TITLE: Understanding implications of consumer behavior for wildlife farming and sustainable wildlife trade

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ABSTRACT

Unsustainable wildlife trade affects biodiversity and the livelihoods of communities dependent upon those resources. Wildlife farming has often been proposed to promote sustainable trade but characterizing markets and understanding consumer behaviour remain neglected, but essential, steps with important implications for its design and evaluation. We used sea turtle trade in the Cayman Islands as a case study – where turtle meat for consumption has been produced for almost 50 years, to explore consumer preferences towards wild-sourced (illegal) and farmed (legal) products and potential conservation

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implications. Combining methods innovatively (including indirect questioning and choice experiments), we conducted a nationwide trade assessment. Whilst 30% of resident households had consumed turtle in the previous 12 months, the purchase and consumption of wild products was relatively rare (e.g. 64-742 resident households consumed wild turtle meat, representing 0.3-3.5% of resident households), although representing an important threat to wild turtles in the area due to reduced populations. We found marked differences among groups of consumers with price and source of product playing an important role in their decisions. Despite the long-term practice of farming turtle, some consumers showed a strong preference for wild products, demonstrating limitations of wildlife farming as a single tool for sustainable wildlife trade. By using a diversified toolset to investigate demand for wildlife products, we obtained insights about consumer behaviour that can be used to develop conservation demand-focused initiatives. Lack of long-term social-ecological assessments, a common issue worldwide, hinders the evaluation and learning potential of wildlife farming as conservation tool. This information is key to understanding under which conditions different interventions (e.g. bans, wildlife farming, social marketing) are likely to succeed.

INTRODUCTION

Wildlife trade – the sale and exchange of wild animal and plant resources and their derivatives – involves a range of products including skins, medicinal ingredients and food, providing provisioning and cultural services (Phelps et al. 2014). Wildlife products generate a multi-billion dollar trade, with global legal trade, excluding timber, valued at an estimated US$21 billion a year (Engler & Parry-Jones 2007) and the value of illegal trade estimated at US$7-23 billion a year (UNEP-Interpol 2016).

Harvest regimes and biological parameters affect the sustainability of wild-collected products, with other challenges ranging from poor governance and capacity to lack of certification (Challender et al. 2015a). Unsustainable wildlife trade has thus been identified as a key challenge worldwide, with impacts for biodiversity and the livelihoods of communities dependent upon those resources (Nijman 2009).

Wildlife trade management commonly employs a number of tools aimed at the ban or restriction of harvest and trade. Additionally, approaches such as environmental education and social marketing can be used for demand reduction (Challender et al. 2014). Wildlife farming, representing the domestication, cultivation, propagation or breeding of plant or animal species (Phelps et al. 2014), has often been proposed as a "supply side" tool to promote sustainable trade by providing legally sourced products, decreasing harvest from the wild and driving down prices (Bulte & Damania 2005).

Whilst the extent to which these approaches have been successful at promoting sustainable trade can be context-dependent, uncertain and/or hotly debated (e.g. Kirkpatrick & Emerton 2010; Biggs et al. 2013), characterizing wildlife markets and understanding consumer behaviour is an often neglected, but essential, step required to effectively design interventions. For example, although widely discussed, suitable real-world studies of wildlife farming are rare (Phelps et al. 2014), hampering its assessment relating to consumer behaviour. In addition, assessments are often hindered by lack of comprehensive market data, difficulties in obtaining reliable information about illegal behaviours and challenges to assessing preferences towards legally- and illegally-sourced products (Nuno & St John 2015; Challender et al. 2015b).

Using sea turtle trade in the Cayman Islands as a case study, we applied a diverse toolbox combining recently developed conservation methods from the social sciences to conduct a

nationwide trade assessment, targeting turtle consumers and producers of farmed turtle – the Cayman Turtle Farm (CTF). CTF has been producing turtle meat for human consumption for almost 50 years, allowing us to explore consumer preferences towards wild-sourced and farmed products and draw lessons about potential implications for wildlife farming as a conservation tool. In particular, we looked at the prevalence of consumption and purchase of legally and illegally sourced turtle products, identified socio-demographic characteristics of consumers, assessed consumers' preferences and analysed trends in the sales of legal turtle meat. Ultimately, we aimed to explore the application of a multidisciplinary toolset to better understand consumer behaviour and consider how this can be used to inform the design of consumer-focused interventions, considering implications for wildlife farming and sustainable wildlife trade.

METHODS

Study area

The Cayman Islands are a UK Overseas Territory located in the Caribbean Sea. Characterized by a multicultural population with more than 100 nationalities, the latest census estimated 55,036 residents, among which 55% have Caymanian citizenship with the remaining being mostly citizens of Jamaica, UK or USA. Tourism and banking are the main industries, with the agriculture, forestry and fishing sectors employing a total 0.7% of the workforce (ESO 2015).

Throughout the history of the country, turtles have played an important ecological and cultural role; the area may once have supported the largest green turtle (*Chelonia mydas*) rookery in the Caribbean (Jackson 1997), the turtle is a national emblem, represented on the

flag and currency, and turtle meat is considered by some to be the "national dish". Intensive fishing of turtles exhausted local populations by the early 1800s (Bell et al. 2005). Small populations of green and loggerhead (*Caretta caretta*) turtles and critically low numbers of hawksbill turtles (*Eretmochelys imbricata*) have been recorded since then and regularly monitored since 1998, with more than 200 green turtle nests recorded for the first time in 2015 (Aiken et al. 2001; Department of Environment unpublished data).

In 1968, a commercial captive breeding operation, now the Government owned CTF, was established to provide turtle meat for consumption, reduce demand on wild stocks, and replenish the wild population through turtle releases, and has been running since then (Bell et al. 2005). International trade of most turtle products ceased in 1978 as a result of CITES regulations. All animals have been captive-bred since 1978 although eggs and turtles were initially collected from the wild. In 1978, legal protection for the remnant wild turtle nesting population was introduced through prohibiting possession of turtle eggs and take of female turtles during a closed season (Cayman Islands Government 1978); further protections were added in 1985 and 2008. Currently, legal harvest of wild turtles is limited to only a few licensed fishermen (three valid licenses at the time of study) with seasonal and size limit restrictions. Each legally captured turtle must be presented to fisheries officers but no legal take has been recorded since 2008 (Department of Environment unpublished data); therefore, during the 12 months prior to this study there was no legal source of wild turtle meat available to consumers. Violating conservation laws in the study area carries a maximum penalty of CI$500,000 (US$610,000; for comparison, average income was CI$48,344 at the time of study) and one year imprisonment. In practice, penalties for possession of illegal turtle products are generally lower; for example, in a recent case involving four people illegally taking and possessing a wild turtle, each one was fined CI$1000-2000 and sentenced to 100-120 hours of community service, besides confiscation of their fishing vessel. During

the 12 months prior to our study, evidence was found for poaching of two mature turtles, five juvenile turtles and three turtle nests (Department of Environment unpublished data).

Study design and data collection

We used a multi-methods approach combining information from household surveys and turtle meat sales from CTF, allowing us to obtain insights into both individual consumer characteristics and broader purchasing trends. Methods are described below with additional information provided in Appendix S1. Data sources, methods employed and rationale for their application in this study are summarized in Table 1.

Research was approved by the University of Exeter Ethics Committee (Ref. 2014/690). Before administering the questionnaires, the interviewers provided a brief description of the general aims of the project and emphasized the voluntary and anonymous nature of the questionnaire. Because we aimed to protect respondents' anonymity and minimize survey sensitivity, no personal or geographical data were collected that could be used to identify specific households. In addition, specialized techniques developed for investigating sensitive topics were used; these methods ensure respondent anonymity, increase willingness to answer, and critically, make it impossible to directly link incriminating data to an individual (Nuno & St John 2015). Direct questions (DQ) about purchase or consumption of wild turtle products (i.e. illegal behaviours) were placed at the end of the questionnaire and followed a reminder about the anonymity of any information collected, as well as providing an explicit "don't want to answer" option.

Household surveys

After questionnaire development informed by stakeholder interviews and survey piloting (details in Appendix S1), questionnaires were administered by a team of ten trained enumerators through face-to-face interviews at the homes of residents between the 19th September and 2nd December 2014. The household register, listing all households countrywide, was used as a sampling frame; households were randomly selected using disproportionate stratified sampling with 100 households per each of the 6 districts. Interviews were conducted with any household member provided they were at least 18 years old. Further information about survey design and administration is provided in Appendix S1.

Respondents were asked about turtle meat consumption and purchase, participation in illegal behaviours related to sea turtles (i.e. buying turtle meat harvested from the wild and eating turtle eggs), as well as socio-demographic information (potential drivers based on stakeholder interviews: gender, age group, level of education, household size, nationality, being registered to vote, having any grandparents born in the Cayman Islands and district of residence; details in Appendix S1). Those who reported never eating turtle or only had it once were shown a shorter version of the questionnaire, skipping more detailed questions about turtle consumption. The questionnaire is provided in Appendix S2.

Assessing prevalence of illegal behaviours

Several questioning approaches were used to reduce non-response and social desirability biases often encountered when asking about illegal activities (Nuno & St John 2015). To assess prevalence of turtle egg consumption, we used: a recall exercise where respondents were asked to indicate which turtle products they had consumed, with "turtle eggs" being one of the options alongside multiple non-sensitive items (e.g. turtle soup); the unmatched count technique (UCT), a specialized technique developed to reduce question sensitivity (Nuno et

al. 2013); and direct questioning (DQ) to obtain standard information for comparison and explore potential trade-offs between techniques. To assess household purchase of turtle meat taken from the wild, DQ and UCT were used.

In a standard UCT, survey respondents are randomly allocated into control or treatment groups, in which control group members receive a list of non-sensitive items (e.g. food items such as tuna), whereas the treatment group receives the same list but with the addition of the sensitive item (i.e. turtle eggs or wild turtle). To make this technique more statistically efficient by increasing the sample size and reducing estimate error, a double UCT has been proposed (Droitcour et al. 1991) and was used instead; the technique is applied twice to the same sample using a different list of non-sensitive questions each time and both experiments provide estimators of the sensitive behaviour that can be averaged. Every respondent was thus shown 2 UCT cards per behaviour (Appendix S2) and asked to indicate how many, but not which, items applied to them.

Due to occasional theft of turtles from CTF and subsequent sale of their meat to consumers, potentially as wild turtle (M. Orr, enforcement officer, personal communication), we are not able to distinguish between the prevalence of purchase of these two illegal products (i.e. consumers might have bought turtle stolen from CTF as if it was wild). However, our results are suggestive of respondents' willingness to consume and purchase wild turtle, if that is available despite current regulations.

Investigating consumer preferences

To investigate consumer preferences under different policy-relevant conditions and identify consumer characteristics that can be used to inform demand-side conservation interventions,

choice experiments were used; this is a stated preference valuation technique that makes use of hypothetical scenarios to infer preferences and demand for goods (Hanley et al. 1998). The use of hypothetical scenarios has been suggested to make the elicitation of preferences about illegal activities less sensitive (Nielsen et al. 2013), and recent applications in conservation include studies on the orchid trade (Hinsley et al. 2015) and options for reducing illegal bushmeat hunting (Moro et al. 2013). Respondents are presented with a series of choice alternatives, differing in terms of characteristics (attributes) and their levels, and asked to choose their most preferred. Turtle consumers only (i.e. study participants who never ate turtle or only had it once were not asked to participate) were asked to select their most preferred "turtle meat options" among a range of alternatives presented to them. The context for the choice task was given careful consideration; during pilot study some consumers reported preferring to purchase uncooked turtle meat whilst others rather consuming it in a restaurant, so we developed two different versions of the cards to be shown accordingly. Here, we report only on the "uncooked turtle meat" choice experiments; this behaviour is directly affected by consumer decisions while, given current lack of certification, source of turtle in restaurants is difficult to assess and more indirectly related to consumer decisions. Each option consisted of five attributes described in Table 2; all attributes and their levels were chosen based on relevant literature, stakeholder interviews (including consumers and producers of turtle meat; Appendix S1) and survey piloting.

The choice survey was a main-effects D-efficient Bayesian design produced using Ngene software (ChoiceMetrics 2012) with Bayesian prior distributions generated from the results of pilot study; this design maximises statistical efficiency in estimating parameters (Hinsley et al. 2015). The final design consisted of 36 choice scenarios, which we blocked into six groups of six to reduce cognitive demand on respondents. Respondents were randomly

assigned to one of six blocks. Every respondent was shown six choice cards (Appendix S2) and each time respondents were asked to choose their preferred option.

CTF sales data

To explore trends in sales of farmed turtle over time, as well as potential seasonal and demographic effects, monthly information on farmed turtle product prices and amounts sold from April 1995 to December 2014 were provided by CTF; sales and price data can provide insights into actual consumer behaviour (instead of stated preferences such as those obtained through choice experiments; Hinsley et al. 2015). Information on Cayman Islands' consumer price index and resident population size and demographics during the same time period was obtained from the Cayman Islands' Economics and Statistics Office. To enhance comparability of cost of purchasing a similar amount of turtle meat over time, inflation-adjusted prices using 2014 as reference level were obtained by dividing actual prices by annual consumer price index.

Data analysis

Household surveys

To correct for disproportionate stratified sampling, we adjusted for study design through weighting based on district population size using the package *survey* version 3.30 (Lumley 2014) in R (version 3.2.1) (R Foundation for Statistical Computing 2015); when not stated otherwise, analyses were conducted in R. All estimates have thus been adjusted for study design while any sample sizes refer to the actual N.

For each behaviour assessed using the double UCT, two estimators ($\hat{x}_1$ and $\hat{x}_2$) were obtained by calculating differences in means between control and treatment subsamples; these two estimators were then averaged to estimate the overall prevalence of sensitive behaviour ($\hat{x}$). Following Coutts et al. (2011), the sampling variance was estimated using:

$$Var(\hat{x}) = \frac{Var\ (\hat{x}_1) + Var\ (\hat{x}_2) + 2Cov\ (\hat{x}_1, \hat{x}_2)}{4} \quad (1)$$

To investigate the potential effects of socio-demographic variables on behaviour prevalence quantified through DQ, generalized linear models with quasi-binomial error distribution (to account for overdispersion) and a logit link were fitted. We then used the Akaike information criterion (AIC) to select and rank the most parsimonious models, and averaged estimates across all models with ΔAIC<4.

To estimate individual preferences (i.e. utility scores) from choice experiments, attribute levels were dummy-coded to allow for variable marginal utilities associated with each. We constructed both a multinomial logit model (MNL) and latent class models (LCMs) using Sawtooth Software (Sawtooth Software Lighthouse Studio version 9.0.1 – Academic Lab). While MNL is a standard procedure used to determine aggregate preferences assuming that the population is homogeneous, LCMs capture preference heterogeneity across segments of the population allowing us to explore potentially different consumer groups. A first-order interaction between price and source of meat was considered but found not to improve model significantly (2-log likelihood test: p>0.1) and was excluded from further steps. Further description of analysis of data from choice experiments is contained in Appendix S3.

Potential relationships between segment membership and socio-demographic variables were investigated as described above for DQ answers.

CTF sales data

To explore trends in annual sales over time, the amount of turtle meat sold per year was modelled as a function of time from 1996 to 2014. Generalized additive models with a normal error distribution and identity link were fitted to the data, smoothing the time series of annual sales using the package mgcv version 1.8-6 (Wood 2015). In order to explore the shape of the trend, we modelled the year effect as a cubic smoothing spline with up to 19 knots (i.e. places where the polynomial pieces connect), as a linear term or as a constant (null model). Selection of the most parsimonious model was performed using the Akaike information criterion corrected for small sample size (AICc). We considered that non-null models would be acceptable instead of null models, and non-linear instead of linear, only if $\Delta AIC \geq 4$.

A similar procedure was followed to investigate trends in monthly sales for "turtle stew" (a mixture for stewing), the most commonly sold turtle product, from April 1995 to December 2014. To account for potential demographic effects, monthly sales were measured in terms of amount of turtle meat sold per number of residents with Caymanian nationality. Generalized additive mixed models with a Poisson error distribution and log link were fitted to the data, with inflation-adjusted prices added as potential explanatory variable, as well as month and year effects as cubic smoothing splines. A description of how we accounted for temporal autocorrelation is provided in Appendix S3.

RESULTS

Household surveys

We approached, on average, 100 households per district, totaling 597 individuals, of which 37 (6.2%) refused to participate. Survey respondents and refusals did not differ by gender (χ^2 = 0.37, df = 1, p = 0.54), age group (Yates' χ^2 = 2.3, df = 3, p = 0.52), or district (Yates' χ^2 = 5.17, df = 5, p = 0.40). Our total sample was 560 individuals and is characterized in Appendix S1.

Consumption of turtle products

Approximately 54% (95% CI: 50.9-57.2) of resident households had consumed turtle meat at least once in the past, whilst 42% (95% CI: 36.0-48.0) have eaten it more than once, suggesting that around 22% of those who tried it are potentially no longer interested in consuming it (among 50 respondents who answered a follow up question about only consuming once, dislike for taste/texture was mentioned by 44 of them, with other reasons including religion and access). 30% (95% CI: 25.1-35.9) had consumed turtle meat at least once during the 12 months prior to our study.

According to DQ answers, around 1.0% (95% CI: 0.3-3.5) of resident households illegally consumed turtle eggs during the 12 months prior to our study. Through a recall exercise for people who consumed turtle meat more than once ever, we found that approximately 3.4% (95% CI: 1.0-10.8%) of them consumed turtle eggs during the last year, representing 0.4-4.5% of the resident households (i.e. 85-954 households). UCT produced an unrealistic negative prevalence, although overlapping with zero and thus inconclusive (Figure 1a).

Purchase of turtle products

Among resident households that reported consuming turtle during the 12 months prior to our study, 37% (95% CI: 27.0-47.2) bought turtle at CTF. Other sources of turtle meat (respondents were allowed multiple options) were: friends (4% of households; 95% CI: 1.6-11.4), family (4%; 95% CI: 1.4-11.3) and door-to-door seller (1%; 95% CI: 0.3-4.1). The remaining 62% (95% CI: 51.0-71.5) consumers did not buy uncooked turtle meat (e.g. they consumed it at restaurants or a friend's home instead).

Turtle meat sold door-to-door in the area is likely to be of illegal origin. In addition, according to DQ answers, 2% (95% CI: 0.8-4.8) of all resident households bought turtle meat illegally (Figure 1b). Using UCT, a higher estimate was obtained but this overlapped with zero and is not significantly different from that obtained using DQ (t=-0.74, df=559, p=0.23).

Out of the 21 people that provided additional information about where they got wild turtle, one person reported getting it as a gift from a friend, while the others purchased 4-15 pounds of meat (median amount: 9 lbs; 95% CI: 5-10) at CI$4-25 per lb (median price: CI$5/lb; 95% CI: 5-8). For comparison, 1lb of farmed turtle meat was sold for CI$9 at CTF at the time of study.

Potential socio-demographic predictors

Having eaten turtle meat during the 12 months prior to our study was best explained by gender, voting registration, grandparents' nationality and education level, although 95% confidence intervals for education overlapped zero, which decreased our confidence in the direction of this effect (Appendix S3). Being a male, being registered to vote and having at least one grandparent born in the Cayman Islands increased likelihood that respondents had

eaten turtle meat during this period (Figure 2). Other variables also included in the top models but with much less support were household size, age group and district of residence (i.e. smaller relative variable importance; Appendix S3). Findings on potential socio-demographic predictors of purchase of wild turtle are non-conclusive (Appendix S3).

Stated consumer preferences

A total of 182 consumers who preferred purchasing uncooked turtle meat rather than consuming it in restaurants were asked to participate in the "uncooked turtle meat" choice experiments, of which 10 refused due to lack of understanding/belief of trickery (n=5) or because they were no longer interested in purchasing turtle meat in real conditions (n=5). This resulted in 1092 completed choice sets.

When respondents were treated as a homogenous group in the MNL, price and source of meat were the most important factors (attributes and levels defined in Table 2), followed by frequency of consumption, number of nesting turtles and distance to meat selling point, respectively (Appendix S3). For this general group, travelling smaller distances, farmed meat, lower prices, intermediate frequency consumption levels and larger number of nesting turtles in the wild increased the probability of consumers choosing an option which corresponds to these levels (Appendix S3).

When we considered potential differences among consumer groups, the largest segment in the selected latent class model (Appendix S3) included 30.3% of consumers and this group showed significant preferences for low prices and short distances, with price being the most important attribute (relative importance score = 61.2%; Appendix S3). Consumers generally preferred larger population sizes of nesting turtles in the wild, although the smallest segment

(8.8%) showed a significant preference for smaller populations. Most respondents preferred paying lower prices but a key segment including 21.9% of consumers preferred paying the highest prices for turtle meat. In addition, a segment including 13.5% of consumers showed a significant preference for wild meat, whilst all remaining segments preferred farmed meat (Appendix S3). Intermediate consumption frequency (i.e. a few times per month instead of a few times per week or year) was generally preferred.

Belonging to the group that showed preference for wild meat was best explained by age group, district of residence, household size and nationality, although 95% confidence intervals for household size and nationality overlapped zero, which decreased our confidence in the direction of this effect (Appendix S3). Being 35-54 years old and living in George Town district decreased likelihood that respondents were included in this segment. Other variables also included in the top models, but with much less support, were gender, grandparents' nationality and being registered for voting. When asked a direct open-ended follow-up question about preferences towards wild vs. farmed turtle meat, taste was the key reason provided for preferring wild meat (n=23) whilst legality (n= 24) and availability (n=19) were the key reasons provided by those who prefer farmed meat.

Trends in sales by CTF

Annual sales over time were best explained by a non-linear model with 6 knots (k=6), reaching minimum annual sales in 2010 (turtle meat prices increased by 200% in February 2010) followed by an ongoing increasing trend afterwards (Figure 3). Monthly sales of turtle stew per number of Caymanian residents varied significantly with month, year and inflation-adjusted price (Appendix S3). Our results suggest that, for a unit increase in price, the monthly amount of turtle stew sold per number of Caymanian residents decreased 13.9%.

Monthly sales of stew were significantly above the average in November and December, suggesting traditional use of turtle meat for celebrations (i.e. Pirate's week and Christmas). After accounting for price, monthly sales of turtle stew per number of Caymanian residents were significantly above the average from 1995 to 2002, and significantly below the average from 2006 onwards (Appendix S3), suggesting other factors are potentially affecting these dynamics.

DISCUSSION

We used recently developed conservation tools to better understand factors influencing consumer behaviour and characterize wildlife trade, with a focus on legal and illegal behaviours. Understanding rule-breaking is essential to designing effective interventions (Solomon et al. 2015). Real-world investigations of wildlife farming are scarce and this study provides insights into consumer behaviour and potential implications for the efficacy of this conservation tool, which are both key issues surrounding the illegal wildlife harvest and trade (Hinsley et al. 2016).

Consumer-focused conservation interventions

Since its inception, CTF has aimed to provide turtle meat for consumption in order to reduce demand on wild stocks (Bell et al. 2005). This rationale underlies applications of wildlife farming as conservation tool, although empirical studies on consumer effects are lacking (Phelps et al. 2014). Our results suggest that 30% of resident households consumed turtle meat in the study area and that this is mostly an occasional event of traditional nature by residents with strong linkages to Caymanian culture. The illegal purchase and consumption of

wild turtle products is relatively rare, although potentially representing an important threat to wild turtle populations due to reduced size. We found marked differences among groups of consumers with price and source of product playing an important role in consumer decisions.

Cultural constraints are often mentioned as a barrier to consumption of farmed wildlife products (Drury 2009). The widespread adoption of consumption of farmed wildlife products in the study area suggests that CTF currently plays an important role in terms of providing turtle meat, contributing to supporting the cultural dimensions of turtle consumption. For example, current levels of farmed turtle meat being consumed (e.g. 1292 turtles slaughtered in 2014) mean that, under present ecological conditions, similar consumption levels could not be sustained if turtles were taken from the wild. Our study suggests that, under certain conditions, farmed wildlife products can substitute those from the wild and address demand for these products. It is likely that the facts of CTF being government-run and subsidized, the low abundance of wild turtles and the historical and cultural importance of turtle consumption all play a role. For example, respondents were generally aware of CTF currently being the single legal source of turtle meat and the illegality of consumption and harvest of turtle products from the wild, particularly for meat (see summary data from complementary study presented in Appendix S3). Nevertheless, despite the long-term practice of turtle farming, some consumers showed a strong preference for wild turtle meat, suggesting that, for some members of the public, farmed and wild turtle products are non-substitutable. Other studies have found similar preferences towards wild-sourced products elsewhere (e.g. Drury, 2009; Dutton et al., 2011), demonstrating limitations of wildlife farming as a single tool for sustainable wildlife trade.

Consumer perceptions must be considered for effective marketing of wildlife substitutes, with our study illustrating long-term effects (e.g. some consumers reported preferring wild meat

despite not having eaten it for decades). Given that legality and availability of farmed turtle were key factors for those who reported preferring this type of product, special attention should be paid to changes in regulations and production; a more predictive approach could be used to explore potential changes in consumer behaviour under different scenarios. Currently, farmed turtle meat is much more abundant and easily available than wild meat in the area (based on information we reported on farmed amounts, wild populations, survey respondents and recorded poaching events) and our study provides some evidence that wild meat is cheaper (although this is based on a small number of self-reported purchases). If, as recently proposed due to husbandry issues and animal welfare (D'Cruze et al. 2014), a closure of CTF or a drastic reduction in production occurs, it should be accompanied by increased law enforcement and demand reduction initiatives. Given the historical and traditional use of turtle meat in area, it is not likely that all consumers would stop consuming turtle products (D'Cruze et al. 2014) and the potential consequences for wild turtle populations and related cultural dimensions must be considered. Consumer information reported in this study (e.g. certain consumers willing to pay premium prices and only a few consumers preferring smaller wild turtle populations) would be key in developing these initiatives.

Specialized research methods

By bringing together tools from a number of disciplines, we were able to obtain a comprehensive understanding of factors driving resource use. For example, by combining revealed (i.e. sales and price data) and stated (i.e. choice experiments) preference techniques, we were able to gather complementary information about both actual purchasing behaviour over time and potential behaviour under hypothetical conditions. These are essential for conservationists to design interventions based on current conditions and understanding, as

well as, more predictively, considering how interventions may change consumer behaviour. We suggest that a multidisciplinary toolset is essential to better understanding markets and consumer behaviours, particularly when investigating preferences towards illegally sourced products. However, further assessment of these techniques and their limitations is also required. For example, our UCT application was not successful in providing conclusive results, most likely because behaviours were too rare and UCT has considerable statistical efficiency limitations (Nuno & St John 2015).

Whilst DQ provided useful baseline information, it is likely to represent an underestimation of behaviour prevalence. Actual honesty levels were not assessed but, as suggested by potential penalties, higher non-response rates to DQ than UCT (Figure 1) and enumerator notes (Appendix S2) recorded post-completion of each questionnaire (e.g. 29 respondents showed signs suggesting potential dishonesty, such as incongruent responses and change in body language), some participants were reluctant in sharing sensitive information. Similar issues might have affected the choice experiments, although the use of hypothetical scenarios is likely to reduce question sensitivity and has great potential for evaluating determinants of illegal behaviour (Nielsen et al. 2013). In addition, an increased sample size and more complex choice experiment design, developed to robustly investigate both main effects and interactions, could be used to identify potential levels at which consumers switch between illegal and legal products. Specialized research methods, such as UCT and choice experiments, should thus be recognized as key components of the conservationist toolbox.

Assessing wildlife farming for sustainable wildlife trade

A robust and comprehensive evaluation of wildlife farming as conservation tool must consider a wide range of social and ecological impacts; in our study, we focus on consumer

behaviour and implications for its efficacy. The lack of long-term social-ecological assessments remains an important challenge to the success of this strategy, hindering its evaluation. For example, despite being in operation for almost 50 years, virtually no detailed socio-economic information about turtle consumption in Cayman was available until now. Similar issues of lack of monitoring and impact evaluation affect our ability to learn from successes and failures of wildlife farming facilities worldwide. In addition, to assess links between ecological (e.g. wild population trends) and social (e.g. consumption prevalence) outcomes from wildlife farming, a better understanding of confounding factors (e.g. conservations efforts elsewhere) and feedbacks over time is required. In our study, information over time on how many turtles were available for slaughter is unavailable; this would be important for disentangling supply and demand effects. Monitoring and evaluation information is key to understanding under which conditions different interventions are likely to succeed; for example, the perceived and actual efficacy of law enforcement in the area remains to be explored, while headstarting has showed some positive impacts, with released turtles contributing to the local breeding population (Bell et al. 2005). The same principle should apply to other related interventions, such as consumer campaigns and law enforcement, so that trade-offs and synergies between strategies could be analysed. This will contribute to an evidence-based evaluation of those interventions, ultimately identifying ways forward for a key conservation challenge.

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Table 1. Summary of data sources, key methods employed and rationale for their application in this study.

Data source	**Key method employed**	**Rationale for application in this study**
Nationwide household survey (questionnaires conducted in Sept-Dec 2014)	Unmatched count technique (UCT; double version)	Ensure respondent anonymity, increase willingness to answer and make it impossible to directly link incriminating data to an individual (Nuno et al. 2013; Nuno & St John 2015) in order to estimate prevalence of illegal behaviour.
	Diet recall exercise	Reduce question sensitivity in order to estimate prevalence of illegal behaviour.
	Direct questioning	Estimate prevalence of legal and illegal behaviours and explore potential trade-offs

		between survey techniques.
	Choice experiments with open-ended follow-up question	Investigate respondents' preferences and demand for legal and illegal wildlife products under different policy-relevant scenarios, making the elicitation of preferences about illegal activities less sensitive (Nielsen et al. 2013).
CTF sales records (compiled April 1995 to December 2014)	Sales trend analysis	Explore trends in annual sales over time, as well as exploring potential seasonal and demographic effects.

Table 2. Description of all attributes and their levels chosen for the choice experiments. All attributes and their levels were chosen based on relevant literature, stakeholder interviews and survey piloting (Appendix S1).

Attribute	**Rationale and description**
Distance travelled	We aimed to investigate the potential effect of creating additional distribution points across the country, given that, currently, there is only one legal selling point for uncooked turtle meat, located at CTF. This attribute represents the distance (measured in miles; one-way journey) that respondent would have to travel to buy turtle meat. Divided into three levels: 5, 15, 20 miles (approx. 8, 24 and 32 km respectively).
Source of meat	The use of farmed turtle meat as a substitute product has been questioned given the potential consumer preference for wild-source turtle. To

	investigate this further, we included an attribute considering whether the turtle meat was sourced from the wild or farmed, making the elicitation of preferences about illegal activities potentially less sensitive (Nielsen et al. 2013).
Frequency	Limitations in farmed turtle production and lack of regular turtle availability were suggested by stakeholders as challenges to the contribution of CTF to meeting demand. This attribute represented how often the respondent would be able to buy turtle meat. Divided into three levels: a few times per week, a few times per month, a few times per year.
Number of nesting turtles in the wild	Based on wild turtle abundance, interest in purchasing turtle meat may change. We aimed to investigate potential trade-offs between turtle conservation and consumer behaviour. Divided into three levels representing the number of nesting turtles in the wild: 20, 100, 600. In the absence of accurate population estimates, these levels were chosen to represent: below the current level (20), around the current level (100) and above the current level (600).
Price	While price is generally a primary determinant of demand (Bulte & Damania 2005), we aimed to investigate potential changes in demand due to price. This attribute represents the price (measured in CI$[*]) of one pound (0.45 kg) of turtle meat (this is the same unitary measure of price as used by CTF; at the time of study, 1lb of farmed turtle meat=CI$9). Divided into three levels: 5, 10, 20 CI$.

* CI dollar is fixed to the value of the US dollar: 1 KYD (CI$) = 1.22 USD (US$).

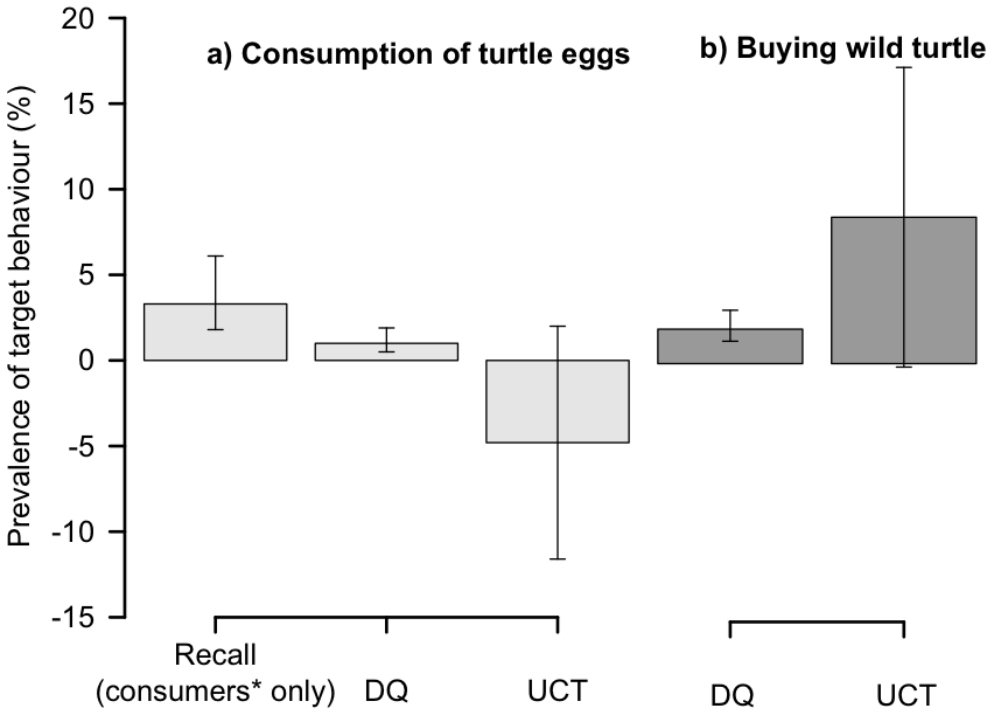

Fig. 1. Estimated prevalence (SE) of target illegal behaviours in the Cayman Islands: a) Consumption of turtle eggs - estimates obtained using three different questioning techniques: recall only among respondents who consumed turtle more than once ever ("Which of the following describes the ways in which you ate turtle in the Cayman Islands during the last year? [tick all that apply]"; n=280); DQ (direct question "Have you eaten turtle eggs in the Cayman Islands in the last year?; n=537); UCT (unmatched count technique; n=553); b) Buying wild turtle - estimates obtained using: DQ ("Have you, or someone from this house, bought (cooked or uncooked) turtle meat taken from the wild in the Cayman Islands in the

last year?; n=540); UCT (n=553). * Respondents who consumed turtle more than once ever.

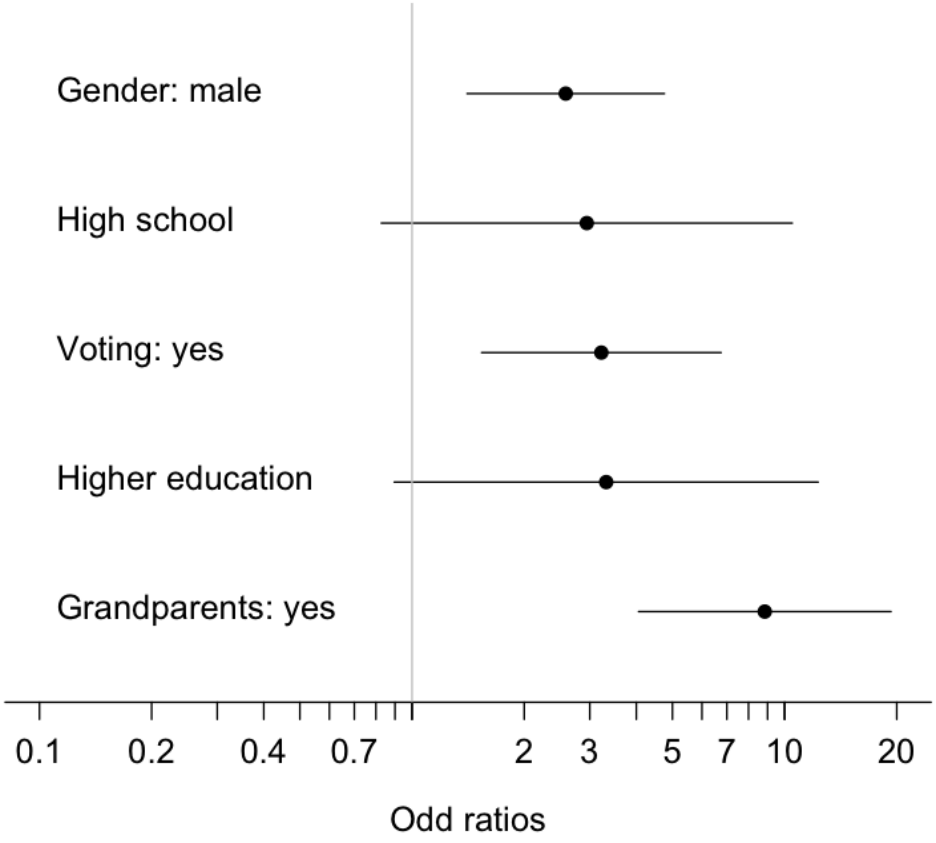

Fig. 2. Effects of main socio-demographic categorical variables presented as odd ratios (with 95% confidence intervals) of having eaten turtle meat during the 12 months prior to this study; back-transformed from parameters presented in S3. Each level shown here is compared with the following reference levels: female (gender), not being registered for voting in the Cayman Islands (voting), not having at least one grandparent born in the Cayman Islands (grandparents) and respondent with primary education only. Grey line

represents odd ratio = 1 (both groups have same odds).

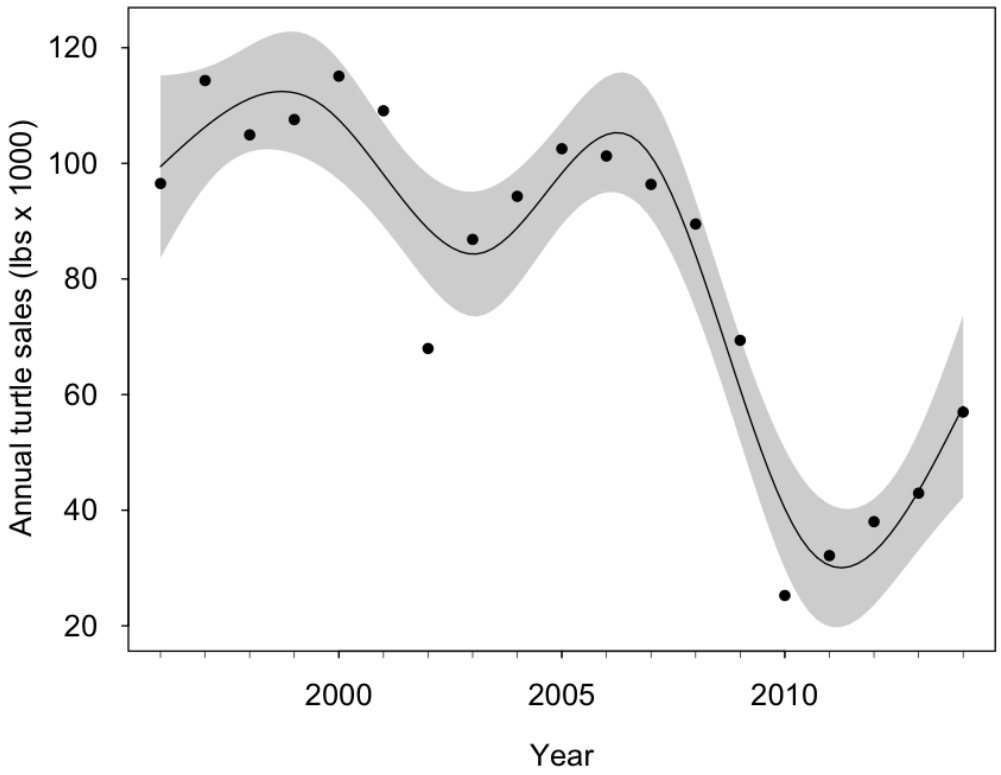

Fig. 3. Estimated annual trend fitted to CTF sales of turtle meat (measured in thousands of lbs) from 1996 to 2014 (n=19), along with 95% confidence bounds. Points represent raw data. Adjusted R^2 = 0. 90. The following sections were delineated: relatively stable sales from 1996 to 2001 with drastic decrease in 2002 (CTF severely affected by hurricane in late 2001); post-hurricane recovery period which peaked in 2005 and decreased afterwards, reaching minimum annual sales in 2010 (turtle meat prices increased by 200% in February 2010); and an ongoing increasing trend afterwards. The CTF deliberately reduced the amount of turtle meat available for sale in 2009 due to production sustainability issues (T. Adam, personal communication) but no other information on supply produced by the CTF over time was available.