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Techniques for identifying predators of goose nests

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We used cameras and artificial eggs to identify nest predators of dusky Canada goose *Branta canadensis occidentalis* nests during 1997-2000. Cameras were set up at 195 occupied goose nests and 60 artificial nests. We placed wooden eggs and domestic goose eggs that were emptied and then filled with wax or foam in an additional 263 natural goose nests to identify predators from marks in the artificial eggs. All techniques had limitations, but each correctly identified predators and estimated their relative importance. Nests with cameras had higher rates of abandonment than natural nests, especially during laying. Abandonment rates were reduced by deploying artificial eggs late in laying and reducing time at nests. Predation rates for nests with cameras were slightly lower than for nests without cameras. Wax-filled artificial eggs caused mortality of embryos in natural nests, but were better for identifying predator marks at artificial nests. Use of foam-filled artificial eggs in natural nests was the most cost effective means of monitoring nest predation.

Key words: Alaska, artificial egg, Branta canadensis occidentalis, camera, dusky Canada goose, nest predator

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Nest predation is the principle cause of nest failure for most birds (Martin 1993) and thus, identifying nest predators is important to understanding why nests fail. Approaches to accomplishing this task vary depending on whether the objective is to simply identify predators by species or also to quantify predation. Among the techniques that have been employed to identify nest predators and quantify predation rates are direct observation (Samelius & Alisauskas 2000), artificial nests (Major & Kendal 1996, Hernandez et al. 2001), artificial eggs (Møller 1987, Pasitschniak-Arts & Messier 1995), time-lapse photography (Liebezeit & George 2003), videography (Pietz & Granfors 2000, Stake & Cimprich 2003), and evidence at nests. Photographic monitoring of nests is preferred because identification of predators is conclusive, but this technique has limitations (Cutler & Swann 1999). Use of infrared-triggered cameras or treadle triggers to monitor active nests is often impractical due to the activity of incubating females (Hernandez et al. 1997). Use of time-lapse video cameras avoids many of the problems of other techniques (Thompson et al. 1999, McQuillen & Brewer 2000), but high cost and significant power requirements make them impractical for many field situations and greatly reduces sample size. In waterfowl studies, evidence at nests has been used to identify predators (Campbell 1990, Sargeant et al. 1998, Opermanis et al. 2001), but few investigators have attempted to observe individual waterfowl nests for extended periods (Stickney 1991, Samelius & Alisauskas 2000). Until new technologies provide a cost-effective, unbiased technique for monitoring nests, quantifying the effects of nest predators will continue to be difficult. However, by using a number of current techniques one can reduce the likelihood of misjudging the importance of a nest predator. We describe techniques to identify nest predators of dusky Canada geese *Branta canadensis occidentalis* during 1997-2000. First, we modified a camera system (Danielson et al. 1996) to monitor artificial nests and natural goose nests. Secondly, we used artificial eggs constructed from emptied eggs of domestic geese filled with wax or urethane foam, and also wooden eggs, to identify predators at natural nests. Finally, we used artificial nests to determine the entire suite of potential nest predators on the study area.

Material and methods

Study area

The largest concentration of breeding dusky Canada geese occurs on the Copper River Delta, Alaska. Elevation and hydrologic changes following the 1964 earthquake resulted in large-scale geomorphic and vegetative changes (Crow 1971). Associated with the successional changes in the land cover since the earthquake, predator populations have become more diverse and increased in numbers. Coincidentally, predation rates on dusky Canada geese and their nests have increased while populations on wintering and breeding grounds have declined from about 20,000-25,000 in the late 1970s to about 12,000-14,000 in the 1990s (Bromley & Rothe 2003).

We searched for nests on 13 km^2 of the west Copper River Delta in south-central Alaska (60°N 145°W) in a region used in previous investigations (Bromley 1976, Campbell 1990; C. Trainer, unpubl. data). The area is located in the medium/high nesting-density strata (40-80 nests/km^2), as defined by earlier studies (Bromley 1976; C. Trainer, unpubl. data) and aerial surveys of breeding pairs (W. Butler, J. Crouse, R. Stehn & W. Eldridge, unpubl. data). The study area contains about 6% of the total dusky Canada goose nesting habitat on the Copper River Delta and about 10% of all nests. The study area is representative of the uplifted marsh habitat, which is a dominant landscape on the west Delta (Boggs 2000). It is delimited by large tidal sloughs, which attract large numbers of bald eagles *Haliaeetus leucocephalus* to feed on spawning eulachon *Thaleichthys pacificus* in most years (Bromley 1976; C. Trainer, unpubl. data). As a result of the uplift and subsequent leaching of soils, the sedge-dominated salt marsh that occupied the outer delta in this region has been replaced by fresh-water wetlands with bordering and interspersed stands of sweetgale *Myrica gale*, willow *Salix* spp., and alder *Alnus* spp. (Thilenius 1990). Potential predators of geese and their eggs that inhabit the region are gray wolf *Canis lupus*, red fox *Vulpes vulpes*, coyote *Canis latrans*, mink *Mustela vison*, river otter *Lutra canadensis,* brown bear *Ursus arctos*, bald eagle, northern harrier *Circus cyaneus,* short-eared owl *Asio flammeus,* glaucous-winged gull *Larus glaucescens*, herring gull *Larus argentatus*, mew gull *Larus canus*, parasitic jaeger *Stercorarius parasiticus*, northwestern crow *Corvus caurinus,* common raven *Corvus corax* and magpie *Pica pica* (Bromley & Rothe 2003).

Remotely triggered cameras

A weatherproof, auto-wind camera with an electronic shutter was modified according to Danielson et al. (1996) such that depressing a micro-switch released the camera shutter. Because the camera used by Danielson et al. (1996) was not available, we adapted a newer model with an energy-saving feature that required an additional switch to first activate the camera before a picture could be taken. Because of the presence of brown bears and the

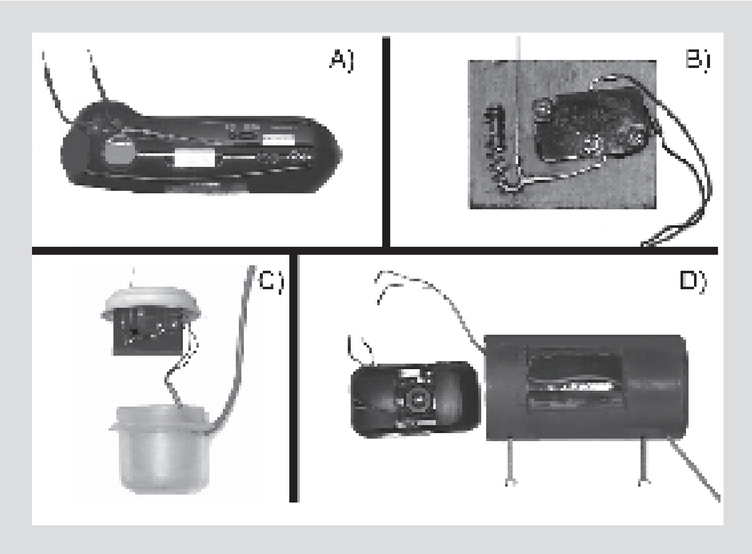

Figure 1. External wiring to electronic shutter release of nest camera (A), micro-switch attached to high-density polyethylene block for triggering camera shutter release (B), micro-switch assembly mounted on lid of polyethylene container with wiring to camera (C), and camera and wiring with weather-resistant housing made of polyvinyl chloride pipe (D).

extreme inclement weather of the area, we built a plastic camera housing that was rugged and water resistant, but small enough so that several units could be carried in a backpack for deployment during nest searching. At the camera we soldered male junctions to the two leads from the shutter-release terminals in the camera and secured them with shrink tubing (Fig. 1A). The free ends of two wires in 4-m long telephone cable that were connected to the micro-switch were similarly adapted with female junctions so that the camera and micro-switch assembly were independent, facilitating replacement of damaged or malfunctioning components in the field. The micro-switch was anchored to a 35 × 45 × 12-mm block of high-density polyethylene with #4 sheet metal screws. A small coil spring was attached to the end of the micro-switch arm so that about 0.5 kg of force was required to activate the micro-switch (see Fig. 1B). To activate the micro-switch a 45-cm length of 6.8-kg test fishing line was tied to the arm of the micro-switch. The polyethylene block with the micro-switch was attached to the lid of a 118-ml polyethylene container with a #8 sheet metal screw (see Fig. 1C). A small hole was drilled in the lid of the container through which the fishing line exited. Cameras were housed in an 8.75 × 17.00-cm, polyvinyl chloride plumbing pipe (one end sealed and an overlapping cover on the other) with an 80 × 55-mm, plexiglass-covered opening on the side (see Fig. 1D). The camera was secured in the housing by a 6.25-mm × 6.87-cm bolt passing through the housing into a threaded mounting-hole (6.25-mm diameter) in its base. A second bolt was attached near the opposite end of the housing, which allowed the camera housing to be mounted on 2 2.5-cm diameter by 45-cm long pieces of electrical conduit that were driven into the ground. A piece of lightweight, camouflaged hide material (30 × 36 cm) was wrapped around the housing and secured with rubber bands when the cameras were deployed in the field. The rubber bands were also used to secure vegetation to the housing for additional camouflage.

When possible, we deployed the camera system 3-4 m south of each nest to optimize field-of-view and lighting conditions. The micro-switch assembly was anchored in the ground beneath a nest in an excavated depression with a 25-cm gutter spike through a hole drilled in the bottom of the polyethylene container. The fishing line tied to the micro-switch was threaded through the nest material with a mechanical pencil used like a large needle and then attached to an egg in the nest. Initially (1997-1998) we glued a loop of the fishing line along the long axis of a goose egg with cyanoacrylic glue. However, because of the excessive time required to prepare and glue eggs that were wet and decreased hatching success of glued eggs, in the last year that cameras were used (1999) we attached the fishing line from the micro-switch to a loop of fishing line that had been embedded in the filler material of an artificial egg. We adjusted the length of the line between the trigger egg and the micro-switch so that when the egg was moved 7-10 cm, the camera was activated and a second pull released the camera shutter. In 1999, we placed cameras only at nests with ≥ 3 eggs to reduce the likelihood of abandonment. All nests were revisited at 10-day intervals to determine their fate.

Artificial eggs

During our study we experimented with three types of artificial eggs: domestic goose eggs emptied of their contents and filled with paraffin:petrolatum (hereafter termed wax eggs), emptied eggs filled with urethane foam (hereafter termed foam eggs), and painted wooden eggs. Domestic goose eggs came from a commercial waterfowl farm with the contents emptied through a single 6-mm hole in the larger end of the egg. The circumference of the eggs along the long axis was 20.3-

21.6 cm, which approximated the size of dusky Canada goose eggs measured at several hundred nests in our study area. The cleaned eggs cost $0.90 each. Paraffin and petrolatum were combined (1:1.3 by weight) by heating the compounds to liquid. We filled the emptied eggs with the liquid compound by using a 6-mm diameter piece of copper tubing connected to a plumbing valve that was soldered to the side of an 8-l metal bucket. The emptied eggs were backlit with a small spotlight during filling to monitor the level of the liquid paraffin: petrolatum mixture and prevent overfilling. A paper clip attached to a 20-cm loop of fishing line was inserted through the hole in the emptied eggs and embedded in the wax as a point of attachment. In 1999, wax eggs were placed in natural nests but the contents, which seeped through the pores of the eggshell contaminating goose eggs, were toxic to embryos so their subsequent use was limited to artificial nests. In 2000, we filled emptied eggs with urethane foam (density = 1.7 kg/m^2) by using syringes containing 5-7 ml each of urethane base and catalyst, which caused the formulation to expand to the full volume of the eggs before hardening. A 20-cm loop of fishing line was also set in the urethane foam. Preliminary experiments indicated commercially available wooden eggs made from pine were too hard to be marked by normal handling of resident predators so we had eggs custom-made from tupelo *Nyssa aquatica* wood at a cost of about $2.50 per egg. Wooden eggs were painted white and fitted with a 20-cm loop of fishing line anchored with a #8 panhead wood screw in the large end of the egg. A filled eggshell and a wooden egg were placed in natural nests and anchored in the nest bowl to a 25-cm long gutter spike with about 7 cm of fishing line each. We identified predators from photographs and marks on the artificial eggs, which were compared to a reference set of skulls, beaks, and claws of species inhabiting the study area.

Locating natural nests

Natural goose nests were located as part of a broad-based study of breeding biology of dusky Canada geese (Grand et al. 2006). To locate nests, we searched the entire study area thoroughly twice each year. We began in early May and searched a second time about three weeks later upon completion of the first search. Nests found on the study area incidental to other activities were also included in analyses. We mapped nests on aerial photos and recorded Universal Transverse Mercator (UTM) coordinates using Precision Lightweight Global-Positioning-System Receivers (PLGR+). No visual markers were used at nests. Nests were revisited at 10-day intervals until termination, and during each visit we recorded the presence of the female, condition and number of eggs, and estimated stage of incubation by candling (Weller 1956).

Artificial nests

In 1999 we used artificial nests with cameras to identify potential predators of natural nests, determine relative importance of nest predators in the study area, and test the effectiveness of our approach to identifying predators. We constructed artificial nests from local vegetation and goose down collected from abandoned nests from another study. Each artificial nest contained a wax egg attached to the camera trigger and two domestic chicken eggs. To increase the probability that nests would be found by predators, locations of artificial nests were selected randomly from 500 sites of nests that had been preyed upon in previous years. We tried to attract predators to artificial nests because our objectives were to identify all egg-eating species in the study area and obtain artificial eggs with marks by known predators. Therefore, about 50 g of fish meal was sprinkled around nests to attract mammalian nest predators (Jones & Raphael 1993, Whelan et al. 1994). To attract avian predators, eggs in half of the artificial nests were not covered with grass or down (Götmark & Åhlund 1984, Vacca & Handel 1988).

Analysis

We compared abandonment and predation rates among natural nests with cameras (195 nests) or artificial eggs (237 nests) and a control group (919 nests) with no predator monitoring devices. Only nests that were active when found were included in these comparisons. Abandonment rates were measured using known-fate models, and differences in predation rates were compared with daily survival rates (DSR) generated by nest-survival models with program MARK (White & Burnham 1999). Nests monitored for predation with cameras or artificial eggs were compared to natural nests found on the same days. Temporal effects were first incorporated into models to explain variability due to year, calendar date and the age at which a nest was found. We then used the temporal model with the lowest (AIC_C) value to look at effects of cameras and eggs. Models included the main effect and those that incorporated interactions with nest age and year. We calculated average effect size and confidence intervals for cameras and artificial eggs with the model with the lowest AIC_C value. We used a logit link to constrain estimates between zero and one, and we used AIC_C to select among our set of candidate models (Burnham & Anderson 1998).

Table 1. Numbers (with proportion in %) of dusky Canada goose nests at which cameras or artificial eggs were deployed, of nests preyed upon, of artificial eggs recovered, and of predators identified from photographs or from marks in artificial eggs during 1997-2000 at Copper River Delta, Alaska.

	Deployed	Preyed upon	Recovered	Predator identified
Natural nests				
Cameras	195	49 (25)	-	18 (9)
Wax-filled eggs	129	106 (82)	58 (45)	44 (34)
Foam-filled eggs	134	30 (22)	24 (18)	14 (10)
Artificial nests				
Cameras	60	60 (100)	---	13 (22)
Wax-filled eggs	60	60 (100)	40 (67)	25 (42)

Table 2. Proportions of dusky Canada goose nests with and without cameras that were abandoned after being found active during laying or incubation in 1997-1999 at Copper River Delta, Alaska. Values are from the model selected using AIC_C, which included an additive effect of cameras on abandonment rates and were calculated for mean values of date, nest age and year.

		Abandoned		
Year	Nesting period	Camera	No camera	Difference
1997	Laying	0.33	0.13	0.20
	Incubation	0.15	0.05	0.10
1998	Laying	0.45	0.21	0.24
	Incubation	0.23	0.09	0.14
1999	Laying	0.12	0.04	0.08
	Incubation	0.05	0.02	0.03

Results

Remotely triggered cameras

We deployed cameras at 44 goose nests in 1997, 100 nests in 1998, and 51 nests in 1999. In 1997 and 1999, we required about 15 minutes to record data and 15 minutes to set up cameras at nests. In 1998, due to excessively wet and cold weather, these tasks required being at nests for up to one hour. Predators destroyed 49 of 195 goose nests that were monitored with cameras in 1997, 1998 and 1999 (Table 1). In 1999, predators destroyed all 60 artificial nests. Bald eagles were photographed at 23 nests, brown bears at four nests, glaucous-winged gulls at two nests, and a coyote and a common raven at one nest each. Only bald eagles and brown bears were photographed at natural nests. Because we used a different camera than Danielson et al. (1996), two pulls of the fishing line were required to take the first picture. Consequently, many predation events were not photographed when predators pulled the fishing line only once. As many as 10 exposures were photographed when a bald eagle preyed upon a nest, but half of the nests at which bald eagles were photographed had only one exposure and all of the other predators were photographed only once at each nest. Incubating geese were photographed as a result of moving eggs at only two nests during all years. The camera housings withstood several attacks by bears and the cameras continued to function. However, in each case the plexiglass window was removed from the housing and the switch mechanism was damaged. Eagles also damaged switch mechanisms and wiring.

Artificial eggs

Wax eggs were placed in 129 natural nests in 1999, and in 2000 134 foam eggs were deployed (see Table 1). In 1999, 52 nests had goose eggs that became addled after the artificial eggs were placed in the nests. Also in 1999, 48 of 129 wax eggs placed in goose nests were completely destroyed or missing. Based on mixture model analysis of evidence from these nests (Anthony et al. 2004), eagles were the most likely predator at 38 nests ($P = 0.99$), bears at two nests ($P = 0.91$), and other predators at eight nests ($P = 0.99$). At 44 of 58 destroyed nests from which wax eggs were recovered in 1999, we were able to identify bald eagles from V-shaped scoring made by beaks and talon marks on eggs recovered (Fig. 2A). In 2000, 30 of 134 goose nests with foam eggs were preyed upon. Only 14 of 24 artificial eggs that were recovered had marks that conclusively identified predators. Bald eagles were identified from talon or beak marks in three wooden eggs (see Fig. 2B) and seven foam-filled eggs. Brown bears were identified by molar marks in three wooden eggs and canine tooth marks in one foam-filled egg (see Fig. 2C).

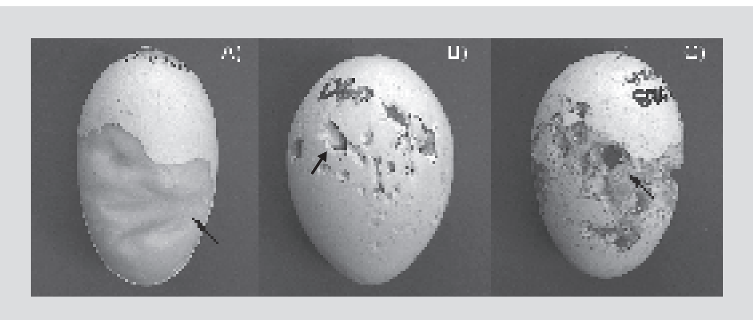

Figure 2. Wax-filled egg (A) recovered from a nest preyed upon by a bald eagle with a V-shaped groove (arrow) from the eagle's beak near the side of the egg. Wooden egg (B) recovered from a nest preyed upon by a bald eagle with a deep V-shaped puncture mark (arrow) that fits an eagle's beak. Urethane foam-filled egg (C) recovered from nest preyed upon by a brown bear. Marks were made by molar and canine teeth (arrow).

Analysis

Because temporal effects were included in models of the effect of cameras and artificial eggs on abandonment and predation rates, estimates of effect size are presented for mean values of date, nest age and year. The best model for explaining abandonment included a camera effect (Table 2). For all years combined, nests with cameras had an abandonment rate of 19% and were 3.1 times more likely to be abandoned than those without cameras. Abandonment rates were higher for nests found during laying than those found during incubation, regardless of whether they were monitored. In 1999 when cameras were deployed later in laying (≥ 3 eggs present), abandonment rates were lower than those in 1997 and 1998 and more similar to nests without cameras (see Table 2). Abandonment of nests without cameras was lowest in 1999. The best model for abandonment rates of nests with artificial eggs compared to natural nests did not include an artificial egg effect. DSR for nests with cameras was 0.0056 greater (CI_{95}: -0.003 to 0.0098,) than for natural nests, which resulted in 11% lower predation estimate for the 35-day laying and incubation period of a 6-egg clutch. DSR for nests with artificial eggs was 0.0016 less (CI_{95}: -0.0046 to 0.0007) than for natural nests, which resulted in 4% higher predation rate for the 35-day life of a nest.

Discussion

Using cameras at artificial and natural nests, we were able to document nest predation on geese by bald eagles, which had been previously overlooked as a nest predator (Anthony et al. 2004). In addition, we obtained artificial eggs damaged by known nest predators that were used in the identification of predators at nests without cameras. The relatively low cost (< $100 for camera and materials) of our camera system allowed monitoring of a large sample of nests, which is important, especially at lower predation rates or when the predator diversity is high. The majority of incubating geese tolerated the presence of a camera near their nest, particularly during incubation and the later stages of laying, and rarely triggered the shutter while rearranging eggs in the nest. However, cameras increased abandonment rates, particularly early in laying, and the problem appeared to be exacerbated under poor weather conditions or when too much time was spent at the nest. Therefore, we recommend that cameras be deployed no earlier than late laying (≥ 3 eggs) and setup time be minimized. The camera housings provided adequate protection from the extreme weather of southeast Alaska and from attacks by brown bears.

Success in photographing predators at natural nests was limited, largely because the camera model that we used had a battery-saver function that required two pulls on the trigger mechanism to activate the camera and then record the first photograph. Therefore, we recommend the use of cameras without battery-saving functions (see York et al. 2001). At artificial nests, a more reliable alternative to using a micro-switch to trigger the camera is a mercury switch imbedded in a foam-filled eggshell (J. Schamber, pers. comm.). The proportion of depredated nests was higher among nests without cameras so the presence of the camera near nests probably influenced the behaviour of predators. The behaviour of coyotes was probably affected by the presence of cameras at nests because they were more wary of anthropogenic objects than other predators that were common in the area. However, it is also likely that some predators (e.g. bears and birds) discovered nests after first detecting the presence of the camera housing due to its novel appearance. Although partial predation was rare in this study, the use of a single egg to trigger the camera shutter greatly reduced the probability of identifying predators that might not destroy the entire clutch (e.g. gulls or common ravens).

Artificial nests often fall short of representing actual nests due to material and methods of construction of nests and eggs (Major 1991, Roper 1992, Haskell 1995, Major & Kendal 1996), which lead to biased responses by nest predators. However, we found artificial nests to be useful in identifying potential predators of nests. In our study, relative frequency of predation by different species was similar, as measured by artificial and natural nests that were monitored with cameras. In addition, predation by those species photographed only at artificial nests was confirmed to occur at natural nests through independent observations in the field.

Artificial eggs in natural nests were the most cost effective technique for identifying nest predators because of low cost of materials and efficiency of deployment. Like other techniques, this approach had limitations and biases. Artificial eggs were often completely destroyed or removed, leaving no evidence for predator identification. Analysis of nests remains indicated that nests with missing artificial eggs were destroyed by common predators (primarily eagles and bears) at a rate relative to their abundance. Only about half of all the artificial eggs recovered from depredated nests had sufficient marks to identify a predator. Eggs filled with paraffin:petrolatum, which recorded marking by predators best, were toxic to goose embryos due to leakage of oil through the pores of the artificial eggs. Therefore, they should not be used in natural nests. Small amounts of oil have been demonstrated to be toxic to embryos of other birds (Hoffman 1978, Blokpoel & Hamilton 1989, Pochop et al. 1998). Eggs filled with polyurethane foam were durable and had no effects on goose eggs, but did not record marks of predators as well as eggs filled with paraffin: petrolatum. Although the eggs that were damaged provided unique evidence for identification of the predators in our study area, we had no measure of the frequency of scavengers damaging artificial eggs following initial destruction of nests. Nonetheless, results from this technique for predator identification were similar to those from photographs at natural and artificial nests and also from remains at depredated nests (Anthony et al. 2004); that is, bald eagles and brown bears were most commonly identified. We suggest a lower proportion of petrolatum (e.g. 1:1.1, paraffin:petrolatum by weight) for artificial eggs that will be used in artificial nests in areas with higher ambient temperatures. The formulation that we used was better suited for artificial nests in regions with cooler temperatures. Finally, in artificial nests we suggest the use of domestic goose eggs filled to about two-thirds of the total volume with the wax mixture and topped with urethane foam (to plug the filler hole and embed the anchor line), which may increase the number of eggs marked by predators and reduce the number of artificial eggs completely destroyed or removed.

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