 20 June 1996 and 14 April to 18 June 1997. Swan nests were spotted from fixed-wing aircraft from a survey altitude of 90–152 m and later visited either on foot or by boat. Each nest location was marked on maps (scale 2.54 cm = 2,000 m) and assigned randomly to either a control or treatment group. Three eggs from each nest were floated to estimate the stage of embryo development using the techniques described by Westerkov (1950) and Walter & Rusch (1997), and their incubation stage adjusted for a 36-day incubation period (*i.e.* full-term incubation for Mute Swans; Scott & The Wildfowl Trust 1972; Reese 1975; Ciaranca *et al.* 1997). The estimated hatching date (EHD) for each clutch was thus calculated by adding 36 days to the estimated date of clutch completion and clutches were then classed as being at the early (18–36 days before EHD) or late incubation stage (1–17 days before EHD).

Eggs in treatment nests were addled (*i.e.* embryo development curtailed) by coating

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with 100% food-grade corn oil. Oil was applied with a one-litre, hand-held spray bottle with an adjustable nozzle. Eggs were removed from the nest, and thoroughly spray coated with *c.* 60–100 ml of oil at a distance of *c.* 12 cm. Eggs in treatment nests that were wet from floating were wiped dry prior to oiling. Eggs in control nests were floated, wiped dry and returned to the nest. All eggs in treated and control nests were visually monitored every 1–4 days until nest termination to determine the fate of nests and eggs, *i.e.* whether the eggs were hatched, unhatched, predated or abandoned. For nests that terminated without hatching, we searched for signs of re-nesting within 300 m of the original nest site for a period of 30 days following abandonment. In Chesapeake Bay, Reese (1980) reported that re-nesting ranged from 11–30 days and averaged 18 days after loss of the first clutch.

To test whether there was an increase in pre-EHD nest abandonment for oil-treated versus untreated nests, we performed a chi-square test of proportions. A chi-square test was also used to compare pre-EHD nest abandonment between nests treated early and late in incubation (Snedecor & Cochran 1967). Differences in clutch size between years and between control and treated nests were tested by a 2-sample *t*-test at $\alpha = 0.05$.

Beginning in April 2002, the MDNR applied test results of treating Mute Swan eggs with corn oil to a large-scale, integrated control programme aimed at reducing the Mute Swan population in Maryland. The objective was to treat > 60% of the Mute Swan nests in the State (MDNR 2003). In March 2002, the MDNR sent a fact sheet to > 4,000 shoreline property owners who had previously licensed waterfowl hunting blinds offshore of their property. The fact sheet contained information about the deleterious effects of Mute Swans and the agency's plans to oil the eggs in Mute Swan nests. Property owners who had known Mute Swan nests on their properties were also contacted by the MDNR to seek multiple year permission to access their property for the purpose of oiling swan eggs.

Swan nests were located by aerial surveys in mid-April in 2002 through 2014. Following the aerial surveys, swan nests observed from the air were visited either by boat or on foot and all eggs were treated with corn oil. Nearly all (*c.* 98%) property owners with Mute Swan nests on their lands allowed nests to be treated (L. Hindman, unpubl. data). No nests were treated in 2004 as a U.S. District Court order prevented the U.S. Fish and Wildlife Service from issuing the MDNR, the required federal depredation permit (McGhee 2004). The following year the resolution of legal actions and the adoption of federal legislation (*i.e.* Migratory Bird Treaty Reform Act of 2004) resulted in regulatory authority for Mute Swans being returned to the U.S. states. Thus, beginning on 28 July 2005, the MDNR initiated its integrated swan control programme of combining egg oiling with the culling of adult swans by ethical lethal methods (American Veterinary Medical Association 2000, 2007). Lethal methods to reduce the Maryland Mute Swan population involved euthanasia by shooting and by mechanical cervical dislocation using an emasculatome.

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Using vital rates of 1,689 nests treated × 6.07 (mean clutch size) × 82.8% (mean hatching success) × 88% (survival to fledgling; Reese 1975) × 83% (post fledging survival rate; Reese 1996) for Mute Swans, we calculated the number of swans that would have entered the non-breeding population that would have required culling if the MDNR had not undertaken a large-scale egg oiling effort. The calculations assumed no emigration or immigration of swans into the population, which we believe to be the case.

Results

We monitored 26 nests (11 control and 15 treated) in 1996 and 28 nests (15 control and 13 treated) in 1997. Mean clutch size did not differ between years (1996: mean ± s.e = 5.5 ± 0.43 eggs; 1997: 6.5 ± 0.43 eggs; t_{52} = 1.59, n.s.) and overall averaged 6.0 eggs (s.e. = 0.31; *n* = 54). Clutch size for both years combined did not vary between control (mean = 6.1 ± 0.44 eggs, *n* = 26) and treated nests (mean = 6.0 ± 0.43 eggs, *n* = 28) (t_{52} = 0.12, n.s.). Nest data from both years was combined for statistical analysis.

All control nests that reached EHD (*n* = 21) hatched at least one egg and overall 82.8% or 111 of 134 eggs hatched. In contrast, no eggs (0/118) in oil-treated nests that reached EHD (*n* = 19) hatched regardless of whether they were treated early (*n* = 5) or late (*n* = 14).

A similar proportion of control and treated nests reached EHD (control: 21 of 26 nests; treatment: 19 of 28 nests) (χ^2_1 = 1.17, n.s.). Furthermore, although samples were small, a similar proportion of control and treated nests reached EHD for both early-treated (control: 7 of 10 nests; treatment: 5 of 10 nests) (χ^2_1 = 0.83, n.s.) or late-treated (control: 14 of 16 nests; treatment: 14 of 18 nests) (χ^2_1 = 0.55, n.s.) nests. Nest loss was attributed solely to nest abandonment; there was no evidence that any active nest was predated. Additionally, no new nests were found within a 300 m radius of the original nests. Swans incubating treated clutches that reached EHD continued incubating *c.* 2 weeks (mean = 16.4 ± 2.63 days; range: 1–46 days, *n* = 18) past EHD.

Starting on 8 April 2002, the MDNR applied the test results of treating Mute Swan eggs with corn oil to a large-scale, integrated control programme aimed at reducing the Mute Swan population in Maryland. Over a 13-year period (2002–2003, 2005–2014) the MDNR treated 1,689 Mute Swan nests containing 9,438 eggs (Fig. 1). The number of treated nests per year ranged from 382 in 2005 to 3 in 2013 (Fig. 1). The egg-oiling effort prevented an estimated *c.* 6,200 Mute Swans from entering the non-breeding population. Thus, egg oiling not only reduced annual productivity of the swan population but it also reduced the related manpower, animal welfare concerns and expense that would have been required to cull these additional swans. Legal action (Cucuzella 2004) precluded the use of lethal methods of swan control until the summer of 2005. Between 2005 and 2014, the MDNR combined swan nest treatment with the culling of adult swans (*n* = 5,056) to reduce the Mute Swan population in Maryland from *c.* 3,995 in 1999 to *c.* 41 in 2014 (L. Hindman, unpubl. data).

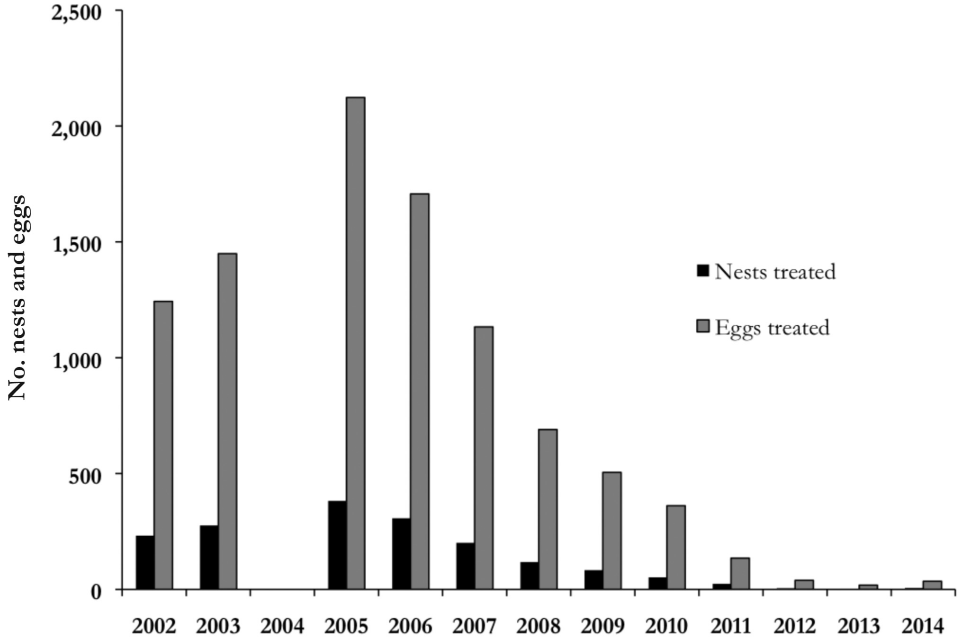

Figure 1. Number of Mute Swan nests and eggs treated with corn oil in Chesapeake Bay, Maryland, USA, during 2002–2003 and 2005–2014. No nests were treated in 2004.

Discussion

Corn oil proved 100% effective in preventing hatching of Mute Swan eggs and was equally as effective early in incubation as it was late in incubation. Although the Humane Society of the United States suggests that egg oiling for overabundant Canada Geese be undertaken during early incubation, the American Veterinarian Medical Association (AVMA) does not provide guidance on the addling of eggs under field circumstances (AVMA 2000, 2007). Nonetheless, there are no federal (U.S.) or Maryland regulations that prohibit the oiling of Mute Swan or other bird eggs for population control at any stage of incubation (U.S. Department of Agriculture 2001). Management agencies, such as the U.S. Department of Agriculture (USDA) Wildlife Services, now commonly use corn oil to reduce hatching success of overabundant bird species and apply the oil without regard to incubation stage, (USDA 2001). Treatment that provides effective control at a wide range of incubation stages reduces manpower and programme costs by eliminating the need for multiple flights and surveys to locate nests at specific stages of incubation. Moreover treating nests did not prompt early abandonment and re-nesting. We conclude that the effectiveness of corn oil displayed in this study would limit any need for nest searches for re-nests. We do not know if swans that abandoned their clutches before EHD re-nested; but if they did, they did not re-nest in the immediate vicinity of the original nests, *i.e.* no new nests were found within a 300 m radius of the original nests. Furthermore, Reese (1996) suggested that Chesapeake Bay Mute Swans lay a second clutch only if the first is lost before 10 May. Because the peak of hatching for Mute Swan eggs in Maryland is the first week in May, most swans incubating oiled eggs would continue incubation well past the threshold for re-nesting identified by Reese (1996), thus further limiting the possibility of re-nesting.

Alternative control measures, such as the removal and disposal of eggs, usually requires more labour than oiling eggs because the swans may re-nest at a high rate. In areas with small discrete breeding populations, egg shaking has been shown to be an inexpensive and effective method of limiting swan reproduction (Eltringham 1966). In Rhode Island (USA), shaking was the most practical method of controlling Mute Swan productivity because no additional tools and materials needed to be carried to the nest (J. Meyers, unpubl. data). However, shaking may not be as effective in inducing embryo mortality late in incubation (Cleary 1994), and if large numbers of eggs are involved may result in physical exhaustion of field personnel (Christens *et al.* 1995), which would also reduce its efficacy.

Pricking swan eggs with a sharp-pointed instrument has also been shown to be a practical method of terminating embryo development (Eltringham 1966; Allin *et al.* 1987). However, if puncture holes are not sealed, decomposition may accelerate and produce egg odour that may contribute to increased mammalian predation and nest abandonment. Pricking needs to be done carefully, because if the female detects that the eggs are damaged she may desert the nest and re-nest and lay another clutch elsewhere (Natural England 2001). Because abandonment in early or mid incubations prompts re-nesting, this method of egg control may simply lead to greater effort to find and treat new nests.

Spraying eggs of Ring-billed Gulls *Larus delawarensis* (Blokpoel & Hamilton 1989; Christens & Blokpoel 1991), Double-crested Cormorants, and Canada Geese (Christens *et al.* 1995) with white mineral oil prevented them from hatching. Coating Mute Swan eggs with penetrating oil, formalin or clear lacquer also prevented hatching (Allin *et al.* 1987). However, mineral oil, other petroleum-based oils and other toxic materials may not be used as an avicide without obtaining either federal registration or a permit from the EPA. In contrast, corn oil (a non-toxic, vegetable by-product) may be applied to incubating eggs of nesting gulls, waterfowl and other birds without a federal registration by virtue of an EPA exemption authorized by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA; Section 25b). However, the appropriate state regulatory agency should be contacted to ensure that corn oil could be used under the FIFRA exemption. Further, government authorization may be required to treat swan eggs as Mute Swans are regulated in most states and provinces in North America.

Egg oiling is widely accepted by the

public as a method of population control for overabundant species, such as resident Canada Geese (Laycock 1982). A telephone survey of 625 Maryland citizens in 2005 revealed that a majority (62%, *n* = 388) supported lethal control of the Mute Swan population at Chesapeake Bay and 63% (*n* = 402) supported egg addling as a population control tool (Hindman & Tjaden 2014). Spraying Mute Swan eggs with corn oil reduces the proportion of nests that successfully produce cygnets (*i.e.* hatching success). This has a direct benefit by reducing the number of swans that must be culled if lethal control is part of an integrated control strategy to reduce a Mute Swan population. Egg oiling also reduces the manpower and expense required to cull additional swans.

While egg oiling can reduce the production of cygnets, however, merely treating eggs does little to reduce the swan population. Egg oiling targets that portion of the population with the greatest natural mortality rate and, thus, has the least effect on population control or reduction (Cooper & Keefe 1997). Ellis & Elphick (2007) determined that management that reduces reproductive rates, without changing survival rates, is unlikely to be an efficient strategy for reducing Mute Swan populations. Similarly in Rhode Island, Mute Swan breeding output was limited by aggressive egg addling; 79% of all active nests were addled between 1979 and 1998 but the population continued to rise by 5–6% per year between 1986 and 1999 (Allin & Husband 2004). In long-lived species, like Mute Swans, population growth is most sensitive to adult survival (Alisauskas *et al.* 2011; Lebreton & Clobert 1991). Thus, reducing hatching success must be combined with reducing adult survival to reduce swan population growth.

Egg oiling is also a labour intensive and time-consuming operation which must be maintained for several years to affect population growth. Model simulations of Maryland's Mute Swan population have shown that it would require reducing hatching success by 80% over a 10-year period to reduce the population by *c.* 10% (Hindman & Harvey 2004).

In most instances, it is impractical to locate and treat enough nests over a multiple year period to reduce the population. Thus, if managers desire to reduce a Mute Swan population quickly (*i.e.* < 5–10 years), an integrated strategy of treating swan nests and culling adult swans (*i.e.* reducing annual survival) by lethal means should be considered. Nevertheless, our findings provide resource managers desiring to control Mute Swan population growth with a safe, nontoxic method of effectively reducing Mute Swan productivity.

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Photograph: Female Mute Swan on her nest at Harris Creek, Chesapeake Bay, Maryland, USA, by Larry Hindman.

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