Trade of legal and illegal marine wildlife products in markets: integrating shopping list and survival analysis approaches

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Abstract
Wildlife is an important source of nutrition and income for rural communities. The International wildlife trade of endangered species is regulated by CITES, but domestic wildlife markets are rarely subjected to this degree of scrutiny. Market surveys provide important domestic trade data but suffer limitations. Occupancy modelling, using search effort, can be applied to market surveys. To compare the availability of marine consumables from species threatened with extinction, we undertook market surveys using a ‘shopping list’ of threatened species. Items included turtle eggs and shark products. Turtle eggs from the Ostional Egg Project are sold under a certification scheme, but non-certified eggs are readily available. The surveyors were local residents employed to complete the market survey. The search effort for each item was compared using an adaptation of survival analysis. Time to find each item indicated availability. We tested whether demographics and shopping habits affected surveyors’ ability to find the items. Shark products were found fastest and were, therefore, the most readily available item. Non-certified eggs were found as easily as Ostional certified eggs, implying there are few deterrents to the open sale of non-certified eggs. The shopping habits of surveyors had no effect on their ability to find eggs. Integrating the shopping list with survival analysis can reveal valuable information on demand and supply, which would otherwise be difficult to obtain using traditional surveys.

Introduction
In 2005, the legal transnational wildlife trade, including fisheries and timber, was estimated to be US$332 billion a year (Barber-Meyer, 2009). This figure was derived from import permits regulated by the Convention on International Trade in Endangered Species (CITES), that aims to ensure wildlife trade remains sustainable. However, this type of estimate is much harder to attain in the case of illegal or domestic wildlife trade (Robinson et al., 2015). Due to its clandestine nature, estimating the value of illegal wildlife is difficult, and current approximations sit between US$8–US$21 billion per year (Scheffers et al., 2019). However, domestic trade rarely comes under the scrutiny afforded to cross-border trade, and with this comes a shortfall in trade data. This is particularly the case for countries that are rich in natural resources but lack the capacity to monitor extraction or enforce domestic wildlife laws. As wildlife is an essential source of income and nutrition for rural communities worldwide (Roe et al., 2002; Brooks et al., 2010), understanding domestic markets that exist outside international regulation is crucial.

A common methodology for estimating the impact of domestic wildlife trade is to survey markets. This is considered quicker, cheaper and more practical than attempting to estimate species abundances in areas suffering high hunting pressure (Fa, 2007; Allebone-Webb et al., 2011). However, the secretive nature of the illegal wildlife trade may make it difficult to ascertain the availability of certain products. Methods for conducting market surveys have traditionally involved surveyors searching for items of interest that are openly for sale (Moyle & Conrad, 2014). Sampling markets in this way for animal parts, species of interest, prices and quantities can be used to estimate the total volume of species or individuals traded (Barber-Meyer, 2009). Market surveys are based on assumptions that items of interest are sold openly, the market is the only source of supply and supply is even across time (Noss, 1998). However, traders may conceal sensitive products, for fear of legal repercussions, and
this presents detection issues (false absences). These issues are analogous to those of ecological field surveys and can be addressed using occupancy modelling. Barber-Meyer (2009) analysed Sumatran tiger market survey data in this way, finding occupancy modelling suitably robust, with potential for application at various spatial scales. Another approach is the shopping list method, developed and piloted by Moyle & Conrad (2014). This technique does not aim to quantify the abundance of items in the trade per se, but compares the availability of items on a ‘shopping list’. The order in which shopping list items are found indicates the availability of each item. When buying a product, the customer undergoes two costs; the actual cost of the product, and the time spent finding the item at a price they are willing to pay – the Search Cost or Search Effort (Stigler, 1961). Popular and easily available items have a lower search effort than rarer items. This rationale extends to legal vs illegal items, with illegal items having a higher search effort when law enforcement is an effective deterrent. Search effort is a fundamental element of time-to-detection models used in ecological surveys (Garrard et al., 2008). These models specifically incorporate the probability that a species will go undetected despite being present. Failure-time models adopt a similar approach and focus on the probability of a species going undetected. They are strongly paralleled with survival analysis where the subject (species) is detected. Survival analysis (Bewick et al., 2004) aims to estimate the probability of an event occurring in a given time period, such as a species going undetected. In this context, the event is the detection of a species.

Our aim was to estimate the availability of marine wildlife in food markets in Costa Rica, and to identify opportunities to launder illegal turtle eggs through these markets. Building on the shopping list method, we assumed that availability correlated with search effort – the faster an item could be located, the more readily available it was. We sent surveyors into markets to search for a list of marine consumables. The surveyors recorded the search effort, in minutes, for each item. We used an adaptation of survival analysis to compare the search effort for turtle eggs with other marine consumables, with a view to identifying wildlife laundering. We believe this is the first time survival analysis has been applied in such a way. To test whether the surveyor’s ability to find items was influenced by the surveyor’s themselves, we collected demographic and shopping habit data from the surveyors and compared these with their ability to find the items listed.

Materials and methods

Study sites

Surveys took place in San José, the capital and main transport hub of Costa Rica. Legally extracted turtle eggs from Ostional beach arrive in the city and are distributed within the Central Valley and the Caribbean. We surveyed three sites in San José, the streets around Downtown and two large permanent indoor food markets situated within the Downtown study area: Mercado Central and Mercado Borbón. Mercado Central occupies one block, with additional stalls on the opposite side of the main road. This market has a fresh fish section, as well as bars and canteens that serve turtle eggs. Mercado Borbón is also one block in area and, apart from a few clothes stalls, is almost exclusively made up of fresh food produce and a small number of stalls selling dried medicinal plants and lotions. This market caters to Costa Rican locals and, unlike Mercado Central, is rarely visited by tourists. Mercado Borbón is on the edge of Downtown. Many bars in Downtown San José sell turtle eggs as bar snacks, and mobile vendors, specializing in turtle eggs, sell from cool boxes on the street and to customers in bars. Sporadic street stalls and shops also sell turtle eggs when there is high availability. For these reasons, Downtown San José was chosen as a study area.

Recruitment for surveys

We invited surveyors to participate in a market survey using the shopping list method. To avoid arousing suspicion from vendors, we employed local Costa Ricans as surveyors. As our aim was to assess the availability of items, we chose local residents who were familiar with the study sites, thus insuring they would not waste time searching unfamiliar territory. We advertised through the local unemployment Facebook page Empleos506 and through boosted adverts on Latin American Sea Turtles’ Facebook page. All materials were in Spanish and piloted in advance. Surveyors were paid US$20.

Questionnaire survey

On arrival, surveyors completed a questionnaire on their shopping preferences in relation to marine consumables and their demographic information. We informed surveyors that we were looking for a wide variety of people to complete the survey and there were no right or wrong answers, nor would we look at the questionnaires until after the survey. The first section asked a series of closed questions about their shopping habits in relation to marine consumables, how often they buy products, from where, and what influences their consumer choices, inviting them, where applicable, to tick all responses that apply. Towards the end, we asked about their previous experiences or willingness to eat shark meat and turtle eggs and whether they recognized the Ostional certification scheme logo. Shark is met with some sensitivity in Costa Rica; high-end supermarket Automercado refuses to sell any shark products and, at the time of our study, two marine conservation Non-Governmental Organizations (NGOs) were running widespread billboard campaigns, highlighting the environmental impact of eating shark (HP pers. obs.; Jones et al., 2015). Vendors are legally obliged to label all fish but often use synonyms for shark (Cazón/
Bolillo/Bolillón), possibly due to these sensitivities. We specifically chose to use the word Tiburón shark in our questionnaire to remove any ambiguity. We asked for gender, age, education level, occupation, number of people in their household and years lived in San José.

Shopping list

The market survey required surveyors to visit study sites and record the time it took them to find six marine consumables. Desk-based research, informal interviews with marine conservation NGOs and time spent living in the country (HP pers. obs.), followed by a pilot of San José Central Market helped generate the shopping list. We chose sensitive marine consumables with varying degrees of threat or difficulty in identifying species of origin. The items were: sea turtle eggs in packaging bearing the certification scheme logo (certified), sea turtle eggs sold outside certified packaging (non-certified), shark steak, shark fillet, and shark liver oil and lobster – whole or parts.

Ostional, located on the Pacific coast of Costa Rica c.280 km west of San Jose, hosts one of the most globally important nesting rookeries for olive ridley Lepidochelys olivacea turtles. Synchronized mass nesting events, or arribadas, occur most months in Ostional and may comprise of up to 100,000 female turtles simultaneously depositing eggs (Valverde et al., 2012). Arribadas occur over the course of several days, and high volumes of early nests are destroyed by subsequent turtles digging nests. The Ostional community association, ADIO (Ostional Integral Development Association), is permitted to extract these doomed eggs and sell them nationally under a certification scheme. Eggs are sold in heat-sealed bags in denominations of ten eggs, bearing the ADIO logo and date of the most recent arribada. Government ministries issue permits to transport and sell Ostional eggs. ADIO sell to middlemen who trade directly to the public or to other vendors (pers. obs.). This is the only source of legal turtle eggs in the country (Campbell, 1998). During the study period, 245,000 certified eggs arrived for sale in San Jose Province (Lobo-Glez, 2017). However, despite this legal trade, the illegal extraction and sale of non-ADIO extracted olive ridley eggs, and eggs of other turtle species, occurs across the country. It is known that black market turtle eggs are sold door-to-door and in the street, however, it is also possible that turtle eggs are sold in the open market, laundered through legal channels.

There is high demand for prepared eggs, either cooked or cracked raw into a salsa known as Sangrita, to be consumed with alcohol. An exception, within the certification scheme, allows vendors to sell prepared ADIO eggs for consumption on their premises (Arauz Almengor et al., 2001). However, vendors also sell fresh eggs in non-certified packaging or prepared eggs as a take-away snack. These legal violations open opportunities to launder illegal eggs through legal channels, potentially undermining the legal trade. Due to the visual similarity of cooked and fresh turtle eggs, we did not ask surveyors to look at these separately. We did, however, ask them to record the prices of the items they found. This meant we could distinguish between prepared eggs and fresh eggs without potentially confusing surveyors (cooked eggs and eggs in Sangrita are considerably more expensive and sell at the fixed price of ₡500 per egg as opposed to ₡150 each fresh). We classified these as prepared eggs and removed them before analysis. Our focus, therefore, was on fresh eggs in sealed bags with the ADIO logo (certified) and those not in ADIO packaging (non-certified).

Shark meat is often presented in two cuts; fillet and steak which we separated on our list. The datasheets had items listed with accompanying photograph. Because traders use synonyms for shark meat, we included these in the list to avoid any confusion related to labelling. Lobster was chosen, as spiny lobster Panulirus argus is categorized as either ‘fully’ or ‘over-exploited’ in the Caribbean, with each country regulating their fisheries to conserve stocks (FAO, 2006). To help verify the authenticity of data, we asked surveyors to record price, type of vendor and type of display. This made it easier to see if surveyors had fabricated data, for example surveyors claiming they found shark meat in supermarket Automercado or turtle eggs not sold at the fixed prices, were deemed as suspicious and these data points were removed before analysis. We also made it clear they only needed to find each item once.

Market survey protocol

The meeting point was the same for each survey. Monthly survey dates were randomly chosen, never on consecutive weeks and took place on Saturdays from July to December 2017. This timing ensured that our surveys took place in the months when the arribadas were the largest and the greatest volume of eggs would be traded. All surveys began between 09.30 and 11.30. We provided training either individually or in small groups. Surveyors were required to undertake two surveys on the same day, one in Downtown San José and the other in either Mercado Central or Mercado Borbón. While surveying Downtown they were instructed not to enter either market. To reduce bias, surveyors were randomly allocated a market and randomly allocated again whether they went to the market or Downtown first. Requiring everyone to survey inside and outside the markets ensured more of the city was covered. No-one surveyed the same site twice. For markets, start and end times were the minute they entered and exited the market. As the meeting point for surveys was situated in Downtown San José, we considered the time they left and returned to the meeting point to be the start and end times of their Downtown survey. Surveyors were given a data sheet and it was explained the aim was to find the items by any method they wished to employ. When they located an item they recorded, to the nearest minute, the time they found it. Surveyors were not given a specific route to follow nor asked to keep track of the number of stalls/vendors where they found items. The objective was for surveyors familiar with the local shopping area, to find each item once, as quickly as possible, therefore giving an indication of an item’s availability, compared to the other items on the list.
We gave no information to the surveyors regarding purchase points or seasonal availability of products. To reduce bias from surveyors searching for items in the order they were listed, we randomized the order in which each item appeared on their data sheet. We encouraged surveyors to be as discreet as possible during the survey, but if they wished to record data on their phone, they were welcome to do this. All surveyors were paid regardless of their success at finding the items. Twenty-four participants visited Mercado Central and 20 searched in Mercado Borbón. A total of 43 participants searched Downtown.

**Market survey analysis**

The resulting dataset included the start and end time of the surveys and a series of times at which each item was found (search effort) if it was found. As a result, items found by each surveyor were allocated a score of 1 or 0 according to whether the surveyor had found or failed to find it respectively. We needed an analysis technique that accounted for a surveyor failing to find an item. For this reason, we used an adaptation of a clinical trial analysis, Survival Analysis, to compare the search effort of each shopping list item, while factoring in the end time of the search and accounting for failure to find all the items on the list.

Survival analysis is used in clinical trials to compare the effectiveness of different treatments by monitoring patients’ responses to those treatments. This is done by recording the time patients take to either go into remission or develop a new symptom (an event) (Bewick et al., 2004; Schütte, 2018). Importantly, it can accommodate the effectiveness of different treatments if the dataset is incomplete because the response of interest does not occur within the study timeframe. Survival analysis commonly employs the Kaplan–Meier Method (Bewick et al., 2004) to predict the probability the patient will survive past time t and obtain an estimated survival probability as a function of individual characteristics. The output is displayed as an estimated survival probability curve for each treatment. The survival probabilities for each treatment are compared using a Log Rank Test. For further discussion of survival analysis see Muenchow (1986), Bewick et al. (2004), LaMorte (2016) and Schütte (2018).

In our adaptation of survival analysis, we modelled each shopping list item separately, with minutes to find as the ‘event’ and each surveyor as the ‘patient’. This produced separate survival curves for each item. In its simplest form, survival analysis considers time-to-death as the outcome. If a patient drops out of the study, goes into remission or dies it is known as a censor. A higher survival probability score is an indication the patient has taken longer to develop a new symptom. In our case, however, we were scoring the probability of finding the item; a high survival probability score suggests it takes longer to find an item. Scores closer to 0 indicate the item was found faster than items with a higher score (notice the inverted Y axis in Fig. 1). We then compared the survival curves and confidence intervals of each item. We used a $P$-value $< 0.05$ to indicate a significant difference in search times for each product. Each site was analysed separately to give a more detailed representation of the availability of eggs, and to identify differences between markets. When survival probability curves showed a significant difference between items, we compared the resulting estimated survival curves to try and establish which curves differed significantly from the rest. Items that appeared to give rise to the overall survival analysis outcome were removed and the analysis re-run to see what effect this had on the level of significance in the difference between the survival curves of remaining items.

![Figure 1 Estimated probability of finding items in a). Mercado Central, b). Mercado Borbón, c). Downtown. Note inverted Y axis; for our data, a survival probability of 1 meant the surveyor failed to find the item, steps in the item’s timeline represent the number of minutes it took to find the item (censor score = 1), crosses in the item timeline indicate the minute at which a surveyor dropped out of the survey (censor = 0), dashed lines represent upper and lower confidence intervals](image-url)
Demographic data analysis

Using questionnaire responses, we tested whether shopping preferences and demographics of surveyors affected their ability to find items. All participants found shark meat in the two markets and only one participant failed to find it Downtown, so it was unnecessary to analyze data on shark meat. The search effort results found turtle eggs to be most appropriate for this analysis. We compared whether participants found certified and uncertified turtle eggs against their shopping preferences and demographics. We visualized the relationships of these variables by plotting pairwise correlations in a matrix. We were interested in identifying important predictors of the surveyors’ ability to find certified and uncertified eggs in the markets or Downtown. To achieve this, we fitted four logistic regression models (certified-market, certified-downtown, uncertified-market, uncertified-downtown) with the following as potential explanatory variables: if they buy fish for their household, if they have ever eaten turtle eggs, did they recognize the ADIO logo before the survey, month of survey and whether they visited a market or Downtown first. Subsequently, we used a backward elimination model selection process with AIC as a model selection criterion. We note that in two of these logistic regressions, perfect separation of success or failure to find eggs occurred according to at least one of the explanatory variables, and hence these models were fitted using bias-reduction techniques (Firth, 1993).

R for windows running packages dplyr (Wickham et al., 2020), ggplot2 (Wickham, 2016), survival (Therneau, 2015), survminer (Kassambara et al., 2020) and tidyselect (Henry & Wickham, 2020) was used for survival analysis. MASS using the drop1 function (Venables & Ripley, 2002) and packages BRGLM (Kosmidis, 2020a) and BRGLM2 (Kosmidis, 2020b) were used for the analysis of demographic data (R Core Team, 2019).

Ethics

This study was approved by the School of Anthropology and Conservation’s Research Ethics Advisory Group (University of Kent) (Ref. No.: 0381617c). All research assistants were over the age of 18, made aware of the purpose of the research and provided written consent via a signed consent form. Data were anonymized before analysis.

Results

Survival analysis

The Log Rank test showed no significant difference in the search effort between certified or uncertified eggs at any of the sites (Mercado Central $P = 0.130$, Borbón $P = 0.450$, Downtown $P = 0.430$). Therefore, it was unnecessary to distinguish between the two egg types in the subsequent survival analysis.

There was a significant difference in search effort for each product in Mercado Central ($P = 0.001$); shark meat was the fastest and turtle eggs were the slowest to find (Fig. 1a, Supporting Information). There was no significant difference in time to find shark steaks and fillets ($P = 0.730$). However, upon closer inspection of estimated survival curves, it became evident that turtle eggs were giving rise to the significant result. Removing turtle eggs from the analysis meant the difference between the estimated survival curves of the other times was no longer significant (albeit the corresponding $P$-value was only 0.053). There was a significant difference in search effort between all products in Mercado Borbón ($P < 0.001$) (Fig. 1b, Supporting Information). Closer inspection of estimated survival curves suggested that shark products were giving rise to the significant difference. These cuts of meat were found the fastest but did not differ from each other in terms of search effort ($P = 0.800$). Once the shark meats were removed, the remaining items were no longer found to be significantly different from each other ($P = 0.700$). There was a significant difference in time to find all products in Downtown San José ($P < 0.001$) (Fig. 1c, Supporting Information). Shark products were the fastest to find and when removed the remaining products were not significantly different from each other in their search effort ($P = 0.770$).

Demographics

In total, 43 surveyors participated, of which 26 were male and 28 had an university-level education. When asked if they were responsible for the purchase of fish products for their household, 39 responded yes. Only nine respondents acknowledged they had knowingly eaten shark meat and 26 claimed to have never eaten turtle eggs. Prior to training, only three recognized the ADIO logo associated with legally certified turtle eggs. We found that none of these covariates affected surveyor’s ability to find certified eggs in the markets. We found a similar result for searches for uncertified eggs Downtown (Table 1, Supporting Information). Here, having never eaten turtle eggs had a small effect on the surveyor’s ability to find turtle eggs, however, the ΔAIC was less than 1. We, therefore, conclude that none of the variables affected the surveyor’s ability to find uncertified eggs in town. Conversely, we found surveyors who buy fish products for their household had a slightly increased ability to find certified eggs. In Downtown, however, the AIC score increase between the null model and that which included buying fish was under 1, suggesting this covariate is having a nominal effect (null AIC = 58.692, buying fish AIC = 58.566). Finally, buying fish for the household, having never eaten eggs and ability to recognize the logo had a positive effect on surveyors’ abilities to find uncertified eggs in the markets.

Discussion

Survival analysis found no difference in search effort between certified and non-certified eggs at any survey site. Eggs classified as non-certified may have been either illegally extracted, or certified eggs removed from legal
packaging. The Ostialon Egg Project has come under opposition from parties concerned the project allows laundering of illegal eggs through open channels (LAUDI-UCR, 2015; Preserve Planet, 2017). In 2017, this led to the development of a certification scheme (MINAE & SINAC, 2017). The scheme required ADIO to alter their packaging system from sacks of 200 loose eggs to heat-sealed bags of ten eggs. However, consumer demand was not considered when developing this scheme (pers. comm) and may explain the high volume of uncertified eggs in the market. Customers who purchase food from markets are typically on low incomes and unwilling to buy quantities of food greater than their daily need. This may provide an incentive to open ADIO bags and sell fewer than ten eggs. While we identified clear evidence of turtle eggs being sold outside of the certification scheme, we did not identify these as being illegally extracted. This agrees with the findings of Pheasey et al. (2020) who tracked illegal eggs from both coasts in Costa Rica, but did not link them to open market sales.

Surveyors found shark products significantly faster than other products on the shopping list. Shark derivatives including oils are generally absent from trade statistics, as the market for these products is limited (Clarke, 2004). Our method enabled us to incorporate this under-researched product into our dataset. At the time of the survey, 23 species of shark were listed in Appendix II of CITES (CITES, 2017) but identifying species in the market is difficult. While shark fins are one of the most expensive seafood products available (worth c.US$400-US$550 million per year), meat is often of low value but is increasing in demand as a cheap protein source (Abercrombie et al., 2005; Clarke et al., 2007). There is a reasonable likelihood that a large proportion of the shark meat in this study came from silky shark Carcharhinus falciformis; the most frequently caught species using long-line fisheries in Costa Rica, and added to CITES Appendix II in 2017 (Dapp et al., 2013; CITES, 2017). In 2013–2014, a forensic examination of shark meat sold in the Central Valley of Costa Rica, revealed 87.3% of shark meat was C. falciformis (O’Bryhim et al., 2017).

An important element of marine conservation is ensuring the consumer can make informed and sustainable choices, based on transparency within the seafood industry (Bornatowski et al., 2013). However, visually identifying shark species on a market stall is virtually impossible, as distinguishing features such as heads and fins are often removed in the preparation process (Abercrombie et al., 2005). Mislabelling shark meat further prevents the general public from making these informed consumer choices (Bornatowski et al., 2013). Our study circumvented this by ensuring all synonyms for shark were included in the shopping list information. Our questionnaire revealed that only 10% of surveyors were familiar with the ADIO logo, which appears somewhat damning of the traceability scheme. However, this may simply be due to a lack of exposure to the logo. The ten-bags sold to customers were only introduced in 2017. Prior to this, eggs were decanted in smaller denominations from sacks of 200 eggs, unlikely to be kept on display due to the space a large sack occupies.

The shopping list method does not require the use of skilled surveyors, and therefore provides a good indication of a product’s availability and potentially better represents the behaviour of the consumer population. With one exception – having never eaten turtle eggs increased the surveyors ability to find uncertified eggs – the shopping habits of the surveyors did not affect their ability to find items. This seems illogical, however, it is possible the AIC is choosing a too complex model, as the method can tend towards the selection of too many parameters (Burnham & Anderson, 2003). Given that other models did not find any covariates that had a significant effect on surveyors’ abilities to find eggs, we treat this result with caution. Any effect these covariates have will be minor. It is also noteworthy, that these step-wise models, while common in ecology and other disciplines, can lead to biased inferences (Heinze & Dunkler, 2017). We therefore tentatively conclude that surveyors’ shopping habits do not influence their ability to find eggs and that this methodology can be easily applied to non-habituated surveyors. Furthermore, the month of the survey did not affect the ability to find items, suggesting there was no seasonal difference in the availability of the items over the study period.

The shopping list method has the potential for wider application. Market surveys are an important source of trade data for understanding the drivers of demand, and demand for alternatives. This is important in predicting changes in consumption and management of a sustainable supply (East et al., 2005). However, market surveys often involve the same researchers repeatedly visiting markets and recording everything relevant. The shopping list method is advantageous in being easier for surveyors to collect reliable data than attempting to record everything available in the market. It is also possible to generate price data, which are an important barometer of temporal trade fluctuations. The objective of the shopping list method is to compare the availability of products and its strength lies in situations where specialist identification skills are not required. In bushmeat surveys, identification of certain meats can be limited if the meat has been prepared, mislabelled, the trade includes juveniles or the body sizes between species overlap (Minhos et al., 2013). The shopping list method has the potential to

### Table 1 Models that best identify the shopping habits affecting surveyors’ ability to find certified and uncertified turtle eggs in the markets and Downtown

| Response category       | Best fitting model                                         | AIC Score |
|-------------------------|------------------------------------------------------------|-----------|
| Certified market        | CERTIFIEDmarket – buyfish + market + neverturttleeggs + recognizelogo | 65.157    |
| Uncertified town        | UNCERTIFIEDdowntown – buyfish + market + neverturttleeggs + recognizelogo + month | 64.393    |
| Certified town          | CERTIFIEDdowntown – buyfish + market + never tartleeggs     | 60.221    |
| Uncertified market      | UNCERTIFIEDmarket – buyfish + never tartleeggs + recognizelogo | 47.335    |
overcome some of these issues as it involves the researchers finding fewer, more easily identifiable items. If the research interest is at a wider taxonomic level rather than species, this method would be easy to apply.

The shopping list method is not restricted to surveyors finding a physical item; it could easily be applied to searches of menus or online markets. The internet is now a major marketplace for trading illegal wildlife, the scale of which is hard to quantify (Sajeva et al., 2012). There is little evidence of even the most high-profile wildlife parts being traded on the dark web (Harrison et al., 2016), with many transactions undertaken on social platforms; for example slow lorises Nyccticebus sp. are openly traded on Facebook (Molly, 2016). As traders are not attempting to hide illegal online transactions, this method would be easy to apply to virtual marketplaces.

Moyle & Conrad (2014) first used the shopping list method to look at the availability of ivory in China. We applied this method to a different selection of items and confirm that we found it an affordable, systematic way of surveying markets, while circumventing entrapment concerns or arousing suspicion. One of the main strengths of this method is it does not require specialist surveyor knowledge. Citizen science is on the rise and the simplicity of this method means it might be appropriate for the type of data collection. We found that even a relatively small number of surveyors, (n = 43), can collect enough data to give us the power to identify significant differences between items in terms of search effort. Our findings are supported by other studies that have found validity in focusing on search effort. Borrand et al. (2014) compared time-to-detection models with traditional occupancy modelling in vegetation surveys, finding both methods to be equally robust. Garrard et al. (2008) found failure-time models allow for accurate detection rates in plant surveys while coping with imperfect survey data. We extended Moyle & Conrad’s (2014) approach by incorporating survival analysis and were able to account for situations where items would have been jointly ranked or undetected. Integrating the shopping list with survival analysis can reveal valuable information on demand and supply that would otherwise be difficult to obtain using traditional survey methods.

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**Supporting information**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Table S1.** Confidence intervals for a. San José Central Market, b. Borbón Market, c. Downtown. Search effort column represents steps in the survival curve (Fig. 1a-c).

**Table S2.** All model AIC scores that identify the shopping habits affecting surveyors’ ability to find certified and uncertified turtle eggs in the markets or Downtown, a. calculated using drop1 functions, b. calculated using bias-reduction techniques.