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 been proposed to promote sustainable trade, but characterizing markets and understanding consumer behavior remain neglected but essential steps in the design and evaluation of such operations. We used sea turtle trade in the Cayman Islands, where turtles have been farm raised for human consumption for almost 50 years, as a case study to explore consumer preferences toward wild-sourced (illegal) and farmed (legal) products and potential conservation implications. Combining methods innovatively (including indirect questioning and choice experiments), we conducted a nationwide trade assessment through in-person interviews from September to December 2014. Households were randomly selected using disproportionate stratified sampling, and responses were weighted based on district population size. We approached 597 individuals, of which 37 (6.2%) refused to participate. Although 30% of households had consumed turtle in the previous 12 months, the purchase and consumption of wild products was rare (e.g., 64–742 resident households consumed wild turtle meat [i.e., 0.3–3.5% of households] but represented a large threat to wild turtles in the area due to their reduced populations). Differences among groups of consumers were marked, as identified through choice experiments, and price and source of product played important roles in their decisions. Despite the long-term practice of farming turtles, 13.5% of consumers showed a strong preference for wild products, which demonstrates the limitations of wildlife farming as a single tool for sustainable wildlife trade. By using a combination of indirect questioning, choice experiments, and sales data to investigate demand for wildlife products, we obtained insights about consumer behavior that can be used to develop conservation-demand-focused initiatives. Lack of data from long-term social–ecological assessments hinders the evaluation of and learning from wildlife farming. This information is key to understanding under which conditions different interventions (e.g., bans, wildlife farming, social marketing) are likely to succeed.*

Keywords: CITES, commercial breeding, consumer research, poaching, sea turtle

El Entendimiento de las Implicaciones del Comportamiento del Consumidor para la Crianza de Fauna Silvestre y el Mercado Sustentable de Fauna

Resumen: *El mercado no sustentable de fauna silvestre afecta a la biodiversidad y al sustento de las comunidades que dependen de esos recursos. La crianza de fauna ha sido propuesta para promover el mercado sustentable, pero caracterizar los mercados y entender el comportamiento del consumidor siguen siendo ignorados a pesar de ser pasos esenciales en el diseño y la evaluación de dichas operaciones. Utilizamos el mercado de tortugas marinas en las Islas Caimán, en donde las tortugas han sido criadas para el consumo humano durante casi 50 años, como un estudio de caso para explorar las preferencias del consumidor por productos capturados (ilegales) o criados (legales) y las implicaciones potenciales para la conservación. Por medio de la combinación innovadora de métodos (incluyendo el cuestionamiento indirecto y los experimentos de opción), realizamos una evaluación del mercado a nivel nacional por medio de entrevistas personales*

de septiembre a diciembre de 2014. Se seleccionaron hogares al azar por medio del muestreo estratificado desproporcionado y las respuestas se sopesaron con base en el tamaño poblacional del distrito. Nos acercamos a 597 individuos, de los cuales 37 (6.2%) se rehusaron a participar. Aunque el 30% de los hogares habían consumido tortuga en los últimos doce meses, la compra y el consumo de productos capturados fueron raros (p. ej.: 64–742 hogares residenciales consumieron carne de tortuga, es decir, 0.3 - 3.5% de los hogares) pero representaron una amenaza importante para las tortugas silvestres debido a sus poblaciones reducidas. Las diferencias entre los grupos de consumidores estuvieron definidas, conforme se identificó en los experimentos de opción, y el precio y el origen del producto jugaron un papel importante en sus decisiones. A pesar de la práctica de larga duración de la crianza de tortugas, 13.5% de los consumidores mostraron una fuerte preferencia por los productos capturados, lo que demuestra las limitaciones de la crianza de fauna como herramienta única para el mercado sustentable de fauna. Cuando utilizamos una combinación de cuestionamiento indirecto, experimentos de opción, y datos de venta para investigar la demanda de productos de fauna, obtuvimos un entendimiento sobre el comportamiento del consumidor que puede usarse para desarrollan iniciativas de conservación enfocadas en la demanda. La falta de datos de las evaluaciones socio-ecológicas de larga duración dificulta la evaluación y el aprendizaje de la crianza de fauna. Esta información es importante para entender bajo cuáles condiciones es probable que tengan éxito las diferentes intervenciones (p. ej.: vedas, crianza de fauna, mercadotecnia social).

Palabras Clave: caza furtiva, CITES, crianza comercial, investigación sobre el consumidor, tortuga marina

摘要: 不可持续的野生动物贸易会影响生物多样性和依赖于这些资源的社区居民的生计。为促进可持续贸易, 人们提出了野生动物养殖, 但对市场特点和消费者行为的认识仍然被忽略, 而这些是设计和评估相应操作的必需环节。开曼群岛(the Cayman Islands)有近五十年养殖海龟供人类利用的历史。我们用当地的海龟贸易作为一个案例, 来探究消费者对野生来源 (非法) 和养殖 (合法) 的生物制品的偏好及其对保护的潜在意义。我们创新性地结合了不同研究方法 (包括间接询问和选择实验), 在2014年9-12月通过面对面访谈进行了全国范围内的贸易评估。我们用不等比分层抽样法随机选择了受访家庭, 并按照该地区的人口数量对他们的回答进行加权。我们尝试调查了597人, 其中37人 (6.2%) 拒绝参与。虽然有30%的家庭在过去12个月中消费过海龟, 但购买并消费野生制品的很少 (举例来说, 64-742个居民家庭消费过野生海龟肉, 占居民家庭0.3-3.5%), 而这对当地种群下降的野生海龟构成巨大的威胁。我们通过选择实验找出了消费者群体间明显的差异, 其中产品的价格和来源在他们决策中起到重要作用。尽管海龟养殖已经存在很长时间, 13.5%的消费者仍对野生制品表现出强烈的偏好, 这表明野生动物养殖作为可持续野生动物贸易的唯一手段还存在局限性。我们通过综合使用间接询问、选择实验和销售数据来研究人们对野生动物制品的需求, 深入了解了消费者行为, 这可用于制定以保护需求为中心的措施。长期社会生态评估数据的缺乏阻碍了对野生动物养殖的评价和研究。而这是理解不同的干预措施 (如贸易禁令, 野生动物养殖, 社会营销) 适用于何种情况的关键。翻译:胡怡思;审校:魏辅文

关键词: 濒危野生动植物种国际贸易公约 (CITES), 商业育种, 消费者调查, 偷猎, 海龟

Introduction

Wildlife trade—the sale and exchange of wild animal and plant resources and their derivatives—involves a range of products that provide provisioning and cultural services (Phelps et al. 2014). Wildlife products are a multibillion-dollar trade. Global legal trade, excluding timber, is valued at an estimated US$21 billion a year (Engler & Parry-Jones 2007), and the value of illegal trade is estimated at US$7-23 billion a year (UNEP-Interpol 2016).

Harvest regimes and biological parameters affect the sustainability of wild-collected products; other challenges range from poor governance and capacity to lack of certification (Challender et al. 2015*a*). Unsustainable wildlife trade has thus been identified as a key challenge worldwide that affects biodiversity and the livelihoods of communities dependent on wildlife resources (Nijman 2009).

Wildlife trade management applies a number of tools aimed at banning or restricting harvest and trade. Ap-

proaches such as environmental education and social marketing are used to reduce demand (Challender et al. 2014). Wildlife farming (i.e., the domestication, cultivation, propagation, or breeding of plant or animal species [Phelps et al. 2014]) is 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).

Although the extent to which these approaches have been successful at promoting sustainable trade can be context dependent, uncertain, and hotly debated (e.g. Kirkpatrick & Emerton 2010; Biggs et al. 2013), characterizing wildlife markets and understanding consumer behavior is an often neglected, but essential, step required for the effective design of interventions. For example, although widely discussed, suitable real-world studies of wildlife farming are rare (Phelps et al. 2014), which hampers its assessment relative to consumer behavior. In addition, assessments are often hindered by lack of comprehensive market data, difficulties in obtaining reliable

information about illegal behaviors, and challenges to assessing preferences toward legally and illegally sourced products (Challender et al. 2015*b*; Nuno & St John 2015).

Using sea turtle trade in the Cayman Islands as a case study, we combined conservation methods from the social sciences in a nationwide trade assessment targeting turtle consumers and the only producer of farmed turtles—the Cayman Turtle Farm (CTF). The CTF has been producing turtle meat for human consumption for almost 50 years, which allowed us to explore consumer preferences toward wild-sourced and farmed products and draw lessons on 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 sociodemographic characteristics of consumers, assessed consumer preferences, and analyzed trends in the sales of legal turtle meat. We explored the application of a multidisciplinary toolset to improve understanding of consumer behavior, to examine how this toolset might inform the design of consumer-focused interventions, and to consider the implications for wildlife farming and sustainable wildlife trade.

Methods

Study Area

The Cayman Islands are a U.K. Overseas Territory in the Caribbean Sea. Characterized by a multicultural population of over 100 nationalities, the latest census estimated a population of 55,036 residents, 55% of which had Caymanian citizenship and the remaining being mostly citizens of Jamaica, the United Kingdom, or United States. Tourism and banking are the main industries; agriculture, forestry, and fishing sectors employ a 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 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 these populations have been monitored regularly since 1998 (Aiken et al. 2001). Over 100 green turtle nests were recorded in 2008 (Echternacht et al. 2011).

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 it 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 it became illegal to possess turtle eggs and to take 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 a few licensed fishers (3 valid licenses at the time of study) on whom seasonal and size limitations are imposed. Each legally captured turtle must be presented to fisheries officers, but no legal take has been recorded since 2008 (J.M.B., personal observation). 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) (average individual income was CI$48,344 at the time of study) and 1 year imprisonment. In practice, penalties for possession of illegal turtle products are generally less severe. For example, recently 4 people illegally captured and possessed a wild turtle, and each person was fined CI$1000-2000 and sentenced to 100 to 120 hours of community service, and their fishing vessel was confiscated. During the 12 months prior to our study, 2 mature turtles, 5 juvenile turtles, and 3 turtle nests were poached (J.M.B., personal observation).

Study Design and Data Collection

We combined information from household surveys and turtle meat sales from CTF to obtain insights into both individual consumer characteristics and broader purchasing trends. Data sources, methods employed, and rationale for their application are summarized in Table 1, and additional information is in Supporting Information.

Research was approved by the University of Exeter Ethics Committee (reference 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. Specialized techniques developed for investigating sensitive topics were used to ensure respondent anonymity, increase willingness to answer questions, and, critically, to 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 behaviors) were placed at the end of the questionnaire and followed a reminder about the anonymity of any information collected and provision of an explicit option to not answer the question.

Table 1. Summary of data sources and primary methods used and rationale for their application in the study of consumer preferences toward wild-sourced (illegal) and farmed (legal) turtle products in the Cayman Islands.

Data source	Primary method	Rationale
Nationwide household survey (questionnaires Sep–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) to estimate prevalence of illegal behavior.
	diet-recall exercise	Reduce question sensitivity to estimate prevalence of illegal behavior.
	direct questioning	Estimate prevalence of legal and illegal behaviors 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 to make the elicitation of preferences about illegal activities less sensitive (Nielsen et al. 2014).
CTF sales records (compiled April 1995 to December 2014)	sales trend analysis	Explore trends in annual sales over time and potential seasonal and demographic effects.

Household Surveys

After questionnaire development informed by stakeholder interviews and survey piloting (details in Supporting Information), questionnaires were administered by a team of 10 trained enumerators through face-to-face interviews at the homes of residents from 19 September to 2 December 2014. The household register, listing all households countrywide, was used as a sampling frame. Households were randomly selected using disproportionate stratified sampling. We selected 100 households in each of the 6 districts. Interviews were conducted with any household member ≥18 years old. Further information about survey design and administration is in Supporting Information.

Respondents were asked about turtle meat consumption and purchase, participation in illegal behaviors related to sea turtles (i.e., buying turtle meat harvested from the wild and eating turtle eggs), and sociodemographic questions (gender, age group, level of education, household size, nationality, voter registration, grandparents born in the Cayman Islands, and district of residence [details in Supporting Information]). Those who reported never having eaten turtle or having eaten it once were not asked the detailed questions about turtle consumption. The questionnaire is in Supporting Information.

Several questioning approaches were used to reduce instances of no response and social desirability biases encountered when asking about illegal activities (Nuno & St John 2015). To assess prevalence of turtle-egg consumption, we used a recall exercise in which respondents indicated which turtle products they had consumed; turtle eggs was one of the options alongside multiple nonsensitive 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 to control or treatment groups; control-group members receive a list of nonsensitive items (e.g. food items such as tuna), whereas the treatment group receives the same list 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. This technique is applied twice to the same sample with a different list of nonsensitive questions each time, and both experiments provide estimators of the sensitive behavior that can be averaged. Every respondent was thus shown 2 UCT cards per behavior (Supporting Information) and asked to indicate how many, but not which, items applied to them.

Because of occasional theft of turtles from CTF and subsequent sale of their meat to consumers, potentially as wild turtle (M. Orr, personal communication), we could not distinguish between the prevalence of purchase of these 2 illegal products (i.e. consumers may have bought turtle stolen from CTF as if they were wild). However, our results suggest respondents' willingness to consume and purchase wild turtle if it were available despite current regulations.

To investigate consumer preferences under different policy-relevant conditions and identify consumer characteristics that inform demand-side conservation interventions, choice experiments were used. This is a

Table 2. Description of all attributes and their levels in the choice experiments based on relevant literature, stakeholder interviews, and a pilot survey (Supporting Information) related to turtle consumption.

Attribute	Rationale and description
Distance traveled	We investigated 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 in the Cayman Islands (Cayman Turtle Farm [CTF]). This attribute represents the distance (1-way journey) a respondent would have to travel to buy turtle meat: approximately 8, 24, or 32 km (respectively 5, 15, 20 miles).
Source of meat	The use of farmed turtle meat as a substitute product has been questioned given the potential consumer preference for wild-sourced turtle. Thus, we considered whether turtle meat was sourced from the wild or farmed, making the elicitation of preferences about illegal activities potentially less sensitive (Nielsen et al. 2014).
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 (a few times per week, a few times per month, or 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 investigated potential trade-offs between turtle conservation and consumer behavior. In the absence of accurate population estimates, we divided the number of nesting turtles in the wild into 3 groups: 20 (below current level), 100 (near current level), 600 (above current level).
Price	Although price is generally a primary determinant of demand (Bulte & Damania 2005), we investigated potential changes in demand due to price (measured in CI$[*]) of 0.45 kg (1 pound) of turtle meat. This is the unit of measure used by CTF; (at the time of study, 0.45 kg of farmed turtle meat = CI$9). We used 3 categories for price: CI$5, CI$10, and CI$20.

[*]*Cayman Island (CI) dollar is fixed to the value of the U.S. dollar: CI$1 = US$1.22.*

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 makes the elicitation of preferences about illegal activities less sensitive (Nielsen et al. 2014), 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. Only turtle consumers (i.e. study participants who never ate turtle or only had eaten it once were not asked to participate) were asked to select their most preferred turtle meat options among a range of alternatives. We considered the context for the choice task carefully. During the pilot study some consumers reported preferring to purchase uncooked turtle meat, whereas others preferred consuming it in a restaurant, so we developed 2 versions of the cards. We report only on the uncooked-turtle-meat choice experiments because this behavior is directly affected by consumer decisions, whereas, given current lack of certification, the source of turtle in restaurants is difficult to assess and more indirectly related to consumer decisions. Each option had 5 attributes (see Table 2). All attributes and their levels were chosen based on relevant literature, stakeholder interviews (including consumers and producers of turtle meat [Supporting Information]), and pilot survey results.

The choice survey was a main-effects D-efficient Bayesian design produced using Ngene software (Choice-

Metrics 2012). Bayesian prior distributions were generated from the results of pilot study. This design maximizes statistical efficiency in estimating parameters (Hinsley et al. 2015). We used 36 choice scenarios blocked into 6 groups of 6 to reduce cognitive demand on respondents. Respondents were randomly assigned to one of 6 blocks. Every respondent was shown 6 choice cards (Supporting Information), and each time respondents were asked to choose their preferred option.

CTF Sales Data

To explore trends in sales of farmed turtle over time and potential seasonal and demographic effects, monthly information on prices of farmed turtle products and amounts sold from April 1995 to December 2014 were provided by CTF. Sales and price data provide insights into actual consumer behavior (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 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 with 2014 prices as reference were obtained by dividing actual prices by annual consumer price index.

Data Analyses

To correct for disproportionate stratified sampling, we weighted responses based on district population size

with the package survey (version 3.30) (Lumley 2014) in R (version 3.2.1) (R Foundation for Statistical Computing 2015). Unless otherwise stated, analyses were conducted in R. All estimates were thus adjusted for study design and sample sizes refer to the actual number of respondents.

For each behavior assessed using the double UCT, 2 estimators ($\hat{x}_1$ and $\hat{x}_2$) were obtained by calculating differences in means between control and treatment subsamples. These estimators were then averaged to estimate the overall prevalence of sensitive behavior ($\hat{x}$). Following Coutts et al. (2011), the sampling variance (var) was estimated using

$$\text{var}\left(\hat{x}\right) = \frac{\text{var}\left(\hat{x}_1\right) + \text{var}\left(\hat{x}_2\right) + 2\text{cov}\left(\hat{x}_1, \hat{x}_2\right)}{4}, \quad (1)$$

where cov is the covariance. To investigate the potential effects of sociodemographic variables on behavior prevalence quantified through DQ, generalized linear models with quasibinomial 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) with Sawtooth Software (Sawtooth Software Lighthouse Studio version 9.0.1, Academic Lab, Orem, UT, USA). Although MNL is a standard procedure used to determine aggregate preferences based on the assumption that the population is homogeneous, LCMs capture preference heterogeneity across segments of the population, which allowed us to explore potentially different consumer groups. A first-order interaction between price and source of meat was considered but did not improve the model significantly (2-log likelihood test: $p > 0.1$) and so was excluded from further steps. Analytical details of the choice experiments are in Supporting Information. Potential relationships between segment membership and sociodemographic variables were investigated as described above for DQ responses.

CTF Sales Data

To explore trends in annual sales over time, the amount of turtle meat sold per year was modeled as a function of time (1996–2014). We fitted generalized additive models with a normal error distribution and identity link to the data and smoothed the time series of annual sales with the package mgcv version 1.8-6 (Wood 2015). To explore the shape of the trend, we modeled 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). We selected the most parsimonious model with the AIC corrected for small sample size (AIC$_c$). We considered non-null models instead of null models and nonlinear models instead of linear models acceptable only if ΔAIC ≥ 4.

A similar procedure was followed to investigate trends in monthly sales of 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, and inflation-adjusted prices, as a potential explanatory variable, and month and year effects, as cubic smoothing splines, were added. A description of how we accounted for temporal autocorrelation is in Supporting Information.

Results

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

Consumption of Turtle Products

Approximately 54% (95% confidence intervals [CI], 50.9–57.2) of resident households consumed turtle meat at least once in the past, and 42% (95% CI, 36.0–48.0) have eaten it more than once, suggesting that around 22% of those who tried it were potentially no longer interested in consuming it. Among 50 respondents who answered a follow-up question about only consuming it once, dislike for taste or texture was mentioned by 44 of them. Thirty percent (95% CI, 25.1-35.9) consumed turtle meat at least once during the prior 12 months.

According to DQ answers, around 1.0% (95% CI, 0.3–3.5) of resident households illegally consumed turtle eggs during the prior 12 months. Through a recall exercise for people who consumed turtle meat more than once ever, 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). The UCT produced an unrealistic negative prevalence, although results overlapped with zero and thus were inconclusive (Fig. 1a).

Purchase of Turtle Products

Among resident households that reported consuming turtle during the 12 months prior to our study, 37% (95%
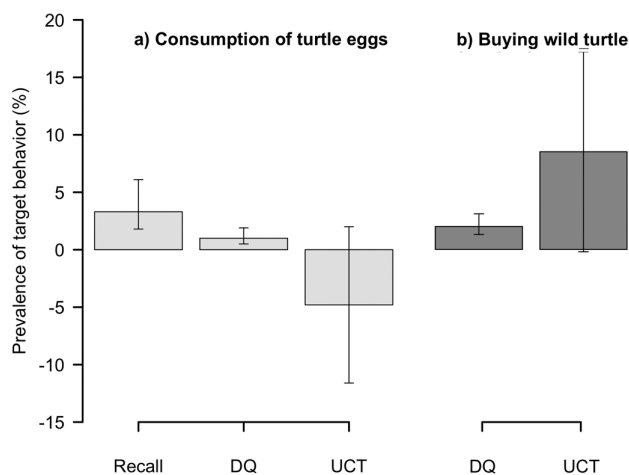
Figure 1. Estimated prevalence (SE) of illegal behaviors in the Cayman Islands based on responses of households: (a) consumption of turtle eggs based on diet recall only among respondents who consumed turtle more than once ever (recall) (n = 280), direct questioning (DQ) (n = 537), and unmatched count technique (UCT) (n = 553) and (b) buying wild turtle based on DQ (n = 540) and UCT (n = 553).
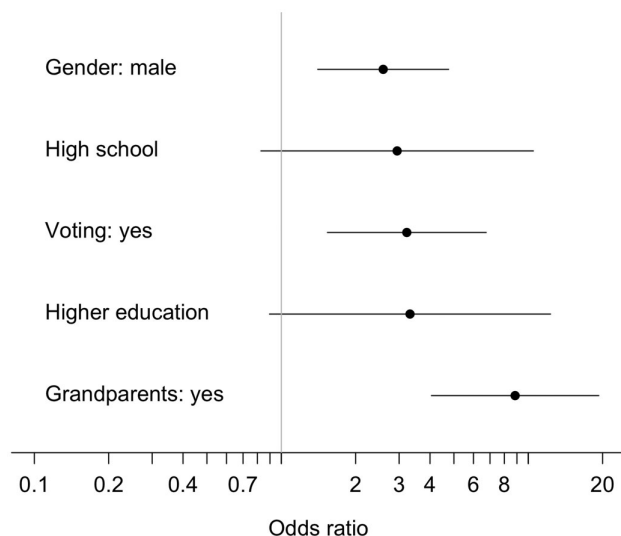

Figure 2. Effects of main sociodemographic categorical variables, presented as odds ratios (95% CI), on having eaten turtle meat during the 12 months prior to the survey (back-transformed from parameters presented in Supporting Information) (gray line, odds ratio = 1). Each category is compared with the following reference levels: female (gender), not being registered to vote in the Cayman Islands (voting), not having at least one grandparent born in the Cayman Islands (grandparents), and respondent with primary education only.

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 sellers (1%; 95% CI, 0.3–4.1). The remaining 62% (95% CI, 51.0–71.5) of consumers did not buy uncooked turtle meat (e.g., they consumed it at restaurants or a friend's home).

According to DQ answers, 2% (95% CI, 0.8–4.8) of all resident households bought turtle meat illegally (Fig. 1b). The UCT showed a higher estimate, but this overlapped with zero and was not significantly different from that obtained using DQ ($t = -0.74$, df = 559, $p = 0.23$).

Out of the 21 people who provided additional information about where they got wild turtle, one person reported getting it as a gift from a friend and the others purchased 1.8–6.8 kg (4–15 pounds) of meat (median 4.1 kg [9 lbs]; 95% CI, 2.3–4.5) at CI\$9–56/kg (CI\$4–25/lb) (median CI\$11/kg [CI\$5/lb]; 95% CI, 11–18). For comparison, 0.45 kg (1 pound) of farmed turtle meat was sold for CI\$9 at CTF at the time of study.

Potential Sociodemographic 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% CIs for education overlapped zero, which decreased our confidence in the direction of this effect (Supporting Information). 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 (Fig. 2). Other variables also included in the top models but with much less support were household size, age group, and district of residence (Supporting Information). Findings on potential sociodemographic predictors of purchase of wild turtle were nonconclusive (Supporting Information).

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 or believing they were being tricked ($n = 5$) 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 (Supporting Information). For this general group, traveling shorter distances, farmed meat, lower prices, intermediate frequency of consumption levels,

and larger number of nesting turtles in the wild increased the probability of consumers choosing an option that corresponded to these levels (Supporting Information).

When we considered potential differences among consumer groups, the largest segment in the selected latent class model (Supporting Information) included 30.3% of consumers, and this group showed significant preferences for low prices and short distances; price was the most important attribute (relative importance score = 61.2%; Supporting Information). 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 21.9% of consumers preferred paying the highest prices for turtle meat. In addition, 13.5% of consumers showed a significant preference for wild meat, whereas all remaining segments preferred farmed meat (Supporting Information). 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% CIs for household size and nationality overlapped zero, which decreased our confidence in the direction of this effect (Supporting Information). Being 35–54 years old and living in George Town district decreased likelihood that respondents were included in this segment. Other variables included in top models, but with much less support, were gender, grandparents' nationality, and being registered to vote. When asked a direct open-ended follow-up question about preferences toward wild versus farmed turtle meat, taste was the key reason provided for preferring wild meat (*n* = 23), whereas legality (*n* = 24) and availability (*n* = 19) were the key reasons provided by those who preferred farmed meat.

Trends in Sales by CTF

Annual sales over time were best explained by a nonlinear model with 6 knots (*k* = 6). The following sections were delineated (Fig. 3): relatively stable sales from 1996 to 2001 with drastic decrease in 2002 (CTF severely affected by hurricane in late 2001); after the 2001 hurricane, sales peaked in 2005 after which they decreased to a minimum annual sales in 2010 (turtle meat prices increased by 200% in February 2010); and ongoing increase in sales after February 2010. 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. Monthly sales of turtle stew per number of Caymanian residents varied significantly with month, year, and inflation-adjusted price (Supporting Information). Our results suggest that, for a unit increase in
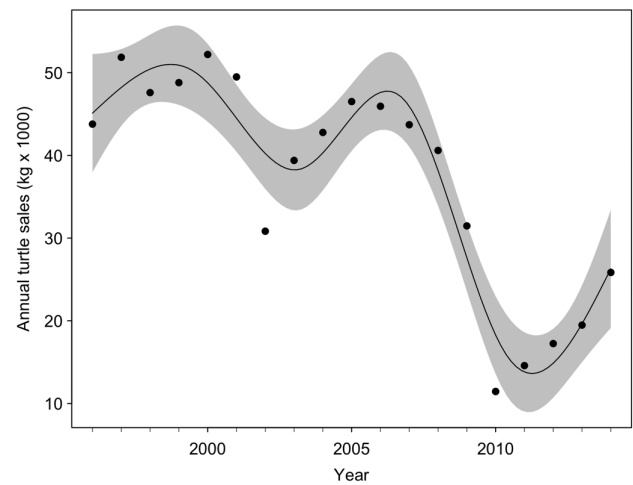

Figure 3. Estimated annual trend in Cayman Turtle Farm (CTF) sales of turtle meat from 1996 to 2014 (shading, 95% CI; points, raw data; adjusted R^2 = 0. 90).

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 average from 1995 to 2002 and significantly below average from 2006 onwards (Supporting Information), suggesting other factors are potentially affecting these dynamics.

Discussion

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 it may represent an important threat to wild turtle populations due to their reduced size. Behavior among consumer groups differed markedly and price and source of product played 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 CTF currently plays an important role in terms of providing turtle meat and contributing to 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 results suggest 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 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 Supporting Information). 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 show similar preferences for 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; our results show 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 behavior under different scenarios. Based on our results, farmed turtle meat is much more abundant and easily available than wild meat in the area, and we found 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 the 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 here (e.g., certain consumers willing to pay premium prices and 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 actual purchasing behavior over time and potential behavior under hypothetical conditions. These are essential for conservationists to design interventions based on current conditions and understanding and, more predictively, to consider how interventions may change consumer behavior. We suggest a multidisciplinary toolset is essential to better understanding markets and consumer behaviors, particularly when investigating preferences for 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 behaviors were too rare and UCT has considerable statistical efficiency limitations (Nuno & St John 2015).

Although DQ provided useful baseline information, it is likely to represent an underestimation of behavior prevalence. Actual honesty levels were not assessed but, as suggested by potential penalties, higher nonresponse rates to DQ than UCT (Fig. 1), and enumerator notes (Supporting Information) recorded after completion of each questionnaire (e.g., 29 respondents showed signs of dishonesty, such as incongruent responses and changes in body language), some participants were reluctant to share sensitive information. Similar issues may 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 behavior (Nielsen et al. 2014). An increased sample size and more complex choice experiment design, developed to robustly investigate 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. We focused on consumer behavior and implications for its efficacy. The lack of long-term social–ecological assessments remains an important challenge to the success of this strategy and hinders its evaluation. For example, despite being in operation for almost 50 years, virtually no detailed socioeconomic information about turtle consumption in Cayman was available until now. Similar issues of lack

of monitoring and impact evaluation affect the ability to learn from successes and failures of wildlife-farming facilities worldwide. 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 was unavailable. Such information is important for disentangling supply and demand effects. Monitoring and evaluation information is key to understanding the conditions under which different interventions are likely to succeed. For example, the perceived and actual efficacy of law enforcement in the area remains to be explored, whereas headstarting has showed some positive impacts (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 analyzed. This will contribute to an evidence-based evaluation of those interventions, ultimately identifying ways forward for a key conservation challenge.

Acknowledgments

Supporting Information

Additional methods description for household surveys (Appendix S1), the questionnaire (Appendix S2), and supplementary information supporting results (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than the absence of the material) should be directed to the corresponding author.

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