Methods of and motives for laundering a wildlife commodity beyond captive farming-based systems: The harvest of olive ridley sea turtle eggs

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Abstract

Wildlife is an important source of nutrition and income for rural communities, yet illegal wildlife trade can threaten biodiversity and economic development. Where wildlife is traded legally, laundering of illicit goods can still occur, yet opportunities to study this process are rare. Despite operating for over 30 years the legal extraction and commercialisation of olive ridley sea turtle eggs from Ostional, Costa Rica is shrouded in controversy. This is due to the high level of illegal egg collection that takes place on other beaches, with critics arguing the legal trade is stimulating illegal extraction and enabling illicit egg sales. This research aimed to identify whether the Ostional harvesting programme was being used to launder illegally collected eggs and whether local vendors were adhering to the traceability regulations in place for this trade. The illegal extraction of turtle eggs in the Caribbean was driven by motivations that were not exclusively livelihoods based. Through semi-structured interviews, it was established that dependency on narcotics by people marginalised from society was the main driver of illegal extraction. This was coupled with under-resourced law enforcement in relation to wildlife crime. However, substance misuse appears to be driven by poverty, which needs to be addressed if illegal egg extraction is to be reduced. Market surveys found a high proportion of vendors sold eggs outside legal packaging, and eggs prepared for consumption generated a greater revenue than fresh, certified eggs. A value chain analysis of the legal trade highlighted vulnerabilities and inequalities in revenue generated from Ostional eggs between different actors in the chain. A comparison of trade routes identified several locations where the legal and illegal trades geographically overlap, and where evidence of laundering would be expected. However, almost all eggs in the trade were olive ridley, and illegal sales made no reference to the commercialisation of eggs from Ostional. While an illegal trade in fully protected species is clearly flourishing, it appears to be operating independently of the Ostional egg project. This research offers a rare opportunity to examine a long standing wildlife trade and its impact beyond the scope of the livelihoods of the source community. Extracting natural resources is often seen as detrimental, however this research has shown how the use of a natural resource can assist in alleviating poverty and improve local livelihoods. In addition, it informs policy regarding wildlife laundering. Despite both the legal and illegal trades appearing to be driven by the supply of eggs, and the benefits

of rule-breaking outweighing the costs, no evidence of laundering was found. The fact (1) there are relatively few actors entirely dependent on Ostional eggs; and (2) that the Atlantic turtle populations appear to be recovering, suggest that the legal trade in turtle eggs is having a negligible impact on the other turtle species that nest in Costa Rica.

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CHAPTER 1

Introduction

1.1. Background – Global threats to biodiversity

Valuable ecosystems, human wellbeing and possibly civilisation itself are critically threatened by the loss of biodiversity (Ceballos et al. 2010; Ceballos et al. 2015). While extinction is a natural process, balanced by speciation, it is becoming increasingly recognised this rate of extinction is higher than the natural rate of species loss (Ceballos et al. 2015). Over the last 500 years, human activities have caused local and global extinctions, on a scale and rate that have only been seen five times in the history of Earth (although technically, two of these events were mass depletions rather than extinctions) (Barnosky et al. 2011). These activities include resource extraction, direct killing of species, alien species introduction, habitat destruction, pathogen spreading, and climate change (Dirzo and Raven 2003; Barnosky et al. 2011). In 1995, it was estimated that we were facing a human-induced biodiversity crisis which is likely to be the sixth mass extinction event (Pimm et al. 1995; Barnosky et al. 2011). In 2004, it was predicted that over the next 50 years up to 50% of species will be lost, the recovery from which may take millions of years (Pin Koh et al. 2004; Barnosky et al. 2011).

The significance of biodiversity loss cannot be overestimated. Humans rely on natural resources for ecosystem, function and stability, as well as the economic benefit from wild goods (Singh 2002). Agricultural resilience and production are dependent on biodiversity, providing ecosystem services such as nutrient cycling, pest control, or pollination (Garibaldi et al. 2016). Yet, the demand for wildlife products is so great that some species are being driven to extinction (Scheffers et al. 2019). In 2005, it was estimated that the annual legal international wildlife trade, excluding fisheries and timber, was worth ~US$24 billion (Engler and Parry-Jones 2007). Much harder to quantify, illegal wildlife trade is estimated to be worth between US$19-26.5 billion a year and is believed to be fourth, in terms of transnational trafficking, after narcotics, humans and counterfeit goods (Hanken 2011; IATA 2018). However, t'Sars-Rolfe et al. (2019) contest this figure on the grounds that quantifying illegal trade is almost impossible. Estimates are based on seizure data, biased towards countries with greater

enforcement capacity and, cargo that reaches its destination unhindered cannot be included in the statistics. While fisheries and timber constitute most of the wildlife trade, traditional medicines, pets, luxury goods and ornamental plants are also important components. In recent years, geographical barriers to trade have been removed, resulting in greater freedom of movement and increased trade opportunities. This means that former subsistence harvesters are now able to trade internationally (Sigouin et al. 2017). An example of these new markets is the millions of freshwater turtles from farms, ranches and the wild, that were exported from the USA to Asian food markets between 2002 and 2012 (Mali et al. 2014). Efforts to curb the rate of extraction to protect traded species have included domestic legislation against extraction and export, evicting communities from newly established protected areas or more militarised protectionist strategies. Botswana, Kenya, Nepal, Uganda and Zimbabwe for example have shoot-to-kill policies for elephant and rhino hunters (Bulte and Damania 2005; Duffy et al. 2015). However, these draconian measures are in direct conflict with the Conservation Initiative for Human Rights (CIHR) and have created disquiet in the conservation community (IIED 2020). Calls have been made for international standards on human rights in conservation (Roe et al. 2010). The term "poacher" carries with it historical and colonial cultural overtones, and the term is often rejected in conservation dialogue. As surveillance technologies improve, opportunities increase for their utilisation in anti-smuggling efforts. The use of Unmanned Aerial Vehicles (drones) or audio moths, offer the potential to collect real time data on illegal hunting, at a fraction of the cost or skillset required for foot patrols (Pin Kho and Wich 2012; Mulero-Pázmány et al. 2014; Pajares 2015; Hill et al. 2018). However, these techniques, particularly drones, raise ethical concerns as they may be perceived as menacing surveillance or may be associated with warfare (Hulme et al. 2014).

At the international level, the Convention on International Trade in Endangered Species (CITES) lists threatened species in three Appendices. Appendix I species cannot be traded for commercial purposes. Appendix II allows for a regulated trade (via permits and quotas) and applies to species not currently threatened, but may become so if rates of current trade continue. Appendix III contains species under the protection of one or more parties that requires the support from their trading neighbours to regulate trade (CITES 2020).

A significant driver of the consumption of wildlife is the human fondness for rarity, which increases demand for scarce resources. The rarer a species becomes, the higher it is prized. This increases the market value leading to greater demand and accelerated extraction. According to Courchamp et al. (2006), the value a consumer places on a species is disproportionately skewed towards rarity, which could increase demand for that species. Supplying that demand further increases its rarity until extinction (Hall et al. 2008). Courchamp et al. (2006) refer to this as the anthropogenic Allee effect, stating "*the human predisposition to place exaggerated value on rarity fuels disproportionate exploitation of rare species, rendering them even rarer and thus more desirable, ultimately leading them into an extinction vortex*" (Courchamp et al. 2006; Biggs et al. 2013). Commodities such as rhino horn and elephant ivory are examples of such products, whose value increases as their availability decreases (Vandergrift 2013; Gao et al. 2016). Illegal extraction has been found to be more strongly related to the wealth of demand countries, than poverty in supply countries (Duffy et al. 2015). CITES listing can therefore precipitate the unintended consequence of highlighting a species' rarity, increasing its value and driving its subsequent greater extraction. Newly described species in the pet trade have been found to enter the market at inflated prices. CITES listed reptile and amphibian species have been found to be significantly more expensive than non-CITES species, probably due to their perceived rarity (Courchamp et al. 2006; Stuart et al. 2006).

While blanket trade bans are widely advocated, they are often incompatible with the Convention in Biological Diversity (CBD 2020). Bans may conflict with the livelihoods of local communities and, in countries where law enforcement is under-resourced, can be little more than paper protection. Often the financial value of an item increases from harvester to end retailer, with harvesters – often in poor countries – receiving the lowest return (Robinson et al. 2018). With little financial incentive to protect species and law enforcement often under-resourced, alternatives to trade bans that include local communities are much needed. CITES Appendix II and III listings that offer regulated trade opportunities present an alternative to blanket bans.

1.2. Conservation through sustainable use

In 1980, the World Conservation Union highlighted sustainable utilisation in its definition of conservation as: "*the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations, while maintaining its potential to meet the needs and aspirations of future generations.* (IUCN 1980). Since then, the international conservation narrative has shifted in two ways. Firstly, towards recognising that markets can be used to enhance conservation and not necessarily threaten species in demand (Hutton and Webb 2002). Secondly, the movement away from "no-touch" preservation, to one of inclusivity, embracing local resource users as stakeholders and sustainable use as a valid component of conservation (Campbell 2007; Larsen and Olsen 2007). Sustainable use is the "*use of resources in a way and at a rate that does not lead to the long-term degradation of the environment, thereby maintaining its potential to meet the needs and aspirations of present and future generations*" (InforMEA 2020). A legal trade can be used to reduce illegal extraction if (1) having a legal supply does not increase demand; (2) the legal product is a suitable substitute; and (3) it is more cost effective to supply the product legally than illegally, so that laundering can be avoided (Tensen 2016). Methods to produce wildlife commodities may involve farming, for example domesticating a target animal species or cultivating and propagating plants (Phelps et al. 2013), or supplying demand from stockpiles or synthetic alternatives (Bulte and Damania 2005). However, open trade channels also provide distribution networks for illegal commodities, meaning a regulated trade can encourage and increase illegal extraction for trade (Bulte and Damania 2005; Tensen 2016). As Michael Sutton, director of land and wildlife programs for the World Wildlife Fund stated "*Giving wildlife commercial value is a double-edged sword. Poachers like wildlife with commercial value too*" (Keller 1992). Wildlife can be supplied from three sources that vary in intensity. Wildlife farms, such as those for bear bile, keep animals in closed captivity and carry ethical considerations regarding animal welfare (Kikuchi 2012). Ranching may involve free-ranging animals inside corrals i.e. rhino, or head-starting programs such as rearing offspring from wild collected eggs. The third and least intensive is direct take from the wild (Bulte and Damania 2005).

The trade in crocodilian skins is one of the most successful examples of sustainable use of wildlife in conservation. Prior to the 1960s, laundering took place in several source countries. Since then however, legal trade has largely outcompeted the illegal trade (Moyle 2017). This success is attributed to 30 countries engaging in wild harvesting, ranching and captive breeding 12 species of crocodilian and trading their products, namely skins. These programs operate to produce skins seemingly without negatively impacting on the conservation of the species. So successful was this model, that the current 11 species with highest commercial value are also the least threatened with extinction, success attributed to the legal trade undermining the illegal market (Hutton and Webb 2002). However, proposals for the sustainable use of a similar species was rejected by CITES. In 1997 and 2000, Cuba attempted to down-list hawksbill turtles (*Eretmochelys imbricata*) from Appendix 1 to Appendix II (Mortimer et al. 2007). Sea turtles share similar life history traits with crocodilians: they are widely distributed, slow maturing, aquatic, egg laying reptiles (Meylan and Meylan 1999). Prior to Cuba becoming a signatory to CITES, as many as 5000 sub-adults and adults were extracted annually. This was used to feed local people and export the shell plates (scutes) to Japan for the Tortoiseshell, or "Bekko", industry (Limpus and Miller 1990; Webb 2002). Based on the fast growth rates of turtles, it was clear the population could sustain this – or possibly higher - levels of harvest. However, the proposal for a legal harvest was rejected by CITES on the grounds that as hawksbills are migratory, harvesting in feeding grounds can impact the nesting populations outside Cuba. Trading by one nation, therefore, may have a deleterious effect on the conservation efforts of several other nations (Mortimor et al. 2007). Nevertheless, Webb (2002) suggests the rejection was due more to the charismatic appeal of hawksbills, than their incompatibility with sustainable harvest; an issue that did not arise with crocodiles. In 1999, Cuba continued to take under 500 turtles a year, stockpiling their scutes in the hope of a future trade exemption (Webb 2002).

Opponents of conservation through sustainable use, cite three concerns. Firstly, any market will be misused for short term profits, secondly, demand will be stimulated, and thirdly, market forces are more powerful than law enforcement. Collectively, this could drive over-exploitation of the commodity in question. Further complicating the issue is the fact that not all countries in a species' range may be signatories of CITES, and this may promote laundering. Prior to Mexico becoming a signatory to CITES

in 1991, the country was used as a transhipping hub for Caribbean-hawksbill products (CITES 2020). This was described as a "vast laundering operation" and was the catalyst for Mexico to join CITES (Aridjis 1990; Canin 1991). Whether legal trade increases illegal trade has important conservation and livelihood implication and finding answers should be prioritised (Hutton and Webb 2002).

1.2.1. Laundering

One of the most widely cited concerns regarding the use of wildlife for conservation, is the fear that a legal trade will stimulate illegal markets. Opening trade of a wildlife product also opens opportunities to launder illicit goods through a legal market, with the potential of increasing illegal extraction and resource depletion (Hutton and Webb 2002). When trade is illegal, illegal harvesters and traffickers can only trade illegally. Where a legal trade exists however, a second avenue opens to launder illegal products though legal channels. This means that illicit sales may increase, rather than decrease, in the presence of a legal market (Moyle 2017). Sourcing wildlife from captive breeding/propagating facilities is at the forefront of this issue.

Captive breeding can be used both for recovering/sustaining endangered populations or to produce animals and plants for trade. The problem arises in giving rare species a commercial value, which in turn may lead to wild harvested species being resold as captive bred/artificially propagated, examples include parrots, tortoises, birds of prey and orchids (Ogden et al. 2009). Reptiles exported from Indonesia to the European Union are a clear example of captive breeding providing a loophole for trade in wild caught specimens. Examination of trade statistics of five reptile species, highlighted discrepancies between import figures and the number of individuals a breeding facility can produce. This indicates that wild caught individuals were used to make up the deficit (Nijman and Shepherd 2009). Similar concerns have blighted efforts by the Cayman Turtle Farm to trade farmed green sea turtle (*Chelonia mydas*) meat. Opponents were concerned that the availability of legal turtle meat would stimulate demand for illegal, wild sourced meat, particularly due to the possible consumer preference for wild meat. Overheads associated with farmed meat meant it was not a cost-effective alternative to that from the wild (D'Cruze et al. 2015). Further, without the involvement of molecular techniques

differentiating between farmed and wild meat is virtually impossible, which raised concerns about laundering wild meat as farmed (Fleming 2001).

Differences in legislation between countries can enable wildlife laundering through the exploitation of differing domestic regulations. Under the Lacey Act (1900), non-CITES listed, wild caught Southeast Asian newts cannot legally be imported into the US. However, the EU does not have these same import restrictions, meaning newts can be imported, relabelled as captive bred and then exported to the US (Rowley et al. 2016). Other strategies to launder species include bribing officials and transporters to allow safe passage of illicit cargo, or hiding illegal items within legal shipments (Natuch and Lyons 2012). This is facilitated by a lack of law enforcement capacity to correctly identify species, further exacerbated by taxonomic changes, meaning more species can be traded under previous synonyms. This creates a loophole allowing the trade of non-quota species thought the quota system (Natuch and Lyons 2012).

Correctly identifying species and ensuring traceability from trader to end consumer are two important components in curtailing wildlife laundering. Relatively recent advances in wildlife forensics mean that species identification no longer relies on morphological characteristics. Using DNA profiling to distinguish between species, endangered hammerhead sharks (*Sphyrna* sp.) were identified in Hong Kong's largest fin market (Abercrombie et al. 2004). Similar techniques use genetic markers to allow DNA profiles to verify parentage, which can be used to reduce laundering in ex-situ breeding facilities (Ogden et al. 2009). Selling an animal with the shell from which it hatched, video or photographic evidence of the animal hatching, or selling the neonate with yolk attached or egg tooth are all techniques used to confirm captive bred status (Lyons and Natusch 2011; Sy 2015). While these 'low-tech' options may not seem particularly rigorous, it should be noted that in some source countries, simply requiring the shipments to contain egg shells will be sufficient, as many facilities do not have the breeding capacity and therefore lose any capability to "fake" captive breeding (Nijman and Shepherd 2009; Lyons and Natusch 2011).

1.3. Community-based conservation

While farming and ranching options are mostly led by private firms or businesses, wild-take often occurs inside a less formal structure, with individuals and communities at the forefront. In the past, wildlife resource management, a traditionally "no-touch" approach largely developed in Africa, led to local resource users seen, by wildlife managers, as perpetrators in overexploitation (Hope 2002). Some of the world's poorest countries are the richest in biodiversity, creating a conflict between meeting basic human livelihood requirements and species conservation (Rosser and Mainka 2002; Kaimowitz and Sheil 2007; Leberatto 2016). In much of the world, rural communities rely on access and entitlement to natural resources to fulfil their livelihood requirements. People cannot uphold sustainable livelihoods when pervasive food insecurity and poverty drives them to assume practices that degrade the natural resources upon which they depend (World Bank 2000; Hope 2002; Roe 2002; Broad et al. 2003). The Convention on Biological Diversity (CBD) recognises a countries' sovereign right to utilise its natural resources; acknowledging that without access rights, people will not value nature, which will lead to its subsequent destruction (Robinson and Redford 1991; CBD 2020). An alternative to the preservationist line, is one characterized by the neo-liberal approach to the use of resources, often referred to as the community-based approach. This adopts a bottom up strategy inclusive of local communities and integrates development with conservation and sustainable use of wildlife (Hulme and Murphree 1999).

Sustainable resource management has proven to be an effective alternative to complete trade bans and access prevention, and can be a useful strategy in the management of natural habitats the conservation of ecosystems (Becerra 2003). Sustainable use secures future resources and economic benefits are generated for local communities. In turn, the community recognise the resource value and work towards its conservation (Hulme and Murphree 2001; Becerra 2003). Successful examples of community-based conservation exist, that not only demonstrate that harvesting wild goods is not detrimental to populations, but in some cases may actually benefit the species in question. The yellow spotted river turtle (*Podocnemis unifilis*) is an example of a successful community-based project in the Ecuadorian Amazon. Nests doomed to flooding are harvested by the Cofan people, who are encouraged to relocate

nests to safety and monitor nest sites. In addition, they are financially rewarded for successful hatching events (Caputo et al. 2005). The success of this project has been attributed to the number of eggs lost to flooding exceeding the food and commercial needs of the community (Sigouin 2017).

While this example appears to offer a win-win solution to managing rare resources, it should not be assumed this model is a panacea. This approach is limited when a lack of capacity at the local level creates an uneven distribution of benefits. Despite often being required to absorb management costs, resource harvesters rarely receive an equitable share of the rewards (Lutz and Caldecott 1996). The remainder of this thesis will focus on one species that is harvested for its eggs by communities across Central America, the olive ridley sea turtle (*Lepidochelys olivacea*). Whilst other species of sea turtle are unsuitable for a sustainable harvest, the olive ridley may be an exception due to the unique nesting behaviour of *Lepidochelys* species and its relatively high abundance.

1.4. Sea turtles - nesting strategies, threats and as candidates for sustainable harvest

1.4.1. Basic life history

Sea turtles are egg-laying, migratory reptiles with pantropical distribution. There are seven extant species belonging to two families (Cheloniidae and Dermochelyidae) which have been present in the fossil record since the Cretaceous period (Miller 1996; Pritchard 1997) (Table 1). Sea turtle species share several reproductive characteristics. Turtles are iteroperous; after reaching sexual maturity, they continue to reproduce for the remainder of their life. All species exhibit stereotyped nesting behaviour, lay large clutches of eggs and will nest several times in the same season. Additionally, sea turtles display a powerful preference for nesting on the same stretch of coastline as their natal beach (Miller 1996). While there is some inter- and intraspecific variation in the life cycle of sea turtle species, they follow the same basic life history, comprising several similar ontogenetic habitat shifts (Bolten 2003) (Fig. 1.4.1.). On emergence, hatchlings head straight for open ocean where they remain for 1-2 years utilizing floating sargasum beds for shelter and nutrition (Carr 1986; Carr 1987; Meyland and Meyland 1999;

Reich et al. 2007; Mansfield et al. 2012). Once large enough to deter most predators, they migrate to their neritic (shallow water) sub-adult feeding grounds, where they may remain for 20-50 years before reaching sexual maturity (Bjorndal et al. 2000). They then migrate to their breeding ground offshore from their natal beach, nesting occurs at night, on the same stretch of coast as their hatching site. Nesting may occur several times in a season, before female turtles re-migrate to their feeding grounds, which can be thousands of kilometres away (Miller 1996; Musick and Limpus 1996). The remigration interval may be 2-8 years for individual females and this cycle of migrating between feeding and nesting grounds will continue for the remainder of the turtle's life (Lohmann et al. 1996).

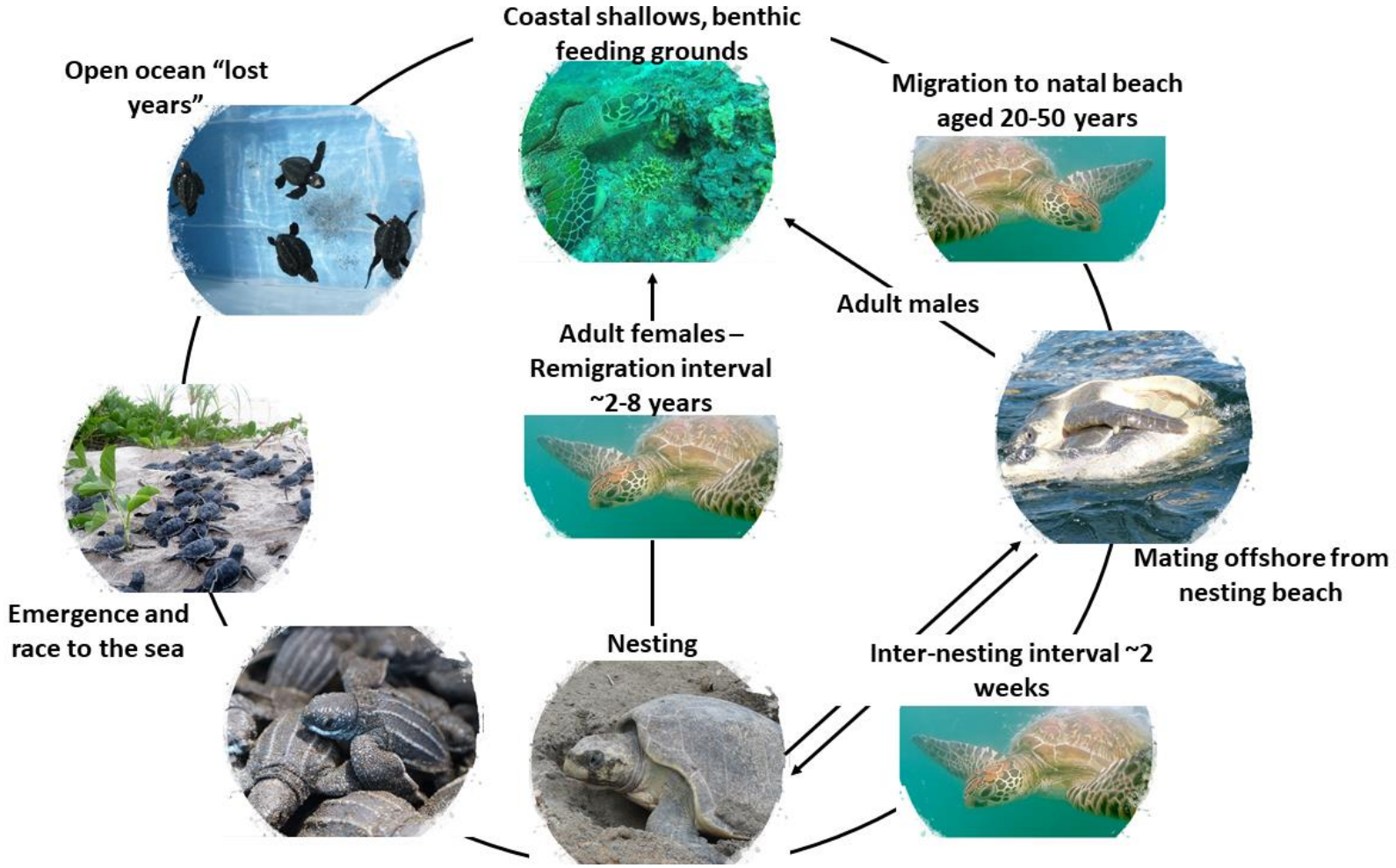

Figure 1.4.1. Generalised life cycle of sea turtles representing the species that nest in Costa Rica (Photo credits: Heidemeyer, M., Nash, B., Pheasey, H.)

1.4.2. Threats

Six of the seven extant turtle species nest on Latin American beaches and all are threatened with extinction (Davenport 1997; IUCN 2020). In Costa Rica, Green (*C. mydas*), Atlantic leatherback (*Dermochelys coriacea*) and hawksbill (*E. imbricata*) turtles nest on the Caribbean coast. The critically endangered Pacific leatherback (*D. coriacea*), the black (*Chelonia mydas agassizii*) a subspecies of the green, and olive ridley nest in the Pacific. Loggerheads (*Caretta caretta*) also nest occasionally on Caribbean beaches (Table 1.4.2.).

Table 1.4.2. Overview of sea turtle species, conservation status and reproduction found in the Pacific and Caribbean coasts (Pritchard and Mortimer 1999; IUCN 2020).

Common name	**Species name**	**IUCN status***	**Latin American Distribution**	**Nesting strategy**	**Clutch size**
Leatherback	*Dermochelys coriacea*	Global: V, decreasing Pacific: CR	Caribbean and Pacific	Solitary	80-90 (Eastern Pacific: 60-65)
Green	*Chelonia mydas*	EN, decreasing	Caribbean and Pacific	Solitary seasonal	110-130
Pacific Black	*Chelonia mydas agassizii*	See green	Pacific	Solitary seasonal	87
Hawksbill	*Eretmochelys imbricate*	CR, decreasing	Caribbean and Pacific	Solitary seasonal	110-180
Loggerhead	*Caretta caretta*	V	Occasionally in Caribbean	Solitary seasonal	110-130
Olive ridley	*Lepidochelys olivacea*	V, decreasing	Pacific	Solitary and *arribada*	105-120
Kemps ridley	*Lepidochelys kempii*	CR	Pacific	Solitary and *arribada*	104

*IUCN Criteria: Vulnerable (V), Endangered (EN), Critically Endangered (CR).

The IUCN criteria are based on global abundance estimates, and often individual populations, or Regional Management Units (RMUs) are considerably more vulnerable than the global criteria describe. The Pacific leatherback faces extinction while the Atlantic population appears to be in recovery (Spotila et al. 2000; Stewart et al. 2011). Human induced threats affecting turtles occur both at sea and on land. Mortality induced entanglement in fishing gear is significant. Araúz et al. (1997) estimate that 90% of incidental capture in the shrimp fleet of Costa Rica are olive ridleys, with a

mortality rate of 37%. Deliberate or accidental catch by individuals or fishing fleets are high in Costa Rica. At sites where turtles congregate off-shore before nesting, mortality rates of four turtles per 1000 hooks have been estimated in long line fisheries (Whoriskey et al. 2011). The damaging environmental impact of plastics, particularly in the oceans, is becoming increasingly apparent, and sea turtles are at the forefront of this issue (Ivar do Sul et al. 2011). The viral Youtube video of a plastic straw being extracted from an olive ridley's nostril sparked a campaign to raise awareness about plastic pollution (Figgener 2015). On land, nesting beaches are increasingly lost to coastal erosion thought to be from rising water levels, and artificial lights behind nesting beaches serve to disorient hatchlings attempting to navigate to the sea (Bourgeois et al. 2009). Rising sand temperatures result in increased mortality of embryos and as turtles are subject to temperature dependent sex determination, they are vulnerable to skewed sex ratios as warmer incubating temperatures increases the number of female hatchlings (Fuentes et al. 2010; Laloë et al. 2017). Turtles are particularly vulnerable during the nesting process, with few defences, and stereotyped nesting behaviour, they are easily killed for their meat or shell - a practice widespread across the tropics (Hart et al. 2013). Incubating nests are also vulnerable to predation by domestic mammals (Pheasey et al. 2018).

1.4.3. Olive ridley turtles and arribadas

Sea turtles have three nesting strategies; solitary - individually, colonially - where they coincidently emerge with other members of the same species, and aggregated - synchronised mass nesting events comprising hundreds to hundreds of thousands of females (Eckrich and Owens 1995; Plotkin et al. 1997; Bernardo and Plotkin 2007; Valverde et al. 2012) (Fig. 1.4.3.).

Figure 1.4.3. Aggregated mass nesting event, or *arribada,* in Ostional, Costa Rica (September 2018).

This aggregated nesting phenomenon, known as an *arribada* (Spanish for arrival), only occurs in a number of beaches in the Eastern Pacific, Indian and South Atlantic Oceans (Valverde and Gates 1999) (Fig. 1.4.3.1.). The Eastern Pacific has eight of these beaches, three of which are in Costa Rica. Synchronised nesting is exclusive to the genus *Lepidochelys* - kemps ridley and olive ridley (Richard and Hughes 1972; Márquez and van Dissel 1982). The kemps ridley is the most critically endangered of all turtle species, whereas the olive ridley is the most abundant (Limpus 1995; Abreu-Grobois and Plotkin 2008). The high abundance of the olive ridley is possibly due to the olive ridley's tropical and subtropical distribution and nesting in aggregations, while the kemps ridley is restricted to the eastern coast of the US and Mexico (Valverde and Gates 1999; Eckert and Abreu Grobois 2001; Valverde et al. 2012).

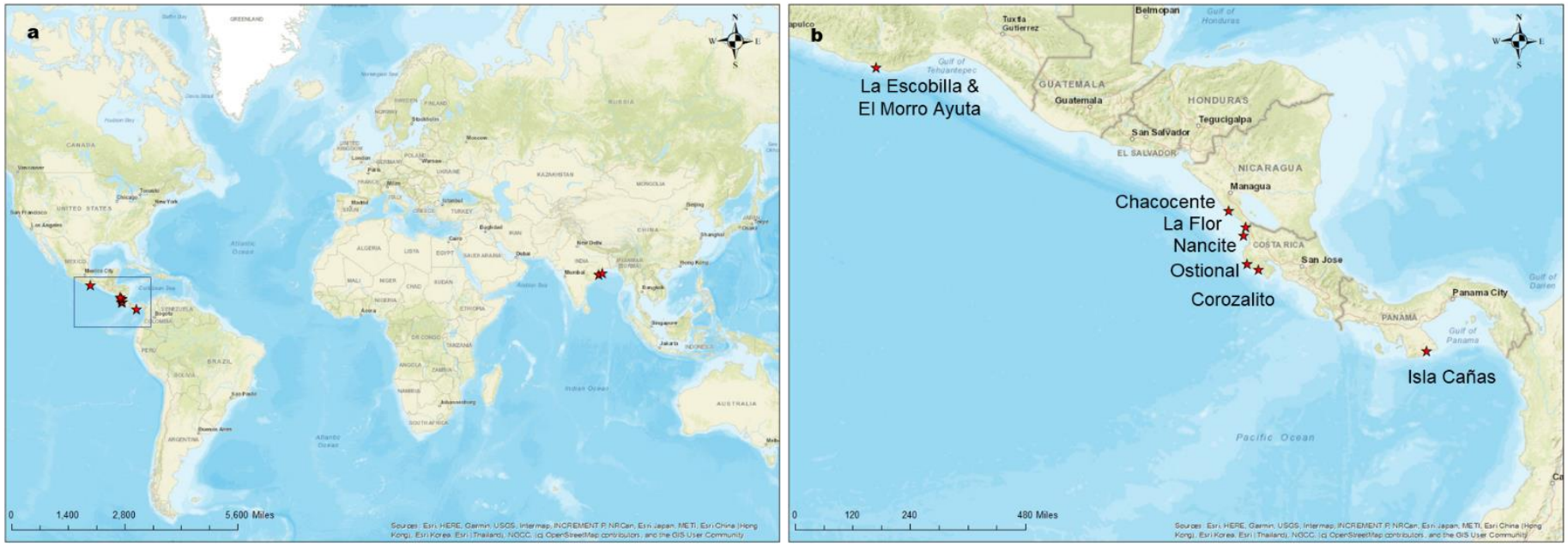

Figure 1.4.3.1. Global olive ridley (*Lepidochelys olivacea*) turtle *arribada* sites (a) Global *arribada* sites, India Nadiakhia Muhana (northern) and Gahirmatha (southern) and Eastern Pacific, (b) Eastern Pacific (Valverde 1998; Bernardo and Plotkin 2007).

Arribada nesting behaviour was formally described by Hildebrand (1963) from a 1947 film of a kemps ridley *arribada* in Rancho Nuevo, Mexico. *Arribadas* may include between 5,000 to 150,000 turtles nesting over the course of several consecutive days (Cornelius et al. 1991; Plotkin et al. 1997; Valverde et al. 2012). Thought to have evolved to be a predator satiation strategy (Eckrich and Owens 1995), or possibly a mechanism to maximise fertilization opportunities in a female biased assemblage (Fonseca et al. 2009), the biological mechanisms that trigger *arribada* events are largely unknown (Orrego 2014). *Arribada* events loosely correlate with the lunar phase, the Eastern Pacific *arribadas* often - but not exclusively - occur in the third quarter moon (Ballestero 2000; Bernardo and Plotkin, 2007). Recent work by Bezy et al. (2020) has revealed that no one mechanism is responsible for triggering an *arribada* and it is more likely that several environmental and physiological factors are working in combination.

In Nicaragua and Costa Rica, *arribada* events are larger and more frequent during the "peak" wet season (June – January) (Hope 2002). The incubation period for olive ridley eggs is 45-65 days, meaning, particularly during the wet season, a subsequent *arribada* will occur before the previous nests have hatched. Many incubating nests are destroyed by turtles exhuming eggs whilst digging nests (Cornelius et al. 1991; Honarvar et al. 2016). Fluctuations in temperature and moisture, as well as proximity to other nests and tidal variation also affect hatching success (Hope 2002). Olive ridley hatching success at solitary nesting beaches (i.e. where olive ridleys nest individually, not in *arribadas*) is around 90% whereas *arribada* beaches are as low as 15% (Fonseca et al. 2009; Valverde 2012). While the root cause of low hatching success is unknown, it is possible that the increase in protein in the sand from eggs destroyed during an *arribada* may play a significant role (Valverde 1999). This increase in protein may create conditions that allow for a rise in fungal and bacterial loads (Cornelius et al. 1991). Macroinvertebrates generated from the biomass of unexcavated eggs contaminate other nests that may otherwise have been viable. It is thought that these factors leading to the low recruitment of hatchlings into the population, may explain why *arribada* beaches, despite

being a natural phenomenon, are prone to sustained population declines and eventual collapse (Clifton et al. 1982; Fonseca et al. 2009; Valverde 2012). This occurred in Nancite, however after a period where no *arribada* events were recorded, they have resumed at this site (Fonseca et al. 2009; National Geographic 2018).

Underlying the conservation of turtles are two fundamental and related problems. Firstly, opportunities to study turtles are largely restricted to their brief terrestrial phase – nesting, an incredibly small part of their life history and is entirely female biased. However recent developments in mitochondrial DNA techniques are beginning to fill the knowledge gap in the phylogeny of turtle populations (see Formia et al. 2006 and Gaos et al. 2016 for examples). In-water projects to study males and other life phases are increasing, however these are costly and often outside the capacity of many conservation programs. Secondly, with slow maturing, egg laying species, it may take many years before impacts on the population, that occurred during the egg incubation period, are visible in the adult population (Mortimer 1995). The reproductive value of eggs and hatchlings is much lower than a sexually mature female, meaning nesting females are more important to the survival of the population than a nest of eggs (Heppell 1997). However, no population can sustain intensive egg extraction and, due to the inability to study different life phases and the time lag between hatching and returning as adults to nest on their natal beach, the impact of harvest may not appear on nesting beaches for several decades. (Mortimer 1995; Hepple 1997). As stated by David Ehrenfeld during the Western Atlantic Turtle Symposium 1983, "*Looking at green turtle population data, for example, is like looking at the light from a star 25 light years away: it appears to be shining now, but in fact, you are looking at history, and there is no way of telling whether, during the past 25 light years, that star has increased in brightness, or perhaps has gone out altogether*" (Bacon et al. 1984).

1.4.4. Illegal and legal turtle egg harvesting

Despite their impressive size, *arribada* assemblages are not immune to overharvesting by humans (Valverde 2012). It is likely that nesting beaches were the original encounter site for humans and turtles. As people moved to coastal areas, finding slow moving, egg laying animals made easy pickings for subsistence hunters and egg collectors. *Arribadas* reoccur on the same beach meaning there is little time or effort involved in harvesting *arribada* eggs (Hope 2002). Subsistence collection quickly evolved into localised trade and larger commercial markets, and with it local communities felt a sense of ownership over the resource. *Arribadas* provide a convenient source where eggs can be efficiently extracted for sale on national and international markets (Cornelius et al. 2007). The Eastern Pacific nesting populations have experienced severe declines which has been attributed to both fishing for olive ridleys for their leather and the extraction of eggs (Trinidad and Wilson 2000; Cornelius et al. 2007). Of the three main nesting rookeries in Mexico only one, Oaxaca still hosts *arribadas*, the other two were overexploited to the point of collapse with peak extrapolation occurring over a five year period in the late 1960s. At this time, the volume of eggs extracted by humans was far higher than natural mortality rates (Clifton et al. 1982). Loss of eggs to human predators is a threat that continues today (Valverde et al. 2012).

While it is completely illegal to harvest turtle eggs in Mexico, legal extraction projects exist in the Eastern Pacific. In Guatemala and El Salvador, Tortugueros (egg collectors) are paid for "donating" a proportion of the nest to a hatchery (Handy et al. 2006). By providing an economic incentive to collectors black market sales may be undermined (Massey and McCord 2017). In Guatemala, this system has offered a livelihood opportunity to impoverished communities and has generated support for turtle conservation activities (Massey and McCord 2017). However, nest success from hatcheries is often low and eggs trafficked from Mexico and Nicaragua can be sold legally in the markets of Guatemala with no way of tracing eggs back to their source (Massey and McCord 2017).

Legal *arribada* harvests have taken place in Panama, Nicaragua and Costa Rica, with varying degrees of success. The underlying premise is that if a community values a resource, it will be more incentivised to protect it for the future. However, all suffer with the issue of inequity of revenue, with the harvesters receiving a disproportionately low return on their time and energy investment (Hope 2002). In Isla de Cañas, Panama, INRENARE (the Panamanian natural resources agency) have overseen the collection of turtle eggs since 1995. They allow community members to harvest 50% of solitary nests and require them to patrol the beach to deter illegal harvesters. In addition, the community can harvest all the nests from the first night of an *arribada* but are required to protect nests laid on subsequent nights (Evans and Vargas 1996). Nicaragua has two *arribada* beaches, Chacocente and La Flor. Chacocente has a long and chequered history of egg harvesting which has been influenced by the unstable political situation in the country before, during and after the civil war (Campbell 2007). In 1998, a system was created where collections could take place on the first night of an *arribada* and the community was required to protect the beach for the remaining nights. Eggs were distributed amongst the community, for personal consumption, on a rota system. However, despite it being illegal to sell turtle eggs, market sales are commonplace in Nicaragua. Further, an unequitable distribution of wealth occurs with the collectors receiving the least in terms of economic benefits whilst investing the most. Restaurants, then market vendors, reap the highest rewards (Hope 2002; Campbell 2007). The disjuncture between being permitted to harvest, but not sell, eggs in Nicaragua has been particularly apparent in La Flor. It has been suggested that this policy stimulated over-exploitation and has driven the trade underground. Harvesters, often unemployed with few livelihood options, are rarely able to sell eggs independently and are vulnerable to exploitation by middlemen and traders, better positioned to reap the higher revenues (Hope 2002). Recent political unrest in Nicaragua means few conservation organisations operate in the country and the current situation regarding legal and illegal harvesting is unknown.

Finally, Ostional in Costa Rica is possibly the most famous and well documented legal harvest of sea turtle eggs. Hailed as a socio-economic success but heavily criticised by some conservationists, this legal extraction project will be the focus of the remainder of this thesis.

1.5. Case study: the legal extraction of olive ridley turtle eggs from Ostional, Costa Rica

1.5.1. Costa Rica

Costa Rica is a biodiversity hotspot and considered a leading example in environmental conservation (Almeyda Zambrano 2010). The country is home to an estimated 5.4% of the world's biodiversity and over a quarter of its territory is protected (Kohlmann et al. 2007). Corcovado National Park on the Osa Peninsula, is the largest protected area in Central America, spanning c.425 km^2 (Almeyda Zambrano 2010). Costa Rica derives nearly a quarter of its revenue from tourism, much of which is ecotourism (Braun et al. 2015) and many visitors are drawn to its two globally important sea turtle nesting beaches; Tortuguero and Ostional. Tortuguero in Limón Province sees the largest aggregation of nesting green turtles (*C. mydas*) in the Atlantic Basin (Troëng and Rankin 2005) and Ostional is possibly the largest *arribada* beach in the Pacific coast (Bjorndal 1982; Spotila 2004). *Arribada* nesting events also occur in Nancite and Corozalito beaches making Costa Rica one of the most important countries for olive ridley sea turtles in the world (Bjorndal 1982).

1.5.2. Arribadas in Ostional

Ostional is a 4 km long beach in Guanacaste province, on the Nicoya Peninsular, Pacific coast of Costa Rica. Three species of sea turtles nest here: leatherback, black and olive ridley (Chaves and Solís 2017). The olive ridley turtle nests both solitarily and in *arribadas* in Ostional. *Arribadas* generally occupy 880 m of beach in front of the Ostional village and usually occur monthly (Ballestero et al. 2000). However, during the peak season (August to September) 1-3 *arribadas* a month can occur, while some dry season months do not have *arribadas* (Arauz Almengor et al. 2001). *Arribadas*

in Ostional last 3-10 days, with dry season estimates of between 20,000 and 60,000 turtles and 90,000 to 180,000 in the rainy season (Richard and Hughes 1972; Ballestero et al. 1998); the El Niño event in 2009 saw as many as 231,896, while during the 2010-2011 La Niña saw numbers of 489,940 (Chaves and Solís, 2017).

1.5.3. Ostional: Historical overview of legalisation of egg extraction from Ostional

The first reports of sea turtle eggs being illegally extracted from Ostional coincided with the arrival of the first settlers in the 1940s (Campbell 1998). It was not until 1969 however, that the scientific community became aware of *arribada* events occurring on this beach (Richard and Hughes 1972). By this time, olive ridley eggs were collected and consumed by the Ostional community. It was a chaotic unregulated harvest with locals plundering as many nests as possible, selling eggs on the black market and allowing their pigs to roam free on the beach during *arribadas*. Efforts to curb this, in the form of policing the beach, were largely unsuccessful. Hostilities from the community were directed at the University of Costa Rica, suspicious of the researchers' intentions and who did not understand the purpose of their turtle tagging and monitoring research (Campbell 1998). By the early 1980s the situation deteriorated further. The risk of arrest for taking nests increased forcing the community to sell eggs on the black market, controlled by unscrupulous middlemen. In 1981, a committee was formed to legalise and regulate the harvest, whilst recognising a need for scientific input. In 1984, the community formed the first organised harvest of eggs, in what has become ADIO (Association for Integrated Development of Ostional). By 1987, supported by some of the scientific community, a legal harvest and sale of eggs was permitted (Campbell 1998) (for extended overview of the history of Ostional see Supporting Information, Table S1.8).

1.5.4. Rationale for the harvest at Ostional

The rationale for the harvest were: (1) To allow the community to financially benefit from doomed eggs that would be destroyed by subsequent nesting turtles; (2) that removing doomed eggs may

increase hatching success; (3) that extracting eggs does not harm the population of nesting females; and (4) that a legal supply of eggs could depress the illegal trade (Chaves and Solis 2017). The high concentrations of turtles nesting during an *arribada*, naturally leads to the majority of nests laid on the first few nights being excavated and destroyed by turtles on subsequent nights (Cornelius 1986; Cornelius et al. 1991; Campbell 1998; Arauz Almengor et al. 2001; Chaves and Solís, 2017). Due to the destruction of existing clutches by nesting turtles and the increase in microorganism load, as discussed above, Ostional exhibits low hatching success, typical of *arribada* beaches. In theory, removing these nests prior to their destruction may assist in reducing the levels of contaminants. Some researchers have argued that a regulated harvest may in fact increase hatching success (Cornelius and Robinson 1985, 19 86). This theory was tested by undertaking a five year comparison between Ostional and Nancite, an *arribada* beach in Santa Rosa National Park where virtually no human disturbance has taken place. Nancite was found to have hatching rates as low as 1-4%, during peak nesting months, 17 times lower than Ostional (Cornelius and Robinson 1985; Cornelius et al. 1991). However, in 1992 Araúz and Mo (1994) found hatching success rates at Ostional to be approximately 8%. Critics however, cautioned using Nancite as a comparison. Since 1981, the nesting population in Nancite has sharply declined (Cornelius et al. 1991; Plotkin et al. 1997; Valverde et al. 1998) giving rise to the argument that harvesting eggs in Ostional is a positive process as that population has not crashed. However, size differences between these beaches is significant; Nancite has only 800 m for turtles to nest compared to 4 km in Ostional. Therefore, turtles on Nancite were forced to nest at higher densities which may have resulted in lower hatching success (Honarvar et al. 2008).

To accept that a harvest is not affecting the population of adult turtles, it needs to be agreed that the population is stable (Heppel 1997). However, this presents challenges in slow maturing animals such as turtles. Flawed counting methodologies have further hampered the process in Ostional. Previous methods used to estimate *arribada* size, failed to accommodate the fact that *arribadas* at Ostional do not always occur on the same section of beach (Ballestro 2000). It was not until 1996 that Gates et al.

(1996) published what is now recognised as being an accepted methodology for estimating *arribada* size. This started long-term data collection, but is currently insufficient in duration to identify long-term trends in the population. Finally, it has been theorised that a legal extraction could ensure a national supply of eggs, to be sold at prices low enough to depress illegal trade by making it unprofitable to sell eggs from other beaches (Arauz-Almengor et al. 2001). This has yet to be tested.

1.5.5. Management plan

By 1999, it was proposed that a more formal approach to the extraction of eggs was needed, and a management plan supported by the government was introduced (Valverde 1999). The most recent version of this five year plan was produced in 2017. Regulations include measures to ensure the community only remove doomed eggs, by limiting extraction to the first 36 hours of an *arribada* (Article 3 No 20007 MAG; Valverde et al. 2012). The community must also undertake conservation activities such as protecting the beach from illegal harvesters, clearing space for nesting turtles by removing beach debris, protecting hatchlings from predators and keeping domestic animals off the beach (Pritchard 1984b; Ordoñez et al. 1994; Valverde et al. 2012).

1.5.6. Ostional today

Today, the village has c.600 residents, a permanent government station (Ministerio de Ambiente, Energía y Turismo - MINAET) and a University of Costa Rica field station. A school, community centre, pizzeria, churches, small catering outlets and convenience stores are the extent of the services available in Ostional. In addition, there are several tour operators and guesthouses providing for tourists who visit Ostional specifically to witness an *arribada*. The collection of eggs is much the same as when the extraction began, the villagers gather at dawn and dusk to collect eggs. The men find the nests using their feet and the women extract them by hand into large sacks. Groups of men wash these sacks in the sea before transferring them to the packing plant where they are packed, with sand, into sacks of 200 eggs carrying the ADIO logo and then distributed across the country (Ordoñez, et al. 1994; Acuña et al. 1999). The profits from the sale are split amongst the community members,

minus 30% which is used for the development of Ostional. Developments have included electricity for the village (Campbell 1998) health centre, teacher's house, ADIO office and packing plant (Ordoñez et al. 1994; Ordoñez and Ballestero 1994). The residents of Ostional actively avoid using the term harvest, they recognise they are extracting eggs from a species without any feeding or cultivation involved.

1.6. Outline of this thesis

1.6.1. Aims and objectives

While much of the focus on Ostional has been in relation to sustainable-take and socio-economics, little attention has been paid to links with the illegal trade. Critics have accused Ostional of enabling laundering of illegal eggs under the Ostional brand. Historically, eggs from Ostional were sold in labelled sacks of 200 eggs, which once open could potentially be refilled with eggs sourced from outside Ostional. However, new traceability regulations, introduced in 2017 aim to tighten the regulations surrounding the sale of eggs, by packaging eggs in small, heat-sealed bags that cannot be reused once open. This offered a timey opportunity to undertake an in-depth analysis of the Ostional egg project and issues surrounding illegal trade of turtle eggs in Costa Rica. This thesis aims to: (1) understand the problem of illegal harvesting in Costa Rica, by examining drivers and sensitivities surrounding the removal and the consumption of illegal sea turtle eggs. (2) Assess the availability of turtle eggs in the markets of San José by using search cost analysis, a method that to our knowledge has only been used once before, (3) Understand the supply chain by undertaking a value-chain analysis and (4) Look for evidence of the Ostional project enabling the trade of illegal turtle eggs, by undertaking market surveys and analysing point-of-sale data.

1.6.2. Thesis outline

Wildlife trade regulations have failed to reduce the rate of decline for numerous high profile species, and opportunities to launder illegal wildlife exist wherever there are legal trade routes. Both *ex-situ*

and *in-situ* opportunities are available to launder wildlife. However, chances to study this type of system are less common. Many debates on legalising trade or commercialising wildlife lack empirical data to inform decision makers. This thesis addresses that knowledge gap through studying this type of system, and its effect both on the same and other species. The legal harvest of turtle eggs from Ostional, Costa Rica provides a rare chance to assess *in-situ* wildlife laundering within a national legal trade. This thesis is made up of the following chapters each written as an independent research paper.

Chapter 2: The Caribbean coast of Costa Rica is a sea turtle trafficking hotspot and almost every beach relies on stewardship projects to protect nesting turtles. This chapter identifies, for the first time, the drivers of illegal extraction and looks at sensitivities of the general public towards the illegal trade in sea turtle eggs.

Chapter 3: This chapter offers a novel application of survival analysis to look at the availability of different marine consumables in relation to certified and uncertified turtle eggs in San José, Costa Rica. Research assistants visited markets and the Downtown area of San José using a shopping list of items and recording how quickly items were found. Their ability to find turtle eggs was compared with their shopping habits.

Chapter 4: By undertaking value chain analysis, this chapter looks at the costs and benefits of the legal extraction of eggs from Ostional from the community through to the end consumer. This chapter describes the supply chain, detailing the actors involved and the importance of turtle eggs to stakeholders. The work then goes further by undertaking a similar analysis of the illegal trade and highlights geographical locations of where and why illegal eggs would be expected to be laundered.

Chapter 5: This work builds on the previous chapter by reporting the results of market purchases in an effort to identify illegal eggs. Combining genetic analysis with information collected at the point

of sale this is the first time it is possible to answer the question of whether illegal species are being traded under the banner of Ostional.

Chapter 6: Draws together the chapters of this thesis, commenting on the main points of each and how the chapters relate to each other. Finally drawing a conclusion as to whether the legal extraction of sea turtle eggs from Ostional is enabling laundering of illegal species eggs.

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1.8. Supporting information

Table S1.8. History of Ostional (Richard and Hughes 1972[2]; Pritchard 1984a[5], b[6], Cornelius and Robinson 1985[3]; Campbell 1998[1]; Arauz Almengor et al. 2001[7]; Chaves and Solís 2017[4]).

Date	Historical event	Source
1940	Humans settle in Ostional; turtle eggs consumed for subsistence.	1
1969	First *arribada* from Ostional reported to the outside world by a peace corps volunteer.	1
1970	Aerial survey confirmed mass nesting events.	2
	Construction of road between Santa Cruz and Ostional brings settlers. Large scale illegal extraction of turtle eggs and black market egg sales. Douglas Robinson, University of Costa Rica (UCR) builds a base in Ostional.	1
1977	UCR suggest a legal harvest but the idea is shut down by public opinion and media	1
1979	"*Guardia rural*" (local guards) begins beach patrols, but is corrupt and enrages the community whilst failing to reduce illegal extraction. UCR also experience hostility from the community resulting on an arson attack on Douglas Robinson's house. The locals are unhappy about the disorganisation of illegal collection and unscrupulous middlemen, but also resent outsiders. The danger of arrest for taking turtle nests increases.	1
1981	Committee created to find a way to legalise and regulate a harvest with a recognition that a scientific approach is needed.	1
	Passing of Executive Decree 13200-A declaring Ostional a protected area.	
1983	Passing of Wildlife Conservation Law 6919 allowing a limited, commercial sale of animal products from the Refuge provided that: (1) scientific study justified use; and (2) community members formed a legal development association.	1
	Ostional is officially designated a wildlife reserve (RNVSO – Wildlife Reserve Ostional).	5
1984	Community meets the second criteria of Wildlife law 6919 by forming the 'Association for the Specific Development of the Rational and Scientific Exploitation of Marine Turtle Eggs at Ostional, Santa Cruz, Guanacaste'.	5
	Turtle biologist Peter Pritchard calls for opinions on alternative management / exploitation for Ostional turtles 4 options: 1: no take 2: sustainable harvest 3: business as usual 4; international commerce. International sea turtle biologists largely agree on option 2 a sustainable harvest. The first management plan circulated amongst the scientific community with talk of limiting collections either temporally or spatially and which species can be exploited within the reserve etc.	1, 3, 5,6
1985 – 1987	Creation of the Asociacion de Desarrollo Integral de Ostional (ADIO) (Integrated Development Association of Ostional) which now includes the mandate to develop the area.	1, 4
1987	October: The first sales of eggs are made official, delivery routes granted to families of Ostional.	4

	Establishment of a legal framework for the extraction of eggs (Law 7964: Egg extraction by Ostional and Decree 17802: Regulations for the use of eggs).	
1988	The first ADIO labelled packaging. Eggs storage facility and ADIO offices built.	4
1989	ADIO contracts a sales distributor for the national market.	7
1990s	Ostional population growth slows – probably due to the legal harvest limiting participation thereby removing the incentive to move to Ostional. (Population c.390 people in 84 households in 1997).	1
1991	The tourist information hut is built and the first group of ADIO guides is organized with funds from the sale of eggs.	4
1993	Electricity is installed in Ostional by the Coopeguanacaste, for which ADIO contributes 50% of the costs of this service.	4
1995	Attorney General's Office rules that the extraction is the responsibility of MINAE, and the commercialization and transport is under the jurisdiction of INCOPESCA (Costa Rican Institute for Fish and Aquaculture).	4
1996	Purchase of truck for transporting eggs. First MINAE ranger stationed – objective to charge an entrance fee to tourists	4 1
1999	AIC (Inter-Americana Convention on Sea Turtle Conservation grants an exception to Costa Rica for the use of eggs from Ostional - Decree 28203: UCR begin daily monitoring of nests.	4
2005	Five-year plan on the use of eggs 2006-2010 between ADIO, ACT, UCR and INCOPESCA. New *arribada* counting methods employed.	4 7

CHAPTER 2

Narcotics-driven illegal extraction of sea turtles

Formatted for Conservation Biology

Pheasey, H., Griffiths, R.A., & Roberts, D.L. 2015. Narcotic driven illegal extraction of sea turtles

2.1. Abstract

Illegal wildlife trade can threaten biodiversity and economic development. Criminal enterprises may add illegal wildlife to their list of illicit goods by utilizing established trade routes, networks and individuals. On the Caribbean coast of Costa Rica, killing of sea turtles and removal of nests is commonplace. However, beyond conservation NGOs reporting evidence of this, little is known about this illegal activity. Through semi-structured and informal interviews with law enforcement, NGOs and illegal harvesters at three nesting beaches, data were gathered on the socioeconomics and motivations for participating in illegal activities. We identified a rare example of the illegal extraction of a wildlife product being driven by motivations that were not exclusively livelihoods based. Practitioners in illegal behavior ranged from subsistence harvesters, through to narcotics traffickers. Dependency on crack cocaine and marijuana was prevalent at our study sites, and revenue generated from turtle eggs to procure drugs, was the most cited reason people illegally harvest. Informants reported that prosecutions were rare, and we found no evidence of bribery. In addition, we used Randomized Response Technique to investigate illegal behaviors surrounding sea turtles, but participants did not generally regard the subject as sensitive. Low education levels and high unemployment rates may increase susceptibility to narcotics. While substance misuse and addiction appear to drive illegal extraction, associated poverty and marginalization may explain why drug dependency is so prevalent in Caribbean Costa Rica. Increased work opportunities and drug rehabilitation programs may assist in reducing illegal take of turtle eggs on nesting beaches.

2.2. Introduction

Illegal trade in wildlife is a multibillion-dollar industry and severe enough to threaten biodiversity and economic development (Rosen & Smith 2010). Wildlife trafficking and other illegal activities such as drug trafficking may overlap in time and space, as criminals use the same trade routes, networks and individuals (Mackenzie 2002). For example, the South Africa–China illegal trade route for the abalone (*Haliotis midae*) is a known path for other illicit goods including counterfeit materials, synthetic drug

precursors, trafficked humans and possibly diamonds (Steinburg 2005). Traffickers often exploit vulnerable people through coercion into drug activity, forced labor and prostitution. However, unlike these trades, wildlife is rarely prioritized for law enforcement, making trafficking wildlife a low-risk yet high-return activity. This enables criminals to add wildlife to their repertoire whilst operating largely unhindered. Our study identified links between narcotics trade and illegal trade in sea turtles on the Caribbean coast of Costa Rica.

Globally, sea turtles are utilized for their meat, shell, penis, calipee, oils and eggs. In some countries, turtle eggs are considered a delicacy or aphrodisiac and in other places a protein source (Thorbjarnarson et al. 2000). Despite international and domestic laws designed to protect sea turtles, killing for meat and theft of eggs remains a problem across Latin America (Campbell 2003). Sea turtles are slow to mature and reproduce, so removing eggs could affect recruitment which may not be apparent for many years (Seminoff 2004). In Costa Rica, sea turtles are specifically protected under Costa Rican law #8325 and a more general wildlife law #7317. In the Caribbean, theft of turtles for meat, eggs and shell is widespread and beaches rely on stewardship programs to protect nesting females and eggs. While the clandestine nature of illegal wildlife trade makes it difficult to quantify illegal extraction rates, there are numerous examples of nesting beaches suffering from this, despite the actions of stewardship projects. Further, despite being famed for its ecotourism, every season Tortuguero National Park loses adult turtles and nests to the illegal trade (García Varela et al. 2015). To improve sea turtle conservation, a better understanding of socio-economic drivers of illegal take is required (Mancini & Koch 2009).

To encourage behavioral change in conservation, we need to understand drivers of destructive behaviors and motivators of wrongdoing (Nuno et al. 2013). In Costa Rica, the drivers of illegal take of turtles are poorly understood. To try and bridge this knowledge gap we used a mixed methods approach. We employed a sensitive question technique, semi-structured interviews and informal

interviews to determine: (1) What is driving sea turtle extraction? (2) How great is demand? (3) Who are the illegal harvesters? (4) What level of law enforcement exists?

2.3. Methods

The School of Anthropology and Conservation's Research Ethics Advisory Group (University of Kent) approved this research (Ref. No.: 0381617a). All participants were over the age of 18, were made aware of the purpose of the research and provided signed consent.

2.3.1. Study sites

Green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and leatherback (*Dermochelys coriacea*) turtles nest annually on the Caribbean coast of Costa Rica. These species are categorized as vulnerable to extinction to some degree by the International Union for Conservation of Nature (IUCN 2019). Research took place between May 2017 and November 2018. We conducted our research in Limón Province on the Caribbean coast of Costa Rica. The inhabitants of the region have traditionally consumed green sea turtles and eggs; Puerto Limón possessed a flourishing green turtle fishery with numerous abattoirs up until the 1960s (Campbell 2007). Costa Rica is also a narcotic trafficking route, used as a refueling stop by smugglers moving drugs between Colombia and Panama to Mexico and the US (Vice News 2015).

We undertook sensitive question techniques in 4 towns; Siquirres, Batán, Cariari, Guapiles and 3 villages near or on nesting beaches Pacuare, Playa Norte (San Francisco) and Tortuguero (Fig. 2.3.1.). We also conducted interviews where most of our participants were in Pacuare, San Francisco and Tortuguero.

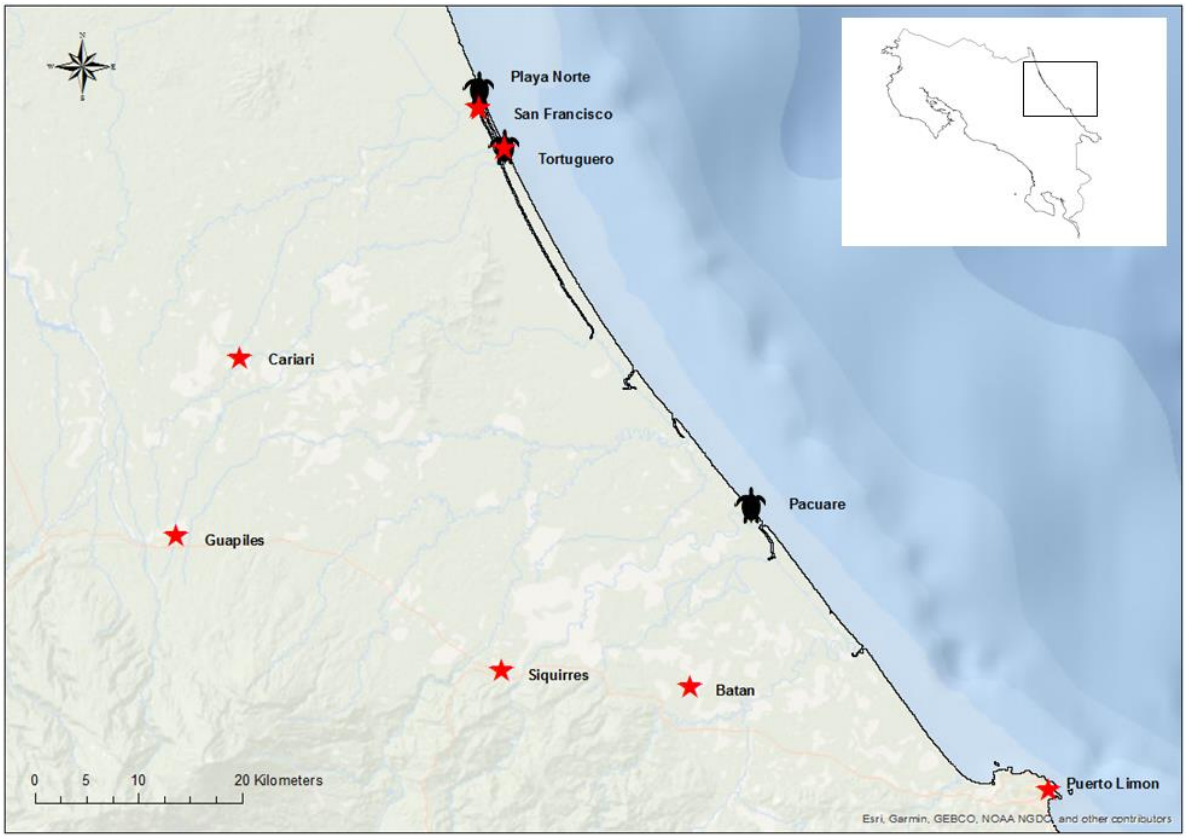

Figure 2.3.1: Limón Province, stars represent towns and villages and turtle symbol represents the nesting beaches.

2.3.2. Nesting beaches

Tortuguero is a 29 km beach that has the largest nesting aggregation of green turtles in the Atlantic (c.27,000 nesting females) (Troëng & Rankin 2005; Campbell 2007). Historically, the local community has harvested turtles for meat and eggs. More recently, in 2004, it received over 80,000 ecotourism visitors (Harrison et al. 2005). The nesting season officially runs from June to October. It is illegal to be on the beach at night without a guide or research permit. There is a police station and Ministerio de Ambiente y Energía (MINAE – Costa Rican Ministry of Environment) office in Tortuguero village. Sea turtle nests remain *in-situ*.

Playa Norte is 5 km long and directly north of Tortuguero and separated by a river. This beach has <300 turtle nests per season. Illegal harvesting occurs for both eggs and meat. Playa Norte is closed to the public at night during the nesting season and is only accessible to those holding research permits. Nests are protected *in-situ* along a 5 km research transect. The nearest village is San Francisco; with c.600 residents. It suffers from low employment although there are work opportunities in tourism in Tortuguero. The nearest police station is in Tortuguero, but police presence rarely reaches San Francisco. Petty theft, drug use and prostitution are common in San Francisco (pers. obs.).

Playa Pacuare is a short (c.5 km) sand bank, c.40 km north of Puerto Limón, which houses few permanent occupants (<40). The residents are mostly male, aged 16-65. Infrastructure facilities are largely absent, but there is clean well-water, a supply of coconuts and marine and freshwater fish. This beach is situated outside the protected Reserva Pacuare. Public access is permitted day and night. Illegal removal of turtle nests is undertaken openly but killing turtles for meat is more discrete. A stewardship project relocates nests to a hatchery. A coastguard station is located at the southern end of the beach.

2.3.3. Interviews

We conducted 38 in-depth semi-structured key informant interviews and an additional 17 informal interviews. We defined key informants as those persons with knowledge or experience of illegal harvesting in the region. Participants were expert sea turtle biologists (n=3), non-governmental organization (NGO) employees in sea turtle conservation (n=7), community members near nesting beaches (n=11), sea turtle guides (n=4) and law enforcement officials (n=5). We also interviewed 8 illegal harvesters. This group were residing in Pacuare and were either self-proclaimed “poachers” (n=3), were witnessed actively extracting eggs by the principle investigator or NGO (n=4) or were arrested during the study period (n=1). Subsistence harvesting was openly discussed by 2 participants: a current and a former illegal harvester. Our aim was not to compare different key informants but to

speak with those who could offer different perspectives on the subject. We used targeted and snowball sampling to identify potential interviewees, by using recommendations from initial respondents to contact other potential informants. This enabled us to identify respondents with the broadest range of experience and viewpoints whilst circumventing possible prejudices due to researchers' understanding of the subject (Newing 2011). Due to consistency of responses and reaching saturation - where we received little or no new information on a topic - we did not ask everyone the same questions. We asked informants what they could tell us about illegal extraction, who engages in this and why, who buys eggs, about the trade, concerns regarding law enforcement and if they could recall any experiences of bribery. The trade of turtle meat was discussed when the conversation moved into the subject. The 17 additional informal interviews comprised impromptu interviews with NGO staff, community members, law enforcement officials or members of the public, aware of the study.

2.3.4. Analysis

Interviews were undertaken in Spanish or English, audio recorded and transcribed by a native speaker and analyzed in English. We coded relevant text according to themes that emerged from the transcript (Newing 2011). We adopted an inductive approach, coding solely on interview transcript contents and identified a key word (code) that summarized the sentences/paragraphs of the text. These codes were organized into emergent themes using software package NVivo 12 (QRS International 2006) which produced summaries of each theme, the content of which we used to create the narrative (Fig. 2.3.4.).

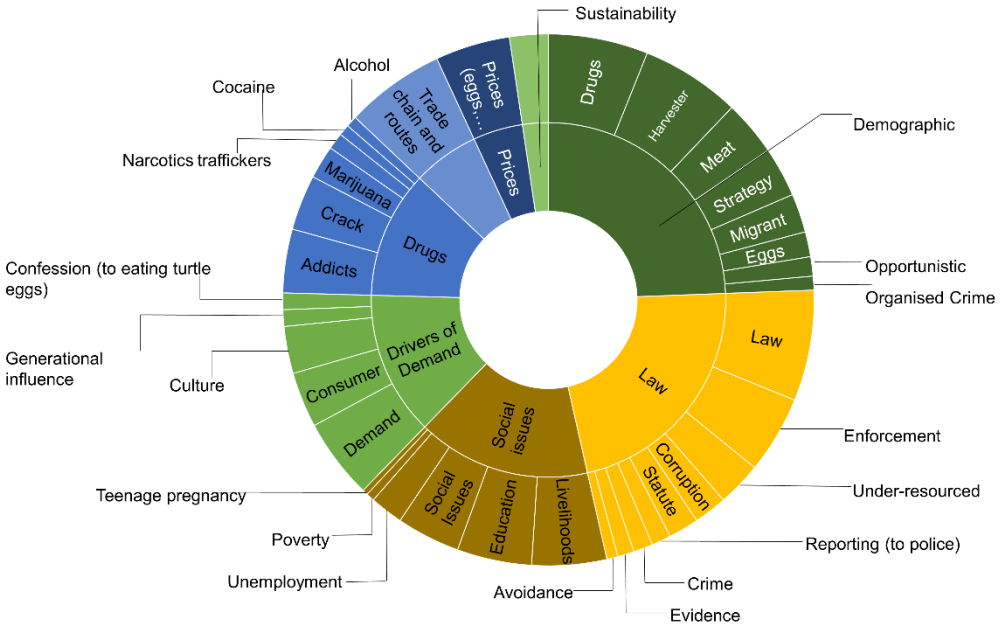

Figure 2.3.4. Schematic of interview codes and themes. The proportion of interviews that discussed a subject which was coded (outer circle) and then classified to become a theme (inner circle, differentiated by colour). Themes formed the narrative.

2.3.5. Sensitive question technique surveys

To try and quantify illegal behaviors relating to turtle eggs we needed to address 3 questions on demand (trade), destruction of nests (poaching) and evading capture (bribery): *In the last 12 months have you:* (1) *bought or sold turtle eggs believing them to be illegal?* (trade); (2) *illegally removed turtle eggs from the beach?* (poaching); (3) *paid a bribe in relation to a "turtle crime"?* (bribery). The term *poaching* is used here for succinctness of reporting.

We chose the last 12 months to prevent recall bias and ensure the data were current to the 2 most recent nesting seasons. For demand, we focused on purchase and sale of eggs, as it is illegal to sell eggs, but not to consume or buy them. We assumed more people buy eggs than sell them, however wording the question in this way covered both groups.

When asked sensitive questions, respondents may be influenced by 2 types of bias: social desirability bias eliciting a dishonest response or, non-response bias (Warner 1965; Fisher 1993). To try and reduce these biases several techniques have been developed, including Randomized Response Technique (RRT) (Warner 1965). This works on the premise that a randomizing device (e.g. a rolled dice) anonymizes the participant's response, thus providing a greater chance of participation and honesty (Gavin et al. 2010). Following a pilot to check the specific wording of the questions and ability of respondents to grasp the concept of the technique, we conducted surveys with assistance from a native Spanish speaker. We asked participants to roll a dice but keep the number hidden. They were then asked the 3 questions (trade, poaching and bribery) which had a yes or no response. If they rolled a 1, they were required to respond "yes", a 2, they had to respond "no" and 3-6, they had to respond honestly.

The frequency of law breaking in the sample population (π) can be estimated as follows:

$$\pi = \frac{\lambda - \theta}{\mathrm{S}}$$

Where λ is the estimated proportion of yes responses, θ the probability of a participant being forced to answer yes and *S* the probability of having to answer truthfully (Nuno & St John 2015).

Using convenience sampling (Newing 2011), we invited people in public spaces or outside their homes to participate in the sensitive questions survey. An additional 19 of our key informants (7 illegal harvesters, 8 community members, 2 law enforcement officials and 2 tour guides) also participated. The majority were based in Pacuare or Playa Norte and included because a translator was available at the time. We asked 3 sensitive questions using RRT and demographic questions in the form of a short answer questionnaire (Appendix 1). Gender, age, number of children and household occupancy were recorded to give information on their position in the household and number of dependents on their income. Occupation was allocated to an employment category, based on our data. Due to people being unlikely to discuss or accurately report their own illegal drug

consumption, we asked participants to estimate the percentage of people in their neighborhood who they felt had dependency issues with illegal drugs or alcohol. On completion of the demographic questions, we invited participants to respond again to the 3 sensitive questions in ballot form where they answered on a piece of paper and placed their answers in an envelope (herein referred to as Direct Questions: DQs). Response sheets were numbered to link demographic data to RRT and DQs. The DQs provide a baseline to compare with RRT and therefore measure sensitivity of the question.

2.3.6. Analysis

To determine if there was a significant difference between RRT and DQs, we estimated 95% confidence intervals (CIs) of proportion of law breakers for each question, by bootstrapping 1,000 samples of our data (St John et al. 2010) using RStudio 1.2.1335 (R Core Team 2019). For both RRT and DQ responses we modelled demographic variables and all binary responses to the 3 law-breaking questions by plotting pair-wise correlations in a matrix to visualize which variables interact. Variables that correlated with binary responses were then modelled using logistic regression to test if the correlation was significant.

2.4. Results

2.4.1. Demographics

More participants living in southern towns (Pacuare, Limón, Siquirres and Batán) admitted to buying or selling turtle eggs ($z=2.526$, $df=2$, $p=0.0115$). This indicates a possible geographical divide in sensitivity of the subject. We found education level of respondents to be low; 83.4% had only secondary school education. Incomes were also low; 75.3% earned no more than a middle income with cash-in-hand employment, of which 33.9% were in the low-earner bracket. The average household size was 3.4 persons. 68.1% felt that over half of their neighbors had substance dependency issues.

2.4.2. Demand for sea turtles

Demand for sea turtle eggs and meat is high and driven by culture. We discussed who eats turtle products and why with 29/38 participants. It was explicitly stated by 17 respondents, that Costa Rica has a long-established tradition of eating turtle products. This suggests demand was high because people have enjoyed turtle products for many generations. Participants reported that in San José, there was a shift away from consumption of turtle eggs by younger generations, though many people still claim that eating turtle eggs "es *mi cultura*" ("it's my culture").

2.4.3. Illegal take

Consumers of turtle products rarely extract themselves. Based on 30 formal and 6 informal interviews we identified 4 broad categories of illegal harvester. Firstly, subsistence harvesters or those that take turtles or eggs for cultural reasons. Although using sea turtles and their eggs for subsistence has largely ceased, traditional consumption remains. Local stewardship projects reported it was typical to see an increase in extraction around national holidays. In Pacuare, 2 participants – a current and a former subsistence harvester – discussed competing with drug addicts for nests:

"When I arrived here, the stone [crack cocaine] *was already here…It was more harmful, worse, because drug addicts were walking at dawn with eggs...I could not almost take a nest to buy my food to continue living".* Participant 009.

The second group are petty criminals and illegal drug users. This was the most cited group. Drug dependency was frequently cited as driving illegal take; 34 participants (89%) of 38 key informants, plus 2 informal interviewees cited drugs. Within these 36 respondents, 23 (63%) referred to illegal harvesters as drug addicts, 20 (55%) referred to crack cocaine, and 12 (33%) mentioned marijuana use as a driver of illegal extraction. Alcohol users were mentioned by 4 interviewees. Increased

harvesting at weekends suggests recreational as well as drug dependency. Eggs or meat are sold locally, as quickly as possible, to finance drug purchase. In Pacuare, eggs were directly exchanged for drugs or alcohol. In Tortuguero, harvesters were often homeless young male street-sleepers. At other beaches, seasonal migrants were given refuge in local homes. Others were locals, permanently based in the area:

"There are a number of people doing it, we know most of them, but some come in every year and they are known poachers…but normally live elsewhere…and we have some families who we have always know to be poaching families…all of the ones I know are drug users" Participant 021.

The majority of the Pacuare population are in some way marginalized from society. Some have mental health issues, a high proportion are homosexual who have been cast-out from their communities, and many have criminal records having spent time in prison. For these reasons, many harvesters are unemployed and move to the beaches along the coast where they can survive by accessing natural resources, including turtles. In Pacuare and San Francisco petty crime increases as criminals move in for the turtle season, while in Tortuguero crime decreases, as criminals switch from petty theft to illegally removing turtle eggs. Outside the turtle season they either leave or apparently shift their behavior to committing local robberies:

"*Unfortunately, it is easier to go to the beach, get some eggs and sell them… in turtle season criminality in the village* [Tortuguero] *is going down because they can easier make money with turtle eggs than if you steal something*". Participant 025.

Historically, alcohol-driven illegal extraction was prevalent in Tortuguero. Today, due in large part to ecotourism, far fewer people engage, but those who do are motivated by crack cocaine dependency. A Tortuguero policeman cited at least 10-12 known individuals and stated San Francisco residents are

known to illegally harvest on Tortuguero beach. Sales occur inside Tortuguero or may be linked to a longer trade chain:

"…some of the younger kids now are into crack, they are the ones that sometimes that go out there and steal some turtle eggs, if they sell it, it's going to be for other people from different communities…who has come and asked them for doing it" Participant 035.

The third group were chieftains; older men no longer able to walk the beach but who extort young boys to steal for them. In Pacuare, we identified 2 examples where it was clear these boys received drugs for their efforts. A similar example was seen in Playa Norte where a known crack user would take his son to steal nests. His child was too young to be arrested and could therefore carry the eggs (pers. obs. Playa Norte 2014).

The fourth group were reportedly part of organized crime syndicates. They were rarely present on beaches but would harpoon turtles at sea. In 2016, a boat reportedly containing 16 turtles was visible from Playa Norte actively harpooning turtles in daylight. Some San Francisco residents, known to take nesting turtles, may also harpoon them at sea. More frequently, it was reported that harpooners' primary activity was running quantities of cocaine from Colombia, or marijuana from Jamaica, to the US (reports from Coastguards and NGOs). They have boats and criminal networks in place, so turtles may be a convenient source of income when returning with an empty boat. This group would occasionally land on beaches to take nesting turtles and eggs.

2.4.4. Trade chain

The trade chain in eggs and meat is short. In Tortuguero and Playa Norte petty criminals predominantly sell to consumers door-to-door. Meat theft is opportunistic, and if not sold, meat is discarded, alongside undesirable turtle parts. In Pacuare, if the harvesters do not eat the meat

themselves, they sell it in Batán. Here they kill turtles to order and have a network of households that purchase the meat. Black market prices fluctuate, with green turtle meat retailing at ₡3,000 (US$6) a kilo or ₡150,000 (US$300) a whole turtle. Prices of eggs varied between beaches. In Pacuare, 12 eggs would sell for ₡2,000 ($4) or directly exchanged for 1-2 rocks of crack cocaine or marijuana cigarettes. Similar prices were reported in San Francisco, but in Tortuguero harvesters sell half or whole nests (c.60-120 eggs) for ₡2,000. In towns, turtle eggs are cooked and 3 eggs retail at ₡1,000 ($2).

2.4.5. Law enforcement

It is illegal to "*possess, transport or sell*" (Participant 034) unregulated turtle eggs or meat in Costa Rica, with a sentence of up to 3 years in prison for repeat offenders. However, this was little deterrent as prosecution was easy avoided. Assailants must be in the possession of eggs when apprehended. This is easy to circumvent on a beach where patrols are infrequent, and police use bright lights:

"…the problem is that here the poachers are already alert to the police…after midnight there is no one walking the beach, the police do not walk the beach, then they [the poachers] *arrive, they get in and loot the eggs"* Participant 022.

One participant claimed that if he sees the coastguard coming, he simply abandons the eggs and escapes into the jungle (Participant 007). In addition, participants cited prison overcrowding as why prosecutions were low:

"…the jails of this country are overcrowded; they will not put a person who stole turtle eggs and leave out one who killed another person…some things are more important than others" Participant 019.

With these challenges, in combination with a lack of resources, there is little incentive to make arrests:

"The problem is the laws of Costa Rica. We grab a boy with eggs, the expense of having him here, then a boat to take him to Guápiles and the same day they release him. They do not do anything to him!" Participant 022.

This low level of law enforcement may explain why we found no evidence of bribery. When asked, respondents typically stated that illegal harvesters have nothing to bribe officials with and it was unnecessary as they knew they would likely go unpunished:

"*Nobody here bribes any policeman because the laws are so stupid that you go with eggs and say* "I had no eggs, the eggs were there, [points to the floor] they are not mine". *Then the judge throws the paper,* "take your letter of freedom, you are free"*"* Participant 007.

At sea it is impossible to ambush traffickers. If challenged, harpooners simply discard any evidence overboard.

2.4.6. Illegal behaviors

Participants occasionally failed to complete the direct questions appropriately, which we attribute to the low literacy levels of some respondents. For this reason, we only included answers that were given in full, therefore each question had a different sample size (trade = 452 (100.0%), poaching = 448 (99.1%) and bribery = 451 (99.8%)). We experienced a 96.8% participation rate. Refusals, 4.2% (n=19), were due to participants not wishing to partake in *any* survey, rather than a survey specifically regarding turtles.

We found no significant difference between RRT and DQ when comparing 95% CIs for each question (Fig. 2.4.5.), suggesting the questions are not considered sensitive. Therefore, DQs were used to estimate law breaking frequency. No DQ CIs overlapped with zero, suggesting there was little to no admission to law breaking. However, a significantly higher number of people admitted to buying/selling eggs they believed were illegal, whereas only 1.6% (n=7) admitted illegally extraction and 0.9% (n=4) admitted bribery.

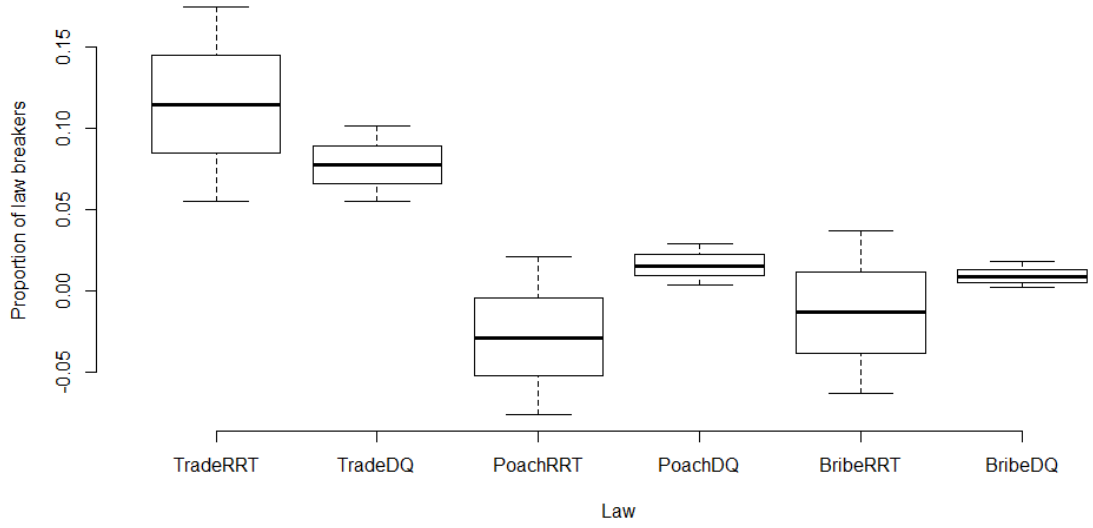

Figure 2.4.5. Estimated proportion of respondents that had participated in each illegal activity, between March 2016 and November 2018. The variables on the x-axis signify each of the 3 laws that may have been broken and enquired about in the sensitive questions (Trade, Poaching, Bribery) and method of response (RRT or DQ). The bold line signifies the median, the top and bottom box edges indicate the interquartile range, the error bars show 95% Confidence Intervals from bootstrap sampling.

2.5. Discussion

Our study identified a case of non-livelihood driven illegal harvesting in an area where consumption of illegal sea turtle eggs is not deemed a sensitive issue by the local population. Unsurprisingly, significantly more respondents admitted to buying or selling turtle eggs than harvesting or paying bribes. No significant difference between RRT and DQ suggests our questions were not sensitive. However, we identified a geographical trend, with more southern respondents admitting to buying or selling potentially illegal eggs than those from the north. The proximity of these southern towns to Puerto Limón, with its long history of sea turtle consumption, may influence this lack of sensitivity to the subject (Hart et al. 2013). Conversely, northern beaches require permits to access the beach at night, and the high number of tourists in Tortuguero may stigmatize trade in the north (Hart et al. 2013). The narrower interquartile ranges for the DQs is due to fewer participants responding 'yes' than were forced to using the dice, suggesting these respondents were less likely to respond truthfully if they had broken a law.

Substance misuse and addiction appear to drive illegal extraction. However, this links to poverty and marginalization, and communities with low income and education levels are most susceptible. As a result, smoking marijuana may start in the teens, and this is a potential gateway to harder drugs (Golub & Johnson 2001). Taking drugs may simply be a social norm or status symbol. However, to maintain this lifestyle, criminals need to finance the habit. Unlike the US or Europe where addicts may shoplift (Stevens 2010), in coastal Costa Rica funding a drug habit may come from turtle harvesting and petty opportunistic theft.

Potential wrongdoers undertake an implicit cost-benefit analysis when deciding whether to engage in illegal behavior: if benefit outweighs risk, it pays to steal (Mancini et al. 2011). In Costa Rica, the likelihood of arrest and prosecution are both low. Law enforcement officials reported needing double the personnel to be effective. Additionally, one respondent commented that drug addicts would not

go to prison for a small amount of a drug deemed for personal consumption (Participant 029). In 2013 prisons were 137% over-capacity (Woods 2015), leading to reforms resulting in lighter or no sentences for minor drug related crimes. The result is fewer harvesters incarcerated for possession of either turtle products or drugs, with benefits of stealing now outweighing the risks. Conversely, a heavily enforced law, carrying a prison sentence of 6 months is Costa Rica Family Law (#5476 codigo de familia), which relates to failure to pay child support and custody (Law Firm Meléndez & Bonilla 2016). A key informant (Participant 036) in Pacuare, discussed how readily these custodial sentences are imposed, and the knock-on effect on offenders. Following marginalization from their community and fewer job prospects they may become drug addicts. The natural resources and revenue available from turtles at beaches such as Pacuare, offer opportunities to this demographic with otherwise limited options.

Our study identified an unusual case where a wildlife commodity of low monetary value is exchanged for cheap drugs in a localized domestic trade. Most turtle products remain inside Costa Rica and are traded close to beach of origin. However, previous studies in the region did not identify a link between turtles and drugs. In Cahuita, turtle eggs are a source of easy money but Hart et al. (2013) did not find a connection with drugs. Nevertheless, in Baja California Sur, researchers touched on a link between sea turtle trade and drug trafficking. In 2008, a single respondent in their study stated that "*It is also well known that the illegal trade in sea turtles is tied to the drug traffic*" (Senko et al. 2011). Also in this region, high mortality rates of loggerhead turtles were linked to fishing practices by fishers abusing crack cocaine and methamphetamine (Aldhous 2006). As in the case of Costa Rica, these drugs were introduced to coastal communities by narcotics traffickers using the area as stopovers. While these cases touch upon the issue, we believe our research is the first in-depth analysis linking substance misuse with illegal sea turtle trade.

The illegal turtle trade in Costa Rica draws parallels between 2 international illegal wildlife trades, South African abalone and Russian Caviar. Abalone fishers using methamphetamine is well documented and substance misuse may appear to be the main driver of abalone harvesting (Steinberg 2005; Brick et al. 2009). However, the abalone issue is more complex with organized crime syndicates, porous international borders, devaluation of the rand against the dollar and, importantly, the marginalization of communities stemming from the apartheid era (Steinburg 2005). The harvester profiles identified in our research reflect those of the illegal caviar trade. In the Caspian Sea migrating sturgeon are taken from rivers, while organized criminals extract from the open ocean and a 3rd group utilize coastal waters (Vaisman 1997; Tayler 2001; Pires & Moreto 2011). Both turtles and sturgeon are threatened by illegal harvesters ranging from local opportunists to organized criminals. Our research has identified similar drivers and trade structures to those of abalone and caviar, with the key difference being that turtle trade is for domestic markets. This domestic trade in sea turtles draws closer comparisons to the trade in parrots, taken by locals in Bolivia and Mexico, and songbirds in Indonesia. These birds are all easily acquired, sold locally, are in high demand, and there is little risk of being caught (Pires & Clarke 2011; Chng et al. 2016). However, these examples did not identify substance misuse as a driver.

Our case study highlights the complexities of illicit wildlife trade and identified issues that extend beyond law enforcement. Even with greater resources, it is unlikely law enforcement will be enough to reduce illegal take. A lack of motivation and understanding of the species, coupled with reactive rather than pro-active policing, does little to inhibit wildlife crime (Pires and Moreto 2011). Wildlife trade is too socially, culturally and economically complex to be tackled through law enforcement alone: the real need is to address the socioeconomic causes of extraction and trade (Velázquez Gomar & Stringer 2011). Our research is a first step to identifying these drivers in the case of turtle trade in Costa Rica. Removing the key driver, in this case drugs, is unlikely to impact demand for turtle eggs but it could affect supply. Turtle eggs are of low economic value and seasonally available – essentially

a treat. With little to no livelihood dependence driving the illegal extraction of eggs/meat, it is unlikely the trade-off would fall in favor of illegal take for someone who is not motivated by hunger or addiction. Turtle meat is more profitable, but the effort to find a nesting turtle and risks associated with being caught, reduce the incentives. Therefore, the introduction of drug rehabilitation programmes and increased work opportunities might reduce the extraction of eggs. Policing against the more organized drug dealers will, however, be more challenging.

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CHAPTER 3

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

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3.1. Abstract

Wildlife is an important source of nutrition and income for rural communities. International wildlife trade of endangered species is regulated by CITES, but domestic markets are rarely subjected to this degree of scrutiny. Market surveys provide important domestic trade data but can suffer limitations. An alternative is the shopping list method, where researchers look for items from a specific list, rather than trying to record everything of interest. Time to find each item indicates availability. We applied this method to survey marine consumables in Costa Rica, which has a legal, certified, trade of sea turtle eggs. We adapted survival analysis to compare the availability of legal and illegal sea turtle eggs with other sensitive marine consumables. We then compared participants' shopping habits with their ability to find items. Shark products were found fastest and were therefore the most readily available item. Uncertified eggs were found as easily as certified eggs, implying there are few deterrents to the open sale of uncertified eggs. Shopping habits of participants 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.

Key words: Illegal wildlife trade; *Lepidochelys olivacea;* Ostional; survival analysis; sea turtle eggs; sharks.

3.2. 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 trade is difficult, and current approximations are between US$8-US$21 billion per year (Scheffers et al. 2019). However, domestic trade rarely comes under the same 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 capacity to monitor extraction or enforce domestic wildlife laws. As wildlife is an essential source of income and nutrition for rural communities across the globe (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 illegal wildlife trade may make it difficult to ascertain the availability of certain products in markets. Methods for conducting market surveys have traditionally involved surveyors searching for items of interest that are openly for sale (Moyle and 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. Market surveys are therefore often used in conjunction with other methods, including surveyors posing as buyers, analysis of existing trade data, interviews and anecdotal information.

Moyle and Conrad (2014) proposed the shopping list method as an alternative to traditional market surveys. They piloted this method to research the availability of ivory items in China. 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 the 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 (Stigler 1961). Popular and easily available items have a lower search cost than rarer items. This rationale extends to legal vs illegal items, with illegal items having a higher search cost when law enforcement is an effective deterrent. Here we use the shopping list method to investigate a novel problem: the opportunity to identify wildlife laundering in food markets with a focus on sea turtle eggs.

We chose marine consumables, vulnerable to extinction, with varying degrees of threat or difficulty in identifying species of origin, for our list. Sharks are apex predators and marine ecosystem regulators, that are slow growing, late to mature and have low fecundity; characteristics that increase a population's susceptibility to collapse (Abercrombie et al. 2005). Mesopredators have been found to increase in areas where shark abundances have declined, which can cause cascade effects and a reduction in the population of species at lower tropic levels (Dapp et al. 2013). At the time of our survey, 23 shark species were listed on the CITES Appendix II (CITES 2017) but it is difficult to know which species is being traded from a market stall. The spiny lobster (*Panulirus argus*) is categorised as either "fully" or "over-exploited" in the Caribbean, with each country regulating their fisheries to conserve stocks (FAO 2006). Ostional, Costa Rica, offers a unique opportunity to assess *in-situ* wildlife laundering. Ostional is home to the only legal extraction of sea turtle eggs in Costa Rica (Campbell 1998). Olive ridley turtles (*Lepidochelys olivacea*) are characterized by *arribadas*; mass nesting events lasting 2-10 days comprising of up to 100,000 nesting female turtles (Valverde

et al. 2012). Costa Rica's Wildlife Conservation Law #6919 states that olive ridley eggs from Ostional can be extracted within the first 36 hours of an *arribada* (Campbell 1998). This extraction is managed by the ADIO (Ostional Integral Development Association). Eggs are sold across the country in heat-sealed bags bearing the ADIO logo and date of the most recent *arribada*. With the exception that proprietors may sell eggs individually for consumption on the premises, all turtle eggs must be sold in certified ADIO packaging. There is high demand for prepared eggs; either cooked or cracked raw into a salsa known as *sangrita*, to be consumed with alcohol (Arauz Almengor et al. 2001). However, vendors sell fresh eggs in non-certified packaging or prepared eggs as a take-away snack. These legal violations open opportunities to launder eggs illegally through legal channels potentially undermining the legal trade.

Our aim was to use the shopping list method to estimate availability of marine wildlife in food markets in Costa Rica with a focus on turtle eggs, and to identify opportunities to launder illegal wildlife in markets. We did this by first comparing availability of uncertified turtle eggs to that of legal yet vulnerable marine consumables, which we chose as a benchmark for comparison. We assumed that availability correlated with search cost – the faster the item was located within the market the more readily available it was. We created a list of marine consumable items and invited survey participants to recorded how quickly they found them. Secondly, using demographic data collected from survey participants (our shoppers), we compared shopping preferences of participants and their demographics with their ability to find the items listed. Building on the shopping list method, as proposed by Moyle and Conrad (2014), we used an adaptation of survival analysis to compare the search costs of items in *in-situ* markets with a view to identifying wildlife laundering. We believe this is the first time survival analysis has been applied in such a way.

3.3. Material and Methods

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. Research assistants were financially compensated for their time.

3.3.1. Study sites

Surveys took place in San José, the capital of Costa Rica and main transport hub for the country. Legally extracted turtle eggs from Ostional arrive in the city and are distributed within the Central Valley and Caribbean. Downtown San José has two large indoor permanent food markets, Mercados Central and Borbón. Mercado Central occupies one block and has 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 for Costa Rican locals and is, unlike Mercado Central, rarely visited by tourists. Mercado Borbón is on the edge of Downtown. Many bars in Downtown San José sell turtle eggs, as do mobile vendors that visit these 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 third study area.

3.3.2. Recruitment for surveys

We invited participants to take part in a market survey based on the shopping list method. As with any market survey, we needed to avoid arousing suspicion from vendors, and therefore we employed local Costa Ricans. We advertised through local unemployment Facebook page *Empleos506* and through adverts on Latin American Sea Turtles' Facebook page. All materials were in Spanish and piloted in advance. Participants were paid US$20. The meeting point for each study site was the same

for each survey. Survey dates were randomly chosen, but were never on consecutive weeks, and took place on Saturdays once a month from July to December 2017. All participants began their surveys between 09.30 and 11.30. Twenty-four participants visited Mercado Central and 20 searched in Mercado Borbón. A total of 43 participants searched Downtown. The demographics of the participants are shown in Table 3.3.2.

Table 3.3.2: Participant demographics

Demographic		Count	Percentage
Sex	Male	29	66
	Female	15	44
Age group	18-24	21	48
	25-34	15	34
	35-44	5	11
	45-54	1	2
	55-64	2	5
Education level	Secondary	8	18
	Collage/apprenticeship	7	16
	University	29	66
Number of people in household	One	10	23
	Two	5	11
	Three- five	21	48
	Six plus	8	18
Employment status	Student	11	25
	Unemployed	4	9
	Employed	29	66

3.3.3. Questionnaire survey

On arrival we invited participants to complete a questionnaire on their shopping preferences in relation to fish and other marine consumables and a section with demographic questions (Appendix 1). We informed the participants 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 was complete. 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 to them. Towards the end of the questions we asked about their previous experiences or willingness to eat shark meat and turtle eggs. Consuming shark meat 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 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 as we wanted to remove any ambiguity.

3.3.4. Search Cost Market Survey

The market survey required participants 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. The items were: Sea turtle eggs in an ADIO bag with a logo (certified), Sea turtle eggs sold outside of an ADIO bag (uncertified), Lobster – whole or parts, Shark steak, Shark fillet, and Shark liver oil. Due to the visual similarity of cooked and fresh turtle eggs we did not ask participants to look for these separately. We did however ask them to record prices of the items they found. This meant we could distinguish between prepared eggs and fresh eggs without potentially confusing participants (cooked eggs and eggs in *sangrita* are considerably more expensive; up to ₡500 per egg, as opposed to ₡150 each fresh). We classified these as *prepared* eggs and removed them from analysis. Our focus was on fresh eggs in sealed bags with the ADIO logo (certified) and those not in ADIO packaging (uncertified). Shark meat is often presented in two different cuts; fillet and steak which we separated on our list. The datasheets had items listed, accompanied with a photograph. Because traders use synonyms for shark meat, we included these on the list to avoid any confusion related to labelling. We also asked participants to record any further details, such as price, type of vendor, and type of display. This helped verify the authenticity of data collected as it was easier to see if participants had fabricated the information they provided. For example, participants claiming they found shark meat in supermarket Automercado or turtle eggs not sold at the fixed price

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. We provided training to participants face to face either individually or in small groups. Participants were given a data sheet and it was explained that their focus was to find the items by any method they wished to employ and record, to the nearest minute, the time that they found each item. To reduce bias from participants searching for items in the order they were listed, we randomized the order in which each item appeared on their datasheet. We encouraged participants to be as discreet as possible during the survey, so if they wished to record data on their phone, they were welcome to do so.

Participants were required to undertake two surveys, one in Downtown San José and the other in either Mercado Central or Mercado Borbón. Whilst surveying Downtown they were instructed not to enter either of these markets. To reduce bias, participants 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. 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. All participants were paid regardless of their success at finding the items.

3.3.5. 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 cost) if it was found. As a result, items found by each participant were allocated a score of 1 or 0 according to whether the participant had found or failed to find it, respectively. We needed an analysis technique that accounted for participants failing to find an item. For this reason, we used an adaptation of a clinical trial analysis, Survival Analysis, to compare the

search costs of each of the shopping list items whilst 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) (Schütte 2018). Importantly, it can accommodate the effectiveness of different treatments if the dataset is incomplete. 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 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 participant as the "patient". This produced separate survival curves for each item. Survival analysis looks at the effectiveness of a treatment given to a patient by measuring the time to develop a symptom (event). 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 that 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. 3.4.4.). 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 cost times for each product. Each site was analyzed separately to give a more detailed representation of 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 establish which curves differed significantly

from the rest. Items that appeared to give rise to the overall result were removed and the analysis re-run to determine what effect this had on the level of significance in the difference between the survival curves of remaining items.

3.3.6. Demographic data analysis

We tested whether the shopping preferences of participants affected their ability to find items. We used the presence or absence of an item in the participant's survey and selected the most relevant items based on our search cost results - certified and uncertified eggs. We used participants' responses to the questionnaires in the analysis. We modelled these variables by plotting pairwise correlations in a matrix to visualize the relationships.

We were interested in identifying important predictors for the participants' ability to find certified and uncertified eggs in the markets or Downtown. To achieve this, we fitted four different 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 Ostional logo before the survey, the month of the 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, ggplot2, survival, survminer and tidyselect was used for survival analysis. MASS using the drop1 function and packages BRGLM and BRGLM2 were used for the analysis of demographic data (R Core Team 2019).

3.4. Results

3.4.1. Demographics

All participants found shark meat in the two markets and only one participant failed to find it Downtown, so it was unnecessary to analyse data on shark meat. Across San José, 43 participants took part in the survey. When asked if they were responsible for the purchase of fish products for their household, 38 responded yes. Only nine respondents acknowledged that 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 participant's ability to find certified eggs in the markets. We found a similar result for searches for uncertified eggs Downtown. In this case, having never eaten turtle eggs had a small effect on the participant's ability to find turtle eggs, however the ΔAIC was less than 1. We therefore conclude that none of the variables affected the participant's ability to find uncertified eggs in town. Conversely, we found participants 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 participants' abilities to find uncertified eggs in the markets.

3.4.2. Survival analysis

The Log Rank test showed no significant difference in the search cost 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.

3.4.3. Mercado Central

There was a significant difference in search cost times for each product in Mercado Central (p=0.001); shark meat was fastest and turtle eggs slowest to find (Fig. 3.4.4.a, Table S3.8.a). 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).

3.4.4. Mercado Borbón

There was a significant difference in search cost between all products in Mercado Borbón (p<0.001) (Fig. 3.4.4.b, Table S3.8.b). On this occasion, closer inspection of estimated survival curves suggested that it was shark products that 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 cost (p=0.800). Once the shark meats were removed from the analysis, the remaining items were no longer found to be significantly different from each other (p=0.700).

3.4.5. Downtown

There was a significant difference in time to find all products in Downtown San José (p<0.001) (Fig. 3.4.4.c, Table S3.8.c). Shark products were fastest to find and when these were removed the products were not significantly different from each other in their search costs (p=0.770).

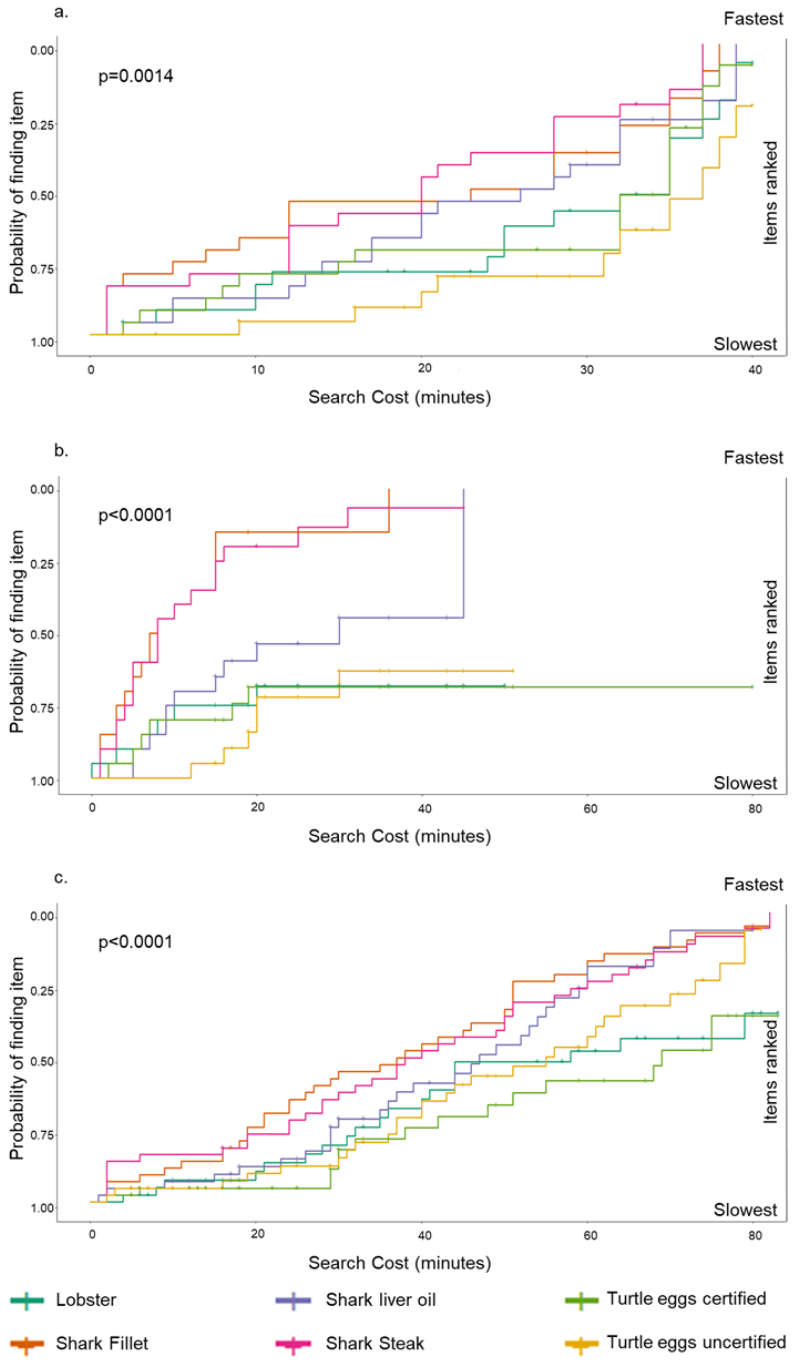

Figure 3.4.4. Estimated probability of finding marine consumables in San José. (a) Mercado Central, (b) Mercado Borbón, (c) Downtown. Note inverted Y axis; for our data a survival probability of 1 meant the participant failed to find the item, steps in the item's time line represent the number of minutes it took to find the item (censor score = 1), crosses in the item timeline indicate the minute at which a participant dropped out of the survey (censor = 0).

3.5. Discussion

Participants found shark products significantly faster than other products on the shopping list. A possible explanation is the physical size of the cuts of shark meat being larger, per unit, than turtle eggs, which could possibly make them more visible to the shopper. However, both shark meat and turtle eggs are often displayed in full trays on the fish counter, meaning they occupy the same amount of space. Further, the green and yellow of the ADIO logo, mean bagged eggs may stand out against a display of fish products, which are typically pinks and greys. It seems unlikely, therefore, that shark meats were more visible than turtle eggs.

Shark derivatives including oils are generally not included in 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. In Costa Rica, sharks comprise 15% of targeted landings in pelagic long-line fisheries; namely silky shark (*Carcharhinus falciformis*) and hammerheads (Sphyrnidae) (Trujillo et al. 2012). Much more commonly, however, sharks are caught accidentally as by-catch (Dulvy et al. 2008; Swimmer et al. 2010). A 60% decline in pelagic sharks due to exploitation by fisheries was seen between 1991-2000 (Whoriskey et al. 2011; O'Bryhim et al. 2017). While shark fins are one of the most expensive seafood products available (estimated to be worth 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 in Costa Rica, using long-line fisheries 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 sea food 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 2004). Mislabeling 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.

We found, using survival analysis, no difference in search costs between certified and uncertified eggs at any of the survey sites. A possible explanation is that refrigerated turtle eggs can keep for up to three months, meaning that the market may be saturated, and the supply is not dwindling between *arribadas*. Given that the surveys took place in the run up to and during peak nesting season, this is a possibility. Eggs we classified as uncertified may have in fact been certified eggs removed from the legal packaging. The incentive for this would be vendors having difficulty selling eggs in quantities of ten. Customers who purchase food from markets are typically on low incomes and unwilling to buy quantities of food greater than their daily need. Were this to be the case, we would expect vendors to be offering eggs for sale in smaller quantities than those sold by ADIO (at the time of the study 10 for ₡1500). However, comparing prices of fresh eggs on sale, it was possible to deduce that in Mercado Central all 10 reports of uncertified eggs were sold in similar quantities and at similar prices to ADIO bags, 2 out of 5 were doing this in Borbón and 13 out of 14 in Downtown San José. Unless vendors have a financial rationale to sell fewer than 10 eggs, there is no reason to open ADIO bags and sell unmarked eggs. The fact that these vendors are selling eggs at the same price and in similar quantities to those in ADIO packages, implies these eggs did not come from ADIO. The Ostional egg project has been criticized by parties concerned that the project allows laundering of illegal eggs through open channels (LAUDI-UCR 2015; Preserve Planet 2017). This concern resulted in the development of a five-year management plan which introduced the traceability regulations in 2017 (MINAE and SINAC 2017). Our results show that while it is now possible to clearly identify certified fresh eggs, uncertified eggs sold in similar quantities, at similar prices are still openly available. We believe we

have identified clear evidence of technically illegal eggs being sold i.e. out of packaging; however, it remains unclear whether these eggs were legally sourced from Ostional or a different, illegal, nesting beach.

The shopping list method does not require the use of highly skilled participants, and therefore provides a good indication of a product's availability and potentially better represents the behavior of the consumer population. The finding that shopping habits did not affect a participant's ability to find an item, further strengthens this method. The only exception to this was in the case of searching for uncertified eggs in the markets, which created an anomaly. The finding that participants who buy fish for their household were better at finding eggs is logical based on them spending more time in markets. Recognizing the logo when finding uncertified eggs may be explained by their ability to distinguish between certified and uncertified eggs, possibly making it more likely they know how to select uncertified eggs. Having never eaten turtle eggs should not, however, increase their ability to find uncertified eggs. It is possible the AIC is choosing a too complex model, as the method can tend towards selection of too many parameters (Burnham and Anderson 2002). Given that other models did not find any covariates that had a significant effect on participants' abilities to find eggs, we treat this result with caution. Any effect these covariates have will be minor. We therefore tentatively conclude that participants' shopping habits do not influence their ability to find eggs.

The shopping list method has 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 the 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 participants to collect reliable data than attempting to record everything available in the market. It is also possible to generate price data, which is an important barometer of temporal trade fluctuations.

The objective of the shopping list method is to compare 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 in cases where the meat has been prepared, mislabeled, the trade includes juveniles, or the body sizes between species overlap (Minhós et al. 2013). The shopping list method has the potential to 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 than species, this method would be easy to apply.

The shopping list method is not restricted to participants 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 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 loris (*Nycticebus* 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. With the 2003 outbreak of severe acute respiratory syndrome (SARS-CoV) and the 2020 strain of Coronavirus (COVID-19) documented as originating from Chinese wildlife markets (Chomel et al. 2007; Swift et al. 2007), the significance of zoonosis as a world health issue cannot be underestimated (Bell et al. 2004). Closure of physical markets as a result of biosecurity concerns could drive an increase in online wildlife trade, making adaptable market survey techniques, more valuable.

Moyle and Conrad (2014) first used the shopping list method to look at 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, whilst 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 an

appropriate method for this type of data collection. We found a relatively small sample of surveyors could collect enough data. We extended Moyle and Conrad's (2014) approach by incorporating survival analysis and were therefore 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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3.8. Supporting information

Table S3.8a: Confidence intervals for San José Central Market. Search cost column represents steps in the survival curve (Fig. 3.4.4.a).

Lobster			**Shark Fillet**			**Shark Liver Oil**			**Shark Steak**			**Turtle Eggs Certified**			**Turtle Eggs Uncertified**		
Search Cost	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**
1	0.6968	0.997	2	0.8816	1	1	0.6968	0.997	2	0.8816	1.000	9	87%	1	1	0.6968	0.997
2	0.6448	0.972	5	0.7522	1	6	0.6448	0.972	3	0.8125	1.000	16	79%	1	2	0.6448	0.972
5	0.5953	0.945	12	0.6968	0.997	12	0.4585	0.852	7	0.7522	1.000	20	0.7126	1	5	0.5953	0.945
7	0.548	0.916	13	0.6448	0.972	15	0.416	0.818	8	0.6968	0.997	21	0.6419	0.997	7	0.548	0.916
9	0.5024	0.885	14	0.5953	0.945	20	0.2967	0.708	9	0.6448	0.972	31	0.5324	0.974	9	0.5024	0.885
12	0.3749	0.783	17	0.5024	0.885	21	0.2595	0.669	15	0.5953	0.945	32	0.4376	0.936	12	0.3749	0.783
23	0.3351	0.746	20	0.416	0.818	23	0.2237	0.629	16	0.548	0.916	35	0.3165	0.899	23	0.3351	0.746
28	0.2237	0.629	21	0.3749	0.783	28	0.125	0.5	32	0.3486	0.774	37	0.2158	0.844	28	0.2237	0.629
32	0.1463	0.541	26	0.3351	0.746	32	0.0955	0.454	35	0.1422	0.585	38	0.132	0.776	32	0.1463	0.541
35	0.079	0.445	28	0.2967	0.708	35	0.0596	0.41	37	0.0431	0.483	39	0.0647	0.704	35	0.079	0.445
37	0.0254	0.346	29	0.2595	0.669	37	NA	NA	38	0.0115	0.454				37	0.0254	0.346
38	NA	NA	32	0.1273	0.533										38	NA	NA
			37	0.0784	0.486												
			39	NA	NA												

Table S3.8b: Confidence intervals for San José Borbón Market. Search cost column represents steps in the survival curve (Fig. 3.4.4.b).

Lobster			**Shark Fillet**			**Shark Liver Oil**			**Shark Steak**			**Turtle Eggs Certified**			**Turtle Eggs Uncertified**		
Search Cost	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**
0	0.859	1.000	1	0.7071	1.000	5	0.778	1.000	1	0.7777	1.000	2	0.859	1.000	12	0.844	1.000
3	0.778	1.000	3	0.5823	0.966	7	0.707	1.000	3	0.6426	0.996	5	0.778	1.000	19	0.739	1.000
6	0.707	1.000	4	0.5254	0.933	9	0.582	0.966	4	0.5823	0.966	6	0.707	1.000	20	0.558	0.998
8	0.643	0.996	5	0.4712	0.897	10	0.525	0.933	5	0.4195	0.858	7	0.643	0.996			
10	0.582	0.966	6	0.4195	0.858	15	0.471	0.897	8	0.2772	0.731	17	0.571	0.966			
20	0.498	0.934	7	0.3226	0.775	16	0.414	0.857	10	0.2339	0.684	19	0.505	0.931			
			8	0.2772	0.731	20	0.353	0.815	12	0.1926	0.636						
			10	0.2339	0.684	30	0.258	0.775	15	0.117	0.534						
			12	0.1926	0.636	45	NA	NA	16	0.0832	0.481						
			15	0.0528	0.426				25	0.0407	0.437						
			36	NA	NA				31	0.0108	0.413						

Table S3.8c: Confidence intervals for San José Downtown. Search cost column represents steps in the survival curve (Fig. 3.4.4.c).

Lobster			**Shark Fillet**			**Shark Liver Oil**			**Shark Steak**			**Turtle Eggs Certified**			**Turtle Eggs Uncertified**		
Search Cost	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**	**Search Cost**	**Lower 95% CI**	**Upper 95% CI**
4	0.933	1.000	2	0.8571	1.000	1	0.9327	1.000	2	0.7629	0.971	2	0.933	1.000	3	0.9045	1.000
8	0.887	1.000	6	0.8242	0.998	2	0.8926	1.000	6	0.7338	0.955	6	0.891	1.000	11	0.8363	1.000
9	0.847	1.000	9	0.7929	0.985	9	0.856	1.000	17	0.7056	0.939	30	0.787	1.000	20	0.7783	1.000
21	0.803	0.999	12	0.7629	0.971	16	0.8197	0.998	20	0.649	0.904	31	0.696	0.964	33	0.6638	0.975
22	0.762	0.983	17	0.7056	0.939	19	0.7842	0.985	25	0.5949	0.867	33	0.651	0.942	37	0.6082	0.949
27	0.721	0.966	19	0.677	0.922	24	0.7491	0.969	27	0.5686	0.848	39	0.603	0.919	44	0.5557	0.921
29	0.682	0.947	20	0.6217	0.886	27	0.7141	0.952	29	0.5172	0.808	43	0.557	0.892	45	0.5056	0.889
32	0.645	0.926	22	0.5686	0.848	30	0.6156	0.895	31	0.4921	0.787	49	0.513	0.864	56	0.4419	0.855
33	0.609	0.904	25	0.5172	0.808	31	0.583	0.873	33	0.4674	0.766	52	0.467	0.834	61	0.3748	0.816
36	0.572	0.881	27	0.4921	0.787	36	0.5477	0.851	35	0.4431	0.745	56	0.423	0.802	62	0.3127	0.773
37	0.536	0.857	28	0.4674	0.766	37	0.5134	0.827	38	0.3955	0.701	69	0.366	0.767	65	0.255	0.726
41	0.501	0.831	30	0.4431	0.745	38	0.48	0.802	39	0.3722	0.679	70	0.312	0.729	71	0.1903	0.676
42	0.467	0.805	31	0.4191	0.723	40	0.4474	0.777	41	0.3493	0.656	76	0.2	0.641	74	0.115	0.629
45	0.369	0.722	36	0.3955	0.701	45	0.4134	0.750	43	0.3267	0.633				79	0.0265	0.683
59	0.333	0.691	38	0.3722	0.679	47	0.3803	0.722	45	0.3044	0.610				3	0.9045	1.000
65	0.289	0.657	39	0.3493	0.656	48	0.3481	0.693	50	0.2825	0.586				11	0.8363	1.000
79	0.191	0.635	41	0.3267	0.633	50	0.3167	0.664	51	0.2397	0.538				20	0.7783	1.000
			43	0.3044	0.610	53	0.2861	0.634	52	0.1983	0.488				33	0.6638	0.975
			46	0.2825	0.586	54	0.2563	0.603	57	0.1783	0.463				37	0.6082	0.949
			47	0.2609	0.562	55	0.2274	0.571	59	0.1587	0.437				44	0.5557	0.921
			51	0.2188	0.513	56	0.1993	0.538	61	0.1395	0.411				45	0.5056	0.889
			52	0.1395	0.411	57	0.1721	0.505	64	0.1209	0.384				56	0.4419	0.855
			57	0.1209	0.384	60	0.1459	0.470	66	0.1028	0.357				61	0.3748	0.816
			61	0.0853	0.329	61	0.0884	0.396	68	0.0822	0.328				62	0.3127	0.773
			63	0.0685	0.301	69	0.0417	0.374	69	0.0628	0.298				65	0.255	0.726
			69	0.0526	0.272	71	0.0107	0.365	73	0.0448	0.268						
			73	0.0377	0.243				74	0.0285	0.236						
			74	0.0241	0.214				79	0.0145	0.206						
			79	0.0124	0.185				82	NA	NA						
			82	NA	NA												

CHAPTER 4

The legal and illegal supply chain of sea turtle eggs in Costa Rica

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Pheasey, H., Griffiths, R.A., & Roberts, D.L. The legal and illegal supply chain of sea turtle eggs in Costa Rica.

4.1. Abstract

Many poor rural communities rely on biodiversity to fulfil basic livelihood requirements. Trade bans of natural resources often conflict with poverty alleviation and can stimulate illegal trade. Understanding markets, prices and profitability along both legal and illegal trade chains is crucial if appropriate regulatory mechanisms are to be implemented. Using the legal extraction of sea turtle eggs from Ostional, we used a mixed-methods approach to analyse the legal supply chain. We found an inequitable distribution of revenue along the legal supply chain, with middlemen profiting the most. Geographical barriers to trade flows and competition with illegal trade meant higher profits were achieved by sending the largest volume of eggs the furthest distance. However, this increased the vulnerability of local traders to fluctuations in supply. Comparing legal and illegal trade routes, we identified potential laundering hotspots on the Caribbean coast of Costa Rica. Illegal eggs were cheaper than those available from Ostional on the Pacific coast. However, given the volume of Ostional eggs supplying the Caribbean and the fragility of local trader livelihoods, we advise caution in altering any management plan that could impact supply to the Caribbean, fearing a dwindling supply of legal eggs may stimulate illegal extraction in the Caribbean. Our research is directly relevant to the policies of the Convention on International Trade in Endangered Species, Convention on Biological Diversity and UN Sustainable Development Goals, in that it highlights the fragility of trying to balance species protection and sustainable livelihoods, approaches enshrined by these conventions. Our research enhances our understanding of how natural resource use can help alleviate poverty, improve local livelihoods and inform policy regarding wildlife laundering.

4.2. Introduction

Food insecurity and poverty drives people to adopt unsustainable lifestyles that degrade the natural resources upon which they depend (Broad et al., 2003). In much of the world, rural communities depend on wildlife to fulfil their living requirements and generate income (Roe, 2002). Some of the world's poorest countries are the richest in biodiversity, creating a conflict between meeting basic

human livelihoods and species conservation (Rosser & Mainka, 2002). The trade in endangered species is regulated by the Convention on International Trade in Endangered Species (CITES). While this is a widely adopted approach, signed by 182 states worldwide, it is often incompatible with the Convention on Biological Diversity (CBD, 2014). The CBD recognises a countries' sovereign right to utilise its natural resources; recognising that without access rights, people will not value nature which will lead to its subsequent destruction (Robinson & Redford, 1991; CBD, 2014).

An alternative strategy to regulating wildlife trade is to incentivise communities to protect wildlife, by allowing them to financially benefit through sustainable extraction. While this approach has potential, many projects have fallen short of their objectives pointing to a clear need for a better understanding of supply chains (Robinson et al., 2018). Value chain analysis is used to assess the commercial viability of a product. A value chain is a list of activities or processes that are involved in the creation of a service or supply of a merchandise for a specific market (Nor et al., 2019). Value chain analysis is an economic tool that accounts for all links in the trade chain, from manufacture to consumption. The objective is to highlight unproductive links in the chain, where the producer may be missing an opportunity to maximise profits. For this type of assessment, identifying upstream and downstream activities and the value of each link in the chain is required (Nor et al., 2019). Upstream activities are all the materials and processes involved in the generation of a product, whereas the downstream activities include marketing and distribution to the end consumer.

Our research considers the sea turtle egg extraction and commercialisation project in Ostional, Costa Rica. The project is managed by the community association ADIO (Association for the Integral Development of Ostional). Hailed as a socioeconomic success for the local community, without seemingly affecting the turtle population in Ostional, it has been criticised by some turtle conservationists (Campbell, 1998). Critics have accused the Ostional project of stimulating demand and the subsequent illegal extraction of turtle eggs, and enabling the laundering of illegally sourced

eggs through open trade channels (pers. comm.). For this reason, the project is required to sell high volumes of eggs at a low enough price to undermine the illegal trade.

Green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and leatherback (*Dermochelys coriacea*) turtles nest annually on both coasts of Costa Rica and are all threatened with extinction (IUCN, 2019). Olive ridley turtles nest, both in *arribadas* at three sites in Costa Rica (Ostional, Nancite and Corozalito; in order of size of nesting events) and as solitary nesters (Hirth, 1980). Size is the only way to visually differentiate between turtle species' eggs, and it is currently not possible to determine the source of an olive ridley egg sold outside ADIO heat-sealed packaging. Olive ridley turtles do not nest on the Caribbean coast so visually distinguishing between these and other species' eggs found in this region is possible.

However, turtle eggs are a culturally important traditional food source in coastal communities in Costa Rica, and one of the reasons the legal extraction began was intended to curb the illegal extraction in Ostional (Campbell, 1998). However, information on egg extraction rates and illegal trade prior to legalisation are unavailable. This lack of adequate data prevents an accurate comparison of demand before and after legalisation. Turtle egg consumption was traditionally limited to coastal areas and demand in the Central Valley was created by the availability of ADIO eggs (Campbell, 1998; Arauz-Almengor et al., 2001).

Synchronized mass nesting events of olive ridley (*Lepidochelys olivacea*) sea turtles in Ostional, Costa Rica have been reported since the 1940s (Campbell, 1998). Known as *arribadas*, these events occur approximately once a month, with a peak season September-December. In excess of 100,000 individual turtles may nest over the course of 4-10 days (Valverde et al., 2012). However, hatching success is estimated to be below 15%, compared with olive ridley turtles at solitary nesting beaches that have a 90% success rate (Valverde, 1999). This attributed to the high pathogen load in the sand

from rotten eggs caused by mammalian predators and turtles digging up previously laid nests (Valverde et al., 2012). Due to this high natural egg mortality and the need to recognize the potential socioeconomic value of these eggs, the community of Ostional was granted legal permission to remove and sell eggs from the first 36 hours of an *arribada* (thereby only removing doomed eggs) (Article 3 No 20007 MAG; Valverde et al., 2012). This may reduce the microorganism load and increase hatchling success, but scientific agreement on this is yet to be reached (Valverde et al., 2012). The Asociación de Desarrollo Integral de Ostional (ADIO) comprises local community members responsible for managing the extraction of eggs. In return, members of ADIO are required to undertake conservation work to protect the turtles, which is overseen by the government department, MINAET (Ministerio de Ambiente, Energía y Turismo).

We undertook value trade chain analysis of the legal extraction of olive ridley eggs from Ostional. We compiled evidence on the illegal trade in turtle eggs in Costa Rica and identified areas of geographical overlap between the legal and illegal trades. We compared prices of eggs available in the markets, interviews with *socios* in Ostional and *honorarios* across the country, as well as vendors further along the trade chain, to contribute to our understanding of the trade.

4.2.1. Study area

Our research focused on three regions in Costa Rica, the Pacific, Central Valley and Caribbean. Ostional is in Guanacaste province on the Pacific coast of Costa Rica (Fig. 4.4.2.a). Ostional is situated on Ruta 160, a secondary dirt road, typical of the area. The road leads north out of Ostional gradually improving in quality towards the nearest town of Santa Cruz, c.58 km from Ostional. Ostional is bordered by rivers along the north and south, the southern river is often impassable in the wet season. Few services are available in Ostional, a village of c.600 residents.

Records detailing the exact number of ADIO members and active participants are not available, however it is estimated ADIO has c.250 members, not all of whom live in Ostional. In exchange for the sale of eggs ADIO members are obliged to contribute to the conservation of the turtles outside *arribadas*. This includes protecting eggs and hatchlings from predators and clearing the beach of litter and debris. In exchange for this work, each member of ADIO receives a share of 70% of the profits from commercial sales. The remaining 30% is used for the ADIO overheads, maintenance of the village and securing the beach from illegal extractors.

San José, the capital and main transport hub for the country is situated in the Central Valley. Downtown San José has three large markets, as well as numerous bars and cantinas that sell turtle eggs. The country's largest fresh food distributor the CEDANA, Heredia is c.12.5 km from Downtown San José. Many seafood wholesalers and retailers operate from this business park.

Limón province on the Caribbean coast, has a long-standing tradition of sea turtle consumption. Tortuguero, San Francisco and Pacuare are small coastal villages situated near turtle nesting beaches on the northern coast. These villages are only accessible by boat via a jungle river system. Tortuguero is the largest green sea turtle nesting beach in the western hemisphere and attracts 1000s of tourists every nesting season. San Francisco is a small village located close to Playa Norte, adjacent to Tortuguero. Pacuare is predominantly a leatherback turtle nesting beach near the impoverished town of Siquirres. Illegal removal of turtle eggs from these beaches is common. The situation in in Pacuare is particularly severe; any nests left *in-situ* fall prey to illegal harvesters.

4.3. Methods

The School of Anthropology and Conservation's Research Ethics Advisory Group (University of Kent) approved this research (Ref. No.: 0381617a, b). All participants were over the age of 18, made aware of the purpose of the research and provided signed consent.

4.3.1. Interviews

Our research took place in 2017 and 2018. We employed a mixed methods approach involving semi-structured interviews (n= 63) and a short answer survey (n=8), questionnaire responses (n=65), grey literature and an unpublished study by Pheasey et al. (Appendix 2) to describe the legal and illegal trade dynamics of sea turtle eggs in Costa Rica. Our semi-structured interviews with members and non-members of ADIO, included open questions on the trade chain, trade routes and prices in both the legal and the illegal trade. We also asked questions regarding threats to the legal trade. We used a list of contact numbers provided in the ADIO monthly *arribada* reports, to invite *honorarios* (six wholesalers and four retailers) to participate in a semi-structured interview. An additional eight invitees responded to a survey via Whatsapp. We used opportunistic and snowball sampling to locate and interview five additional retailers who were not members of ADIO. We used snowball sampling to recruit members of ADIO board of directors (n=3), law enforcement officials (n=8) and turtle biologists (n=18) to an interview. Further semi-structured interviews were undertaken with 12 community members in Ostional, Corozalito and San Francisco, and seven self-proclaimed "poachers" based in Pacuare, Limón. We completed questionnaires with 65 Ostional residents, of which 49 households had at least one occupant who was a member of ADIO. We asked short answer questions related to the future of the egg project, the positive and negative aspects of, and threats to, the project.

We conducted all interviews, surveys and questionnaires in Spanish. Interviews were audio recorded, transcribed by a native speaker, and analysed in English. We coded relevant sections of text using an inductive approach which involves coding solely on interview transcript contents and identified a keyword (code) that summarized the sentences/paragraphs of the text (Newing, 2011). These codes were organized using software package NVivo 12 (QRS International, 2006), which produces

summaries of each theme based on the code ascribed. We used the content of these summaries to create the narrative.

4.3.2. Changes in monetary value of ADIO conservation activities

We used ADIO annual reports from 2013-2018 and monthly reports from 2014-2019 to calculate the monetary value of conservation activities undertaken by ADIO, and report the volume and distribution of eggs. These reports outline the commercialization of eggs leaving Ostional. The 5-year management plan for the traceability of eggs in the commercial trade chain was renewed in 2017 and the detail of reporting has increased. This provided comparable data on volume and movement of eggs. We combined the data from 2018 and 2019 to create a graduated colour map of the volume of eggs delivered to each province using ArcMap 10.5. (ESRI, 2017). We created an additional map using shapefiles on legal and illegal trade routes and destinations by manually digitizing qualitative data on trade routes and known egg sales points from interviews and *arribada* reports.

4.3.3. Egg prices

During our interviews we collected data on the price of eggs and in addition we recruited participants to visit towns to record egg prices. We categorised eggs into six groups; certified: fresh or prepared, uncertified: fresh or prepared and illegal: town or beach. Certified fresh eggs were easily identifiable due to the ADIO packaging. Fresh eggs not in this packaging were considered uncertified. Prepared eggs were harder to identify as they must be removed from ADIO packs to be prepared. However, if the participant saw the vendor had ADIO packages or removed eggs from an ADIO bag, this was considered certified and when prepared eggs were sold in the street or with no ADIO packaging they were considered uncertified. In total, 69 participants visited markets, bars, canteens and mobile vendors in San José, Limón, Puntarenas, Heredia and Guanacaste on 47 occasions. Due to the difficulty in identifying illegally sourced olive ridley eggs, data on illegal eggs was restricted to the species occurring on the Caribbean. Most of the price data collected on the illegal trade was from

semi-structured interviews, however, some illegal eggs were found for sale in towns. It was harder to differentiate between prepared and fresh egg prices in the illegal trade, so we separated egg prices into beach price (door-to-door sales near nesting beaches) and town price.

4.3.4. Statistical analyses

To test for a significant difference in price between different types of eggs in different regions, we used a Kruskal-Wallis Chi Squared test. Statistical analysis was undertaken in RStudio 1.2.1335 using the package MASS. Graphs were built with R package ggplot2 (R Core Team, 2019).

4.4. Results

From 2015-2019 inclusive, ADIO received c.US$2m (₡979,322,000) from the national sale of eggs. The voluntary conservation activities undertaken by ADIO, in exchange for the permission to sell eggs is calculated at ₡2,000 (US$4) per person per hour and amounts to ₡16,136,000 (c.US$28,369) in 8,068 hours in beach cleaning from 2013-2018 inclusive, and ₡9,052,300 (c.US$15,915) in 99,463 hours in hatchling protection from 2015-2018 inclusive (Lobo-Glez, 2013-2018). Through egg sales, ADIO paid ₡130,400,342 (c.US$299,317) during 2013-2018, in stipends, equipment and transport for security against illegal harvesters (Lobo-Glez, 2013-2018).

When an *arribada* is declared ADIO collect, package and distribute eggs across the country via *honorarios* (intermediaries). ADIO members reported that they receive between ₡25,000 (US$50) and ₡80,000 (US$160) per *arribada*, depending on the volume of turtles nesting and subsequent number of eggs sold. Pensioners, who were members of ADIO, were more dependent on the income from eggs, while the majority (84%, n=41) of ADIO members interviewed, considered the revenue to be either equally important to their other sources of income or a welcome addition.

Most eggs, 95%, are sold nationally via *honorarios* with only 5% comprising local egg sales in Ostional (Lobo-Glez, 2018-2019). ADIO relies heavily on its *honorarios* to sell eggs on their behalf. *Honorarios* include large seafood wholesalers (Participants 054 and 060), bars, middlemen couriers, market stall fishmongers and mobile vendors. The *honorarios* sell eggs to the end consumer, act as middlemen transporting the eggs to the other provinces or may occupy both roles (Fig. 4.4.1.a).

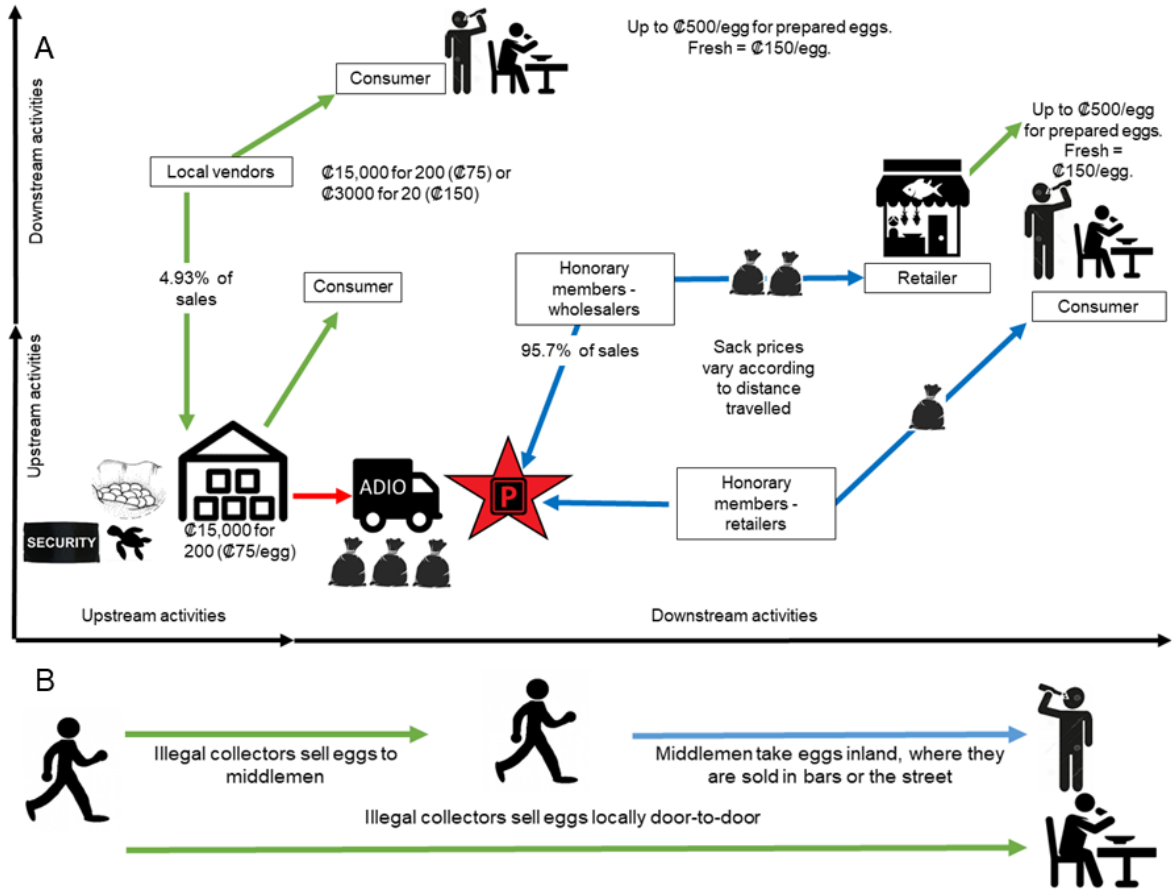


Figure 4.4.1. Legal and illegal trade chains: (a) legal trade chain, (b) illegal trade chain. Red depicts ADIO movement of eggs from Ostional to car park in San José where eggs are distributed amongst *honorarios*. Green arrows represent suppliers, blue arrows represent *honorarios*/middlemen.

Net income in the egg trade varied widely between *honorarios* (n=10), who claimed the eggs were between 2% and 80% of their income. One fishmonger, (Participant 063) stated that eggs are only a small fraction of his profits, however he uses sales of eggs in *sangrita* (chili salsa) to draw customers to his market stall. Mobile vendors reported selling in the region of 150-200 eggs a day. Some have a

permanent street pitch selling other consumables, others may rely on eggs for their entire income; needing to diversify their livelihood strategy in the dry season when there are fewer eggs. This group buys eggs from *honorarios* and may also be *honorarios* or independent of ADIO. Frequently however, they rely on middlemen to bring their eggs closer to home, sometimes buying eggs at a premium or paying a delivery fee. These mobile vendors profit most from egg sales but, due to their dependence on the eggs, are also the most vulnerable to fluctuations in supply. This vulnerability is particularly apparent in the Caribbean where the mobile vendors we spoke to depend on their eggs being delivered. One vendor reported he often experiences problems with supply, stating that the *honorarios* in San José have the monopoly over the trade and can withhold eggs if they desire:

"*And the problem here is that…everything is hoarded in San José…they buy all the egg that comes out…monopolize everything, then they do not care if the egg is lost* [wasted] *or not lost*" (Participant 025).

Another Limón vendor expressed frustration at ADIO, stating that "*in fact this last time they left me without eggs, they called me an hour before and…says* "we are here in the parking lot, at what time will he come for the eggs?"…*I needed at least to call someone to pick them up, go to the bank to deposit, on Sunday it was impossible to do that*" (Participant 002).

In this situation, the vendor pays another *honorario* to deliver his eggs or asks a San José distributer to send them by bus. Once again, subject to middlemen prices or delivery fees.

During our study, the volume of eggs *honorarios* purchased ranged from 400-30,200 eggs from one *arribada*. Limón, San José and Heredia received the highest volume of eggs respectively (Fig. 4.4.2.a). The main overhead for *honorarios* is transportation. Road quality, rather than proximity to Ostional, determines the cost-effectiveness, both in time and fuel, of moving eggs. This is evidenced

by the highest volume of eggs going furthest to Limón whilst a relatively low number of eggs are sold locally in Guanacaste. A critic of the Ostional project stated, "*When it comes down to business they don't come to the beaches around the southern part of the peninsular of Nicoya, they would rather come to San José*" (Participant 026). However, one *honorario* in the Central Valley (Participant 060), stated that when demand requires it, he ships eggs back to the Pacific. Whether this is a significant volume is unknown.

Figure 4.4.2. Trade dynamics (a) volume of eggs, ADIO route and drop off points, number of traders in each province, (b) legal destinations and trade routes (ADIO Reports and interviews) red=ADIO route (line) and drop off (circles), blue=middlemen, (c) Destinations of illegal eggs red=olive ridley turtles originating from Pacific, black=green and leatherback turtles originating in the Caribbean and trade routes grey (interviews and Appendix 2), (d) Close up of Limón province with red targets showing where we would expect to find laundering of green or leatherback eggs in the markets.

The illegal trade in olive ridley eggs in the Pacific reduces the cost-effectiveness of distributing legal eggs around the Pacific coast. Participant 054 stated that towns that are 80-100 km away are not worth visiting as he can only sell a few (c.5) sacks due to the illegal trade arriving before him and undercutting his prices. Quoting his vendors: "*No eggs, not today because I have, the other one has already gone down much cheaper*".

Illegal eggs originating from both coasts, are available to buy on the streets of Costa Rica. On the Pacific, while the illegal take of other species' eggs undoubtedly occurs, none of the participants referred to these being traded in the markets, speaking exclusively about olive ridley eggs. Almost all nesting beaches suffer harvesting pressure, including Ostional, despite the presence of security guards and volunteer patrols on this beach. Corozalito receives small *arribadas* and is another illegal harvest hot spot.

Participants reported that the illegal trade of olive ridley eggs was competing with legal eggs in the Pacific provinces, to such a degree that it was affecting the demand for legal eggs. Before an *arribada* the number of turtles visible in the water and coming to shore to nest increases. This attracts harvesters, able to traffic eggs in advance of an *arribada* being declared. There follows a three day lag between the eggs being harvested and distributed by ADIO, enough time for the illegal trade to undercut Ostional eggs.

"When we call the partner, then he can tell us is that already…they are selling [illegal eggs] *two days ago. So, he cannot buy the amount* [of eggs] *he wanted because the market is already full, so he reduces the sale to us"* (Participant 031).

"The illegal egg, when you come out with the egg already here legal, the illegal egg is already watered everywhere" (Participant 054).

With no time lag between extraction and distribution, or overheads beyond transport costs to locations of their choosing, the Pacific traffickers are better positioned to distribute illegal eggs to retailers of their choice. Pacific traffickers have vehicles and the capacity to move eggs inland and illegal eggs are known to reach the Central Valley (Appendix 2).

"I come with legal eggs…That generates a series of expenses, legalizing transportation and legalizing the sale. The illegal, nothing. You take it and sell it and spend nothing…It hurts us, because sometimes before ADIO distributes the egg, there is already an egg on the street, from the illegal" (Participant 054).

We asked retailers in the Caribbean and the Central Valley about the competition between legal and illegal eggs, none made any reference to competing with illegal olive ridley eggs suggesting illegal movement of eggs from the Pacific stops in, or before, the Central Valley. Although they referred to there being competition, it was always in relation to legal eggs.

"*Here is legal…All are legal*" (Participant 025).

When asked if they are ever offered eggs in unmarked bags or outside ADIO packaging, they also responded in the negative:

"*I do not see, and if it came, it is not bought*" (Participant 062).

"*No, it does not come here*" (Participant 061).

The Caribbean illegal supply chains tend to be short, often from harvester to consumer via door to door sales, as close to the beach of origin as possible. However, green and leatherback turtle eggs were available for sale in several towns along Ruta 32 and these are likely brought inland by middlemen (Fig. 4.4.1.b) "*They have a boat, but there is an intermediary, they are intermediaries for Limón people*" (Participant 043).

Mapping destinations and trade routes of both legal and illegal eggs, we found that regardless of coast of origin, illegal eggs were not crossing the Central Valley (Fig. 4.4.2.b-c). Working on the assumption that only legal olive ridley eggs enter Limón province, we identified hotspots where we can expect to find both illegal and legal eggs and therefore potential locations where we would expect laundering to take place. We identified green and leatherback turtle eggs for sale in Caribbean towns in Limon Province, suggesting towns geographically situated between these locations may also be utilised by traffickers (Fig. 4.4.2.d).

High demand, coupled with transport costs related to distance from source, appear to be driving prices charged by *honorarios*. ADIO sell sacks of eggs for a fixed price, with an annual increase of ₡1,000 (US$2) per sack. In 2018, 200 eggs were sold as a single unit for ₡15,000 (US$30). However, there is nothing to limit the amount *honorarios* charge for a sack of eggs and mark-ups ranged from ₡18,000-₡30,000 (US$36-60) per sack. The price is often reflected in the distance or travel time required to distribute the eggs. Fresh eggs are sold to consumers in small heat sealed bags usually for ₡150 per egg, sold in the pre-packaged units of 20 eggs (previously 10 eggs). The prices consumers pay appear to be unofficially capped, although one mobile vendor in Guanacaste claimed to sell them for ₡200 each. The maximum price we found fresh eggs sold for was ₡500 (US$1) in the Central Valley, however as these were from bars it is likely they were for drinking in *sangrita*, as fresh egg prices at such high prices were uncommon. Mobile vendors walk or cycle the streets of their local

area selling eggs from a cool box, either in public spaces or door-to-door. Occasionally, they sell fresh eggs but, more commonly eggs are cooked or in *sangrita*, increasing the value of each egg to ₡333.33 for cooked eggs, often sold in batches of 3 for ₡1000 (US$2), to ₡500 (US$1) for an egg in *sangrita*. It is illegal to sell ADIO eggs out of legal packaging, with an exception for consumption on the premises. Bar eggs retail at a similar price to those sold by mobile vendors, the highest price we found for an egg prepared in *sangrita* was one for ₡800 (US$1.60).

Illegal eggs sell at lower prices than eggs from ADIO (Fig. 4.4.3.1), which causes problems for legal vendors. One Pacific vendor spoke of the competition experienced with the illegal trade and lower prices they charge for illegal eggs; "*we are affected by the competition that is the illegal eggs…What is illegal has a price, and what is legal, obviously has another price…people are going to buy the cheapest product*" (Participant 003).

Despite the seasonal fluctuations in availability, vendors stated that they keep their prices the same regardless of the quantities available. Our observations agree with this and while we found more variety in prices of uncertified eggs, this did not vary over time. Unsurprisingly it was harder to gather data on the prices of illegal eggs and our sample is based on accounts from participants in Limón province. Once again, despite prices ranging more widely, differences over time varied little (Fig. 4.4.3.2. and 4.4.3.3).

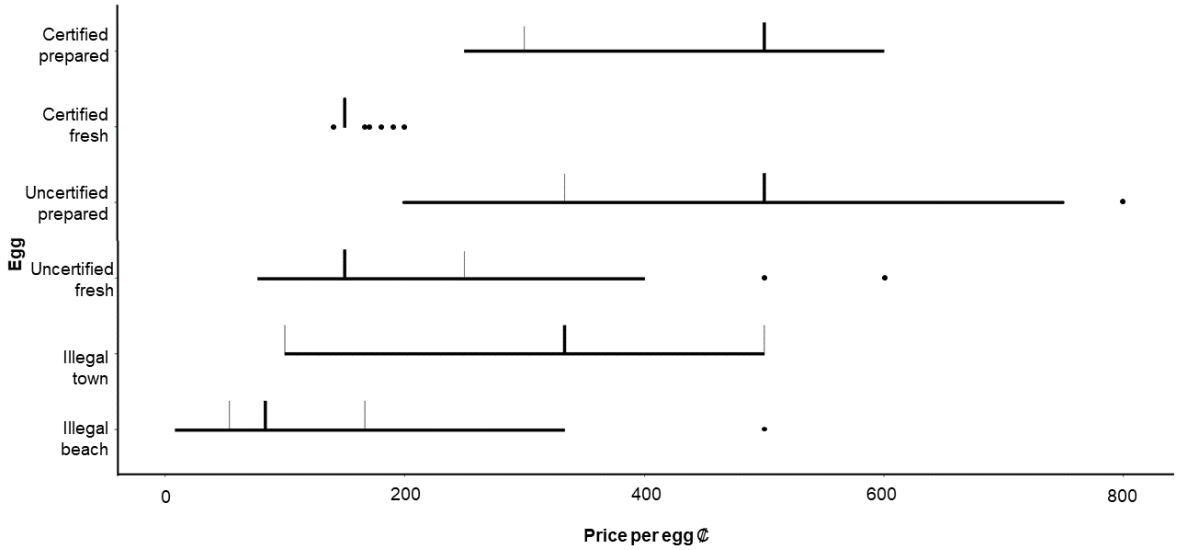
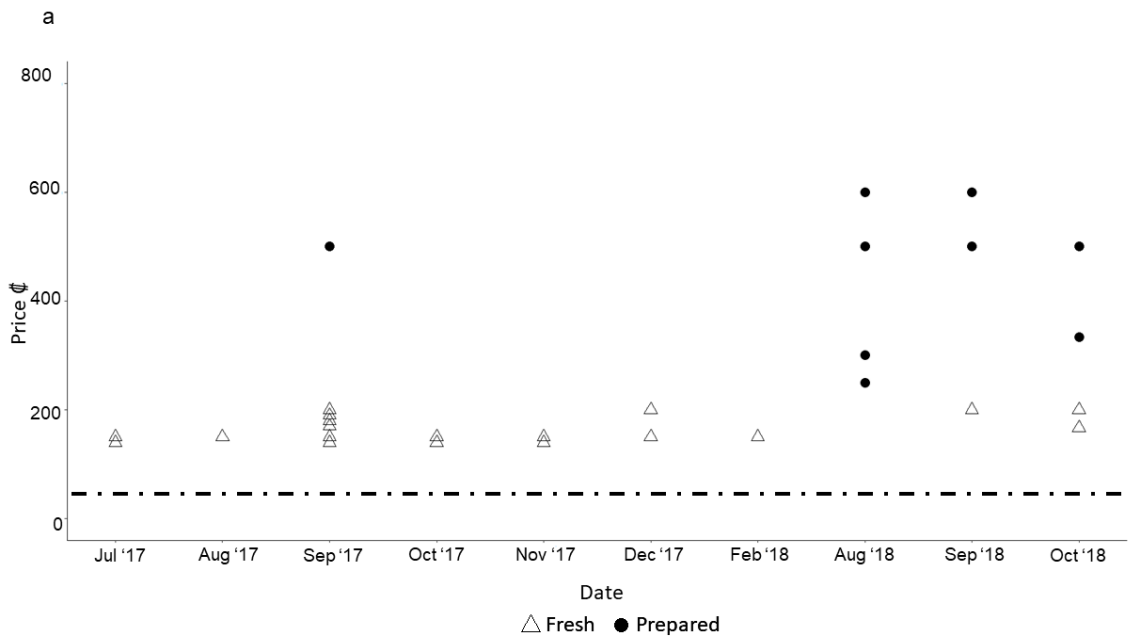


Figure 4.4.3.1. Price comparison between certified, uncertified and illegal eggs. Vertical bars: thick=median, thin=interquartile range, horizontal= range of prices. Certified eggs were sold in ADIO sealed bags, uncertified eggs were sold outside of this packaging. Prepared eggs are cooked or in *sangrita*. Illegal species' eggs are divided into town price and beach price.



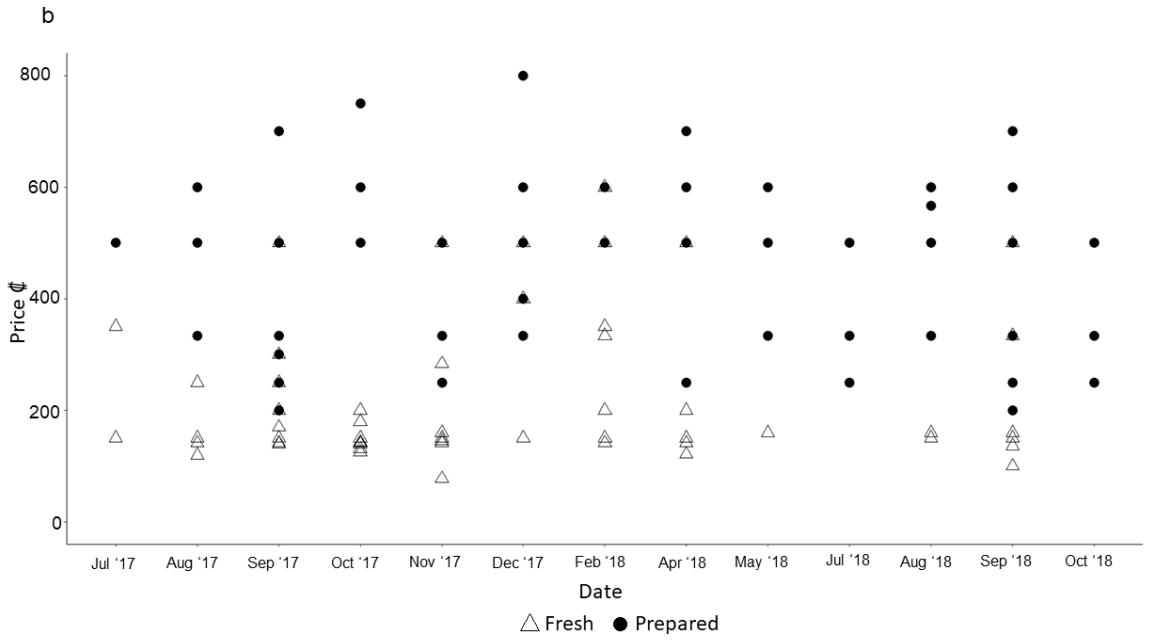


Figure 4.4.3.2 Prepared and fresh egg prices (a). certified and (b) uncertified prices, for prepared and fresh eggs over the period of 15 months, dashed horizontal line represents the price ADIO charges to honorarios (₡75-76 per egg).

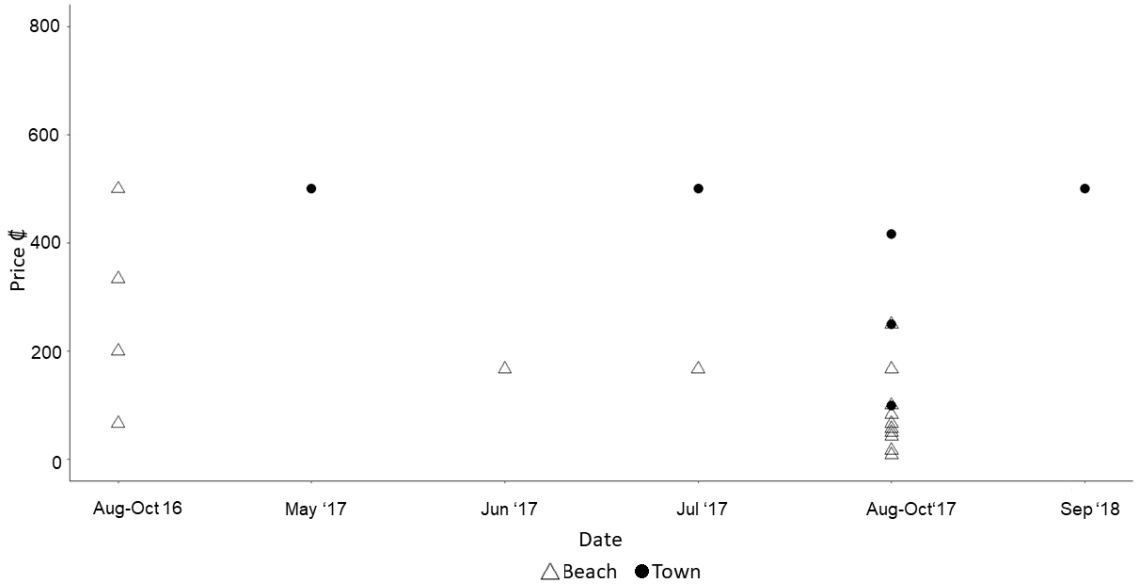


Figure 4.4.3.3. Illegal egg prices. Reported prices over a two year period, note that August-October is peak green turtle season. Interviews were not necessarily conducted at these times, but respondents

referred to the previous season when reporting egg prices that they had witnessed; May-early July are months when it is feasible leatherback eggs may be available.

Finally, we found a significant difference in egg prices between regions (Pacific, Central Valley and Caribbean) for both prepared ($\chi^2(2)=25.304$, $p<0.01$) and fresh ($\chi^2(1)=9.657$, $p<0.01$) eggs. Prepared eggs were found in all three regions, with the Caribbean being significantly cheaper than the Central Valley and Pacific. Prices of fresh eggs were more varied but overall cheaper in the Central Valley than the Pacific. Despite reliable reports that fresh packaged ADIO eggs are available in Limón province, we failed to record any fresh ADIO packaged eggs in the Caribbean.

4.5. Discussion

We identified varying levels of dependence on olive ridley eggs and an inequitable distribution of revenue along the legal supply chain. Mobile vendors receive the greatest returns on investment but were also the most dependent on middlemen, who control supply. We found the highest volume of eggs travel to the furthest province, likely driven by geographical barriers to trade flow and competition with illegal trade in the Pacific. Analysis of the illegal trade chain suggests that most eggs illegally sourced from Caribbean beaches, remain in the Caribbean. Comparing the movements of legal and illegal eggs enabled us to identify potential laundering hotspots in the region. We found eggs sold illegally to be cheaper than ADIO's fixed price.

While few households in Ostional today depend on egg sales for their livelihoods, almost everyone asked valued the additional income. Once eggs leave Ostional, *honorarios* have the monopoly over sales and distribution. Large retailers in the Central Valley make little profit from turtle eggs, using them to supply a demand and provide a popular product. As eggs move down the supply chain and across the country a substantial proportion are prepared before they are sold to the end consumer. This process generates the greatest profit as the added value of prepared eggs is significant. It is often

mobile vendors who sell prepared eggs which are virtually impossible to guarantee were sourced from ADIO. While these vendors make the most profits, they are also the most dependent on the proceeds and most vulnerable to fluctuations in supply. This is particularly apparent in Limón Province where the supply of eggs can be halted in San José, limiting the access options of Limón vendors. Vendors in Limón claim that the Central Valley wholesalers have the monopoly over the trade of eggs, and they indeed pay a higher price for their eggs. Whether this is a true economic monopoly will depend on whether the mark up for the eggs is driven by profit or a genuine need to cover transport costs by the *honorarios*.

We found the highest volume of eggs travel to the furthest province, likely driven by geographical barriers to trade flow and competition with illegal trade in the Pacific. Moving the highest volume of eggs from the Pacific to Caribbean makes economic sense if demand is sufficient and trade flows unhindered. It is noteworthy that Ruta 32, from San José to Puerto Limón, is a well-established tourist route, meaning it has a relatively well maintained highway. Except for ADIO eggs we found no examples of turtle eggs, originating from either coast, crossing the Central Valley. This suggests there is enough local demand to maintain profits without unnecessary transport costs. The reported prevalence of illegal olive ridley eggs in the Pacific, suggests that demand is high but not currently fulfilled with ADIO eggs. On the Caribbean however, it is possible that the supply of legal olive ridley eggs is supressing the illegal market in the towns where ADIO eggs are sold. By mapping the movement of both legal and illegal eggs we found physical barriers limit distribution of both. The vast majority of ADIO eggs are available along road networks with easy trade flows. Physical barriers to this flow include poorly maintained Pacific B roads, southern access from Ostional often impassable in the wet season, and a vast canal network leading to the Caribbean coast. These physical barriers reduce the financial viability of transporting eggs. The presence of an easy, legal source of eggs from Ostional feeding the demand in the Central Valley may be ensuring that the market for eggs of Caribbean origin (undoubtedly illegal) is not financially viable beyond a certain point inland. In the

Caribbean, we found illegal eggs either stay in villages near nesting beaches or moved relatively short distances inland to the towns identified in Figures 4.4.3.2 and 4.4.3.3. The motivations and capacity of illegal traffickers are vastly different between coasts. On the Caribbean, harvesters have been identified as crack cocaine addicts, motivated by a quick sale that is often achieved locally (see Chapter 2). Eggs sold in Limón towns are more likely to have been trafficked by an intermediary than the harvester themselves. On the Pacific, taking eggs for substance misuse was reported, but the situation is not as extreme, with alcohol as the primary intoxicant (pers. obs.). The Pacific harvesters were reported to have vehicles, and while the coastal roads are in poor condition and time consuming to navigate, once on the highway olive ridley turtle eggs can be quickly transported inland, where they can be disguised amongst (prepared) legal eggs.

ADIO is required to keep prices low to flood the market with legally sourced eggs; factors that should undercut the illegal trade. This is paradoxical, aside from ADIO having to conform to a limited extraction period, if higher numbers of eggs were extracted then prices would fall, and returns and incentives would be lower. This would ultimately be to the detriment of local livelihoods. The current constraints on the market keep the prices high enough to prevent this, but enable a viable illegal trade. At the retail end of the supply chain this price ceiling is fixed at the equivalent of ₡150 per egg and importantly they are restricted to selling eggs in specific units. It is unsurprising therefore that we found more price variation in uncertified eggs and illegal eggs than for ADIO eggs. The price of illegal eggs likely reflects a risk premium (i.e. likelihood of arrest) that varies and therefore affects price variation. The price ceiling is likely to be consumer driven, meaning vendors selling non-ADIO eggs may be forced to keep unit prices at the same level. But, as they have more flexibility in the quantities they sell within these units, they can achieve higher prices per egg whilst maintaining the consumer price.

The constant price over time suggest the market has reached equilibrium, reflecting a stable market which is in line with Costa Rica's inflation rate. Since 1984, Costa Rica's inflation rates have fluctuated but steadily decreased until they hit 0% in 2016 (Plecher, 2019). There is little reason to assume that the price of eggs affects the Consumer Price Index, but against the backdrop of stable prices any fluctuations in the price of eggs either reflects supply factors i.e. seasonality, or the supply onto the legal market might be being impacted by the supply of illegal eggs, in which case prices may decrease. As this is the same for both the legal and illegal trades, it suggests the illegal trade does not appear to be significantly influencing the legal trade to the extent seen in rapid price variation. This variation might occur because of rapid changes in supply; in the case of olive ridley eggs the supply from both the legal and illegal trades is probably constant (albeit seasonal), meaning the variation in price must come from the illegal trade.

The rarest species that nest in Costa Rica are the hawksbill, green and leatherback turtles. According to Courchamp et al. (2006), rarity of a species increases its value in the black market, resulting in an extinction vortex due to its value increasing in-line with decreasing abundance; also known as the *anthropogenic Allee effect* (Hall et al., 2008). If in effect, green, hawksbill and leatherback eggs would sell at a premium, this would lower the demand for olive ridley eggs. In contrast, it appears that two trades are operating independently. However, in this instance, the rarity of the species does not necessarily equate to rarity in the consumption of eggs.

We aimed to evaluate the commercialisation of Ostional eggs by using value chain analysis to understand the trade chain. We found the highest volume of legal eggs travelled to the most distant province; the area where fully protected turtle species are most abundant and particularly vulnerable to harvesting. While illegal trade occurs in Limón province, it appears that the legal and illegal trades are operating independently. Legal vendors in Limón province are vulnerable to fluctuations in supply, monopolised by Central Valley *honorarios*. Given that there is clearly a high demand for turtle

eggs, the concern is how great an impact a reduction of a legal supply would have on illegal extraction rates in the Caribbean. To maintain a constant supply and ensure livelihoods of those most dependent on ADIO eggs are secured, we recommend formulating a local association for supplying Limón province. This would ensure a fair return in line with ADIO and enable fair trade for Limón vendors. This could be successful because the obvious way to protect suppliers is to create a monopoly, which already appears to be occurring in the Central Valley. There is reasonable supply, although not sufficient to cause market prices to crash. The legal harvest is therefore large enough to provide an economic return and not to induce a high return for the illegal trade. A local association providing a fair trade price for Limón vendors would therefore be unlikely to negatively affect the market.

Wildlife trade is complex and varied, impacting local economies, society and biodiversity (Broad et al., 2003; Brashares et al., 2004). For sustainable development to be achieved, these components need to be considered in unison. Value chain analysis of wildlife trade offers an integrated approach to wildlife policy and management, which encompasses these three components (Bowen-Jones et al., 2003). Successful wildlife trade models require a clear understanding of socioeconomic variables, and the impact management decisions have on livelihoods and sustainability in range countries. These interconnected issues are priorities for CITES, CBS and the United Nations Sustainable Development Goals (SDG), whose respective concerns are species survival, sustainable use of biodiversity and poverty alleviation (CBD, 2014; CITES, 2016; United Nations, 2020). However, with a few exceptions, such as the trade in crocodilian skins and the Kipepeo butterfly project in Kenya, there is a deficit of cases where these three factors interplay successfully (Hutton & Webb, 2003; Gordon & Ayiemba, 2003). Our research is directly relevant to these policies and offers a rare opportunity to understand a long standing wildlife trade and its impact beyond the scope of the livelihoods of the source community. In line with the targets of the SDG and CBD, our research has enhanced understanding of poverty alleviation through natural resource use, not only in the source community but throughout a complete trade chain. Our work supports CITES in their need for more cases

concerning wildlife laundering and a better understanding of domestic trades, necessary to inform policy at the international level.

4.6. Acknowledgements

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CHAPTER 5

Illegal trade of sea turtle eggs in the markets of Costa Rica

Formatted for Conservation Science and Practice

Pheasey, H., Griffiths, R.A., & Roberts, D.L. Illegal trade of sea turtle eggs in the markets of Costa Rica.

5.1. Abstract

Unsustainable wildlife trade is a major contributor to biodiversity loss; however, trade regulations have failed to prevent the decline of high profile species. Where wildlife is traded legally, opportunities exist to launder protected species through legal channels. The legal commercialisation of olive ridley sea turtle eggs from Ostional, Costa Rica has been criticized by suggesting that the legal trade stimulates illegitimate extraction and sale of eggs. We aimed to identify whether the Ostional project was being used to launder fully protected turtle species' eggs and whether local vendors were adhering to the traceability regulations in place. We surveyed markets across Costa Rica, purchasing openly available sea turtle eggs, recording qualitative and quantitative data at the point of sale. We found that 97% of turtle eggs openly sold in the market were from olive ridley sea turtles. Green and leatherback turtle eggs were only on offer on three occasions, but no vendor referred to Ostional. Vendors frequently breached traceability which appeared to be due to traceability regulations misaligning with consumer demand. Olive ridley eggs cannot be traced back to the beach of origin, so it is unknown if they were sourced from Ostional or from a beach where the species is fully protected. Although the Ostional traceability rules are regularly flouted, there appears to be no laundering of other protected turtle species through this programme. We therefore suggest that more effort focuses on understanding consumer demand so that sustainable solutions within the traceability system can be developed.

5.2. Introduction

Wildlife trade contributes to major biodiversity losses (Rosen & Smith 2010; Lyons & Natusch 2011). Often countries rich in natural resources are the most impoverished and poorly equipped to prioritise conservation (Damania & Bulte 2007). Wildlife trade regulations have failed to reduce the rate of decline for numerous high profile species, and opportunities to launder illegal wildlife exist wherever there are legal trade routes. A legal trade can be used to reduce illegal extraction if (1) having a legal supply does not increase demand; (2) the legal product is a suitable substitute; and (3) it is more cost

effective to supply the product legally than illegally, so that laundering can be avoided (Tensen 2016). However, opportunities exist to launder wildlife at different stages of the trade chain. One of the highest profile cases concerning laundering is the debate around the trade in rhino horn. A chief concern is the difficulty in distinguishing between legal and illegal horn, thereby increasing opportunities to launder the illegal product. Each side of this debate has compelling theoretical arguments, but the debate lacks empirical data to inform policy. In this paper we focus on the legal trade of turtle eggs in Ostional, Costa Rica as an example of wildlife utilization that allows for the further examination of intervening issues.

Sea turtles nest on both the Caribbean and Pacific coasts in Costa Rica, which is home to two globally important nesting rookeries. Tortuguero hosts the largest green turtle (*Chelonia mydas*) aggregation in the Atlantic Basin (Troëng & Rankin 2005; Campbell 2007) and Ostional, in the Pacific, is one of the most important nesting sites for olive ridley turtles (*Lepidochelys olivacea*) and possibly the largest *arribada* beach for this species (Spotila 2004). *Arribadas* are synchronised mass nesting events, comprising hundreds to hundreds of thousands of females nesting in unison over 2 to 10 days (Eckrich & Owens 1995; Valverde et al. 2012). These events generally occur monthly with a seasonal peak in nesting females between September and December. Leatherback (*Dermochelys coriacea*) and hawksbill (*Eretmochelys imbricata*) turtles also nest annually in Costa Rica and occasional loggerhead turtle (*Caretta caretta*) nesting events occur. Under the IUCN Red List, all turtle species that nest in Costa Rica are vulnerable to extinction, from the threatened olive ridley to the critically endangered hawksbill turtle (IUCN 2019).

Anthropogenic threats to turtles at sea include plastic pollution, fisheries by-catch and entanglement in discarded fishing gear. A significant threat to sea turtles on land is the illegal take of their eggs, and killing of nesting females for their meat and shell. Sea turtle eggs are a traditional food source in Costa Rica, particularly on the Caribbean coast where their consumption is culturally ingrained (Campbell

2007). Despite being illegal since the 1970s, illegal harvesting still takes place to a degree that warrants protection of nesting beaches needing volunteer patrols to safeguard nesting females. Few households rely on sea turtle eggs to fulfil protein requirements, but eggs are largely consumed as a bar snack (Arauz Almengor et al. 2001; Chapter 2). While there is significant illegal take of turtle eggs in Costa Rica, there is also a legal extraction and commercialisation, which takes place during *arribadas* in Ostional.

Due to the concentration of turtles nesting over several days, the destruction of nests by turtles excavating existing nests is significant (Cornelius et al. 1991). Nests laid on the first one to three nights of an *arribada* are most likely destroyed by predators or turtles subsequently excavating existing nests. The decomposition of doomed eggs contributes to the microbial load in the sand, reducing the hatching success of incubating nests (Cornelius et al. 1991). The controlled legal extraction and commercialisation of olive ridley eggs is permitted under the rationale that the extraction only removes doomed eggs. This removal theoretically promotes a healthier beach with increased hatchling output by reducing the risk of incubating eggs becoming infected by pathogens from adjacent dead eggs (Cornelius et al. 1991; Campbell 1998). While critics voice concerns over the laundering potential, the commercialisation of the eggs supports the Ostional community and is undeniably a socioeconomic success (Campbell 1998). In exchange, the community protect the turtles by keeping the beach clear of debris, escorting hatchlings to sea when they emerge from nests, providing overnight security against illegal harvesters and controlling the number of tourists who come to witness an *arribada* (Lobo-Glez 2019). The extraction and conservation work are managed by ADIO (the Asociación de Desarrollo Integral de Ostional) who report to MINAET (the Costa Rican Ministry of Environment and Tourism). Costa Rica is a signatory to the Inter-Americana Convention on Sea Turtles, which recognises the commercialisation of eggs from Ostional as an exception to an otherwise complete ban on turtle trade and consumption in Costa Rica. The extraction of eggs from Ostional is permitted under several conditions, one of which is the traceability of the eggs sold

nationwide. The Ministry of Fisheries (INCOPESCA) and Ministry of Health (SENASA) issue permits to transport and sell Ostional eggs, which is legally binding under Executive Decree #28203, specifically written for the Ostional project.

A concern regarding the sale of Ostional eggs, is the potential it offers to launder illegally extracted eggs through open trade channels. Sea turtle eggs are white, soft-shelled spheres, with size being the only feature that enables species to be distinguished; although there is some overlap between species (Pritchard & Mortimer 1999; Moore et al. 2003). Historically, ADIO sold eggs in sacks of 200 loose eggs, closed with a zip tie. Once open, there was no way to restrict the refilling of Ostional sacks with illicit eggs. In response, the Inter-Americana Convention on Sea Turtles requested that Ostional be accountable for the sale and movement of the eggs. This resulted in a five-year management plan with traceability rules introduced in 2017 (MINAE & SINAC 2017). These rules require ADIO to sell eggs in smaller heat-sealed bags, distributed in sacks of 200 eggs. *Honorarios*, licenced intermediaries with permits to transport eggs across the country, resell the eggs to local vendors. ADIO are required to number and date all egg packages that leave Ostional. A receipt of purchase accompanies eggs with the corresponding number. Being in possession of illegal eggs is an offense under the Costa Rican Law #8326.

Despite the traceability rules, many vendors sell turtle eggs loose, in unmarked packaging or they are prepared, either boiled or cracked raw into a chili sauce called *sangrita*. By removing eggs from the legal packaging, they are undermining the certification scheme and with it the assurance the eggs are legally sourced. In Costa Rica, olive ridley turtles only nest on the Pacific coast and exhibit low natal fidelity (Bowen & Karl 2007), nesting both solitarily and in *arribadas* (Plotkin 1997). For these reasons, it is not currently possible to trace an olive ridley egg back to its natal beach and therefore not possible to confirm if a turtle egg found in the market is specifically from Ostional.

Prior to the new traceability rules, the commercialisation of eggs from Ostional provoked wide criticism due to the laundering potential it offers. This research tested the validity of these concerns by addressing two questions: 1. is there evidence of laundering of illegally collected eggs? 2. are local retailers adhering to the new traceability rules?

5.3. Methods

The School of Anthropology and Conservation's Research Ethics Advisory Group (University of Kent) approved this research (Ref. No.: 0381617c). We recruited local research assistants who were over the age of 18, to purchase turtle eggs. They were aware of the purpose of the research, provided signed consent and were given financial compensation for their time. Under normal circumstances an overseas researcher would require a permit from the Ministry of Environment (MINAE) to undertake biological work in Costa Rica. However, this research involves purchasing turtle eggs and this in itself is not illegal and no permits were required. The CIBCM at the University of Costa Rica is permitted to analyse genetic material from any organism (*in-situ* or *ex-situ*). Permission for this project titled "*¿De cuáles especies provienen los huevos de tortuga en el comercio legal de Costa Rica?*" was issued to the CIBCM by the Comisión Institucional de Biodiversidad, Resolución #201.

5.3.1. Study sites

Sea turtle eggs are available to buy from mobile street vendors, bars and canteens, market and street stalls. The Central Valley serves as a major transport hub for legal eggs arriving from Ostional, for distribution throughout the region and to the Caribbean. In the Central Valley, most of our surveys took place in Downtown San José, the capital of Costa Rica, with a few opportunistic surveys in Heredia. Puerto Limón housed green turtle abattoirs until the government outlawed the practice in the 1970s, but remains a hotspot for illegal trafficking of turtle meat and eggs. We conducted monthly egg buying tours throughout Limón province where we purchased eggs in Guapiles, Cariari, Guácimo, Pocara, Siquirres, Batán and Puerto Limón (Fig. 5.3.1.). Cariari is the nearest town to Tortuguero, and

Siquirres is near beaches Parismina and Pacuare, both receive a high number of leatherback turtles nesting each season. Puerto Limón, the regional capital is an economically deprived city close to Moín, another large leatherback turtle nesting beach. The city houses an outdoor market with a row of fishmongers and seafood stalls. Puntarenas is a port city located on a narrow peninsular on the Pacific coast and the main landing dock for pelagic fish on this coast of Costa Rica (O'Bryhim et al. 2017). In Puntarenas, there is a market near the docks which, although small, houses a high percentage of fishmongers offering turtle eggs.

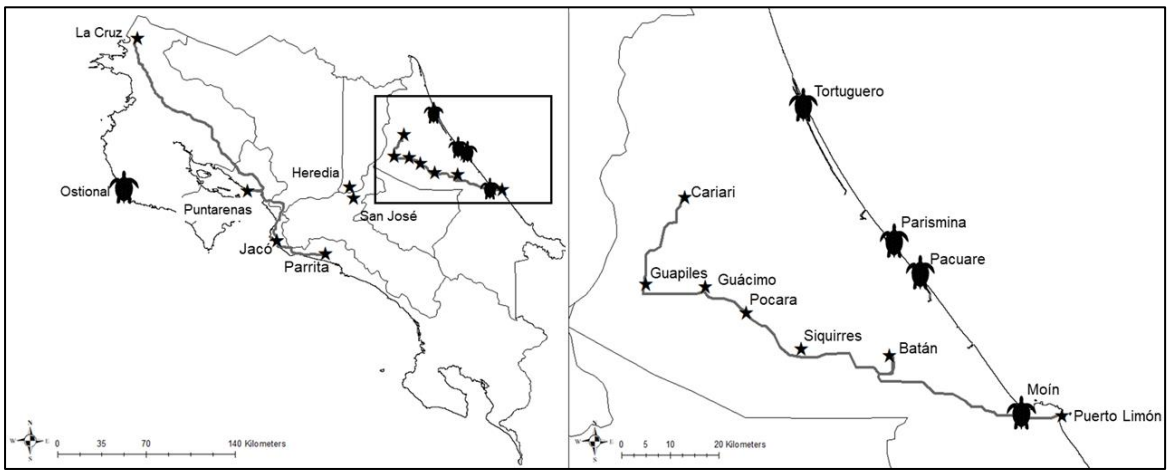

Figure 5.3.1. Egg buying routes and destinations (stars). Beaches with high abundance of nesting female turtles are depicted by the turtle symbol.

5.3.2. Sampling

We purchased turtle eggs between September 2017 and November 2018 in three regions of Costa Rica: The Central Valley, Limón Province in the Caribbean and the northern Pacific coast. In addition, we surveyed bars and canteens along the Inter-Americana highway, between Puntarenas and La Cruz, over two days in January 2018. All surveys were timed to coincide with seasonal nesting events for species other than olive ridley turtles and therefore increase the chance of detecting illegal eggs. In addition to regular surveys, we utilised any opportunity to purchase turtle eggs and included these samples in our dataset.

Under Costa Rica law #8325, it is illegal to interfere with sea turtle nests, transport eggs or sell uncertified turtle eggs. However, it is not illegal to purchase turtle eggs regardless of species. Therefore, permits to purchase turtle eggs were not required.

5.3.3. Market surveys

We recruited 16 local research assistants that had previously worked for us and were known to be reliable and capable. These assistants purchased eggs that were openly available at the study sites. The criteria for purchasing eggs was anything other than a heat sealed ADIO bag (unless the bag contained eggs that were uncharacteristically large); ADIO bags that had been opened, torn and/or retied with a knot or contained the wrong number of eggs (10 or 20 per bag) we classified jointly as misused, cooked eggs and eggs in *sangrita* were all purchased. When buying eggs, the researcher asked the vendor where the eggs were from. This was specifically worded to give the vendor the opportunity to volunteer, without prompting, that the eggs were from Ostional. When buying unpackaged shelled eggs, the research assistants also requested the vendor select the largest eggs. This increased the chances of detecting illegal species' eggs. We sampled as many vendors as possible and made monthly repeat visits when the opportunities arose, however this was limited to permanent establishments/pitches and chance re-encounters with mobile vendors.

The following data were covertly recorded during the purchase: date, location, type of vendor (mobile, market stall, bar/canteen), stall name (if applicable), information on any signage to suggest eggs were from Ostional, if the eggs were on display or hidden from view and if not on display, how the researcher became aware there were eggs for sale (heard/saw mobile vendors or poster/menu etc.), type of egg (cooked, fresh or in *sangrita*), the price and quantity of eggs being sold. We did not ask questions about permits due to the possible sensitivity of this type of question and because the researchers were unlikely to recognise counterfeit permits. It was not always possible to collect complete data due to the vendor's reluctance to answer questions, or there were occasions when we

did not purchase eggs but recorded other data, for example, eggs were only for consumption on the premises or the vendor was out of stock.

Once purchased, we measured eggs using callipers and photographed the eggs. We took samples of yolk, albumen and shell with membrane using scissors, tweezers and single use pipettes. We cleaned instruments between samples using alcohol swabs. We stored samples in Eppendorf tubes in 96 % ethanol. Genetic methods are provided as supplemental material. During our pilot it was established the yolk contained the most DNA material and albumin the least.

5.3.4. Market survey analysis

During the study period, ADIO were not able to use heat-sealed printed bags for two *arribadas*. This was due to an administration error during a change in board of directors and on a separate occasion, the bag heat-sealing machine was not working. This explained the misuse of 25 bags that we recorded, and we removed them from the analysis. On three occasions we identified vendors selling unmarked bags of eggs next to ADIO bags which we also classified as misused. A further two data points were removed from the analysis as they were ad-hoc purchases without accompanying purchase data. We considered eggs advertised or on menus to be *on display*. To gain an understanding of patterns in sales, we compared the number and type of vendors (bar/restaurant, market stall, or mobile) with the type of eggs they sell (fresh, cooked or in *sangrita*) using a Pearson's Chi-squared test of association.

5.3.5. Misdemeanours

In February 2018, ADIO increased the number of eggs per bag from 10 to 20 eggs. To test the hypothesis that vendors are more likely to misuse (open) bigger bags, we used a Pearson’s Chi squared test for association between the number of eggs in a bag and whether they were in a misused (open) ADIO bag or not. We then focused on how bags were being misused. We did not encounter enough examples of misused bags to undertake statistical analysis; however, we were able to plot the number

of eggs sold in open ADIO bags against the ADIO standard (10 or 20 eggs per bag). Finally, we used a 1 sample t-test to test the hypothesis that vendors were selling eggs outside legal packaging at a significantly higher price than ₡150/egg; the informally agreed certified price.

5.3.6. Species identification

All genetic analysis was undertaken using CIBCM protocols and methods (supplemental material). In addition, we ran Chi-sq to test whether preparation method affected amplification. We employed a two sample t-test to compare the diameters of cooked and fresh olive ridley eggs to test the hypothesis that cooking eggs alters the size. We compared the sizes of eggs where we had species confirmation with eggs from which DNA failed to amplify and allocated species to eggs based on our size range – which differed slightly to those reported by the IUCN. In ambiguous cases where there was a size overlap between possible species, we considered variables such as nesting events and geography to allocate a species to an egg. For example, eggs small enough to be hawksbill but purchased in February outside hawksbills nesting season, means there is a greater likelihood the egg is from an olive ridley turtle. All statistical analysis was undertaken in RStudio 1.2.1335 running packages: gmodels, MASS ggpubr, using RStudio 1.2.1335 (R Core Team 2019).

5.4. Results

5.4.1. Egg purchase surveys

We purchased eggs on 163 occasions, from which we identified 82 to 92 individual vendors and businesses selling uncertified eggs. This variation is due to making repeated visits, but some market stalls did not have a visible name and it is also possible different research assistants unknowingly visited the same mobile vendor. We were not concerned this may cause pseudo-replication as surveys were undertaken monthly which gave vendors enough time to exhaust and replenish their stock. Vendors included 30 bars that had catering facilities on the premises, four catering outlets such as canteens that did not additionally sell alcohol, 30 mobile vendors, 28 shops and market stalls;

including a toyshop that also sold turtle eggs during peak *arribada* season. Bars tended to sell eggs in *sangrita* (25.6 %), stalls mainly sold fresh eggs (23.3 %) and mobile vendors (24.4%) sold cooked eggs ($\chi^2(4) = 108.467$, $p < 0.001$).

5.4.2. Misdemeanours

We identified patterns of behaviour that undermine the traceability regulations ADIO are required to adhere to. We found no significant association between size of bag (containing 10 or 20 eggs) and misuse of bags ($\chi^2(1) = 1.096$, $p > 0.05$). We did, however, identify a pattern of vendors removing eggs from ADIO bags and selling fewer eggs than the ADIO units of 10 or 20 eggs. When we plotted the number of eggs sold in each bag, against the number of eggs that should legally be in that bag, we found vendors split bags and reduced the contents by half (Fig. 5.4.2.). When ADIO increased the bag size to 20 eggs, we found the same pattern, with vendors continuing to sell bags containing half of the required content. There were not enough examples of misused bags (10 eggs = 9, 20 eggs = 8) to run statistical analysis, however this pattern is of interest as it suggest that the vendors struggled to sell bags of 10 and this continued to be a problem when ADIO increased the bag size to 20 eggs. To our knowledge it is not possible to acquire empty ADIO bags and therefore it is assumed the remaining "legal" eggs are sold in blank bags.

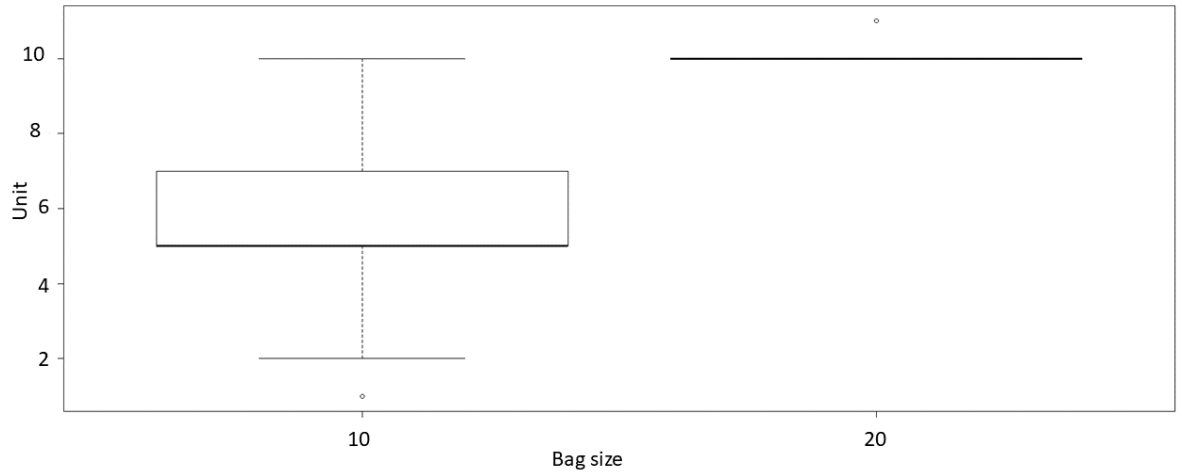

Figure 5.4.2. Legal trade misdemeanours. Number of eggs sold in an ADIO bag that had been opened (y axis) compared to the number of eggs that the bag should have contained (Bag size) (x axis). The bold line signifies the median, the top and bottom box edges indicate the interquartile range, the dots and whiskers show the full range. All misused bags of 20 eggs contained only 10 eggs – with one exception as indicated by the dot. The median unit size for both bag sizes is exactly 50% smaller than the intended ADIO sales amount.

Finally, we found vendors were selling eggs at significantly higher prices than the ADIO price of ₡150 per egg ($t(40) = -247.92$, $p < 0.001$), up to ₡500 per egg.

5.4.3. Species identification

During our surveys, we purchased 360-shelled eggs (fresh or cooked) and 116 in *sangrita*. For unknown reasons, it was only possible to extract DNA from 279 of the original 476 samples. Of those, 106 samples had a positive PCR result, 92 belonged to the species olive ridley (*L. olivacea*) and one to an Atlantic green (*C. mydas*) (Supplemental material). We found no significant difference in diameter size between fresh and cooked egg ($t(28) = -1.7103$, $p>0.01$) suggesting that the size of the

egg does not change in the cooking process. We found a significant association between the method by which eggs were prepared and whether DNA amplified ($\chi^2(2) = 8.24$, $p < 0.05$) reflecting the fact that raw eggs were the least successful at amplification.

5.4.4. Non-genetic species identification

The diameters of the confirmed olive ridley eggs ranged from 35.0 mm to 42.7 mm, 38.9 ± 1.77 (Mean ± SD). Based on the diameters of all shelled eggs, 345 fell within the size range for olive ridley turtle eggs. Therefore, we believe 96.6% of our eggs were from olive ridley turtles. The confirmed green turtle egg (44.0 mm) was purchased with another egg (43.5 mm) which we also believe was from a green turtle. We also suspect that a separate batch of eggs were green turtle (diameters 44.9, 46.6 and 47.0 mm). Any egg over 50.0 mm is unmistakably leatherback as egg sizes do not overlap with other species in our study. Based on their sizes (52.1, 52.8, 50.2, 52.4, 53.8, 52.8 mm) we believe these to be leatherback eggs. Finally, we identified two eggs from a mobile vendor in Puerto Limón during peak green nesting season with diameters 43.4 mm and 42.0. There eggs remain inconclusive as their diameters are borderline with a large olive ridley and small green turtles and they were purchased in Puerto Limón during peak green nesting season.

5.4.5. Qualitative data

During purchase transactions, we recorded additional remarks made by vendors. A mobile vendor in Siquirres made a noteworthy comment during the transaction where we purchased olive ridley eggs from a cool box. The vendor volunteered, *"I only sell larger eggs after dark".* The implication was that the larger eggs were from green or leatherback turtles. Visiting bars near Cariari, two vendors, who did not have eggs in stock at the time said they source their eggs from Tortuguero and Barra del Colorado (north of Tortuguero) but could get Ostional eggs, if required. On two occasions, Central Valley stallholders told us they need to open the ADIO bags as customers often do not want to purchase a full pack of eggs. "*I sometimes sell them singly because people ask for just one or two*".

We also identified situations where vendors appeared keen to demonstrate they were operating within the law. On three occasions, mobile vendors selling eggs from a cool box (two in Guapiles and one in Siquirres) voluntarily showed the research assistant their permits. On a separate occasion, in Limón a mobile vendor selling cooked egg from a cool box, had an open ADIO bag inside the box. We interpret this as an indication that he wanted to show he had legally acquired his eggs.

5.5. Discussion

We identified two types of illegal activities taking place in the open markets of Costa Rica. Firstly, the trade of eggs of protected turtle species such as leatherback and green turtles and secondly, retailers failing to adhere to the traceability rules. We found evidence that eggs from the two protected species were for sale in Limón province, from three separate vendors. However, despite undertaking surveys during the peak nesting period of Caribbean hawksbill turtles (April – July), we did not identify this species in the trade. Hawksbill turtle eggs are unlikely to appear in the open market due to their rarity and lack of a financial premium for the eggs of this species. While illegal take of these eggs undoubtedly takes place, a localised underground black market is a more likely sales outlet, rather than one that carries greater risk by transporting them inland from the Caribbean coast. It is therefore unlikely they are being laundered through the legal market to any degree, if at all. In fact, we found no evidence of laundering during purchases of illegal species' eggs. Indeed, we did not have any evidence that eggs of these species were linked to the black market.

The management plan for ADIO states that eggs must be sold in specific heat-sealed bags. The only exception to this is under Article 11 of Executive Decree #28203 which allows retailers to sell ADIO eggs from an open packet if they are for consumption on the premises. We found three ways vendors were flouting the traceability rules; (1) selling fresh eggs outside ADIO packaging (32.8%); (2) cooked eggs sold off the premises (29.8%); and (3) eggs in *sangrita* also for consumption off the premises (37.4%). We only identified one occasion when a vendor adhered to this rule and refused to

sell their eggs on the grounds they were not for consumption on site. Mobile vendors also commonly sold eggs in *sangrita*, in small disposable pots. Without a fixed point of sale, these vendors cannot adhere to Article 11. Therefore, we found that 96.9% of illegal activity in the trade was due to breaches of the traceability regulations, as opposed to trading illegal species' eggs. In addition, while our findings show that most eggs available in the open market are from olive ridley turtles, we also found vendors sold eggs of olive ridley turtles at higher prices than ADIO, whether this be fresh eggs or prepared. This implies that while ADIO strives to adhere to the traceability rules, these rules are only successful until the eggs reach the retailer. Due to the apparent consumer demand for low quantities of fresh eggs or eggs that have been prepared, the system breaks down between the retailer and consumer as the retailer struggles to sell eggs in the required quantities.

It is important to distinguish between egg collected from a fully protected species (i.e. green, hawksbill or leatherback turtles) and illegally collected olive ridley eggs. Currently it is not possible to trace an olive ridley turtle egg back to the beach of origin, meaning uncertified eggs cannot be traced to Ostional. Mitigation of wildlife laundering to improve the traceability of Ostional eggs is problematical. In the case of the trade in green pythons (*Morelia viridis*) from Indonesia, Lyons & Natusch (2011) recommend the sale package of farmed live pythons to include the egg from which it hatched. This would provide a genetic trace that the python was farm sourced and not harvested from the wild. Requiring bars to sell eggs cracked into *sangrita* with the eggshell would be the equivalent to this. This type of approach may assist in the confirmation that an egg in *sangrita* is from an olive ridley turtle but does not confirm the egg originated in Ostional. Based on eggs that have been identified using DNA analysis, we have shown that olive ridley eggs range in size between 35.0 mm - 42.7 mm in Costa Rica. This varies slightly from the global averages reported by the IUCN (IUCN 37 mm to 42 mm) (Pritchard & Mortimer 1999) and offers enhanced law enforcement opportunities; market eggs outside of these size dimensions are questionable and the species identification can be verified through genetic analysis. Another suggestion has been to use dye to mark Ostional eggs, much

in the same way supermarkets label chicken eggs (Hope 2002), although this is likely to be unfeasible. In 2018, over 3 million eggs were packaged and shipped from Ostional (Lobo-Gelz 2019). The Ostional community does not have the capacity to mark that volume of eggs in a way that would be appropriate for a wet soft turtle egg. Once smudged, or the egg boiled, the mark would be unrecognisable from Ostional.

When marketing a wildlife commodity with the aim of reducing wild or unsustainable offtake, the success of such a system is dependent on the availability of an acceptable alternative, at a lower cost to the consumer (Bulte & Damania 2005). One of the key requirements of the Ostional extraction, is that eggs retail at a price low enough to undermine the illegal trade (Valverde 1999). However, we have found that the current traceability rules are misaligned with consumer demand. Paying less per transaction appears to be more important to the consumer, than the value for money they get from the purchase of a greater quantity of eggs. To realign this, we recommend making the following adjustments to the system: 1. Sell eggs in smaller quantities, ideally 5 or 6 eggs and undertake a feasibility study into 'boil in the bag' options. Consumer demand is currently driving vendors to open the small Ostional bags to cook the eggs. This could be circumvented by removing the need to open the bags by providing eggs inside packaging suitable for boiling (cooked eggs on average retail at 3 eggs for ₡1000 ($2)). 2. Package the fresh eggs in smaller bags so there is less excess plastic to retie the bags. 3. Establish consumer willingness-to-pay for a smaller quantity of eggs, though a market research survey. Based on our data we predict customers would pay ₡1,000 for five fresh eggs. This may prove to be adequate compensation for the additional labour required by the Ostional community to package eggs in smaller quantities. In 2002, Hope suggested "*Labelling the eggs individually or in smaller unit bags that correspond to consumer buying preferences*". This was suggested to be an appropriate response to reducing the confusion that consumers face regarding the authenticity of legal eggs (Araúz-Almengor et al. 2001). Since then, ADIO introduced the smaller bags and our evaluation suggests that while this is a positive direction, a further step is required to ensure the optimum

marketing strategy is adopted. We also urge caution when reconsidering packaging options. The damaging environmental impact of plastics, particularly in the oceans, is becoming increasingly apparent, and sea turtles are at the forefront of the issue (Ivar do Sul et al. 2011; Figgener 2015). We suggest that rather than viewing these as separate challenges, they are considered in unison, to ensure a more sustainable trade both in terms of market forces and waste reduction. Further, Hope (2002) suggested pricing trials to compare demand between seasons and regions, could enhance marketing opportunities. Hope (2002) suggested wholesaler auctions with a "price floor" would assist in establishing more appropriate pricing levels. To our knowledge this is yet to be trialled.

Whether the Ostional project is stimulating demand for sea turtle eggs, or confusing consumers into believing that all turtle eggs are legal, is beyond the scope of this study. In addition to finding no evidence of laundering of illegal species' eggs, we found incidences of the open sale of these eggs to be relatively uncommon. Given that all legally extracted eggs are sold, shows a significant demand for sea turtle eggs and suggests removing the legal trade would allow the potential for illegal eggs to become more profitable – currently held at bay by the physical barriers to illegal trade and the relatively stable fixed price of legal eggs (Chapter 4). The livelihoods of mobile vendors are dependent on egg sales and they predominantly sell cooked eggs. Whilst this group is the least accountable for the traceability of their eggs, we advise caution in reviewing their sale strategy. Mobile vendors are supplying a demand from what currently appears to be a sustainable source. Should this supply diminish it is possible illegal egg sales may increase to fill this gap.

When attempting to address non-compliance or rule breaking in conservation, law enforcement is an obvious consideration. However, this is often hampered by insufficient resources to be effective. Despite its stringent wildlife protection laws, Costa Rica is not exempt from these limitations (Chapter 2). However, in this case law enforcement may not necessarily be the best conservation strategy. We have identified a clear and high demand for sea turtle eggs and governance has been found to be

inadequate in challenging consumer demand (Challender & MacMillian 2014). Further, labelling individuals as criminals when they are simply attempting to undertake basic livelihood tasks and were given no opportunity to input into the conservation process, raises serious ethical considerations (Solomon et al. 2015). This can lead to hostilities and result in petty criminal behaviour as a form of protest, thereby undermining conservation action (Hinsley et al. 2017). Our paper has contributed to a part of this understanding using the case study of eggs from Ostional. We have identified nuances not only in the non-compliance of traders but also in consumer demand and importantly we identified the importance of substitutes and the dangers of removing a legally sourced product from the market. The need to understand human behaviour in relation to rule breaking is key to encouraging compliance in conservation (Solomon et al. 2015). Our paper contributes to the understanding of this complex issue.

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5.8. Supplemental material

5.8.1. DNA extraction and PCR

We extracted whole DNA from approximately 50 mg of egg yolk following a modified salt-extraction protocol (Aljanabi and Martínez 1997). For cellular lysis, 20ul of Proteinase K (20 mg/ ml) was added to 350 ul of extraction buffer (100 mM NaCl, 50 mM Tris-HCl, 1% SDS, %0 mM EDTA, pH 8.0) and incubated overnight at 55°C. To assign species, we performed PCRs

(polymerase chain reaction) to amplify 875-876bp fragments of the cytochrome b region, using the primers designed for restriction fragment length polymorphism (RFLP) species identification (Moore et al. 2003): longGlu-L (5'-TGATATGAAAAACCATCGTTG-3') and longCb3-H (5'-GGCAAATAGGAARTATCATTC-3'). PCRs were conducted in 25 µL reactions containing 2 µL of DNA template, 13.4 µL H2O, 2.5 µL of Buffer, 2 µL MgCl2, 1.3 µL dNTP, 1.8 µL of each primer, and 0.2 µL Taq polymerase. For all reactions, the PCR protocol included an initial denaturation step at 94ºC for 2 minutes, followed by 30 cycles of 50s denaturation at 94ºC, 30s annealing step at 50ºC allowing the primers to bind to the complementary sequences, and a 60s final extension at 72ºC for the *Taq'*s synthesis of new chains. PCRs were carried out in Applied Biosystems® thermocycler. The PCR products were confirmed visually in 2% agarose gel electrophoresis (90V, 45min) stained with GelRed®.

5.8.2. Restriction enzyme digestion

Fragments were digested with the restriction enzyme Alu I, which recognises 5'-AG^CT-3' and produces species-diagnostic RFLPs for species identification (Moore et al. 2003). This restriction enzyme cuts fragments of 156, 168, 228, 417, 471, 498 and 819 bp, and depending on the size of the DNA fragments obtained after the enzymatic digestion – which will correspond to the autapomorphic restriction sites of each species – the identification of the species nesting in Costa Rica is possible (Table S5.9.2.).

Table S5.9.2. Species diagnostics.

Species Common name	Species Latin name	IUCN criteria (Global)[1]	Alu I cut site[2]	Expected base-pair fragment size[2]	Mean diameter egg size (mm)[3]
Leatherback	*Dermochelys coriacea*	Vulnerable: Deceasing	819	819	51-55
Green Atlantic population	*Chelonia mydas*	Endangered: Decreasing	228, 417	189, 226, 460	40-46
Green Pacific population	*Chelonia mydas*	Endangered: Decreasing	156, 228, 417	72, 154, 189, 460	40-45
Hawksbill	*Eretmochelys imbricata*	Critically Endangered: Decreasing	156, 819	58, 154, 663	32-36
Loggerhead	*Caretta caretta*	Vulnerable: Deceasing	417, 819	58, 348, 469	39-43
Olive ridley	*Lepidochelys olivacea*	Vulnerable: Deceasing	498, 819	58, 321, 496	37-42

Sources: [1] IUCN (2019), [2] (Moore 2003), [3] (Pritchard and Mortimer 1999).

5.8.3. Species identification

During our surveys, we purchased 360-shelled eggs (fresh or cooked) and 116 in *sangrita*. Due to issues concerning sample or DNA quality, it was only possible to extract DNA from 279 of the original 476 samples. Of those, 106 samples had a positive PCR result. For this reason, the Alu I digestion was conducted using 106 samples. The enzyme Alu I was successful in digesting 92 out of 106 PCR products. 91 amplified resulted in Cleavage Amplification Polymorphisms (CAPs) at fragment sizes of approximately 60, 300 and 500 bp, indicating they belong to the species olive ridley (*L. olivacea*). Only one of the sampled eggs was from a different species – an Atlantic Green (*C. mydas*), with fragment sizes of approximately 180, 220 and 460 bp.

5.9. References

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CHAPTER 6

Discussion

Discussion

6.1. Biodiversity loss and wildlife trade

Drivers of biodiversity loss are wide, varied and complex, requiring solutions that are equally multifaceted. With the rate of biodiversity loss showing no signs of slowing, there is an urgent need to identify conservation priorities, especially as conservation interventions are often under-resourced (Pullin et al. 2013). Wildlife trade impacts local economies, society and biodiversity, and solutions to avoid species extinction need to encompass these variables, with interventions addressing socioeconomic drivers of extraction and trade (Broad et al. 2003; Brashares et al. 2004; Velázquez Gomar and Stringer 2011). Rural communities that are dependent on a valuable resource are frequently perceived as part of the problem, and only relatively recently were brought into the narrative as realistic contributors to the solution (Campbell 2007; Larsen and Olsen 2007).

Within the Convention on International Trade in Endangered Species (CITES) and United Nations Sustainable Development Goals (SDG), there is a need for policies that take into account population declines of threatened species, socioeconomic circumstances and human livelihood needs (CITES 2016; United Nations 2020). Trade bans have been at the forefront of CITES policy since its inception, however this approach has the potential to stimulate a black market that is harder to regulate (Rivalan et al. 2007). Appendix I listings may accelerate demand, by enhancing the perceived rarity of a species (e.g. Anthropogenic Allee Effect) (Courchamp et al. 2006). Drivers of demand for one wildlife commodity may be different to that of another, and trade restrictions may have the unintended consequence of causing a decline in a substitute species (Zimmerman 2003). Community-based conservation provides an opportunity for a balance to be struck. The Kipepeo butterfly project, Kenya and live-sheering of wild vicuña (*Vicugna vicugna*) in the Andes are examples of successful community-based conservation projects (Gordon and Ayiemba 2003; Shaley et al. 2005). However, where there are open trade routes, opportunities exist to launder illegal commodities though legal channels and potentially stimulate the illegal trade (Bulte and Damania 2005; Tensen 2016).

Opportunities to study laundering in open trade chains are rare and there is a lack of research - especially in domestic settings, that are not subjected to the same scrutiny as international regulation. The overarching aim of this thesis was to use Ostional as a case study to critically analyse this complex issue. The legal extraction of eggs is overseen by the Ostional Integral Development Association (ADIO) This chapter provides an overview of the key findings of this thesis and how this work contributes to the understanding of the subject. In addition, this research trialled two methodologies, one known to have been employed once before, the other a completely novel technology. Policy recommendations for Costa Rica, based on the findings of this work are listed, before discussing how this research has the potential to inform conservation policy and practice. Further research opportunities that arose are also discussed before drawing the thesis to its conclusion.

6.2. Key findings and their contribution to the understanding of the subject

This thesis has three key findings. Firstly, it identified the socioeconomic drivers of the legal and illegal trades. Secondly it was found that the legal and illegal trades are supply-driven. Thirdly, although the legal and illegal trades exhibit spatial and temporal overlap, this work found they appear to operate independently.

6.2.1. Identifying socioeconomic drivers of the legal and illegal trades

While Ostional is a model project of community-based conservation, and the village certainly benefits from the sale of eggs, the Ostional community did not appear to receive a proportionate return on their investment. Chapter 4 looked at stakeholder involvement and dependence on turtle eggs along the legal trade chain and identified inequity in benefit sharing. Aside from a small number of pensioners, the majority of ADIO members were not dependent on the sale of eggs. Most households viewed the additional income as a bonus, or equally valuable to the other income generating activities.

Middlemen received the highest return, whilst depending least on the sale of eggs. However, the most vulnerable stakeholders were the mobile egg vendors in the Caribbean – and possibly further reaches of the Pacific – as they paid the highest prices for their eggs to be delivered and relied on supply from middlemen. This was a minority group and most stakeholders gained little from the sale of eggs. Conversely, returns on investment were much higher in the illegal trade. In the Pacific, traffickers of illegal olive ridley (*Lepidochelys olivacea*) eggs have the capacity to outcompete ADIO. With lower overheads and no three day time-lag between declaring an *arribada* and eggs leaving the beach, traffickers had a head-start on ADIO.

In the Caribbean, the illegal trade does not appear to be out-competing Ostional eggs. Illegal extraction rates in the region were high and would likely increase without beach protection efforts. However, little attention has been given to the drivers of illegal take of sea turtles (see Hart et al. (2013) for an exception). Chapter 2 successfully addressed this knowledge gap by identifying illegal harvester demographics, motivations and socioeconomic variables which drive rule-breaking. Significantly it was found that livelihood needs were not driving the illegal harvest of sea turtle eggs in the Caribbean and illegal take was rarely for subsistence. The Caribbean coast of Costa Rica suffers widespread illegal drug use and the principle egg extractors were victims of substance misuse, namely crack cocaine and marijuana. This is the first time a link between narcotics and illegal take of turtles has been reported from this region. However, subsistence misuse and addiction are symptomatic of a more deep-rooted problem. According to the World Bank (2001), poverty extends beyond malnutrition and low incomes, to include undernourishment, poor health and low levels of literacy. In Pacuare illegal harvesters were mostly men, marginalized from their communities for homosexuality, criminal records or mental health issues. Low literacy and few employment opportunities limited options further. With a ready supply of narcotics and little else to do, it is unsurprising the region had a high rate of drug abuse, and subsequently petty crime and turtle eggs used to procure drugs.

6.2.2. Supply-driven legal and illegal trades

Removing drugs from the Caribbean coast is unlikely to reduce demand, as turtle eggs are regarded as a traditional food source and culturally important. However, turtle eggs are inexpensive, seasonally available and generally consumed as street food or a bar snack. This means the end consumer does not depend on the product. On most Caribbean beaches, searching for nests is time consuming and physically demanding. Without a strong ulterior motive, it is unlikely people living close to a nesting beach would spend time searching for a nest and are more likely to only take one they encounter opportunistically or close to home. This suggests that, while demand is high, the illegal trade is largely supply-side driven. This also appears to be the case in the legal trade. Building on the knowledge that turtle egg consumption is culturally ingrained, Chapter 3 looked at the availability of the eggs in an area that does not have a long-standing tradition of turtle egg consumption, the Central Valley. Turtle eggs have only been available in large and regular quantities in the region since ADIO had the means to transport them wholesale (Campbell 1998; Arauz-Almengor et al. 2001). This suggests that in the Central Valley the legal trade is supply driven, and if deemed necessary, conservation interventions focused on supply – rather than demand – would be appropriate.

Understanding supply and demand dynamics enables targeted conservation interventions (McNamara et al. 2016). If trade appears to be demand driven, focus on supplying alternatives, changing the source of the commodity from wild harvested, or attempting to change consumer preferences may be effective. Conversely, supply-side dynamics may focus on alternative livelihoods for harvesters, increased enforcement, or poverty alleviation interventions that move away from a reliance on the species in question (McNamara et al. 2016). In recognising the need to better understand these dynamics, there has been a recent increase in the focus on consumer demand and preferences (Hinsley et al. 2015; Shairp et al. 2016; Veríssimo and Wan 2018). Chapters 2, 4 and 5 contribute to this understanding focusing on both demand and supply-side dynamics in the Ostional case study. The high demand for turtle eggs both in the Caribbean and Pacific appears to arise from a long-standing

tradition of utilizing turtles, that spans several human generations (Campbell 2007). However, that the supply is seasonal, and provide just a low-value treat, is relevant. In much of the wildlife trade discourse, a key driver of demand is linked to the perceived or actual rarity of a commodity. The rarity of a species increases its value, trapping it in an extinction vortex due to its value increasing in-line with decreasing abundance, a phenomenon known as the *anthropogenic Allee effect* (Courchamp et al. 2006; Shairp et al. 2016). The price comparison analysis in Chapter 4 contributes to this discussion. For the anthropogenic Allee effect to be visible in the egg trade, it would be expected that the eggs of rarer species (i.e. green – *C. mydas*, hawksbill – *Eretmochelys imbricata* and leatherback – *Dermochelys coriacea*) would sell at a premium and olive ridley eggs would be cheaper, but this was not the case. In this instance, the rarity of the species does not necessarily equate to rarity in the consumption of eggs; in other words, if the various types of eggs are considered to be sufficiently close substitutes, it does not necessarily follow that rarer species' eggs sell at a premium.

6.2.3. Spatial and temporal overlap in the legal and illegal trades

As it is not possible to trace olive ridley eggs back to their beach of origin, this work focused on attempting to find fully protected species' eggs in the markets. Despite identifying spatial and temporal overlap between legal and illegal trade (Chapter 4), no evidence that Ostional bags are used to launder eggs from fully protected species was found (Chapter 5). Therefore, concerns that Ostional bags were being used to sell illegally collected eggs from protected species were unfounded. It is more likely that the legal and illegal trade are working independently in the Caribbean. However, Chapter 3 identified numerous vendors that were highly likely to be selling illegally sourced olive ridley eggs. Without forensic techniques, however, this was not possible to verify.

Supply-side conservation carries with it the concern that a legal market will enable laundering (Biggs et al. 2013; Tensen 2016). In the case of Malagasy timbers, difficulties in distinguishing between species in the trade has resulted in more stringent controls. The genera *Diospyros* (ebony) and

Dalbergia (rosewood) are listed together on CITES Appendix II, despite some species suffering lower threats (CITES 2020). One of the greatest limitations of an open trade in rhino horn, is the difficulty distinguishing between legally and illegally sourced horn, and the danger that any trade will stimulate the market and exacerbate poaching (Biggs et al. 2013). Conversely, the trade of crocodilian skins has been hailed as a success due to the suppression of the illegal trade from the legal market (Hutton and Webb 2002). Chapters 3, 4 and 5 contribute to this debate and support CITES in the need for more case studies concerning wildlife laundering and a better understanding of domestic trades to inform policy at the international level. As shown in Chapter 5, almost all mobile traders were flaunting the traceability rules to add value to the eggs by cooking them, generating enough income to support their livelihood needs. This example identified a disjuncture between livelihoods needs and regulations to prevent laundering.

A fundamental issue in conservation is the misalignment between the costs and benefits associated with rule breaking/compliance. While obeying rules may be globally or socially beneficial, the cost of those limitations, or loss of access to a natural resource, may be devastating to an individual resource user or community. The failure of wildlife trade practitioners to adhere to rules or regulations, coupled with low levels of law enforcement, were recurrent results throughout this thesis. At one extreme, Chapter 2 discussed flagrant illegal extraction coupled with low levels of law enforcement. Chapter 4 built on this by using data gleaned from interviews and the research in Appendix 2 to map trafficking routes and identify hotspots for illegal trade. When a perpetrator chooses to engage in a criminal activity, they subconsciously undertake a cost-benefit analysis. If the perceived benefits (the revenue from turtle eggs) outweigh the costs (prosecution) they will continue to engage in illegal behaviour. Chapter 2 found the chance of securing a prosecution for destruction of turtle nests, was so low that arrests were uncommon. This was further supported by the finding that corruption was virtually non-existent as it was unnecessary, and there was a general lack of sensitivity to the subject

of turtle egg trade. This clearly identified the benefit of partaking in an illegal behaviour outweighing the cost.

6.3. New methodologies

6.3.1. Shopping list method

Originally designed as a tool to survey worked ivory in China, the shopping list method has been used once before by Moyle and Conrad (2014). Based on the assumption that availability is a measure of demand, this method can be used to compare the availability of items of interest. Chapter 3 adopted these methods to survey marine consumables in the markets of San José. This method is advantageous in being affordable and systematic, yet circumventing entrapment concerns or arousing suspicion. It does not require specialist identification skills as it involves the researchers finding fewer, more easily identifiable items and incorporates citizen science. The method also generates price data, an important barometer of temporal trade fluctuations. The internet is now a major marketplace for trading illegal wildlife, the scale of which is hard to quantify (Sajeva 2012). The shopping list method is applicable to online searches or menus. Chapter 3 extended Moyle and Conrad's (2014) approach by incorporating survival analysis. 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.

Human health, zoonosis and wildlife markets are at the forefront of current affairs and the importance of zoonosis cannot be underestimated (Bell et al. 2004). An estimated 75% of emerging infectious diseases are zoonotic and wildlife markets provide a transmission site which poses a threat to human health (Chomel et al. 2007). Avian flu (SARS) in 2003, and Ebola in 2013, are thought to have originated from wildlife, and wildlife markets in China are the suspected source of the Covid-19 coronavirus pandemic (Natusch et al. 2020). The dramatic impact of Covid-19 has prompted calls for wildlife trade bans. Aside from difficulties surrounding enforcement, this approach is likely to be

counterproductive. Depending on the risk-reward, trade bans are unlikely to be effective and are more likely to drive trade underground, making markets much harder to monitor and posing a greater risk to public health (Challender et al. 2020). Rather than outright bans, calls have been made for a safer, sustainable trade with greater regulation of markets (Roe 2020). The importance of surveying markets, adopting methods that improve and increase the efficiency of surveys are therefore invaluable. Chapter 3 offers a timely contribution to this discussion.

6.3.2. GPS-GSM enabled decoy turtle eggs

This thesis identified under-resourced law enforcement as a limitation to curtailing illegal trade. Often in wildlife crime, the response is reactive rather than proactive (Pires and Moreto 2011). Appendix 2 of this thesis reports the results of the first field trial of a novel technology intended to enhance future law enforcement. GPS-GSM enabled decoy turtle eggs were deployed in nests vulnerable to illegal harvest on beaches in Costa Rica. The transmitters provided five tracks and in one case identified a likely complete trade chain, tracing a route to a domestic property 137 km from the deployment beach. While still in its infancy, decoy eggs show promise as a possible law enforcement tool that may help disrupt wildlife trade.

6.4. Policy recommendations for Costa Rica

In Costa Rica, legislation surrounding sea turtles is imposed by central government and enforced by MINAE(T) (the Costa Rican Ministry of Environment (and Tourism)), the coast guards and the police. Sea turtles are protected under Costa Rican law #8325 and a wider reaching law, which protects all biodiversity, wildlife law #7317. These prohibit the killing of turtles, destruction of nests, trafficking and sale of eggs, meat or shell. Signatories to the Inter American Convention for the Protection and Conservation of Sea Turtles (IAC), which includes Costa Rica, are required to protect sea turtles on their beaches and in their waters. However, an exception was made for Costa Rica for the commercialisation of eggs from Ostional, under Executive Decree #28203, specifically written for the

Ostional project (IAC 2015). However, these regulations are meaningless without compliance (Keane et al. 2008).

The 2017 Management Plan for the traceability of olive ridley eggs from Ostional, require ADIO to package eggs in small heat sealed bags, bearing the ADIO logo and date of *arribada* from which the eggs were sourced. Except for eggs sold for consumption on the premises, this is the only form in which eggs can legally be sold. Chapters 3 and 5 found widespread failure to conform to the traceability regulations and failure to adhere to these rules appeared to be consumer driven. Turtle eggs are a low value commodity that need to be cooked or served with a sauce in order to generate enough return on investment. These chapters identified a disjuncture between demand (consumer preferences for a small quantity of eggs) and supply (ADIO sales units of a minimum of 20 eggs). This has resulted in a lack of compliance that undermines the traceability regulations which appears to be taking place without legal repercussions.

The following recommendations have resulted from this work and are intended to inform policy in Costa Rica: (1) While an illegal trade in turtle eggs clearly occurs, no evidence was found of green, hawksbill or leatherback egg sales being associated with ADIO or Ostional. This leads to the conclusion that the two types of trade are operating independently. Therefore, the problem of illegal extraction in the Caribbean needs addressing on the beaches not in the markets. It is recommended that protection on the beaches continued but is improved and is better supported by law enforcement – however this is likely to be hindered by a lack of resources. A positive example of adequate and sustained protection efforts is the case of the Atlantic green turtle (*C. mydas*) population in Costa Rica which is appearing to be recovering, suggesting the Ostional project is having little impact on this species (Bjorndal et al. 1999; Troëng and Rankin 2005; Velez-Espino et al. 2018); (2) In the markets, traceability rules were systematically flouted which appears to be a misalignment between the traceability regulations and consumer demand. It is recommended that adjustments should be made

to the packaging of eggs to meet consumer demand (further details of these recommendations are provided in Chapter 5); (3) Given that olive ridley eggs are most prevalent in the market and not possible to trace once removed from ADIO packaging, it is recommended that law enforcement is targeted at market stalls and outlets selling uncertified eggs; (4) However, caution is advised with mobile vendors, especially in the Caribbean. Given that such a large proportion of their incomes are from the sale of cooked turtle eggs, and that olive ridley eggs in the Caribbean are likely to be from Ostional, thus enforcing regulations that disrupt this may prove to be counterproductive. Interrupting the supply of legal eggs to the Caribbean may result in demand being supplied by illegally sourced eggs and thus serve to accelerate illegal harvesting in the region; (5) Given the fragility of the livelihoods of mobile vendors, particularly in the Caribbean, a cooperative or association representing ADIO in Limón province, could serve to ensure a steady flow of eggs is available in the Caribbean at fixed prices, in line with those charged by ADIO. Further, while these policy recommendations tackle the symptoms of illegal trade, the root causes of poverty and marginalisation need addressing if the underlying problems are to be resolved.

A possible link between criminalising the failure to pay child support and illegal extraction of turtles was also identified. For these issues to be resolved and uptake of crack cocaine use reduced, channelling economic development towards secondary school education, mental health services and child support would likely help. Legalising same-sex marriage may be a start towards reducing the stigma of homosexuality. However, homophobia is deep rooted and misunderstood. In 2018, in the belief that sexual education classes would cause homosexuality, parents across Costa Rica protested that schools that were proposing to add sexual education to the curriculum (Sibaja 2018). While abortion is illegal and sex education not provided in schools, it seems unwanted pregnancies and subsequent failure to pay child support are inevitable, with the possible unexpected consequences that lead to marginalisation and illegal extraction of sea turtles.

6.5. Informing international policy and practice

Source countries are often biodiversity rich but economically poor, and tropical rural communities depend on natural resources to fulfil basic livelihood requirements (Broad et al. 2003). Balancing natural resource use with sustainable development, and meeting livelihood requirements are needed for conservation interventions to be effective. All species of sea turtle are listed on Appendix I of CITES, a convention focused on protecting endangered species from unsustainable extraction, by monitoring, restricting and, where necessary, banning trade. However, more recently the convention has recognised the needs of rural communities to access natural resources and noted that trade restrictions may disincentivise communities to conserve those resources (Challender et al. 2015). This discourse is in closer alignment with the policies of the CBD and Goals 1, 14 and 15 of the SDG. The CBD recognises a country's sovereign right to utilise its natural resources, and the UN SDG, Goal 1 works to alleviate poverty in developing nations. Goals 14 and 15 promote the sustainable use and consumption of Earth's marine and terrestrial ecosystems, aiming to halt biodiversity loss (United Nations 2020). By bringing resource users into the narrative, CITES appears to be falling in line with these conventions, however its overarching strategy of restricting trade, may still conflict with the objectives of the other conventions in some cases.

Understanding drivers of demand and the demand for alternatives can be achieved using market surveys and can be important for predicting changes in consumption and the management of a sustainable supply (East et al. 2005). Understanding markets is an important but often overlooked aspect of controlling trade. CITES has been criticized for not giving enough attention to the economics and socioeconomics at play in wildlife trade and with too much emphasis on trade restrictions. It has been suggested CITES remedy this by placing more value on understanding markets (Challender et al. 2015). Chapters 3, 4 and 5 contribute to this knowledge gap by focusing on consumer markets, the trade chain and the importance of this domestic trade to stakeholder livelihoods.

This research has direct relevance to the policies of CITES, CBD, the SDG and offers a rare opportunity to understand a long-standing wildlife trade and its impact beyond the scope of the livelihoods of the source community. In line with the targets of the SDG and CBD, this work provides an understanding of poverty alleviation through natural resource use, not only in the source community but throughout a complete trade chain. The Inter-American Convention for the Protection and Conservation of Sea Turtles makes an exception for Costa Rica by allowing the commercialisation of eggs from Ostional and other countries with high abundances of turtles are keen for similar exemptions (IAC 2015). Therefore, this research is also of direct relevance to the policies of the IAC.

6.6. Further research opportunities

Due to low natal fidelity there is currently no genetic technique that can trace olive ridley turtles to their natal beach, an option available for other turtle species. Eggs from Ostional are packaged with sand to prolong freshness. In the planning stages of this thesis, options for comparing the microbial composition of sand in certified and uncertified packs were explored. This idea proved unfeasible, not least because many of the uncertified eggs were prepared or sold in bags without sand. Sampling would likely have been a significant limitation to this line of enquiry. Further research into a technique capable of tracing an olive ridley egg to its source beach would be invaluable in this avenue of research, especially if it were applicable to cooked eggs.

Although it was not a specific aim of this thesis, the research identified a high demand for turtle eggs in Costa Rica. In addition, the questionnaire in Chapter 3 asked participants in the market survey if they recognised the ADIO logo – with surprisingly few respondents able to answer yes. While the dataset is too small to extrapolate to the general public, further research into the demand for sea turtle eggs and local understanding of the legality surrounding the consumption of eggs, would be an interesting line of enquiry. The findings have the potential to not only assist in answering questions

related to the Ostional project stimulating demand for egg consumption, but also contribute to the wider understanding of culturally driven demand for wildlife.

Chapter 2 identified marginalisation as a key driver of poaching. Costa Rica has soft laws surrounding illegal drugs yet stringently enforces failure to pay child support, with 6 month custodial sentences for offenders. While these laws were touched upon in this thesis, an opportunity for further research into the links between laws regarding sexual education, abortion and child maintenance and marginalisation would be worthy of investigation.

Finally, quantifying the rate of illegal extraction in the Caribbean was not included in this thesis, however this line of enquiry is due to be followed up. Contacts made throughout the course of this research have resulted in a collaboration between three NGOs to analyse and publish long-term datasets on illegal harvest rates in the Caribbean.

6.7. Conclusion

The overarching aim of this thesis was to identify methods and motivations for laundering a wildlife commodity inside a legal trade system. In the past, Ostional eggs were sold in sacks of 200 eggs and it is plausible that respondents had witnessed illegal eggs laundered in this way. In 2017, the management plan for Ostional introduced the new traceability laws and it is possible the smaller bags are proving to be an effective deterrent. However, these rules are regularly flouted and there is clearly a need to streamline regulations with consumer demand. The commercialisation of eggs from Ostional has been in operation for over 30 years and at the same time the Atlantic green and leatherback populations have continued to recover. If Ostional has stimulated illegal harvesting of these species it has not yet resulted in an observable impact on the populations. The continued recovery of species in the Caribbean will benefit far more from protection on the beaches than a focus on the markets. The legal trade in sea turtle eggs in Costa Rica is operating independently of an underground illegal trade.

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Appendix 1 Research tools

Appendix 1A

Chapter 2: RRT questions, demographic questions and visual guide

Practice questions

Asked participant either question a or b from both questions when practicing the RRT "game". Intended to be amusing to put the participant at ease.

1a. In the last 12 months have you eaten rice and beans? (illicit yes response)
OR
1b. In the last 12 months have you walked on a beach? (illicit yes response)

And

2a. In the last 12 months have you eaten elephant meat? (illicit No response)
OR
2b. In the last 12 months have you been to Africa? (illicit No response)

RRT questions

In the last 12 months have you:

1. **Traded in (bought or sold) turtle eggs that you believed to be illegal?** (Trade).
2. **Illegally removed turtle eggs from nests on the beach?** (Poach).
3. **Paid/accepted a bribe in relation to an illegal activity involving turtle eggs?** (Bribe).

Demographic Questions - RRT:

1. Location:

2. Gender:

3. Age: 18-29 30–3940-49 50-59 60-69 70-79 80+

4. Education level: no school/primary/ secondary/ college/ university other_____

5. Number of children:

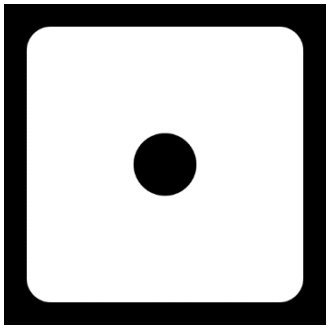
6. Number of people who live in the same house as you:

7. Occupation:

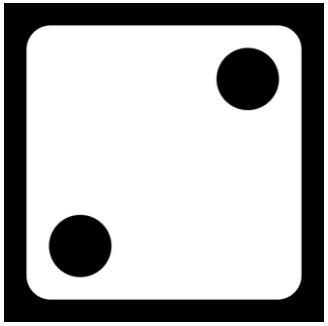
8. Religion: In the last four weeks I have attended church: more than once a week/once a week/once a fortnight/less than once a fortnight/not at all/not applicable.

9. Wealth: I consider myself to be MORE/LESS/EQUALLY fortunate as a normal person in my neighbourhood.

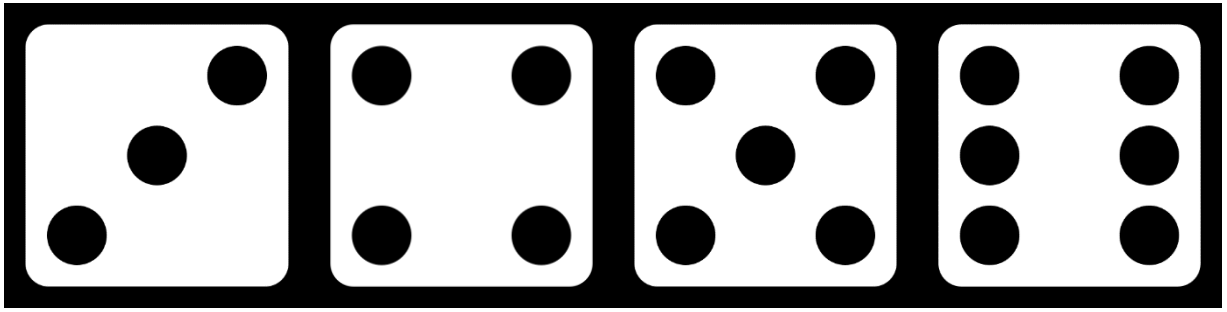
10. Social: in your opinion what percentage of people living here today have problems with dependency on illegal drugs or alcohol?



= Yes.



= No.



=Truth

Appendix 1B:

Chapter 3 Search Cost Questionnaire and data sheet

Fish consumption questionnaire and demographic questions

Name:	Date:
Location:	

Section A: Fish consumption

A1. Do you or your household buy and eat fish and other fishery products?	**Yes**		**No**

If no, why not? PLEASE TICK ALL THAT APPLY

Too expensive		Religious reasons	
Too many bones		Allergic to fish	
Do not like the smell		Do not know how to cook	
Do not like the taste		Vegetarian or vegan	
Do not like the texture		Worried it is not sustainable to eat some fish	
Got sick last time		Other (please specify).....	

If yes:

A2. How often do you or your household eat fresh or frozen fish? PLEASE CHOOSE ONE

Less than once a month	
Once a month	
Once every 2 weeks	
Once a week	
Twice a week or more	

A3. How often do you or your household eat fish products fish (e.g. canned, dried)? PLEASE CHOOSE ONE

Less than once a month	
Once a month	
Once every 2 weeks	
Once a week	
Twice a week or more	

A4. How much fish does your household eat at a typical meal?_____ kg

A5. (i) Where do you normally buy fish? PLEASE TICK ALL THAT APPLY

Catch it myself	
Market	
Fish landing	
Fish Shop	
Door to door seller	
Supermarket	
Other (specify)	

If buy it:

(ii) Why do you buy from these places? PLEASE TICK ALL THAT APPLY

Market		**Fish landing dock**		**Fish Shop**	
Cost		Cost		Cost	
Quality		Quality		Quality	
More convenient		More convenient		More convenient	
Loyalty to seller		Loyalty to seller		Loyalty to seller	
Good variety available		Good variety available		Good variety available	
Other (specify)		Other (specify)		Other (specify)	

Door to door seller		**Supermarket**		**Other (specify)**	
Cost		Cost		Cost	
Quality		Quality		Quality	
More convenient		More convenient		More convenient	
Loyalty to seller		Loyalty to seller		Loyalty to seller	
Good variety available		Good variety available		Good variety available	
Other (specify)		Other (specify)		Other (specify)	

A6. What types of fish do you consume more frequently? PLEASE TICK ALL THAT APPLY

Fresh fish	
Canned fish	
Smoked fish	
Frozen fish	
Salted fish	
Other (please specify)	

A7. Imagine you go out to buy fish or fisheries products (any type), what are the factors that affect the type of fish you buy? PLEASE TICK ALL THAT APPLY

Freshness	
Good quality	
Affordable & fits budget	
Like the taste	
Easy to prepare	
Is healthy	
Mostly look for a specific type of fish	
Other (specify)	

A8. Have you ever eaten shark?

Yes	
No	
Don't know	

If yes how often do you eat shark? PLEASE TICK ONLY ONE

Less than once a month	
Once a month	
Once every 2 weeks	
Once a week	
Twice a week or more	

A9. Which of the following statements are relevant to you: PLEASE TICK ALL THAT APPLY

I would never eat sea turtle eggs	
I have eaten legal sea turtle eggs	
I would eat legal sea turtle eggs	
I would eat sea turtle eggs if the turtles were not in danger of extinction	
I recognize the Ostional logo on legal turtle eggs	
Did not answer	

Section B: Demographic questions

B1. Gender

Male	
Female	

B2: Age group

18-24	
25-34	
35-44	
45-54	
55-64	
65-74	
75-84	
85+	

B3: Education level

Did not go to school	
Primary	
secondary	
College	
University	
Other (Please specify)	

B4: Number of people who live in the same house as you:	

B5: Occupation

Student	
Teacher	
Tour guide	
Shop keeper	
Police/Coast guard	
Fisherman	
Mechanic	
Cash in hand work	
Retired	
Unemployed	
Other please specify	

B6: I consider myself to have MORE/LESS/THE SAME wealth as a normal person in my neighbourhood.
Please circle as appropriate

B7: Do you currently live in Limon City?

Yes	
No	

If yes:

B8: For how long have you/did you live in Limon city?	

Thank you for taking part in this questionnaire, you will now be given instructions for the market survey

Location:	Start time:	End time:	Investigator's name:	
Time stopped for lunch	Time started looking after lunch			

Aim: to see if the following items are available for sale in this city and to see how long it takes to find each item. Please familiarise yourself with the list and use any method you wish to find the following items, when you find an item please record the time to the nearest minute that you found it. It is important to the research to know which order you encountered the items so you do not need to look for them in order! **Please keep your list hidden from vendors and write down the encounter times when you are away from the place of sale.**

Item name	Item photo	At what time did you find the item? (hour: minutes)	How was the product advertised/labelled? (PLEASE CIRCLE ALL THAT APPLY)	Additional questions	Price	Comments
Turtle eggs with the Ostional logo visible on the bag.		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)	**The eggs were in** (PLEASE CIRCLE ONLY ONE): Market stall/shop Bar Cooler box An open sack with the logo Small bags with the logo Other (please specify)		
Turtle eggs sold without the logo		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)	**The eggs were in** (PLEASE CIRCLE ONLY ONE): Market stall/shop Bar Cooler box In closed packets Per egg Other (comment):		
From which species do you think the non-ostional eggs were from? (PLEASE CIRCLE ALL THAT APPLY)	Baula	Verde/ blanca/ amarillo/ negro	Carey	Lora	loggerhead	Don't know
Shark meat fillet		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)			
Shark meat steak		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)			
Shark liver oil		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)			

The you may encounter the following items while you look for the list above. Please do not spend time specifically looking for these BUT *IF* you happen to encounter them please record the follwing data:

Item name	Item photo	At what time did you find the item? (hour: minutes)	How was the product advertised/labelled? (PLEASE CIRCLE ALL THAT APPLY)	Additional questions	Price - if advertised	Comment
Turtle meat		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)			
Hawksbill jewelry/product		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)	Please specify the name of the shop/location		Type of product:
Lobster		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)			
Shark fin		Hour : minute	No label No written advert Written sign/advert Written label Verbal Other (please specify)			
I started my search for the items: (PLEASE CHOOSE ONLY ONE)	In a market	In a bar	In a supermarket/cantina	On line	By asking someone I thought would know	Other (please specify)

Appendix 1C:

Chapter 4: Ostional household questionnaire

Survey No: Date:

Start time: End time:

Location (Ostional, other):

A. <u>FAMILY STRUCTURE, ECONOMIC ACTIVITIES</u>

1. Number of years here?

2. Number of children:

3. Table:

- Number of people who live in the same house as you at this time
- Sex
- Age: (use groups if participant is uncomfortable) (18-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+)
- Years of Education: No school/ Primary/ Secondary/ College University/ Other: ___
- ADIO associate? Y/N In what capacity? Board Honorary Community member
- If no, why?
- Please list all the activities you partake in for earning money or for the household

Participant	**Sex**	**Age**	**Educationn**	**ADIOmember? Capacity/ reasons why not below**	**Economic activities/livelihoods/ (USE THIS LIST FOR NEXT TABLE)**
P1					
P2					

3b. Reasons not in ADIO:

4. Economic activities:

- Please rank these in order of importance (1 is the most important – 0 is not important at all)
- Are these activities for generating income or for the household?
- How many hours do you spend on each activity (per month)?

Activity	**Importance (rank)**	**Details (sale or household use)**	**Hours per month**

B. EGG PROJECT

5.a) How would you describe the impact (the negative and positive aspects) of the project in relation to nature (the turtles, the beach etc.)? (if need clarification - overall good and bad things, how they balance out).

1 Very good	2 Good	3 Fair	4 Bad	5 Very bad	6 don't know

b) Why?

5.b) How would you describe the impact (the negative and positive aspects) of the project in relation to the economic situation of the area?

1 Very good	2 Good	3 Fair	4 Bad	5 Very bad	6 don't know

b) Why?

6.a) How would you describe the impact (the negative and positive aspects) of the project in relation to the people in the community?

1 Very good	2 Good	3 Fair	4 Bad	5 Very bad	6 don't know

b) Why?

7.a) How would you describe the impact (the negative and positive aspects) of the project in relation to you personally?

1 Very good	2 Good	3 Fair	4 Bad	5 Very bad	6 don't know

b) Why?

8. What is the best aspect of the project?

9. What is the worst aspect of the project?

10.a) Do you think the quantity of eggs collected should….

1 Increase	2 Stay the same	3 Decrease	4 Stop	5 Don't know

b) Why?

11. Table:

a) What is the community doing to protect the turtles?

b) Do you participate in these activities?

c) Do you think these activities are worthwhile?

d) Why?

Activity	**a**	**b**	**c**	**d**
Egg collection				
Clean (beach)				

Safeguard Hatchlings				
Guide				
Guards				
Other				

12.a) Do you think the efforts of the community to protect the turtles should…

1 Increase	**2** Stay the same	**3** Decrease	**4** Stop	**5** Don't know

b) Why?

13. Are there other activities that threaten the project?

14. Do you think it is possible the turtles will stop coming?

15.a) If the turtles stop coming what would be the impact on the community?

1 Very good	2 Good	3 Fair	4 Bad	5 Very bad	6 don't know

b) Why?

16.a) If the turtle stop coming what would be the impact on you personally?

1 Very good	2 Good	3 Fair	4 Bad	5 Very bad	6 don't know

b) Why?

17. What other types of development would you like to see in Ostional?

18. In 5 years what economic activities would you like to be doing?

C. FINAL QUESTIONS TO COMPARE OSTIONAL TO OTHER PLACES IN COSTA RICA

19. Wealth: I consider myself to be MORE/LESS/EQUALLY fortunate as a normal person in my neighbourhood.

20. Religion: In the last four weeks I have attended church: more than once a week/once a week/once a fortnight/less than once a fortnight/not at all/not applicable

21. Social: in your opinion what percentage of people living here today have problems with dependency on illegal drugs or alcohol?

Thank you for taking the time to complete this survey

Appendix 1D:

Chapter 5: Egg purchase survey

Code:	Research Assistant:	Date:
Location:	Vendor type (Bar/Canteed/Mobile etc):	
Vendor property name (if relevant):		
Ostional sign Y/N	Verbal confirmation Y/N	Fake Ostional bag Y/N
Permit Y/N/did not ask	Quantity of eggs purchased	Price:
Display/Hidden	Prepacked Y/N	
Comments/observations:		

Appendix 2

Using GPS enabled decoy turtle eggs to track illegal trade

In press: Current Biology

Pheasey, H., Roberts, D.L., Rojas-Cañizales, D., Mejías-Balsalobre, C., Griffiths, R.A., Williams-Guillen, K.

8.1. Using GPS enabled decoy turtle eggs to track illegal trade.

The insatiable appetite for wildlife products drives species to extinction, spreads disease and has negative consequences for source country economies [1, 2]. As a major transnational enterprise, illegal wildlife trade is valued between US$8 and US$26.5 billion annually [3, 4]. Since law enforcement is often reactive, information on trafficking routes is key to disrupting trade and curtailing wildlife crime.

In our efforts to uncover trade routes of illegally extracted sea turtle eggs, we developed and field-tested the InvestEGGator, a 3D printed decoy turtle egg embedded with a GPS-GSM transmitter (Supplemental information: Decoy eggs). Trafficked turtle nests containing a decoy transmitter enabled us to track the movements of smugglers, and thus gain a better understanding of illegal trade routes. The decoys, set to emit a signal once an hour, provided five tracks, the most detailed of which identified an entire trade chain, covering 137 km. Using data provided by the decoys, we identified trafficking routes and on two occasions properties of interest. Decoys also yielded anecdotal information, furthering our understanding of trafficking routes.

We deployed 101 decoy eggs in turtle nests on four beaches in Costa Rica (Supplemental information: Deployment). Of these, 25% were illegally removed. The decoys tracked eggs from five trafficked nests (two green turtle, *Chelonia mydas*; three olive ridley, *Lepidochelys olivacea*) (Fig. 8.1.). Our shortest track emitted its final signal 28 m from a residential property, while another travelled 2 km to a bar. Our furthest moving decoy travelled 137 km inland identifying a near-complete trade chain; spending two days in transit from beach to a supermarket loading-bay in the Central Valley, it transmitted a final signal from a residential property the following day. Given that mobile vendors sell eggs door-to-door in Costa Rica (pers. obs.), the supermarket was a likely handover point between trafficker and salesperson.

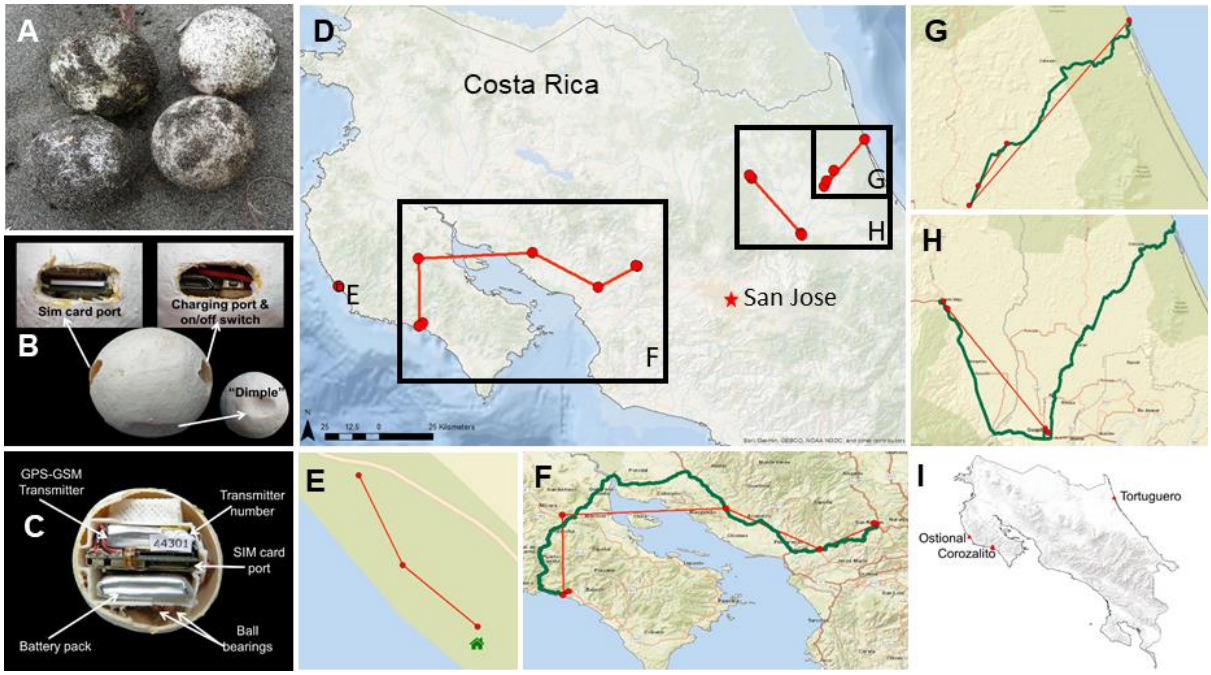


Figure 8.1. Decoy eggs, data, and projected routes used by turtle egg traffickers. (A) Three *Chelonia mydas* eggs and one decoy, (B) external and (C) internal workings of decoy egg, (D) data points provided by four decoy eggs, (E) property where decoy signal stopped (green) identified by decoy route (red), (F-H) tracks provided by decoy (red) and likely route taken by traffickers (green), (the fifth track not shown to maintain anonymity of final destination), (I) important turtle nesting beaches in Costa Rica, Ostional and Tortuguero are globally significant due to the abundance of nesting female turtles they receive.

We also received anecdotal data from reports of discovered decoys. For example, 11 days after one decoy went off-line, we received photographs of the dissected egg from Cariari a town 43 km from the deployment beach. Accompanying the photographs was information on the place of purchase near Tortuguero and quantities of eggs exchanged. Thus, our system is already yielding intelligence from the local community in addition to track data on smuggled eggs. However, this willingness to share also highlights the lack of sensitivity surrounding this illegal trade.

Planted decoys do not affect the viability of actual turtle eggs. On the Caribbean coast we triangulated all nests and exhumed the contents at the end of the incubation period. There was no

significant difference in hatching success (W = 617, P = .105), Stage 1 mortality (W = 455, P = .430), mortality due to microorganism (W = 455, P = .482) or presence of deformities (W = 506, P = .821) between nests with (n=22) and without (n=44) decoys (Table S1 Hatching success between nests containing a decoy and control nests).

We did not receive track data from every nest that was removed. We recovered six decoys on the beach near nests, presumably discovered and discarded by harvesters. Eleven decoys, confirmed as removed, failed to provide data, suggesting the decoy never entered an area with signal reception, or malfunctioned. We estimated the malfunction rate by examining the outcome of 38 nests containing a decoy (13 stolen, 25 recovered). Of the recovered decoys, 17 decoys were functional and eight failed, giving an estimated failure rate of 32% for recovered decoys. We extrapolated from this that 8 removed decoys should have been working; however, we received data from only two, suggesting of the 6 remaining, 2 would be expected to fail and the remaining 4 stayed in an area without signal (Fig. S1 Malfunction rate of decoy eggs).

We found no significant association between the fate of the removed eggs (discovered by harvesters, resulted in a track, or unknown outcome) and species (*C. mydas* and *L. olivacea*) (χ^2 = 3.051, df = 2, p > 0.05). At three beaches, harvesters discovered decoy eggs (which they discarded near the nest) *before* we received data from subsequent deployments, suggesting the discovery of one decoy does not alert harvesters to the possibility of there being more.

In Costa Rica, cooked turtle eggs sell for ~₡500 (US$1) each (pers. obs.), therefore the street value of the nest that travelled 137 km, containing 107 eggs, was potentially ₡53,500 (~US$107). On the night of deployment, an additional three nests were stolen on Playa Corozalito which we estimate to be 295 eggs (clutch size: $\bar{x}$ = 98.25, n = 33, Corozalito, September 2018). The street value of eggs taken that night was ₡201,000 (US$402), and possibly trafficked by the same individual. In Costa Rica, removing a *C. mydas* nest carries a penalty of US$530 and *L. olivacea* $415 per 2.5 nests [5, 6]. Prosecutions resulting from decoys could therefore generate sanctions of $1,558 to $2,222. However, prosecutors also consider loss of offspring, ecological and protection costs of stolen nests and

recommend fines that reflect this. In 2017, a judge awarded a fine of ₡4,197,428 (US$7,370) for illegally removing 224 *L. olivacea* eggs [6]. This case is now used for recommending penalties.

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

8.2. Acknowledgements

This project was funded by USAID Wildlife Crime Tech Challenge and supporters of Turtle Tracks to whom we are most grateful. We thank Sarah Otterstrom for her continued support of this project, staff and volunteers at the deployment sites, MINAE for logistical support and granting permits, and Matt Struebig for editorial support.

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8.4. Supplemental information

8.4.1. Decoy eggs

We made decoy eggs from a 3D printed housing of NinjaFlex, a flexible thermoplastic polyeurethane. Once printed, we filled the hollow chamber with high-grade silicone rubber to add weight and flexibility, and then embedded it with a GPS-GSM (Global System for Mobile Communications) transmitter, supplied by Shenzhen ReachFar Technology Co., Ltd. The decoys weighed the same as the turtle eggs they aimed to replicate – in the case of green turtle eggs we added ball bearings to

ensure they were heavy enough and unevenly weighted to mimic real turtle eggs. We used two transmitter models, V16 (n=70) and V8 (n=31) that run off GSM network bands 850, 900, 1800 and 1900 MHz and GPRS (General Packet Radio Service) standard, Class 12, TCP/IP. The transmitters function between -20 ºC to ~ 70 ºC and 5 % ~ 95 % relative humidity. The transmitter can locate GPS signal within 30 seconds and may reach accuracies of 10-15 m (reachfargps.com) under optimal conditions. When transmitters cannot obtain a GPS fix, they use Location Based Services (LBS) to estimate a position based on local phone masts. The transmitters require a local subscriber identification module (SIM) card. In our case Kolbi 4G supplied by the Costa Rican energy and communications company, Instituto Costarricense de Electricidad (ICE) were used. Kolbi has the greatest coverage across the country and is the only carrier that provides phone signal in the Tortuguero area. The transmitters are linked to a tracking platform via web-based or smart phone applications protected with Advanced Encryption Standard (AES) technology (gps123.org).

Both transmitter models have LED lights indicating on / off and connection status; we disabled the indicator lights before deployment. The V16 model comes equipped with a speaker and three alerts which indicate that the decoy is starting up, shutting down or running, making it possible to double check the on / off status of the decoy immediately prior to deployment. The transmitters were fully charged and, in the event we did not deploy them, we allowed them to run down completely before recharging, in order to maintain battery life. Transmitters were equipped with a single rechargeable lithium polymer battery with a 520 mAh capacity. The battery life of the transmitters ranged from one to six days depending on how frequently it was required to emit a signal – every minute, 10 minutes, once an hour or every 12 hours with the most frequent transmissions draining the batteries the fastest.

We designed the transmitter housing to replicate a sea turtle egg, featuring two portals with covers that enabled the insertion of SIM card and access to the USB charging port and on / off button. Prior to deployment, we placed the covers over the open portals and sealed them shut with a small amount of white paint to conceal the joins. Sea turtle eggs are soft shelled and often indent naturally

on contact, for this reason the decoys were soft, and we incorporated a “dimple” into the design. The decoys used on the Pacific deployments also had a waxy finish that adhered to sand for camouflage and further assisted with waterproofing.

We programmed the transmitters prior to deployment. The transmitters need to be in an area with a phone signal for set up and programming. To enable the transmitter, we sent a short line of code via SMS to the number associated with the SIM card, which linked the transmitter to the mobile phone of the account holder. It was then possible to program the transmitters to a variety of specifications via SMS or the smartphone or webpage applications. We programmed the decoys for the specific requirements of our project either via the smartphone app or by messaging the decoy via SMS. We gave each decoy an identification number. We chose to have the indicator lights off, sound on and for the decoys to emit a signal once an hour. We also set the time zone to local time (UTC-06.00). The battery status of each transmitter was visible via the webpage or smartphone tracking platforms.

8.5. Deployment

Prior to deploying the decoy eggs, we tested them at each field site to ensure they were transmitting accurately. On the Caribbean coast, teams of volunteers walked the beach transect with up to five decoys in their backpacks at one time. A natural canal system with thick rainforest, borders the beach resulting in poor mobile phone signal in the area. A single phone tower is located near Tortuguero. On the Pacific coast, decoys were driven between the accommodations and study sites. Playa Bejuco is accessible by road and there is good GPS and mobile phone coverage. On Playa Corozalito, the beach has irregular mobile phone signal, however coverage returns on the road a short distance from the beach. In Ostional, mobile phone coverage is generally good when available, however signal failures and power cuts do occur. On both coasts we compared the route the teams had taken with the route shown on the tracking platform. It should be noted that we were not attempting to track in real-time as we had set the transmitters to emit a signal every hour. When the decoys were first switched

on, they initially used up to 5% battery power but then the energy usage slowed. All eggs were functioning and charged to at least 95% at the time of deployment.

We deployed decoy eggs during, or immediately after, the turtle was in oviposition. We aimed to position the decoy as close to the centre of the nest as possible. If we encountered the turtle before oviposition and it was possible to count the eggs, we deployed the decoy once the turtle had laid 65 (*C. mydas*) or 45 (*L. olivacea*) eggs. If the turtle was already laying eggs we deployed immediately, irrespective of the number of eggs already laid. In the event the turtle was covering the egg chamber (n=5) we waited for the turtle to return to the sea and excavated the top layer of eggs so the decoy egg could be buried underneath, and the nest re-covered. As the project progressed, we altered our technique and implanted the decoy in the centre of the nest using a latex gloved hand, which enabled us to ensure we placed the egg in the centre of the nest.

We triangulated the nests to find the egg chamber and exhume the nest post-incubation. Nest triangulation involved taking measurements from the egg chamber to three fixed landscape markers, indicated with labelled flagging tape. This enabled us to confirm whether the nest had been stolen and estimate the hatching success once the incubation period was complete. We recorded the coordinates of each nest, to 3 m accuracy, using a Garmin GPSMAP 64s Navigator GPS unit.

8.5.1. Hatching success

In the event the nest was not stolen, we measured the hatching success of nests containing decoy eggs on Playa Norte. We measured overall hatching success (% of nest), mortality due to microorganisms or fungi (content brightly coloured, often purple or pink, with characteristic odour), deformities, and Stage 1 mortality (where the dead embryo occupied < 25% of the egg) (Table S8.5.1).

Table S8.5.1. Hatching success between nests containing a decoy and control nest (related to hatching success).

Variable	Test statistic, p-value	Nests containing decoy ($\bar{x}$, SD) n=22	Control nests ($\bar{x}$, SD) n=45
Hatching success (% of empty eggshells in nest)	W = 617, P = 0.105	71.9, 33.0	84.0, 24.5
Stage 1 mortality	W = 455, P = 0.430	0.5, 1.0	0.3, 0.9
Microorganisms / fungi	W = 455, P = 0.482	2.7, 3.6	1.7, 3.1
Deformities	W = 506, P = 0.821	0.5, 1.7	0.5, 2.0

8.5.2. Malfunction rates

We used Caribbean nests to calculate decoy malfunction rates, it was necessary to exclude six decoys and the remainder were further categorised into stolen or recovered (Fig. S8.5.2). We calculated the failure rate of decoys we recovered and applied this to the amount that were stolen and failed to provide a signal.

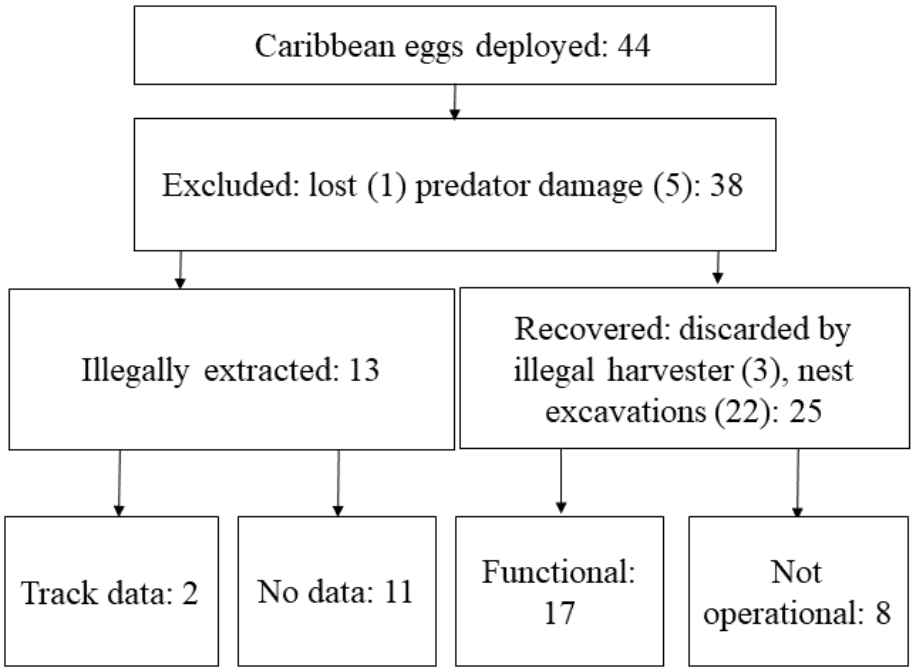

Figure S8.5.2. Malfunction rate of decoy eggs. 44 decoys deployed on the Caribbean coast and the malfunction rates of these transmitters.

8.5.3. Analysis

Hatching success was estimated as the number of empty eggshells as a percentage of the total number of eggs laid. We tested for a significant difference between the success of nests between two treatments: nests with and without a decoy egg, by exhuming them post-hatching using a Wilcoxon Rank Sum Test. We also compared the fate of the eggs (whether it was discovered by harvesters, emitted a signal or the fate was unknown) between species using a Pearson's Chi-squared test. Statistical analyses were undertaken using RStudio 1.2.1335. We used the Measure feature in ArcMap 10.5 to estimate distances between data points provided by the decoy eggs emitting a signal. These distance measurements were calculated using the shortest distances between data points, the actual land route may have been longer.

8.5.4. Tracking

In the event a nest was stolen we tracked its route using a private account on the Reachfar tracking platform or smartphone app (www.gps123.org). After six days of no activity we assumed the battery had run out, the decoy had been discovered or malfunctioned. Whenever the decoy egg emits a signal (once an hour) these data are registered on the tracking platform and it is possible to download the time and location data of the decoy into an Excel spreadsheet. These data are available via the platform for approximately six months.

8.6. Ethics and research permits

The School of Anthropology and Conservation's Research Ethics Advisory Group (University of Kent) approved this research (Ref. No.: 0381617d). According to the Economic and Social Research Council (ESRC) guidelines on research ethics: "*covert research may be undertaken when it may provide unique forms of evidence that are crucial to the research objectives and methodology or where overt observation might alter the phenomenon being studied. The broad principle should be that covert research should not be undertaken lightly or routinely. It is only justified if important*

issues are being addressed and if matters of social significance which cannot be uncovered in other ways are likely to be discovered" (ESRC Framework for research ethics updated January 2015). Our in-country research was conducted under permits from SINAC (Sistema Nacional de Áreas de Conservación), ACTo (Área de Conservación Tortuguero), and MINAE (Ministerio De Ambiente Y Energía): Resolución no. ACT-OR-DR-142-17 and Resolución SINAC ACT-OR-DR-083-2018.