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Using GPS-enabled decoy turtle eggs to track illegal trade

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The insatiable human appetite for wildlife products drives species to extinction, spreads disease and has negative consequences for the economies of source countries [1,2]. As a major transnational enterprise, illegal wildlife trade is valued between eight and 26.5 billion US dollars annually [3,4]. Because law enforcement is often only reactive, information on trafficking routes is key to disrupting trade and curtailing wildlife crime. In our efforts to uncover trade routes of trafficked sea turtle eggs, we developed and field-tested the InvestEGGator, a 3D-printed decoy turtle egg embedded with a GPS–GSM transmitter (Supplemental information). Illegally collected clutches of turtle eggs containing a decoy transmitter enabled us to track the movements of traffickers, and thus gain a better understanding of illegal trade routes. The decoys, set to emit a signal once an hour, provided five tracks, the most detailed of which identified an entire trade chain, covering 137 km. Using data provided by the decoys, we identified trafficking routes and on two occasions properties of potential interest to law enforcement. Decoys also yielded anecdotal information, furthering our understanding of trafficking routes.

We deployed one decoy per nest in 101 turtle nests on four beaches in Costa Rica, of which 25% were illegally taken (Supplemental information). The decoys tracked eggs from five illegally removed clutches (two green turtle, *Chelonia mydas,* three olive ridley, *Lepidochelys olivacea*; Figure 1). Our shortest track emitted its final signal 28 m from a residential property, while another travelled 2 km to a bar. Our furthest moving decoy travelled 137 km inland identifying a near-complete trade chain; spending two days in transit from beach to a supermarket loading-bay in the Central Valley, it transmitted a final signal from a residential property the following day (Figure 1F). Given that mobile vendors sell eggs door-to-door in Costa Rica, the supermarket was a likely handover point between trafficker and salesperson.

We also received anecdotal data from reports of discovered decoys. For example, one decoy went off-line in a residential area near Cariari, a town 43 km from the deployment beach (Figure 1G). After eleven days we received photographs, sent from Cariari, of the dissected egg.

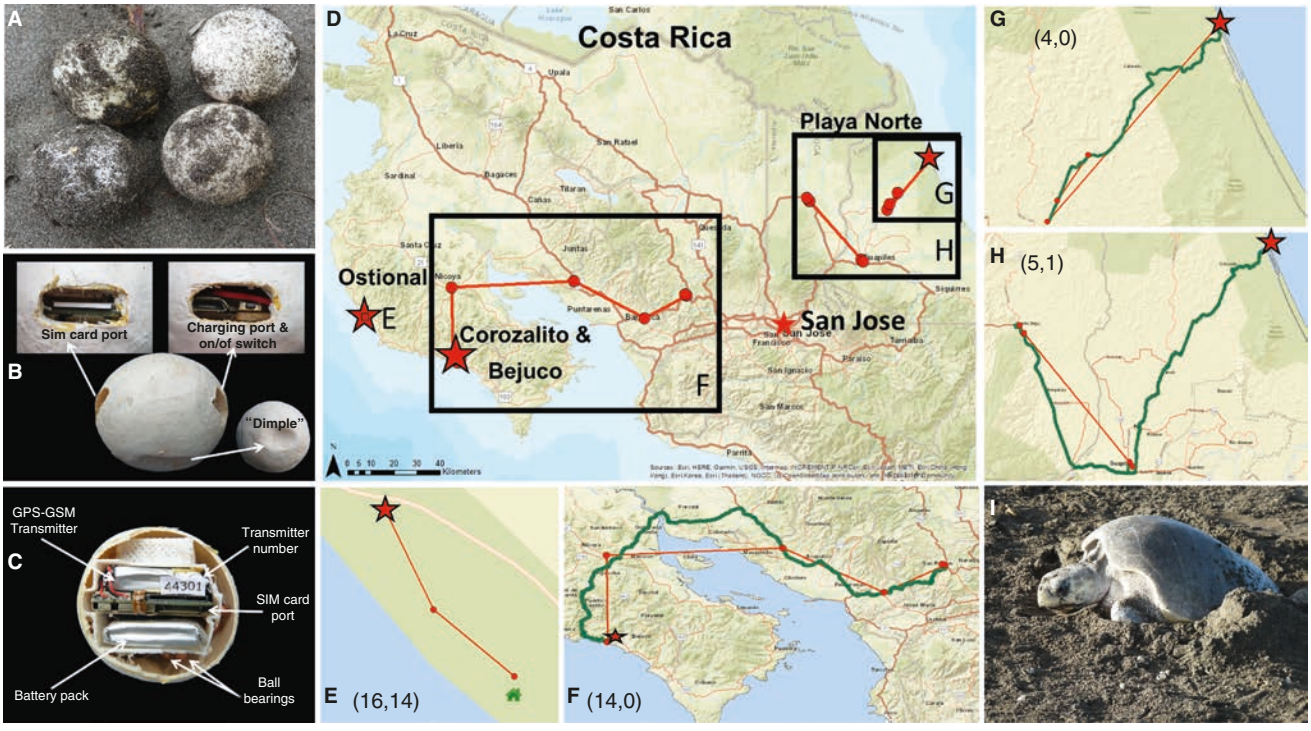

Figure 1. Decoy eggs, data, and estimated routes used by turtle egg traffickers.
(A) Three *Chelonia mydas* eggs and one decoy (bottom left), (B) external (ports are covered prior to deployment) and (C) internal workings of decoy egg, (D) data points provided by four decoy eggs, outlined stars indicate deployment sites, (E) property where decoy signal stopped (green) identified by decoy route (red), (F-H) tracks provided by decoy (red) and likely route taken by traffickers (green), (the fifth track not shown to maintain anonymity of final destination), bracketed numbers represent number of transmissions and repeat transmissions, (I) *Lepidochelys olivacea* during nesting. Map images courtesy of Esri, HERE, Garmin, USGS, Intermap, INCREMENT TR, NR Can, ESRI Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors and the GIS User Community.

Accompanying the photographs was information on the place of purchase near Tortuguero and quantities of eggs exchanged. Thus, our system is already yielding intelligence from the local community in addition to track data from the decoys. However, this willingness to share also highlights the lack of sensitivity surrounding this illegal trade.

Planted decoys do not affect the viability of actual turtle eggs. On the Caribbean coast we triangulated all nests and exhumed the contents at the end of the incubation period. There was no significant difference in hatching success (W = 617, P = 0.105), Stage 1 mortality (W = 455, P = 0.430), mortality due to microorganisms (W = 455, P = 0.482) or presence of deformities (W = 506, P = 0.821) between nests with (n=22) and without (n=44) decoys (Supplemental information).

We did not receive track data from every clutch that was taken. We recovered six decoys on the beach near nests, presumably discovered and discarded by collectors. At three beaches, these discoveries occurred before we received data from subsequent deployments, suggesting multiple egg collectors may be in operation, or that foreign objects in the nest are not perceived as a threat.

We know that some decoys malfunctioned. We estimated the malfunction rate by examining the outcome of 38 nests containing a decoy (13 illegally removed, 25 recovered). Of the 25 recovered decoys, 17 were functional and eight failed, giving an estimated failure rate of 32%. Applying this 32% failure rate to the 13 removed decoys, suggests that five (4.16) would be expected to fail. Of the eleven that did not yield data, we predict that six were functional, but stayed in an area without signal (Supplemental information). We speculate the most likely reason for malfunction, was exposure of the transmitter to moisture that had penetrated the port seals.

In Costa Rica, desecrating a *C. mydas* nest carries a penalty of US$530, and authorities value *L. olivacea* eggs at 600 Costa-Rica-Colóns (₡; US$1.20) each [5,6]. When we consider the additional clutches taken at our study sites on the nights our decoys moved, prosecutions resulting from our study could generate sanctions of US$1,558 to US$2,222. However, prosecutors also consider loss of offspring, ecological and protection costs of nests and recommend fines that reflect this. In 2017, a judge awarded a fine of ₡4,197,428 (US$7,370) for illegally removing 224 *L. olivacea* eggs [6]. This case is now used for recommending penalties.

We have demonstrated it is possible to place a GPS transmitter into a turtle nest and follow a trafficking event from beach to end consumer. A limitation on the Caribbean coast was the low signal reception, but this will improve as infrastructure develops. More importantly, in Costa Rica as in many turtle range countries, it remains extremely difficult to secure convictions for illegal take of wildlife, due to the limited resources available to target traffickers. InvestEGGator eggs therefore have a vital role in documenting trafficking patterns for law enforcement, gather high quality evidence and ultimately disrupt the illegal trade. Decoys are also applicable to other egg-laying reptiles that are under pressure from human egg collectors, such as crocodiles [7,8], and are broadly applicable to other trafficked species, such as birds endangered by egg collectors. Deployment of affordable decoy wildlife products shows great promise as a tool to help curb illegal wildlife trade.

SUPPLEMENTAL INFORMATION

Supplemental Information includes one figure, one table and experimental procedures and can be found with this article online at https://doi.org/10.1016/j.cub.2020.08.065.

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AUTHOR CONTRIBUTIONS

Conceptualization: K.W-G.; Methodology: K.W-G. and H.P.; Software: K.W-G.; Validation: K.W-G.; Formal Analysis: H.P. and R.G.; Investigation: H.P.; Resources: K.W-G., D.R-C. and C.M-B.; Data Curation: H.P.; Writing Original Draft: H.P.: D.R.: D.R-C. and C.M-B.: Writing – Review & Editing: H.P., D.R., R.G. and K.W-G.; Visualisation H.P.; Supervision: D.L.R., R.G. and K W-G.; Project Administration H.P.; Funding Acquisition H.P. and K.W-G.

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