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FISHERS' ECOLOGICAL KNOWLEDGE AND STABLE ISOTOPE ANALYSIS: A SOCIAL-ECOLOGICAL SYSTEMS APPROACH TO ENDANGERED SPECIES CONSERVATION

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Dedication

A los miembros de las comunidades de Bahía de Jiquilisco, El Salvador y Estero Padre Ramos, Nicaragua. Gracias por compartir su conocimiento experto, su tiempo, y su cultura conmigo. Estoy hornada de ser parte nuestro equipo.

To my family: Kevin, Mom, Dad, Ryan, Grandma Anita, Grandma Rose, we did it!

To myself: YOU did it!

To the graduate student community: we are in this together

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by

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Abstract

Identifying developmental habitat is essential for understanding population structure and species resiliency, especially for critically endangered species. In long-lived, oceanic, migratory animals such as sea turtles, elucidating developmental grounds is particularly difficult. When data are deficient or challenging to acquire, scientists often lean towards traditional quantitative methods when a social-ecological systems approach could better provide crucial baseline data and guiding information. Fishers' ecological knowledge (FEK), the combination of experiential and culturally transmitted knowledge, is expert knowledge and should be treated as such. In 2008, FEK led to the "rediscovery" of the critically endangered eastern Pacific (EP) population of hawksbill sea turtles (*Eretmochelys imbricata)*, which nests within an unusual habitat: on the shores of mangrove estuaries. However, we did not know how extensively EP hawksbills use these mangrove estuary habitats throughout ontogeny. To answer this question, we use a social-ecological systems approach, illuminating FEK through participatory action research and informant-directed semi-structured interviews, and integrating FEK with stable isotope analysis. Together, this approach reveals that mangrove estuary habitat is crucial for the development of immature EP hawksbills. Further, this imperiled population exhibits a pelagic stage that puts them at risk to artisanal fisheries before recruiting into their estuarine developmental grounds – where some stay until adulthood. These findings will improve how we conserve this population, highlight the substantial impact social-ecological systems approaches have on conservation, and demonstrate how interdisciplinary studies can reveal data of a revolutionary nature.

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Introduction

Social and ecological systems are conceptually linked, requiring conservation researchers and practitioners to open their minds to diverse knowledge cultures, and combine interdisciplinary strengths to generate the strongest data possible. As such, a social-ecological systems approach to conservation is becoming more popular (Charnley et al., 2007; Ostrom, 2009; Poe et al., 2014; Fischer et al., 2015; Virapongse et al., 2016). This approach integrates the social and natural sciences to provide multi-dimensional, robust understandings of conservation issues. This dissertation takes a social-ecological systems approach to improve our understanding of critically endangered eastern Pacific (EP) hawksbill sea turtles (*Eretmochelys imbricata)*. Specifically, we integrated fishers' ecological knowledge (FEK) and stable isotope analysis (SIA) to reveal crucial information about the life history of this at-risk species. This dissertation was made possible through the work of fishers throughout our study sites, and reflects the power, value, and depth of FEK. As such, throughout this dissertation "we" will be used, even though it was designed, coordinated, implemented, written, and fundraised for by Kathryn R. Wedemeyer-Strombel, it was a truly collaborative effort and, especially the local collaborators deserve credit for their contributions.

FEK is defined here as the combination of culturally transmitted and experientially learned expert knowledge. We choose this broad definition specifically for its inclusion of multiple types of knowledge acquisition. Scientists have called for the integration of FEK into conservation for decades (Johannes, 1981; Haggan et al., 2007; Hind, 2014). As a powerful tool, FEK has substantial capacity to compliment natural science approaches to ecological, evolutionary, and conservation questions (Johannes et al., 2000; Haggan et al., 2007; Hind, 2014). It is especially powerful when baseline data is deficient, and even more so when working with endangered species in threatened ecosystems, when time is of the essence. By employing FEK we are able to use the best available sources to drive our research, thus improving our science, and uncovering new scientific information.

SIA is a powerful tool in wildlife studies because of its ability to resolve questions on habitat use and behavioral ecology. Using SIA, researchers can gain insight into habitat use and foraging behavior from a single sampling interaction, thus minimizing negative impacts to the animal. SIA has been successfully utilized for a wide range of species across various habitats (Hobson, 1999), and is especially useful in evaluating migratory patterns (Cerling et al., 2006; Seminoff et al., 2012; Wunder, 2012; Vander Zanden et al., 2015; Cruz-Flores et al., 2018), and individual-level specialization (Newsome et al., 2009; Vander Zanden et al., 2010; Cryan et al., 2012; Nadjafzadeh et al., 2016). It is successfully used in sea turtle research (reviewed in Jones and Seminoff, 2013), and for hawksbill sea turtles more specifically (Bjorndal and Bolten, 2009; Graham, 2009; Ferreira et al., 2018), although only one other publication focuses on EP hawksbills (Mendez et al. in Review).

EP hawksbills were thought by scientists to be ecologically extirpated starting in the late 1960s and lasting until 2008, when a viable population that "shifts the life-history paradigm" for sea turtles was discovered (Gaos et al., 2010; Gaos and Yañez, 2012). Since its discovery in 2008, strides have been made to add to the growing body of information on EP hawksbills, including: local attitudes towards conservation initiatives (Liles et al., 2015a), nesting (Guzmán Hernández, 2010; Liles et al., 2015b), satellite tracking movement studies (Gaos et al., 2012a; Gaos et al., 2012b), foraging behavior and habitat use (Gaos et al., 2012c; Heidemeyer et al., 2014; Chacón Chaverri et al., 2015; Torres Gago et al., 2016; Llamas et al., 2017), diet analysis (Carrión-Cortez et al., 2013; Mendez et al. in review), and genetic analysis (Gaos et al., 2017; Zuñiga and Espinosa, 2017; Gaos et al., 2018). These collaborative studies over the past decade have greatly increased our knowledge on this population. The pivotal finding is that mangrove estuaries are an important habitat for nesting and foraging adults, with two mangrove estuaries emerging as the primary rookeries for this population (>70% of the ~800 nesting females) that ranges from Mexico to Peru: Bahía de Jiquilisco, El Salvador (Bahía) and Estero Padre Ramos, Nicaragua (EPR). However, prior to this dissertation, it was unknown how EP hawksbills utilize these two mangrove estuaries during other life history stages. This data gap, discovering locations of key foraging habitats, and

finding connections among rookeries and foraging grounds, if any, are top global priorities for sea turtle research (Hamann et al., 2010; Rees et al., 2016). Additionally, these tasks are highlighted as important avenues for hawksbill research in the most recent 5-year species review (Tasks 121 & 217; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). In the 5-year species review, there is also a direct call to identify the oceanic developmental habitat of hawksbills, as well as when they recruit to neritic waters (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). Identifying the important habitat for species conservation is crucial, especially for uniquely behaving populations like the EP hawksbills. However, we could still be looking for them in the wrong places.

In this dissertation, we start by engaging with local fishers to reveal their FEK and create baseline data on EP hawksbills so we know we are looking for them in the right places. Based on FEK, we explored the possibility that Bahía and EPR were important habitats for hawksbills of multiple size-classes, with some hawksbills exhibiting an estuarine residency. We investigated EP hawksbill habitat use through a social-ecological systems approach integrating FEK and stable isotope analysis (SIA). Through this approach, we have identified immature EP hawksbill developmental habitat, at what point they recruit to this developmental habitat, and the connection between this habitat and the region's two primary rookeries: they are one in the same. Throughout this dissertation we classified immature sea turtles as defined in Wildermann et al. (2018): "individuals that have recently transitioned to developmental and/or foraging habitats until they reach sexual maturity". In our case, this includes EP hawksbills that range from 30cm curved carapace length (CCL, cm) – 65cm CCL, as Liles et al. (2015b) reported that the mean CCL of nesting turtles at these two rookeries is 82.6cm (range 68–98cm CCL).

In Chapter 1, we describe in detail the theoretical background that we ground our social science work in, with a focus on participatory action research (PAR). We demonstrate how we integrate the concept of voice into participatory action research, inviting fishers to share their expert FEK on the habitat use of EP hawksbills. Through informant directed, semi-structured interviews with 68 fishers (n=38 Bahía; n= 30 EPR), fishers created the first-ever detailed habitat-

use map of this at-risk population, invented a new method for natural science sample collection (further defined in Chapter 2), and suggest a novel life history theory for this species. More broadly, we demonstrate four advantages to granting voice and creating an equal collaboration with local stakeholders: 1) provides locality-specific information, 2) enhances mutual learning and leadership, 3) incorporates local experience, knowledge, and creativity, and 4) encourages local participation and commitment to the conservation challenge. As mentioned, Chapter 2 expands on advantage three listed above. In that methods chapter, we explain a new method for obtaining carapace samples from marine turtles.

Chapter 3 integrates SIA and FEK to provide quantitative and qualitative data supporting an estuarine developmental phase of EP hawksbills. Through bulk-tissue carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of hawksbill skin tissue (N=388, n=224 Bahía, n=164 EPR) and scute tissue (N=17, n=07 Bahía, n=7 EPR), our data show that at ~37cm CCL, immature hawksbills recruit in from pelagic waters to their respective mangrove estuary, and as they continue to grow, their reliance on estuarine resources increases until adulthood. The data from SIA and FEK are consistent; both support an estuarine developmental phase and food availability as a possible mechanism driving hawksbill habitat use in this region.

Chapter 4 explores a thematic analysis of the 62 recorded interviews. Through this process four themes emerged from the FEK, which we reframed as four research questions: (1) Are immature hawksbills the most commonly found sizes in both estuaries? (2) Are hawksbills found in estuary waters year-round, rather than just during nesting season? (3) Do food, safety, environmental factors, and "happiness" drive habitat use? (4) Do the youngest sea turtle life stages stay within the estuaries after a hatchling release? These questions and their related FEK provide deep insight into how hawksbills utilize their mangrove estuary habitats. FEK provided here offers support to the previous chapters, as well as work done by colleagues in the region. It also provides specific suggestions for future research in the region.

While this dissertation used EP hawksbills as a case study, the methods explained throughout have broader impacts. Through the integration of the social and natural sciences, we

support the calls to integrate the social sciences in conservation (Rees et al., 2016; Bennett et al., 2017; Teel et al., 2018). Specifically, we highlight the depth and value of collaborating with locals and to incorporate FEK in conservation work (Johannes et al., 2000; Haggan et al., 2007). Our social-ecological approach enhances the commitment to the conservation challenge from our FEK collaborators (Chapter 1), leads to the invention of methods (Chapter 2), revealed revolutionary information about these turtles (Chapters 1, 3, 4), and provides directions for future work in this region (Chapter 4). González-Solís

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Chapter 1: Participatory action research for endangered species conservation: Four advantages to engaging fishers' ecological knowledge

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Participatory action research for endangered species conservation: Four advantages to engaging fishers' ecological knowledge

ABSTRACT

Integrating the social sciences in conservation can provide unique insights to a conservation challenge. When baseline data of a vulnerable wildlife population is deficient, social science methods can help fill these critical data gaps. In this study, we integrate social science principles and grounded methodology to generate baseline data on in-water habitat use of critically endangered hawksbill sea turtles (*Eretmochelys imbricata)* and to build mutually beneficial relationships with local stakeholders. Local stakeholders, in this study referred to as fishers, hold expert knowledge they have acquired both experientially and culturally. We integrated the concept of voice into participatory action research (PAR) that invited stakeholders to use their fishers' ecological knowledge (FEK) to enhance conservation of this at-risk species. Our results demonstrate that in addition to producing quantifiable data (e.g., turtle habitat use), there are four advantages to employing PAR to incorporate FEK: 1) provides locality-specific information, 2) enhances mutual learning and leadership, 3) incorporates local experience, knowledge, and creativity, and 4) encourages local participation and commitment to the conservation challenge.

Keywords: Conservation, sea turtles, voice, participatory modeling, habitat use, mangrove estuary

INTRODUCTION

In the Anthropocene, people are increasingly recognized as crucial to conservation (Palsson et al., 2013; Virapongse et al., 2016; Bennett et al., 2017; Ban et al., 2018). For example, many conservation issues involve competition for scarce resources between an endangered species and subsistence/traditional harvesters (e.g. Bulbeck and Bowdler, 2008; Rioux et al., 2012; Liles et al., 2015a), human-generated pollution that harms wildlife and human health (Venter, 2006; Vegter et al., 2014; Schuyler et al., 2015; Wedemeyer-Strombel et al., 2015), among others (Brashares, 2004; Ohl-Schacherer et al., 2007; Lewison et al., 2014; Banerjee, 2016; von Essen et

al., 2016; Regehr et al., 2017; Silvy et al., 2018; Barrios-Garrido et al., 2019). In the European Union and United States, government regulatory agencies responsible for evaluation and enforcement of laws protecting at-risk species and ecosystems are required to engage with local stakeholders, but often do so with reluctance as the process becomes complicated and additional conflict surfaces when trying to reach common ground (Peterson and Horton, 1995; Clarke and Peterson, 2015). International environmental non-governmental organizations (ENGOs) and conservation scientists often face similar struggles when working in low-income regions (i.e., developing countries). While not necessarily a legal requirement, the meaningful participation of local people has proven to be critical for the sustainable success of conservation initiatives (Drew and Henne, 2006; Schafer and Reis, 2008; Liles et al., 2015a).

Although natural scientists increasingly engage with local community members to improve implementation of conservation initiatives, they rarely engage with local people to generate baseline knowledge upon which to build these science and conservation efforts (Drew, 2005; Hind, 2014; Bennett et al., 2017). Lack of baseline data for a population or species of concern offers especially troubling problems, and often leads natural scientists to base their recommendations on data that were collected in other locations and developed for related, but not the same, species (Schafer and Reis, 2008; Liles et al., 2015b). Building effective management plans that enable conservation of at-risk species, however, is difficult without data regarding the target population and species (Fraser et al., 2006; Schafer and Reis, 2008; Seminoff and Shanker, 2008; Wallace et al., 2010; Liles et al., 2015b). One option to create baseline knowledge in these situations is to employ local knowledge to generate baseline data (Johannes et al., 2000; Fraser et al., 2006; Schafer and Reis, 2008).

Two recent review papers (Rees et al., 2016; Bennett et al., 2017) call on conservation scientists to work with social scientists to engage local human populations in management, and numerous reviews have highlighted the value of local knowledge garnered via social science methods (for examples, see Johannes et al., 2000; Drew, 2005; Hind, 2014). They point out that, to benefit from the full potential of local knowledge, scientists must open their minds and research

to other knowledge cultures and approaches (Hind, 2014), a challenging hurdle (Bennett et al., 2017). One difficulty may be that traditional and local ecological knowledge often are seen as merely anecdotal by biologists, even though its value is acknowledged in the fisheries conflict literature (Pauly, 1995; Sáenz-Arroyo et al., 2005; Gaos et al., 2010; Gaos and Yañez, 2012; Liles et al., 2015a), and revered in disciplines such as history and oceanography (Pauly, 1995; Sáenz-Arroyo et al., 2005).

Ignoring this expert local knowledge has been detrimental to conservation on multiple scales (reviewed in Johannes et al., 2000; Drew, 2005; Hind, 2014). For example, from the 1960s through 2008, conservation scientists and international ENGOs appeared to have largely dismissed local knowledge as anecdotal in the case of eastern Pacific (EP) hawksbill sea turtle (*Eretmochelys imbricata*). They thought EP hawksbills were ecologically extirpated, assuming local fisherman were mistakenly identifying green sea turtles (*Chelonia mydas*) as hawksbills (Gaos and Yañez, 2012). In 2008, conservation scientists heeded the advice of local fishermen, and re-discovered this population nesting on the shores in mangrove estuaries (Vásquez and Liles, 2008) – a natural history that is unusual for sea turtles worldwide (Gaos et al., 2012b; Seminoff et al., 2012). Conservation scientists now acknowledge that greater than 70% of the approximately 700 nesting females in this population, which ranges from Mexico through Peru, nest on the shores within *Bahía de Jiquilisco*, El Salvador (Bahía) and *Estero Padre Ramos*, Nicaragua (EPR) (Liles et al., 2015b; Gaos et al., 2017). Limited satellite tracking studies (Gaos et al., 2012a; Gaos et al., 2012b; Gaos et al., 2012c), and genetic analysis (Gaos et al., 2018) demonstrate that adults also forage in these mangrove estuaries, but we know neither the extent, nor how EP hawksbills utilize these habitats across multiple life stages.

In an attempt to answer these questions, we employed participatory action research (PAR) to generate baseline information that may enhance conservation of this critically endangered species (Fals-Borda, 1987; Johannes et al., 2000; Wadsworth, 2006). Our results demonstrate that fishers' ecological knowledge (FEK) can provide significant amounts of high quality data that improve the efficiency of developing appropriate conservation plans and future research, which is

especially important for at-risk species. Our analysis further suggests that this approach to gathering baseline data can be extended beyond fishers, to include other subsistence/traditional harvesters. Specifically, we combined informant-directed semi-structured interviews and participatory modeling to develop the first detailed in-estuary habitat use map for critically endangered EP hawksbill turtles. We demonstrate that by integrating social science principles and grounded methodology, conservation scientists can increase their knowledge base, while creating a mutually beneficial relationship with local people (Drew, 2005). Based on this case study and insights from others (Greenwood et al., 1993; Kapoor, 2001; Drew, 2005), we conclude that employing PAR to incorporate FEK has four major advantages: Doing so 1) provides locality-specific information, 2) enhances mutual learning and leadership, 3) incorporates local experience, knowledge, and creativity, and 4) encourages local participation, ownership, and commitment to the conservation challenge.

THEORETICAL PERSPECTIVE

Fishers' ecological knowledge

Local expert knowledge is often classified as traditional ecological knowledge (TEK) or local experiential knowledge (LEK). These terms are often used interchangeably (Turvey et al., 2014). Turvey et al. (2014) makes an important distinction between the two, however, defining LEK as "experiential knowledge derived from lived interactions with the local environment, and able to provide information about the contemporary status of target species and ecological resources" (P. 189) and TEK as, "representing the cumulative body of ecological knowledge and belief passed down between generations by cultural transmission" (P. 189). When interacting with local resource users, such as fishers, local knowledge may be a combination of TEK and LEK, with the expert knowledge of local resource users being the product of both information passed down through generations, and that obtained through personal experiences. Drew (2005) dissected TEK to include both experiential and generational knowledge, while Johannes et al. (2000), who also studied marine systems, combined TEK and LEK to create FEK. Analogously, attempts to discover knowledge of local resource users in studies focused on terrestrial ecosystems might have

used terms such as Ranchers' or Hunters' Ecological Knowledge. We too refer to the knowledge of local resource users as FEK, as it is both more particular and more general than TEK or LEK: more particular in that it targets people working within a particular profession in a specific part of an ecosystem, and more general in that it combines both methods of knowledge acquisition (i.e., TEK and LEK).

Acknowledging the value of FEK is only one aspect of PAR. Finding ways to incorporate this knowledge into conservation action respectfully and effectively requires professional researchers to step outside their formalized concept of expertise, and recognize that expertise is not limited to those who are academically trained. As Peterson and Horton (1995) note, professional researchers and local resource users can build a foundation of mutual respect to encourage collaborative development of information on which to inform research and, later, management practices.

Participatory action research

Participatory approaches to research require a highly collaborative process where professional researchers relinquish their authority as principle investigator, and both conceptualization and execution of the research is shared between professional researchers and local participants (Greenwood et al., 1993; Johannes et al., 2000; Wadsworth, 2006). It acknowledges there are at least two world views at hand, with professional researchers and local participants working towards a shared goal (Fals-Borda, 1987). Other studies have successfully used PAR and participatory modeling to incorporate FEK, primarily in the fisheries management literature (Close and Hall, 2006; Riolo, 2006; Schafer and Reis, 2008). To achieve full participation, the professional researcher/local participant relationship must be shifted, and framed as subject/subject, rather than the more traditional subject/object (Greenwood et al., 1993). Dissolving traditionally asymmetric relations into a joint effort enables a situation where "… academic knowledge plus popular knowledge and wisdom may give as a result a total scientific knowledge of a revolutionary nature…" (Fals-Borda, 1987, P. 332). To achieve this equality, it is important that participants realize their knowledge is validated and respected.

Trinity of voice

Senecah (2004) suggests one way to indicate that their knowledge is respected, and to build stronger relationships with local participants, is by affording them opportunities to experience access, standing, and influence on conservation. She combines access, standing, and influence as a trinity of voice (TOV), which helps build and maintain trust between professional researchers and participants (Senecah, 2004). Access is provided via multiple pathways, including demonstrated consideration for the participants' schedule and comfort when choosing times and locations for gatherings, and use of accessible language in informational materials (Senecah, 2004). Conservationists can demonstrate that local participants have standing by engaging in active listening and mutual learning, which requires that the research effort include varied opportunities for dialogue (Senecah, 2004). Access and standing together are required to produce influence, where participants' inclusion is more than a formality, and decisions indicate that local expertise has been fully acknowledged and respected (Senecah, 2004).

In addition to building trust between researcher and participant, TOV can help transform the personal identities of participants from resource users to resource experts. For example, Horton et al. (2016) discuss how role-based identities are shaped by multiple communicators in an interaction. This is further supported by Greenwood et al.'s (1993), claim that "…incorporating organization members and the extensive local knowledge they have in the research process results in the development of their own roles and stakes in the research process and outcomes" (P.178). Through researchers' acknowledgment of participants' expertise, the participants may begin to see themselves as expert conservationists.

METHODS AND RESULTS: INTEGRATING TRINITY OF VOICE INTO PARTICIPATORY ACTION RESEARCH

Because PAR is an emergent process that must develop rather than be forced or assumed a priori (Greenwood et al., 1993), we attempted to create a highly-collaborative process whereby mutual respect and knowledge exchange encouraged full participation by informants, allowing FEK to emerge as a central component of the research. To encourage FEK to emerge, we

conducted informant directed semi-structured interviews (McCracken, 1988; Peterson et al., 1994) and aimed to grant TOV throughout each interaction.

Informant directed interviews

Over the past several years, we developed a collaborative relationship with local residents. Five authors (KRWS, MJL, NRS, SC, MV) conducted the interviews 7 May – 8 June 2016 in fishing communities surrounding Bahía (13°13’N, 88°32’W) and EPR (12°48’N, 87°28’W). Interviewees were identified through connections through the local hawksbill conservation network, forged by the Eastern Pacific Hawksbill Initiative (ICAPO, in Spanish), Asociación ProCosta, and Flora and Fauna International, and supplemented with snow-ball sampling ***(Goodman, 1961)***. Authors NRS, SC, and MV are Salvadorans who have lived and worked with the communities in Bahía for a combined total of 36 years; NRS is native to one of the Bahía communities; EA worked for seven years within the EPR community, KRWS spent two weeks living in the communities prior to the interviews, and MJL has lived in Salvadoran communities and worked with residents of both locations for 10 years.

Interviews were conducted in Spanish and followed McCracken’s (1988) long form interview, and were conducted as informant-directed semi-structured interviews, as described in Peterson et al. (1994). We began with generalized questions, encouraged continued discourse with “floating prompts” (e.g., head nods), and ended with a planned prompt, where we provided a map of the informants’ local mangrove estuary to facilitate participatory modeling (McCracken, 1988; Peterson et al., 1994; Yearly et al., 2003). To ensure anonymity, interview citation formatting in this manuscript is adapted from (Horton et al., 2016).

Participatory modeling activity

We employed participatory modeling to produce spatial representations of FEK regarding habitat use by hawksbills within Bahía and EPR (Yearly et al., 2003; Close and Hall, 2006; Riolo, 2006). Participatory modeling uses individual mapping exercises to capture local expert knowledge, where resource users are considered technical experts (Yearly et al., 2003), as their lives and livelihoods revolve around marine resources, including hawksbill sea turtles (Liles et al.,

2015a). Participatory modeling can be used to generate knowledge and to assure the quality of knowledge; here we use it to generate baseline data regarding the in-water habitat use by EP hawksbills throughout their growth and development in Bahía and EPR.

We provided informants with a basic map of their local mangrove estuary. We oriented informants to where we were located on the map by pointing out key landmarks. We then asked each informant to label on the map where within the estuary, or in the open-coast ocean waters, they see hawksbill turtles of various sizes (Figure 1.1). For each interview, a new blank map was used, with an exception of two interviews in Bahía, due to extra interview opportunities arising without extra maps on hand. When asking informants to mark the map, we reminded them that we were only interested in hawksbills in the water, not hawksbills nesting on beaches nor any other turtle species. We prompted informants, as needed, by asking questions such as, "where do you fish", "when you are there fishing, do you see turtles," how many, how often, what size."

To ensure that size categories of hawksbills were referred to consistently across interviews, we provided five cardboard cutouts of hawksbill turtle silhouettes, each labeled with a different letter (A–E). The sizes of the cutouts approximated five size classes and life history stages of hawksbill turtles, and represent the curved length of their dorsal shell, from the top of the shell to the point above the tail. The cutouts were as follows: A ≈ hatchling (4cm), B ≈ yearling (15cm), C ≈ juvenile (30cm), D ≈ sub-adult (65cm), E ≈ nesting adult (84cm; Figure 1.2). When informants talked about seeing turtles in a particular location, we asked them to select the cutout that was closest in size to the turtles they had seen. We directed them to the cardboard cutouts to clarify which sizes they were referring to if they used general statements like, "we'd see small turtles". Participatory modeling was completed when informants indicated they had marked all areas on the map where they observe hawksbills in the water.

(A)

(B)

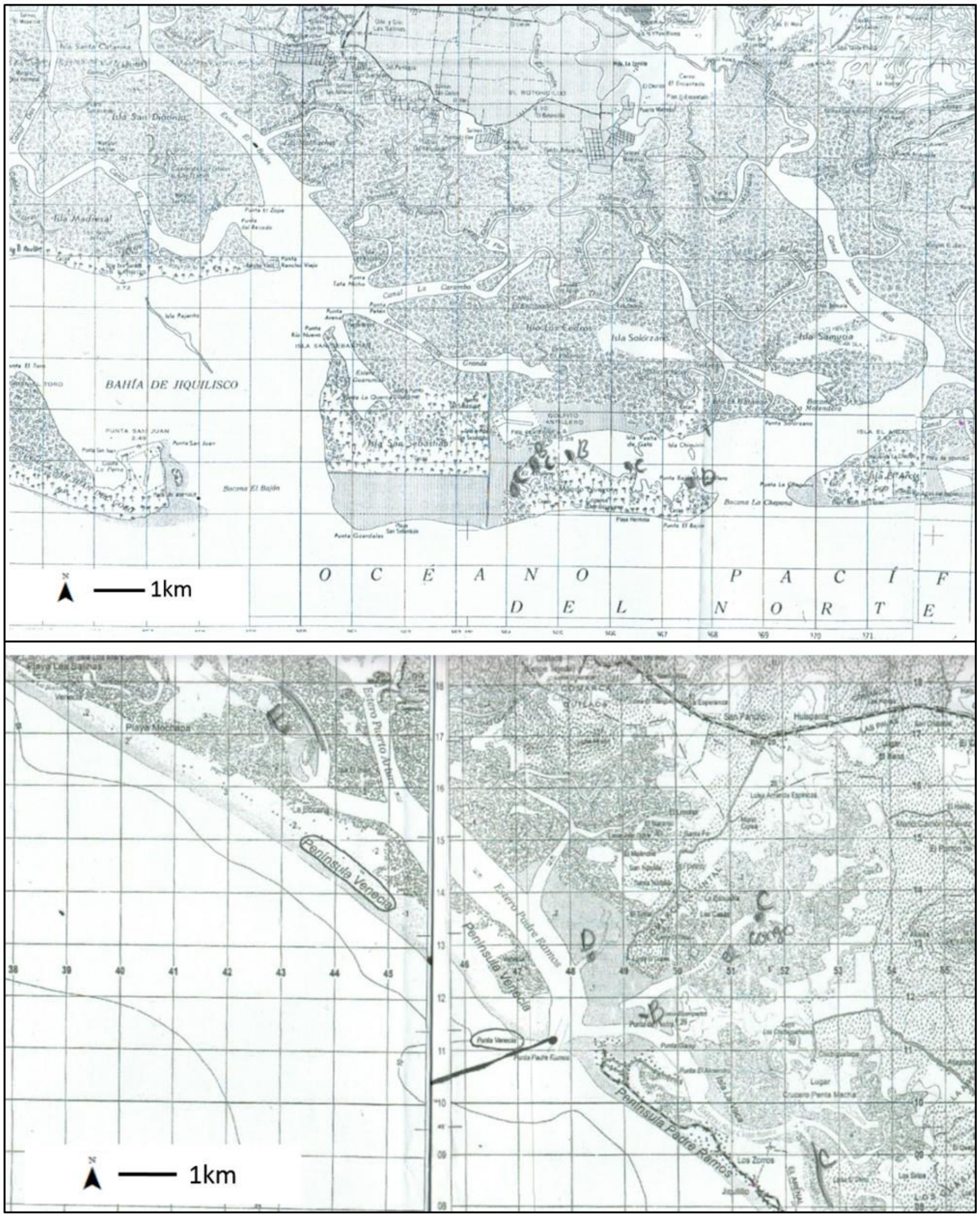

Figure 1.1: Participatory modeling exercise results for individual interviews.

Participatory modeling exercise results for individual interviews: **(A)** Interview 024 in Bahía, and **(B)** interview 063 in EPR. Dots and lines drawn in by informants indicate where they have seen hawksbill turtles in the water (as opposed to nesting), and letters refer to the size class of hawksbills seen at indicated points. Letters refer to the cardboard cutouts that were provided to create consistency when referencing size.

Figure 1.2: Collaborative map making.

RNS (left), a fisher (middle), and KRWS (right) work together on the participatory modeling activity. RNS and a fisher are marking on the map where hawksbill turtles have been seen within the estuary waters. Cardboard cutouts pictured from right to left are: A, hatchling, 4cm CCL; B, yearling, 15cm CCL; C, juvenile, 30cm CCL; D, subadult, 65cm CCL; E, nesting adult, 84cm CCL. Written informed consent was obtained from RNS to include this picture in this manuscript.

Oral informed consent was obtained from all study participants. All informants were asked if they consented to participate in the study prior to the start of the interview, and if they consented to voice recording in addition to the interview. We used voice consent because some of our informants were not comfortable with written language. All interviews were conducted in Spanish. At the end of each interview, we collected basic demographic information about the informants. The University of Texas at El Paso Institutional Review Board approved all interview practices (IRBNET ID 896427-1). Informants were not paid to participate, but were offered a snack after the interviews had finished. Interviews were conducted in both Bahía and EPR until saturation of information was reached.

After all participatory modeling was conducted, KRWS scanned a blank map of each estuary, georeferenced it in ArcMap 10.4.1 (ESRI, Redlands, California), and digitized (Bolstad, 2012) each of the interview data points onto the map. She then identified for each interview point which size classes were identified at that point. After all points were entered, she used the "calculate geometry" function to generate latitude and longitude of the points (Figure 1.3).

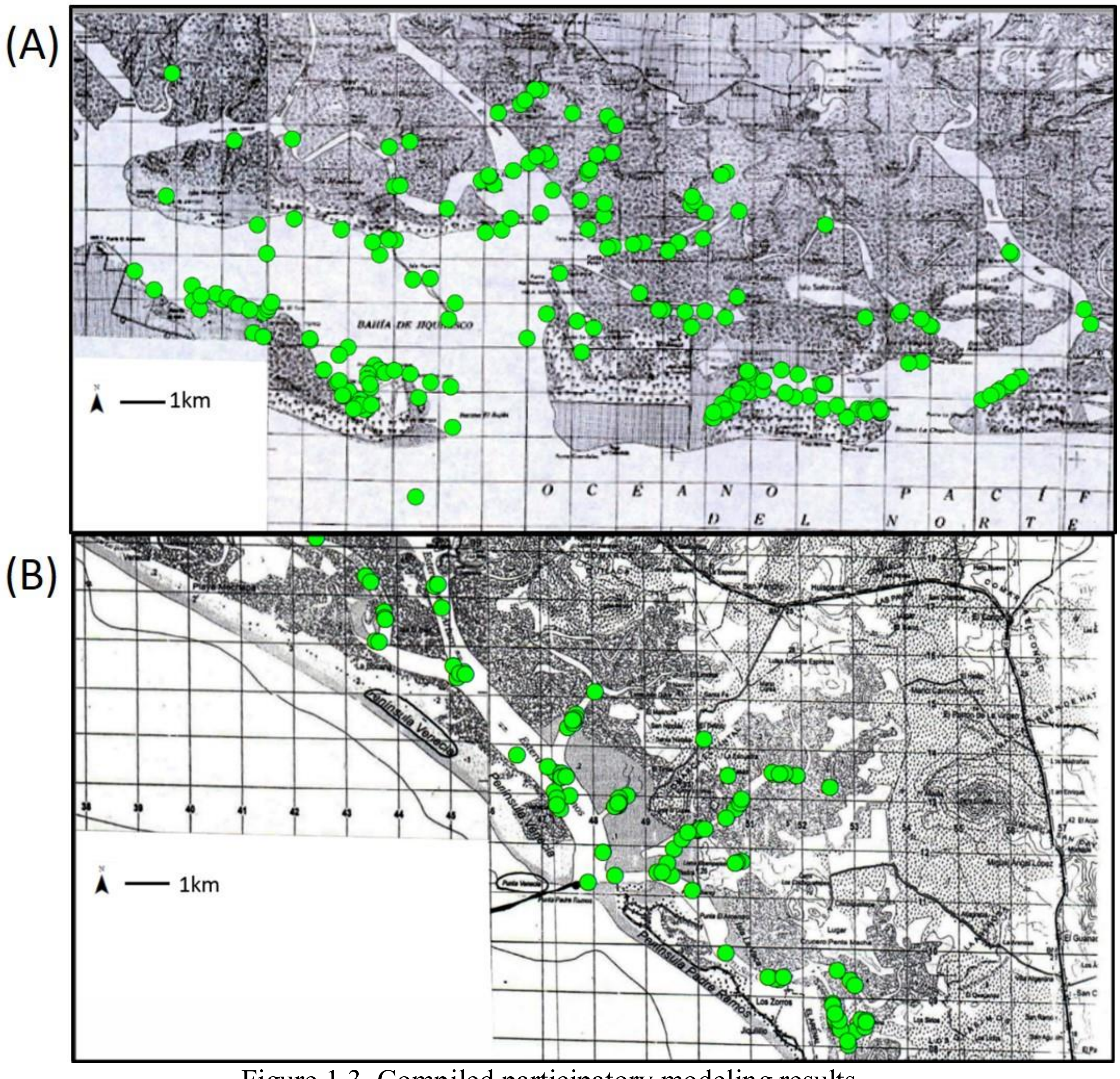

Figure 1.3. Compiled participatory modeling results.

Compiled 301 multidimensional data points from all participatory modeling conducted in **(A)** Bahía (N=38 interviews, 200 data points) and **(B)** EPR (N=30 interviews, 101 data points). Each point represents where a hawksbill turtle has been seen in the water (as opposed to nesting), and each point includes size data of turtles seen at that locality.

Enabling Trinity of Voice

Access: Informants chose where the interviews were conducted to create a relaxed environment where they felt comfortable sharing their knowledge (Senecah, 2004; Liles et al., 2015a). Interviews were ideally conducted with one informant at a time in case some informants would not feel comfortable speaking in front of others (Ferguson and Messier, 1997), but if an informant felt more comfortable being interviewed with another informant, this was permitted. At minimum, two people conducted the interviews, and one of the interviewers was always a respected local community member to the area in which the interview was being conducted (Marín and Marín, 1991). This built trust with the participants and helped create the equal subject/subject dynamic of interviews (Fals-Borda, 1987).

Standing: Before each interview officially started, we explained that we were there to learn from the fishers, that we were interested in understanding their expert knowledge regarding where in the water we can find hawksbill turtles. We emphasized our recognition that, as fishers, they have expert knowledge about their local mangrove estuary and the local hawksbill turtles. As open-ended interviews, the first question was always, "please tell me about your experiences encountering hawksbill turtles in the water within the estuary". We used colloquial words and non-scientific terminology throughout interviews to ensure that the questions were clear. Prior to interviews, all questions were examined by local collaborators to ensure that appropriate terminology was used, and questions were adjusted as necessary for each locality (Marín and Marín, 1991).

Influence: We encouraged informants to exercise influence over the project by asking them to speculate on the significance of their observations, and to propose their own hypotheses on where the turtles go and why. Many of our informants demonstrated awareness of their potential influence by asking follow-up questions about the study, including asking how they could further contribute to the research. The recognition of their own influence enabled us to extend our initial goal of creating baseline ecological data to include additional scientific and conservation benefits, and revealed four major advantages to engaging local experts in all stages of research.

Four major advantages to employing PAR and granting TOV to incorporate FEK

In addition to baseline data generation for this critically endangered species, four major advantages to employing PAR and granting TOV emerged during our study: 1) provides locality-specific information, 2) enhances mutual learning and leadership, 3) Incorporates local experience, knowledge and creativity, and 4) encourages local participation, ownership and commitment to the conservation challenge.

Locality-specific information

Fishers of different kinds (e.g., shellfish fishers, harpoon fishers, single line fishers) from each community fish in different sections of the estuary, and as a result know those areas well. As we wound our ways through the maze of estuaries on the maps provided, they each appeared to know exactly where we were, down to the slightest curve of the channel on the map. In Bahía, we interviewed 38 fishers. The participatory modeling generated 200 points on the Bahía map where they had observed hawksbills. In EPR we interviewed 30 fishers, generating 101 points where they had observed hawksbills. Each data point signifies at least one individual hawksbill turtle. Thus, we generated the first detailed habitat use maps for EP hawksbills near their two primary rookeries (Figure 3). All five size classes of hawksbills were indicated on maps, with some locations hosting multiple hawksbill size classes.

Enhancing mutual learning and leadership

Most fishers were generous with their time and were open to sharing their knowledge. Only one fisher declined our invitation to talk because he was in the middle of re-roofing his house (KRWS, *personal observation)*. One fisher was waved down as he was driving by on the back of a friend's motorcycle, and the interview was conducted on the side of a dirt road, near an angry bull. His friend came back to pick him up after the interview was over and they drove off (KRWS field notes, 6/4/16). During a few interviews, fishers explicitly commented on the mutual learning generated through the project. For example,

> …and of the hawksbill, well (laughter), what I can do is learn with all of you. But we do [collaborate]. We are trying [fighting]. Because that is the point, to learn from one another. (Responses B013.09–.12)

Another stated:

> That's why I tell you that each one of us [fishers] has their own point of view...to collect a little bit from each one and we are going to get something from everyone…we are going to reach a conclusion when you work as a team….we are here to help. (Responses O032.05–.08)

Fishers' use of phrases such as "when you work as a team", and "lean with all of you", illustrate their sense of influence over the project.

Throughout the interview process, leaders emerged within each of the local communities. In El Salvador, the same local fishers accompanied KRWS for most interviews, while in Nicaragua the local collaborator changed depending on the community. In both cases, the local collaborators identified whom we should talk with, and facilitated introductions between KRWS and informants. New local collaborators who assisted with interviews were interviewed prior to assisting to minimize bias that could be developed after witnessing others' interviews. These local collaborators were able to showcase their knowledge of their local estuary, hawksbill turtles, and their connections within their communities. As the interviews progressed, local collaborators gradually began taking greater initiative within the interview process. For example, they clarified questions the informants had without asking for permission to do so, and pointed out estuary landmarks on the map to help orient informants. When walking between interviews they would chat with KRWS about life in their towns, about the hawksbill turtles, and began to postulate their own hypotheses about hawksbill turtle life history based on personal experience, knowledge acquired through the interviews, and ideas generated during conversations with KRWS (KRWS

field notes, May 2016). Through these knowledge exchanges, KRWS and local collaborators learned to challenge what they had previously thought about hawksbill habitat use and to approach the research question in novel ways.

In Nicaragua, one local fisher accompanied KRWS on all interviews throughout one of the communities. Because of the equal-collaborator relationship that was built, when KRWS returned for follow-up in-water capture fieldwork months later, the same fisher immediately took initiative on this next phase of the project, and quickly became the project co-leader once again (KRWS field notes, Nov. 2016).

Incorporating local experience, knowledge, and creativity

The *invention* of a tool designed for collecting sea turtle samples for a related project illustrates the importance of harnessing local experience, knowledge, and creativity. The data points this study provided baseline data for a follow-up in-water capture study. As we were compiling the information from our interviews in El Salvador, our field team, comprised mostly of locals to the area, were testing hawksbill turtle sampling techniques for the next part of our study. We realized immediately that the standard plastic tool used to take the samples we needed would not work on EP hawksbills, as their shells are much denser than other populations and species (personal observations). We shopped around for a tool that would work with no success. Then, one collaborator based in the United States suggested we use a power drill with a diamond coated core drill bit, and one of these was flown to El Salvador from the United States. However, that was also unsuccessful. After several days of troubleshooting, the local ProCosta field coordinator in El Salvador, RNS, asked for one of the original plastic tools so he could think further about it. The next day he came back and said he knew a man on the mainland who could likely forge a custom tool for us to attach to the power drill. Two days later, we had a made-to-order tool. The non-local authors agree we would not have thought of this solution ourselves. RNS was intrigued by the question, and took it upon himself to solve the problem. This new tool (described further in chapter 2), which we named a "Broca Nefta" after its creator RNS, was later successfully duplicated and used to take samples from hawksbills in Bahía and EPR. Not only did this tool

allow us to take the needed samples, it also helped reduce the amount of trash we generated while conducting the research using disposable biopsy punches, which is especially important in remote locations.

Encouraging local participation, ownership and commitment to the conservation challenge

One of the questions we asked in the interviews was: "Do you see hatchlings in the estuary?" Many said no, but also indicated their belief that at least some of the hatchlings remain within the estuaries throughout their lives. In these cases we followed up with: "If we don't see hatchlings after they are released, then where are they? Where do they go?" On several occasions, local fishers were as perplexed by this question as we were, and many said they had not thought about it before (KRWS field notes, May 2016). After some thought, several mentioned the tides could be pulling the hatchlings deep into the mangroves, which is why they did not see them. Others suggested that the tides serve an opposite purpose, pulling at least some of the hatchlings out into the open ocean. Others postulated that food and protection kept the hawksbills in the estuary (e.g. interviews 001, 007, 031, 039, 045).

A few fishers voluntarily added on their commitment to the conservation challenge. For example, at the end of one interview, when KRWS was thanking an informant, the fisher explained:

> But to say it that way; everyone is conscious about what they do [in regards to the turtles] but it is the need of the people that results in the egg going to market when there are no projects. Right; sadly and thanks to the institutions [conservation projects] that in that respect, they are helping a lot and I am one of those that likes to help sometimes. Because to be honest that is not my job. But I do like to help because when one of those projects comes to our community we must appreciate it. (Responses F013.11–.14)
>
> [KRWS] Thank you for everything that –

> [Fisher interrupts KRWS], No, thank you because that's how you learn right, that's how you learn from one another, we all learn. (Response F013.15).

Another informant shared the importance of preserving the turtles for future generations:

> And at least there is a chance that in the time that the kids grow up they will be able to see that turtle and they will say it was good what my parents did or what the others did. Because I think that the parents sometimes, even if all of us are not going around working there, but if we provide the support to the kids that work there and we tell our kids: look you are going to go fish but don't touch the little eggs that are laying there. You are going to go to work but you will not take a Hawksbill out and if you find one its better if you turn it in to a hatchery. (Response A043.38–.40).

In addition to information gleaned directly from the interviews, at the end of each interview day, the local experts who accompanied KRWS to help build trust with community members, and to aid in clarifying questions and colloquial terms during the interviews, shared their own theories about where hatchlings go and why, without being prompted or formally interviewed. After interviews were complete, KRWS returned to the field four months later for follow-up in-water capture studies. One Salvadoran fisher who had accompanied her on several interviews said that because of our interviews, he had become curious to figure out where the small turtles were in the estuary. In the five months between the first and second field visits, he took it upon himself to go out and look for small hawksbills on his own. He reported that on one occasion he did see one hawksbill between sizes B (15cm) and C (30cm), did not have a proper net to catch it, but that he would like to continue searching, because it does not make sense to him that we do not see them more often (KRWS field notes, Oct. 2016). As a community leader and lead collaborator with ProCosta, he has all the training and necessary permits to handle hawksbills for research purposes.

Discussion

In this study, we demonstrate a way to strengthen a PAR framework by focusing on TOV among local experts. In this setting, researchers can respectfully collaborate with local experts to incorporate FEK into the knowledge base for future conservation initiatives. Our results support the insights of Greenwood et al. (1993); Kapoor (2001); and Drew (2005). Greenwood et al. (1993) explicitly points out that, "participatory action research enhances problem formulation, hypothesis formulation, data acquisition, data analysis, synthesis, and application" (p. 177). Data from this PAR project, for example, have provided crucial baseline information for the conservation of a critically endangered species. Further, the project indicates four major advantages to employing PAR and granting TOV: 1) provides locality-specific information, 2) enhances mutual learning and leadership, 3) Incorporates local experience, knowledge and creativity, and 4) encourages local participation, ownership and commitment to the conservation challenge.

The baseline data provided by FEK suggests a narrative describing a novel life history strategy of EP hawksbill turtles, as mangrove estuary residents. This idea, which has only one previous mention in the professional literature (Fryer, 1911), has been disregarded throughout subsequent sea turtle academic literature as merely anecdotal. As such, the original citation (Fryer, 1911) is mentioned briefly in Witzell (1983), which is then cited in The Biology of Sea Turtles Vol 1. (Lutz and Musick, 1997, P. 152), but is left out as a possible life history strategy in the two subsequent volumes of The Biology of Sea Turtles (Lutz et al., 2002; Wyneken et al., 2013). Vol 2 includes a full chapter on life history patterns and variations, but does not include the mangrove estuary resident (Bolten, 2003). Thus far, this study has led to a new problem and hypothesis formulation (i.e. life history strategy of EP hawksbills), novel data acquisition (i.e. baseline habitat use maps), the basis for a capture inventory of EP hawksbills and stable isotope analysis (*in prep*). All of which may contribute to improved conservation initiatives that benefit both the informants (Liles et al., 2015a), and the EP hawksbills with whom they share critical habitat.

This project demonstrates that knowledge gained via PAR is multidimensional and more than just a point on a map. In this example, it provided information not only about where animals

are, but how many are seen in certain areas, seasonality influences, and other environmental factors that are witnessed throughout years on the water, (Schafer and Reis, 2008). Schafer and Reis (2008) gleaned 124 fishing areas through FEK, more than 80% of which were known only to local fishers and previously unknown to researchers. In our study, only some of the identified areas were known to biologists working in the area as hawksbill habitat, and some locations were new to the local fishers aiding in our interviews.

In a recent review regarding incorporating social sciences in conservation, Bennett et al. (2017) note that when financial resources are limited, natural science budgets are often prioritized. However, our study and several others (Close and Hall, 2006; Fraser et al., 2006; Riolo, 2006; Schafer and Reis, 2008) demonstrate that much is to be gained for conservation science through social science methods, particularly when resources such as time and funding are limited. For example, the cost of interviews, including travel to and from the field sites and room and board for KRWS, was $4,046. Previously, satellite tracking studies were able to track 16 adult female turtles over a span of 2 years (Gaos et al., 2012a; Gaos et al., 2012b; Gaos et al., 2012c), which gave important insight into hawksbill habitat by providing 2,981 location points; however, these efforts address only a small number of turtles and life-history stages. Further, satellite tracking costs range from $1,200–$5,000 per tag and about $300–$1500 for ARGOS time, not including travel to and from the field site, cost to capture turtles, and apply the tags. We recognize the numbers provided here are limited to data collection, and do not include costs for analysis, which is required in both social and natural science research. While satellite tracking effectively generates numerous locations on individual turtles, when time and funding are limited, it is impractical to track large numbers of turtles in all age classes.

We are not suggesting discontinuing satellite tracking or other traditional natural science methods, as each approach provides important perspectives to conservation questions. Instead, we argue more robust data could be obtained by conducting social science research grounded in a PAR framework, particularly in areas where habitat of the species being studied and human

presence overlap. Further, collaborative social science could be the first step towards identifying baseline information to guide further natural science studies.

Our approach to developing an equal collaboration with local fishers highlights the value of localized information, mutual learning, leadership, and creativity, and demonstrates how PAR can both disclose and further strengthen the commitment of fishers to conservation goals. We also recognize that collaborative relationships such as those described herein depend largely on groundwork such as that conducted by colleagues over at least a decade (Vásquez and Liles, 2008; Gaos et al., 2010; Gaos and Yañez, 2012; Liles et al., 2015a).

Conclusions and conservation implications

A 2010 review of the global priorities of sea turtle research included a call for future studies to go beyond mark-recapture and satellite telemetry to understand spatial ecology of sea turtles by incorporating multiple approaches such as genetics and stable isotope analysis (SIA) (Hamann et al., 2010). More recently, experts added a call to incorporate local knowledge throughout the research process, from species assessment through management (Rees et al., 2016). Rees et al. (2016) also includes a recommendation for natural scientists to work more closely with social scientists to enhance the conservation impact of their research.

This exploratory study to record the FEK of hawksbill habitat use within local mangrove estuaries produced the first detailed map of EP hawksbill habitat use across all life history stages, from hatchling through adult. This study provides important baseline data, in the form of nominal and geographical identification of hawksbill habitat use as observed by local fishers within Bahía and EPR. Using a PAR framework enabled us to further explore connections identified by Liles et al. (2015a) that extended beyond economic use of hawksbill turtles by local residents to include cultural affinity between turtles and people.

We encourage conservationists to recognize that collaboratively designed social science can create baseline knowledge quickly and efficiently. In addition, developing conservation initiatives without the inclusion of local people can result in push back from the local community, ultimately making the research inefficient and expensive (Schafer and Reis, 2008; Liles et al.,

2015a). Drew and Henne (2006) discuss the value of incorporating the social sciences with the natural sciences for conservation. They note that engaging local community members is highlighted in many case studies, but actual integration of local expertise in the early stages of research is rare (Drew and Henne, 2006). Our paper explains one way to engage local community members in shaping the contours of conservation research, and demonstrates how this approach can be used to generate multidimensional baseline data, as well as encourage critical participation among local residents. It demonstrates the value and depth of local knowledge, the power of social science approaches to conservation, and how if we open our minds and research to other knowledge cultures we can, as Fals-Borda (1987) said, generate knowledge of a revolutionary nature.

CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT:

KRWS conducted all interviews, data analysis, and drafted the manuscript. MJP and SKS provided logistical and writing support. RNS, SC, MV assisted with all interviews conducted in El Salvador. MJL coordinated fieldwork, provided logistical support in the field, and facilitated translation of interviews. CET provided GIS and logistical support. EA, VC provided logistical support in the field. Co-authors contributed to editing the final manuscript.

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Chapter 2: The *Broca Nefta*, a new method for obtaining carapace samples from marine turtles

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The *Broca Nefta*, a new method for obtaining carapace samples from marine turtles

ABSTRACT

A new method is described for taking carapace core samples from cheloniid marine turtles with thick keratin layers (e.g. hawksbill turtles, *Eretmochelys imbricata*). The sample is obtained using a specially designed drill bit, the "*Broca Nefta*", attached to an electric drill to safely and efficiently take 6-mm cores. This method was developed during a study of eastern Pacific (EP) hawksbill turtles for stable isotope analysis after it was determined that study animals' carapace core samples were not possible to collect with traditional plastic biopsy punches. Benefits of this new method include: 1. retrieving even and efficient samples from all turtles, 2. collaborating with locals to create creative solutions to research challenges, and 3. reducing plastic waste when sampling turtles. This method was successfully used on 115 EP hawksbills; the animals were observed to respond to the sampling as they do to traditional biopsy methods, with little apparent stress or discomfort.

Key words: Marine turtles; carapace; scute; stable isotope analysis; sampling

INTRODUCTION

Stable isotope analysis has been widely applied in marine turtle research (reviewed in Jones and Seminoff, 2013). Many studies have focused on sampling soft tissues (Bjorndal and Bolten, 2009; Vander Zanden et al., 2013) and/or egg yolks (e.g. Hatase et al., 2002; Wallace, 2006; Zbinden et al., 2011). Sampling of the carapace allows us to explore multi-year foraging histories of individual sea turtles, providing a longer time-series to compliment those of other tissue types (e.g. Reich et al., 2007; Cardona et al., 2010; Vander Zanden et al., 2010). The traditional method for collecting sea turtle scute samples and our *Broca Nefta* method are compared in Table 2.1.

Our new method follows a similar protocol, but differs in steps three and four (Table 2.1). In step 3, we mark the sampling sites, and thus the dorsal side of the sample, with a red permanent marker prior to sampling; whereas in the traditional method the 'X' is etched in to the dorsal side of the sample after it has been removed from the turtle and biopsy punch. Any residual left from

the permanent marker is removed by lipid extraction during sample preparation. In step 4, we use a reusable metal tool that can be cleaned with alcohol between sampling events. The reusable tool is a custom-made drill bit, the *Broca Nefta,* which is forged to match the dimensions of a plastic biopsy punch and to attach to a battery-powered drill (Figure 2.1), and includes a mark that indicates sample depth.

Table 2.1. Comparison of traditional and *Broca Nefta* scute sampling methods. Shaded boxes highlight differences between methods.

Step	**Traditional Method** (Reich et al. 2007, Reich and Seminoff 2010)	**Broca Nefta Method** (Figures 2.1-2.3)
1	Identify anterior (youngest) and posterior (oldest) sties on the right and left second lateral scutes (n=4 sampling sites)	Identify anterior (youngest) and posterior (oldest) sties on the right and left second lateral scutes (n=4 sampling sites)
2	Remove any mud, barnacles, moss, or other epibiota covering the sampling sites; clean with alcohol	Remove any mud, barnacles, moss, or other epibiota covering the sampling sites; clean with alcohol
3	Use a sterile 6-mm plastic biopsy punch to take a sample at each site; apply pressure to the punch, and listen for a small cracking sound as you cut through the layers of scute	Mark sampling sites with an 'X' with a red permanent marker, thus marking the dorsal side of the sample
4	As each sample is removed, mark its dorsal side with an 'X'; clean off any connective tissue on the ventral surface	Use the *Broca Nefta* to sample at each marked site; drill down slowly until you reach the marked depth, or you feel the sample pull away from the turtle, whichever comes first (Fig. 2.2). Sterilize the *Broca Nefta* between turtles with EtOH
5	Store each sample in a separate, labeled vial or Whirl Pak™ with dry NaCl	Store each sample in a separate, labeled vial or Whirl Pak™ with dry NaCl
6	After all 4 samples are obtained, fill sampling sites with quick-set epoxy to prevent infection and/or colonization by epibionts	After all 4 samples are obtained, fill sampling sites with quick-set epoxy to prevent infection and/or colonization by epibionts (Fig. 2.3)

Figure 2.1 The *Broca Nefta*

The custom-made *Broca Nefta* has a *6*-mm cutting edge (top), and the depth of the core restricts depth of sample. The bottom attaches to a standard electric hand drill. Tape measure shown in cm.

Holding the drill perpendicular to the sample site, simultaneously turn the drill on low while pressing down to cut through the top layer of scute (Figure 2. 2). Once the top layer of scute is breeched, slowly increase the drill speed until the drill reaches the marked depth or you feel the sample pull away from the turtle, whichever happens first. Remove the drill, and use forceps to remove the biopsy punch, then store in individually labeled vial or Whirl Pak™.

Figure 2.2 RNS uses the *Broca Nefta* to collect an EP hawksbill carapace sample

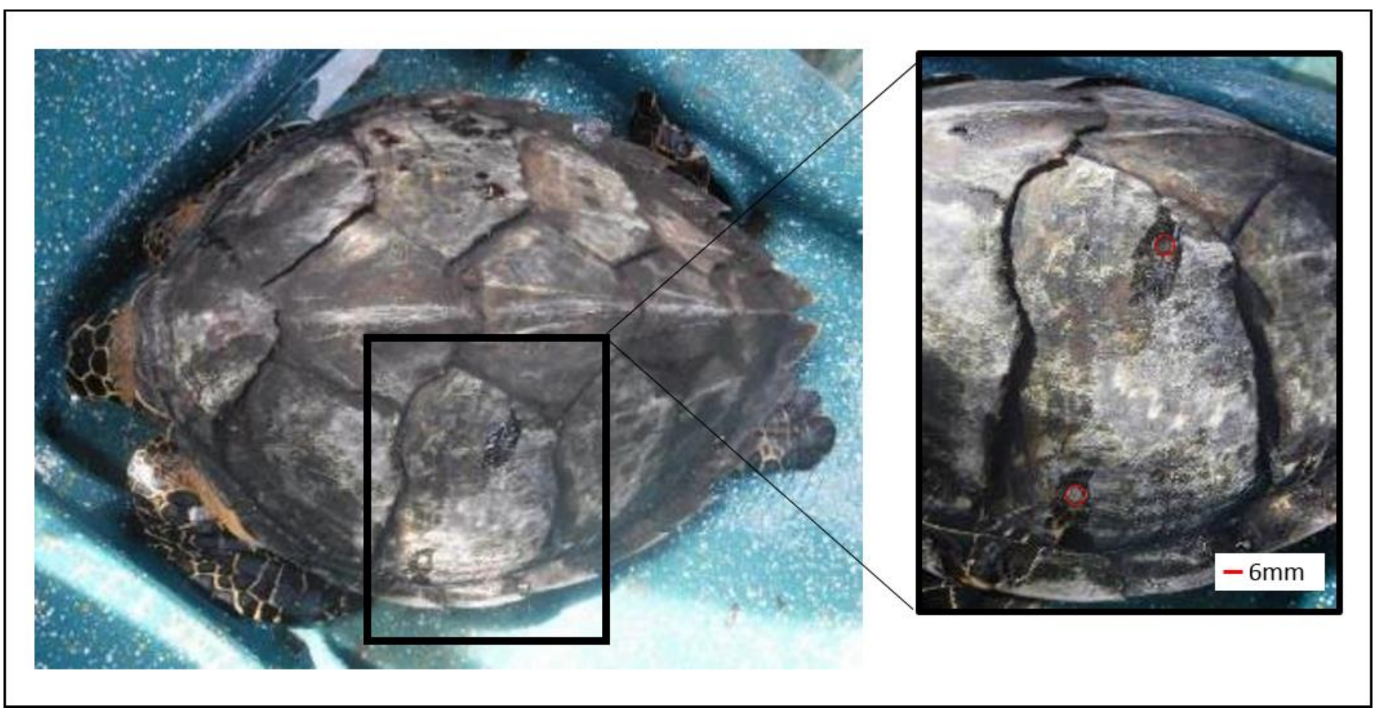

Figure 2.3 Sample sites are filled with quick-dry epoxy prior to turtle release

DISCUSSION

The *Broca Nefta* carapace core sampling technique is an improvement on the traditional plastic biopsy punch coring technique. This tool allows for quicker, more consistent and efficient carapace sampling, especially when working with hawksbills whose carapaces are typically too dense and thick to sample with biopsy punches. This technique can be used for sampling any hard-shelled turtle that possesses a robust keratin layer on its carapace, for softer shelled sea turtles, it could be forged to fit onto the end of a hand-held screwdriver). An added benefit is that it reduces the single use plastic waste generated during sample collection. For stable isotope analysis, tools can be reused and there is no necessity for sterile punches for each turtle, especially when the tool can be wiped clean with alcohol (Reich et al., 2007; Reich and Seminoff, 2010). Sample preparation for analysis is performed the same as in Reich et al. (2007); Reich and Seminoff (2010), and is beyond the scope of this paper. Turtles reacted the same (little noticeable stress) under use of the *Broca Nefta* as they did during our attempts to use the plastic biopsy punches.

Although plastic biopsy punches have thus far been the standard for sea turtle carapace sampling (Reich and Seminoff, 2010), the EP hawksbill carapace surface proved too strong for the plastic biopsies. In some cases, up to 30 plastic biopsy punches were broken in the attempt to take just one carapace sample (K. Wedemeyer-Strombel*, pers. comm.*). In these cases, the short metal cutting edge would bend or become dull quickly, and/or the plastic handle would snap due to the large pressure required to cut through the tough keratinized scute. In an effort to develop a more practical carapace coring technique, the *Broca Nefta* was designed by Ramón "Nefta" Neftali Sánchez of La Pirraya, Bahía de Jiquilisco. In addition to underscoring the value of novel approaches for biopsy sampling, the development of this tool highlights the importance of incorporating fishers' ecological knowledge and collaborating with local experts (e.g. fishers and local conservation program coordinators) to apply creative solutions to research questions and challenges (Chapter 1).

We note that during the development of this sampling too, we also tried using a diamond core bit attached to a power drill; however, this too was not strong enough to breech the EP

hawksbill carapace. These new, custom drill bits, when attached to a battery powered drill easily and efficiently took carapace samples from hawksbills. Two *Broca Neftas* went on to be used to take a total of 460 EP hawksbill samples (four samples per turtle, from 115 turtles), a subset of these samples have been successfully analyzed for stable isotope analysis (Chapter 3).

CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT:

KRWS conducted all interviews, data analysis, and drafted the manuscript. RNS invented the *Broca Nefta*. MJL coordinated fieldwork, provided logistical support in the field. JAS provided logistical support and helped draft the manuscript.

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Chapter 3: Local ecological knowledge and stable isotope analysis confirm that mangrove estuaries are key developmental habitats for critically endangered hawksbill turtles

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ABSTRACT

Effective conservation of endangered, migratory species depends on identification of the habitats used during different life stages. When data are deficient or difficult to acquire, scientists often lean towards familiar quantitative methods rather than relying on local expert knowledge, the latter of which can provide crucial baseline data to guide detailed ecological studies. Through a social-ecological systems approach, we integrated the social (interactive interviews) and natural (population ecology) sciences to test the importance of mangrove estuaries as developmental habitats for critically endangered eastern Pacific (EP) hawksbill sea turtles (*Eretmochelys imbricata*). Our work highlights the effectiveness of a social-ecological systems approach to capture existing knowledge, create testable hypotheses and guide experimental design. Stable isotope data and local ecological data strongly corroborate one another, altering current accepted scientific paradigms on the foraging ecology, habitat use, and the importance of mangrove estuaries to EP hawksbills. This work provides missing critical information for EP hawksbill conservation: immature hawksbill turtles experience a pelagic stage and then recruit to estuaries at ~37 cm curved carapace length, and subsequently increase their reliance on mangrove estuarine resources until they approach adult sizes. This life history strategy makes them especially vulnerable to in-water nearshore threats, and requires an expansion of current conservation efforts throughout the EP.

Keywords: habitat use, fishers' ecological knowledge, foraging ecology, mangrove estuary

INTRODUCTION

The current global biodiversity crisis demands rapid and effective conservation action informed by reliable ecological and sociological information. Conservation efforts are increasingly focused on spatially based mechanisms, identifying key habitats or regions where protection may achieve tangible and enduring benefits. Obtaining detailed scientific information on habitat use,

however, may take decades, particularly in the case of rare, critically endangered long-lived and migratory taxa where rapid protection is most needed. Local ecological knowledge, defined here as the combination of culturally transmitted and experientially learned local knowledge, represents a powerful information source that is often overlooked by scientific endeavor. In many cases, such omission is in part due to unfamiliarity with methodological approaches and rigor required to formally capture local ecological knowledge (Pauly, 1995; Johannes et al., 2000; Haggan et al., 2007, Chapter 1).

Social-ecological systems science, the integration of social and natural sciences, is becoming more important and popular in wildlife studies in the context of conservation and management (Charnley et al., 2007; Ostrom, 2009; Poe et al., 2014; Fischer et al., 2015; Virapongse et al., 2016). In this study, we employ a social-ecological systems approach, drawing on local ecological knowledge synthesized through interviews (Chapters 1 and 4) combined with stable isotope-based inferences about ontogenetic shifts in habitat use. We demonstrate the critical importance of mangrove estuaries in El Salvador and Nicaragua as key developmental habitat for immature eastern Pacific (EP) hawksbill sea turtles (*Eretmochelys imbricata*).

Hawksbill sea turtles are circumglobal and critically endangered throughout their range (IUCN, 2018). From the 1960s–2008, the EP hawksbill population that ranges from Mexico to Peru was thought to be on the verge of extirpation (Gaos and Yañez, 2012). Consideration of local ecological knowledge (LEK) led to scientific "re-discovery" of this population in 2008 and the recognition that, unlike most other hawksbill populations, EP hawksbill turtles are closely associated with mangrove estuary habitats (Vásquez and Liles, 2008; Gaos et al., 2010; Guzmán Hernández, 2010). Specifically, >70% of the ~800 nesting females in the EP population nest on the shores within two mangrove estuaries: Bahía de Jiquilisco, El Salvador and Estero Padre Ramos, Nicaragua. Since 2008, studies have focused primarily on adult hawksbill nesting and habitat use (Liles et al., 2011; Gaos et al., 2012a; Gaos et al., 2012b; Gaos et al., 2012c; Liles et al., 2015b), population genetics (Gaos et al., 2016; Gaos et al., 2017a; Zuñiga and Espinosa, 2017; Gaos et al., 2018), foraging ecology in neritic reef habitats (Carrión-Cortez et al., 2013; Liles et

al., 2017; Llamas et al., 2017), and local perceptions of conservation (Liles et al., 2015a). The pivotal finding of this combined research is that mangrove estuaries are important habitat for nesting adult EP hawksbills (Gaos et al., 2010), and likely for immature hawksbills (Torres Gago et al., 2016, Mendez et al. in review). However, it is unknown at what size (i.e. a proxy for age) hawksbills recruit to mangrove foraging grounds, how hawksbills utilize the mangrove estuary habitat throughout ontogeny, and what mechanisms drive their use of such habitats. The importance of these previously unknown data are highlighted in recent calls for information on immature sea turtles (Wildermann et al., 2018), identifying connections among sea turtle rookeries and foraging grounds (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013; Rees et al., 2016), and on immature EP hawksbills more specifically (Liles et al., 2017; Gaos et al., 2018; Wildermann et al., 2018). A specific area of importance is discovering when EP hawksbills recruit to neritic waters (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013; Liles et al., 2017).

Stable isotope analysis (SIA) is a powerful tool in wildlife studies. Using SIA, researchers can gain insight into habitat use and foraging behavior from a single sampling interaction, thus minimizing negative impacts to the animal. Another advantage of SIA is that, for serially deposited tissues (e.g. baleen, keratin), it can produce time series data and long-term (multi-year) records of habitat use (West et al., 2006). Further, due to its relative low cost in comparison to satellite telemetry, SIA allows for population-level assessments that may include 10s to 100s of individuals (Rubenstein and Hobson, 2004; Hobson and Norris, 2008). SIA has been successfully applied for a wide range of species across various habitats (Hobson, 1999), and is especially useful in evaluating seasonal dietary shifts (Stevenson and Mitchell, 2016; Hanson et al., 2018), migratory patterns (Cerling et al., 2006; Seminoff et al., 2012; Wunder, 2012; Vander Zanden et al., 2015; Cruz-Flores et al., 2018), and individual-level specialization (Newsome et al., 2009; Vander Zanden et al., 2010; Cryan et al., 2012; Nadjafzadeh et al., 2016). This molecular tool has been successful in sea turtle research (Jones and Seminoff, 2013), and for hawksbill sea turtles more

specifically (Bjorndal and Bolten, 2009; Graham, 2009; Ferreira et al., 2018), although only one other publication focuses on EP hawksbills (Mendez et al. in review).

Our study took a social-ecological systems approach by combining local ecological knowledge and SIA to fill critical data gaps regarding habitat use for immature hawksbill turtles. Local ecological knowledge guided sample collection and validated EP hawksbill diet, while bulk-tissue stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis revealed ontogenetic shifts in habitat use and foraging ecology of hawksbill sea turtles (N=388) at the two largest estuarine strongholds for hawksbills in the region: Bahía Jiquilisco, EL Salvador (Bahía) and Estero Padre Ramos, Nicaragua (EPR). Specifically, we quantified the dependence of immature EP hawksbill turtles (n=172) on these mangrove estuaries, and discovered that EP hawksbills experience a pelagic stage and recruit into habitat that serves both as a critical rookery and foraging ground throughout ontogeny. These findings highlight the value of a social-ecological systems approach and provide crucial missing information for this population that will improve the conservation of this critically endangered species.

RESULTS

A total of 388 hawksbills were sampled for SIA (Table 3.1), including 224 from in or near Bahía de Jiquilisco, El Salvador (Bahía) and 164 from Estero Padre Ramos, Nicaragua (EPR). Through in-water capture, we sampled a total of 185 turtles total comprising 172 immature (30–65cm curved carapace length, CCL) and 13 adults (>65cm CCL; Table 3.1In Bahía, three of the nesting adults were sampled twice, and in EPR one immature turtles was sampled twice, and four nesting adults were each sampled twice (Table 3.2).

Stable isotope analysis

Immature hawksbill turtle isotope values (n= 172) show that both $\delta^{13}C$ and $\delta^{15}N$ isotope values decrease as turtles move from pelagic, phyto-plankton based foodwebs, to estuarine, mangrove-based foodwebs, at both Bahía (linear regression model, R^2 = 0.88, df=116, p<0.001) and EPR (linear regression model, R^2 = 0.86, df=72, p<0.001). Across all sampled non-nesting turtles

collected from both study sites (N=173, immature n=172, adult n=13), both $\delta^{13}C$ and $\delta^{15}N$ values decrease with sea turtle CCL, although non-linearly. Generalized additive models (GAM) predicting $\delta^{13}C$ values as a function of CCL alone explained 72% of variance in $\delta^{13}C$ values for Bahía turtles, and 55% of variance in $\delta^{13}C$ values for EPR turtles.

Table 3.1 Summary of SIA sample sizes by life history stage, capture type, CCL mean and range Total N=392, EL Salvador (n=228) and Nicaragua (n=164).

Bahía de Jiquilisco, El Salvador (Bahía)				
Sample size	Life history stage(s)	Capture type	Mean CCL (cm)	CCL range (cm)
12	Immature	By-catch	37.6	14.8–44.2
93	Immature	In-water	47.5	31.5–65.1
6	Adult	In-water	77.8	65.1–90.5
117	Adult	Nesting	84.8	71.5–98.0
Estero Padre Ramos, Nicaragua (EPR)				
Sample size	Life history stage(s)	Capture type	Mean CCL (cm)	CCL range (cm)
67	Immature	In-water	45.4	33.0–65.5
7	Adult	In-water	76.8	72.9–85.4
90	Adult	Nesting	81.9	70.0–98.0

Table 3.2: Turtles resampled for SIA.
If turtles were encountered multiple times, they were re-sampled to compare size and isotope signals across time.

Bahía de Jiquilisco, El Salvador (Bahía)						
Turtle ID	Sample 1 date	Sample 1 CCL (cm)	Sample 1 $\delta^{13}C$	Sample 2 date	Sample 2 CCL (cm)	Sample 2 $\delta^{13}C$
125809	April 2013	85.5	–21.4‰	May 2013	85.4	–20.7‰
116723	May 2013	91.4	–25.4‰	June 2013	91.5	–25.4‰
116740	May 2013	89.1	–24.2‰	July 2013	89.5	–24.1‰
Estero Padre Ramos, Nicaragua (EPR)						
Turtle ID	Sample 1 date	Sample 1 CCL (cm)	Sample 1 $\delta^{13}C$	Sample 2 date	Sample 2 CCL (cm)	Sample 2 $\delta^{13}C$
1413106	April 2016	38.8	–18.5‰	Nov. 2016	42.2	–19.2‰
98395	June 2010	75.0	–19.6‰	Aug. 2012	77.0	–22.0‰
98409	July 2010	79.0	–22.9‰	Aug. 2016	79.0	–21.7‰
114498	May 2012	74.0	–21.6‰	July 2016	75.0	–21.6‰
114501	June 2012	83.0	–25.0‰	June 2016	83.0	–26.1‰

While the relationship between $\delta^{13}C$ values and CCL was non-linear for the entire turtle size range, within each estuary $\delta^{13}C$ values decreased linearly as CCL increases between 37 and 60cm (Fig. 1A–1B). A linear model predicting $\delta^{13}C$ values in all immature turtles as a function of CCL ($R^2 = 0.48$, df=156, $p<0.001$), implies that immature turtles proportionally increase their reliance on estuarine resources (mangrove habitats) ~4% on average with each cm increase in CCL (Fig. 3.1A–B).

Turtle scutes grow incrementally, allowing relatively low-resolution assessment of change in isotopic composition over time within an individual turtle (Reich et al., 2007; Jones and Seminoff, 2013). Scute $\delta^{13}C$ values show that the gradational change in $\delta^{13}C$ values with CCL observed among individuals of varying size is also reflected in individual turtles (Fig. 3.1 C–D). We see a general decrease in $\delta^{13}C$ with scute age, consistent with gradual increase in mangrove estuary use, with greater variation in turtles >60cm CCL (Fig. 3.1), as adults are known to move among estuarine and nearshore coastal habitats (Guzmán Hernández, 2010; Gaos et al., 2012a; Gaos et al., 2012b; Gaos et al., 2012c). Resampled turtles' CCL and isotope values reflect the same increase in estuarine resources (more negative $\delta^{13}C$ value) with increased CCL (Table 3.2). The average $\delta^{13}C$ of red mangroves (*Rhizophora mangle*) analyzed in our study is –28.6‰ ±1.6‰SD, which is consistent with mangrove isotope values elsewhere (Fry and Ewel, 2003; Herzka, 2005; McMahon et al., 2011).

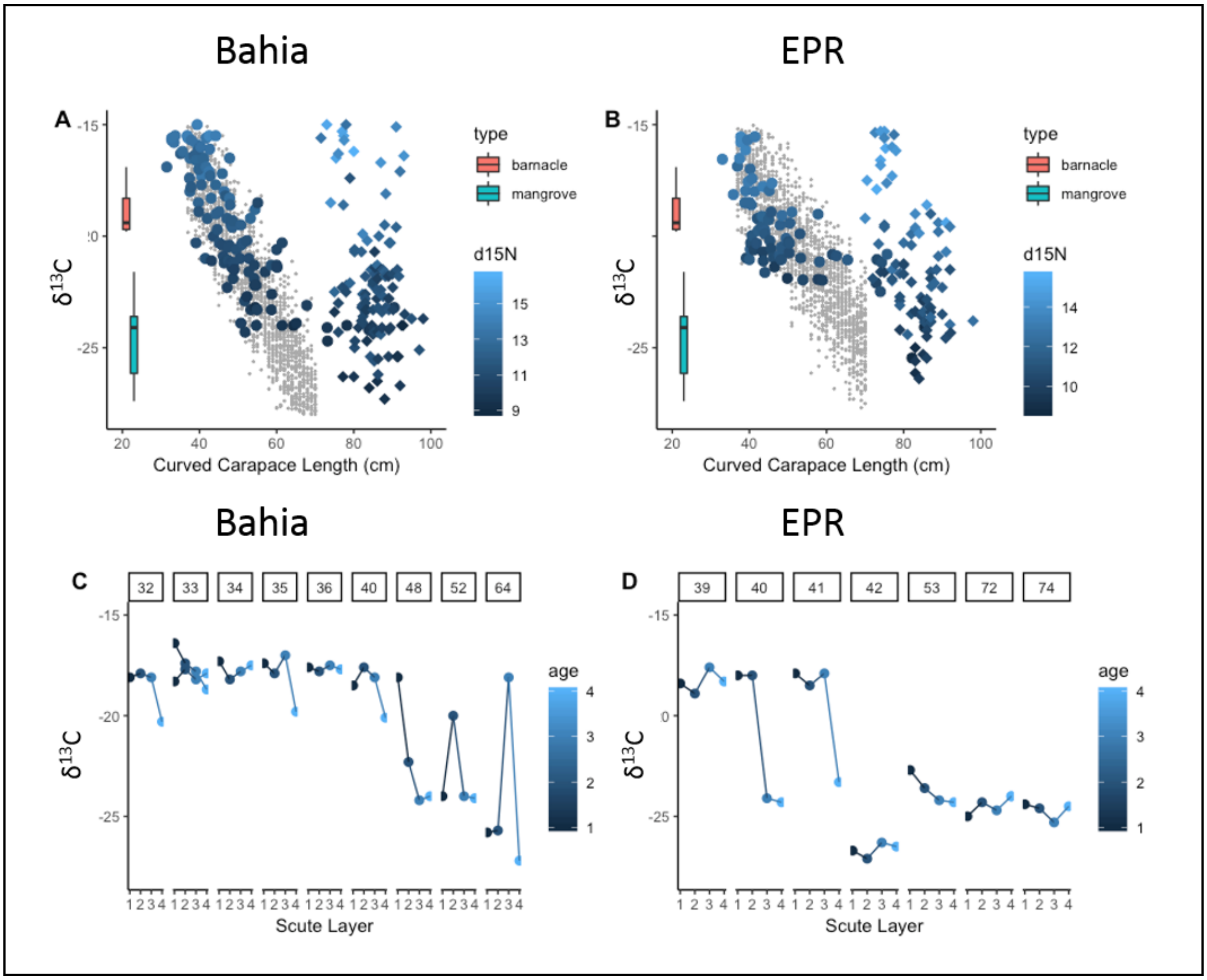

Figure 3.1: Bulk $\delta^{13}C$ and bulk $\delta^{15}N$ isotope values for hawksbill skin (A-B) and scute (C-D) at both study sites

(A) Bahía, El Salvador (n=228): Curved carapace length vs. $\delta^{13}C$, with bulk δ15N in blue for in-water captured turtles (n=111; circles) and nesting turtles (n=117; squares). Gray dots represent modeled data. **(B)** EPR, Nicaragua: Curved carapace length vs $\delta^{13}C$, with bulk $\delta^{15}N$ in blue for in-water captured turtles (n=74; circles) and nesting turtles (n=90; squares). Gray dots represent modeled data. **(C)** Bahía, El Salvador: Scute layer ("age") vs. bulk $\delta^{13}C$, with CCL along the top (N=10 turtles). **(D)** EPR, Nicaragua: Scute layer ("age") vs. bulk $\delta^{13}C$, with CCL along the top (N=12 turtles). Potential prey items (*Balanus sp*. and *Rhizophora sp*.) collected throughout the estuaries are included for reference, +4‰ has been added to barnacle and mangrove $\delta^{13}C$ values to correct to skin collagen, for easier comparison to turtle skin values shown in this graph..

Local ecological knowledge

We conducted 68 long form, informant-directed semi-structured interviews (McCracken, 1988; Peterson et al., 1994) with fishers in Bahía (n=38) and EPR (n=30) between 7 May–8 June 2016. Local ecological knowledge identified 301 localities within our two primary study sites, Bahía (n=200) and EPR (n=101) (Chapter 1), and this local ecological knowledge was exclusively used to direct our in-water capture, which resulted in the sampling of tissues for SIA. In addition to locality information, thematic analysis of interviews (Kincheloe and McLaren, 2005; Liles et al., 2015a) revealed local ecological knowledge about mechanisms driving hawksbill estuarine association, with food, safety and environmental factors (e.g., rocky substrate, tides, water depth & temperature) emerging as the primary drivers (Chapter 4). Fishers were often specific in naming the diet of EP hawksbills, with barnacles (*Balanus sp.)* being the most common, followed by mangroves (*Rhizophora sp*.). One fisher explained:

> And they also eat the barnacle as well and they also eat mangrove's seeds, the seeds from the mangrove that they like a lot. (Response D016.03, translated from Spanish)

Others share first-hand accounts of witnessing hawksbill foraging behavior:

> When the tide is high I have seen them on the shores of the mangrove eating barnacle on the roots. (Response A046.04, translated from Spanish)

> Since we go around harpooning we go under and we go searching for them [fish] and there are times when they [~65cm CCL hawksbills] are eating roots, barnacle like that. (Response F033.02, translated from Spanish)

One fisher who has helped on other scientific studies, including Torres Gago et al. (2016), recalls:

> [Hawksbills] mainly eat barnacle that we called there, [mangrove] roots, that is what we pull out from them when we do the [diet content] analysis. (Response G001.04, translated from Spanish).

In addition to specific diet information, fishers across both sites also reported seeing ~30cm CCL sea turtles more frequently than any other turtle size (including nesters), and very rarely reported seeing turtles <30cm CCL (Chapter 4). Some even touched on the immature estuarine residency phase and the mixed strategy of adults:

> In the case of the young (juveniles) of 30[cm] I think that all year round you can see but as far as the adults, [>65cm], I think that she comes, you can see her more often when the nesting season approaches (Response I003.01, translated from Spanish).

Another fisher mentions recapturing immature hawksbills within the estuary multiple years in a row:

> But of the [30-65cm CCL hawksbills] we have caught in the same place [in the estuary] a lot, two straight years, two, three years I think. (Response 042, translated from Spanish)

This local ecological knowledge supports our two-component mixing model, and the related results that immature sea turtles exhibit an estuarine developmental phase. Further detailed analysis of local ecological knowledge data is beyond the scope of this paper and covered in Chapters 1, 2, and 4.

DISCUSSION

The critical importance of mangrove estuaries as developmental habitat for this imperiled species should garner support for the conservation of threatened estuary habitat throughout the EP, and a closer examination of these habitats as potential sea turtle foraging grounds near other

nesting aggregations (Gaos et al., 2018). Genetic data from Gaos et al. (2018) strongly support our results, as they show that rookeries throughout the EP, including Bahía and EPR, are the primary contributors to proximal foraging grounds in their respective regions. They developed the term, "natal foraging philopatry (NFP)" to describe this relationship, and question what mechanisms may be driving this dynamic. Local ecological knowledge reported here supports reliance on estuarine resources as mechanisms driving NFP, with a particular focus on food availability. The transition to, and dependency on, an estuarine food web throughout immature life stages, as shown in our stable isotope data, further supports food availability as a mechanism driving NFP in this region. This same mechanism – resource availability – is thought to drive individuals of multiple sea turtle species and populations (e.g. *Natator depressus,* Type 1; *Dermochelys coriacea,* and EP *Lepidochelys olivacea,* Type 3*)* to remain in particular habitats throughout their lives (Bolten, 2003).

The size at recruitment reported in our study is of particular importance, as the sizes of turtles first recruiting into the estuaries is consistent with turtles found bycaught in artisanal fisheries off the coasts of El Salvador and Nicaragua (Liles et al., 2017). Unintended capture of hawksbills in nearshore EP fisheries is believed to be the greatest source of mortality for the population, with an estimated mortality of 227 hawksbills over a three year study (Liles et al., 2017). It is possible that the bycaught turtles reported in Liles et al. (2017) were transitioning back into their respective (natal) mangrove estuaries when they were caught. Therefore, it is critical for future studies to better understand the use of pelagic habitats by small (<37cm) hawksbills to ensure that the population is not experiencing an in-water nearshore sink, which could override the extensive work done over the past decade to protect nesting turtles within the mangrove estuaries.

The baseline data used to conduct this study were generated through collaborations with local fishers in Bahía and EPR (Chapter 1), who have long recognized that immature hawksbills utilize their mangrove estuary rookeries for foraging (Chapters 1 and 4*),* a phenomenon that has only recently been suggested (Torres Gago et al., 2016; Gaos et al., 2018; Mendez et al. in prep). Our SIA results are consistent with the local ecological knowledge, highlighting the value and

importance of incorporating this under-utilized source of information early and often in conservation efforts. We realize that local ecological knowledge, however, is most applicable in areas where humans and wildlife rely on shared resources, and thus may not be available to all studies. We also caution against those untrained in social sciences to use such methods without collaborating or consulting with social scientist, as approaches for incorporating local ecological knowledge are context dependent and require nuanced evaluation (Rees et al., 2016; Bennett et al., 2017; Teel et al., 2018, Chapter 1).

We also recognize that our isotope-based approach to assess habitat use has some inherent assumptions. First, our analysis of the hawksbill tissue isotope data is not directly tied to that of potential sources of prey found in pelagic and estuarine habitats, however, we do show that the basal primary producers in these respective ecosystems have very distinct values. The mangrove trees (*Rhizophora* sp.) in our study have mean $\delta^{13}C$ values (–28.6±1.6) consistent with the literature (Fry and Ewel, 2003; McMahon et al., 2011). Fry and Ewel (2003) found that generally only animals found within estuaries have low (–27‰ to –20‰) carbon isotopic values similar to mangrove leavs (–27‰), and McMahon et al. (2011) reported bulk $\delta^{13}C$ of –27.7‰ for mangroves in Panama. Furthermore, the immature hawksbill turtles with the highest $\delta^{13}C$ values that are assumed to primarily forage in pelagic phytoplankton-based food webs are similar to those for pelagic EP olive ridley turtles (*Lepidochelys olivacea*), which have skin $\delta^{13}C$ values ranging from –17.8‰ to –14.5‰ (Peavey et al. 2017). Lastly, although isotopic incorporation rates have not been estimated for hawksbill turtles, Reich et al. (2008) found that skin of captive juvenile loggerhead sea turtles (*Caretta caretta*) integrates ~46 days of dietary input. Loggerheads are a good surrogate for hawksbills as both species are within the suborder Carettini, and both are omnivores. Assuming that hawksbill turtles have similar incorporation rates, our skin isotope data represent habitat use integrated over a month and a half.

Our results provide the crucial link to guide future conservation in the region: young hawksbills experience a pelagic stage, and then recruit into estuaries to complete their developmental stage, before they use a mixed foraging strategy as adults (Fig. 1). The duplication

of our local ecological knowledge and stable isotope findings across both primary rookeries for this population suggest that this is a regional trend, and similar studies (e.g., Mendez et al. in review), need to be conducted at other known estuarine rookeries for this population (Gaos et al., 2017b; Gaos et al., 2018).

More broadly, these results show the impact and validity of a social-ecological systems approach and should encourage more studies to integrate the social and natural sciences. Our social-ecological systems approach strengthened our data by corroborating findings through different methods. For example: both social and natural science findings support food as a primary mechanism driving EP hawksbill use of Bahía and EPR. This interdisciplinary approach was able to generate large and useful datasets efficiently, and at relatively low-cost. More importantly, it has produced new knowledge crucial to the conservation of a critically endangered species. We encourage other scientists to recognize the value of combining different knowledge cultures, and to heed the increasing calls for social-ecological systems approaches to conservation.

METHODS

Study Sites

This study was conducted at the two primary nesting localities for hawksbill turtles in the eastern Pacific (Gaos et al., 2010): Bahía de Jiquilisco, El Salvador (Bahía, 13°13'N, 88°32'W) and Estero Padre Ramos, Nicaragua (EPR, 12°48'N, 87°28'W). Bahía is 635km^2, and as the largest mangrove forest in El Salvador, it is designated as a RAMSAR wetland, and in 2007 was named a UNESCO Biosphere Reserve (MARN, 2013). EPR is 88 km^2 in total area, of which mangrove forest covers 26k km^2; EPR was declared a Nature Reserve in 1983 (MARENA, 2003).

Local ecological knowledge

Methods for engaging local ecological knowledge are described in Chapters 1 and 4. These collaborations with local fishers, which captured the local ecological knowledge (e.g. location and relative size of turtles at each site), were used to guide in-water capture of turtles for tissue collection. We clustered the identified locality points and created a 500m radius buffer around them (Bolstad, 2012), as known hawksbill displacement at these sites is usually <500m (Torres

Gago et al., 2016). We conducted sampling surveys within and outside of the buffer areas to assess the effectiveness of LEK in identifying critical foraging areas, and to prevent survey sampling bias.

Turtle and potential prey sample collection

We identified turtles as immature following Wildermann et al. (2018), which in our case includes EP hawksbills that range from 30–65cm curved carapace length (CCL, cm), as Liles et al. (2015b) reported that mean CCL of nesting turtles in our primary study sites is 83cm (range 68–98cm ccl). Hawksbill sea turtles were captured during in-water capture surveys in Bahía (April 2016 to Jan. 2017, n =99) and EPR (December 2015 to December 2016, n=74). Hawksbills were sampled using continuously monitored tangle-nets deployed from small (7m length), open-hull fishing skiffs with outboard motors. Once captured, turtles were kept in a shaded location aboard the boat, they were weighed and measured for curved carapace length (CCL) and curved carapace width (CCW). Turtles were checked for Inconel tags and passive integrated transponder (PIT) tags; if none were found new tags were applied to the front flippers and the right shoulder, respectively. We also sampled an additional 12 immature hawksbills that were bycaught in nearshore fisheries within Bahía. For all turtles, skin and carapace tissue samples were taken for SIA after measurements and tagging were completed. Nesting females (n=207) were sampled following Gaos et al. (2016).

Skin samples were collected from the shoulder region (Gaos et al., 2016) using a variation on standard methods (Reich et al., 2008; Reich and Seminoff, 2010) where a scalpel, instead of a biopsy punch, was used to collect two ~6-mm diameter skin samples from each turtle. All connective tissue was removed and only the epidermis layer from each sample was retained. Two 6-mm diameter scute samples were taken from each of the second vertebral scutes (Reich et al., 2007). Scute samples were collected using novel tools as described in Chapters 1 and 2. Skin samples were stored in a saturated salt solution and scutes were stored in Whirl Pak™ bags with dry NaCl. Putative prey items based on local ecological knowledge were collected from around each estuary (Chapter 4), including barnacles (*Balanus sp.)*, red algae (*Rhodophyta)*, sponges

(*Axinella sp.*), as well as red mangrove (*Rhizophora mangle)* roots, leaves, and seeds. These potential hawksbill foods were dried, pressed, and stored in airtight plastic bags, or preserved in 70% EtOH if too large for pressing and drying.

Stable isotope analysis

Skin from each turtle sampled was analyzed for bulk $\delta^{13}C$ and $\delta^{15}N$. Two samples from the right marginal scute were sub-sampled for the top (oldest tissue) and bottom (newest tissue) layers for a sub-set of the turtles (n=17: Bahía = 10 and EPR = 7) that were run for skin bulk $\delta^{13}C$ or $\delta^{15}N$. Skin and scute samples were transferred from their original vials to 20ml Glass scintillation vials, and rinsed with DI water to remove any residual NaCl from storage. Each sample was rinsed once every hour for six hours, repeated over two days. Samples were soaked in DI water in the refrigerator between rinses and overnight. Skin and scute samples were then lipid-extracted via three 24-hour soaks in a 2:1 chloroform:methanol solvent solution, followed by thorough rinsing in distilled water and lypholization. After lipid-extraction, skin samples were dried in a Labconco freezone 4.5Plus, scute samples were air dried under the hood. Finally, ~0.5–0.6mg of dried skin and scute tissue were weighed into tin capsules for SIA. Prey items were rinsed as per skin and scute, but were not lipid extracted. Barnacles, corals, and anything with a carbon-based shell were washed in 0.5N HCl solution to remove non-dietary inorganic C (e.g., carbonates precipitated into shells) from the samples. After washing was completed, all prey samples were dried in a Labconco freezone 4.5Plus. Dried samples were then weighted into tin capsules for SIA. Samples were weighted to ~0.4–0.6mg for barnacles, ~1–3.5mg for sponges, and ~4–8mg for mangroves.

$\delta^{13}C$ and $\delta^{15}N$ values of skin, scute, and potential prey samples were measured with a Costech 4010 (Valencia, CA) elemental analyzer interfaced with a Thermo Scientific Delta V Plus isotope ratio mass spectrometer at the University of New Mexico Center for Stable Isotopes (Albuquerque, NM). Isotopic results are expressed as δ values, where $\delta^{13}C$ or $\delta^{15}N$ = 1,000 X ($R_{sample} – R_{standard}/R_{standard}$), where R_{sample} and $R_{standard}$ are the $^{13}C/^{12}C$ or $^{15}N/^{14}N$ of the sample and standard, respectively. The internationally accepted standards for $\delta^{13}C$ and $\delta^{15}N$ values are Vienna Pee Dee Belemnite (V-PDB) and atmospheric nitrogen, respectively, and units are parts per

thousand, or per mil (‰). Precision for $\delta^{13}C$ and $\delta^{15}N$ was estimated by analysis of internal protein standards; within and among run variation (SD) was ≤0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$. We also analyzed the weight percent carbon and nitrogen concentrations, reported as [C]/[N], of each sample via comparison with protein standards with known [C] and [N].

Statistical analysis

All statistical analysis were performed in R. Linear regression models were run for immature turtles (between 37–60cm CCL) to predict $\delta^{13}C$ signals as a function of CCL for each site separately, and for both together. General additive models (GAMs) were run on the whole CCL range at both sites to account for the non-linear relationship, adding in location as a co-variate did not significantly improve the GAM. The relationship between skin $\delta^{13}C$ value and curved carapace length in the transition period between 37cm and 60cm is explained by a simple linear model describing two-component mixing between end member values. The two extreme turtle skin $\delta^{13}C$ values that we measured were used as end members reflecting nearshore marine (–16‰) and estuarine (–23‰) resource use. These end member values are supported by data of potential prey collected within and adjacent (nearshore marine ecosystems) to the estuaries. The rate of change in proportional use of estuarine resources during transition between nearshore marine and estuarine resources as a function of turtle carapace length is then estimated from the slope of the best-fit linear model where y-axis units are scaled between 0 (no estuarine use) to 1 (complete dependence on estuarine resources). The full range of measured data were simulated using Monte Carlo resampling of linear models including 5% standard deviation around the predicted $\delta^{13}C$ values.

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CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT:

KRWS designed the study, coordinated and conducted all interviews, turtle capture and tissue collection, prepped all tissue samples for stable isotope analysis, conducted stable isotope analysis, and drafted the manuscript. JAS helped design the study, provided sample collection and laboratory support, and guidance on how to prepare and analyze isotope data, coordinated importation of samples, and provided comments to improve the manuscript. MJL provided field support, assisted in turtle capture and tissue sampling and coordinated exportation of samples for stable isotope analysis. RNS, SC, MV provided critical field logistical support in El Salvador, conducted interviews, turtle capture, turtle tissue sampling, and coordinated exportation of samples. EA, and VG provided critical field logistical support in Nicaragua, EA assisted with interviews, and turtle capture and coordinated sample exportation. MJP provided financial and logistical support for fieldwork and helped design the turtle capture methods. TRP provided financial and logistical support, helped design the interview methods and provided guidance on

interview data analysis. KJS helped with SIA analysis, and helped draft early versions of the manuscript. CNT conducted the statistical analysis, made the figures, and commented on early versions of the manuscript. SDN provided laboratory space, access to stable isotope analysis materials and equipment, guidance on how to prepare and isotope analyze data, and helped edit the manuscript.

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Chapter 4: Fishers' ecological knowledge provides crucial insights to the conservation of a critically endangered species

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Fishers' ecological knowledge provides crucial insights to the conservation of a critically endangered species

ABSTRACT

There have been several recent calls to incorporate the social sciences in conservation. In areas where habitat for vulnerable wildlife and human livelihoods overlap, the expert knowledge of locals can prove invaluable. In this study, we explored the potential of a specific type of knowledge, fishers' ecological knowledge (FEK): the combination of the experiential and culturally transmitted knowledge of fishers. Fishers in our study area were instrumental in the 2008 scientific re-discovery of critically endangered eastern Pacific hawksbill sea turtles. However, their expert knowledge of the local sea turtle population has not been further explored in over a decade. For this partially emergent thematic analysis, we allowed FEK to generate research questions pertinent to the conservation of this critically endangered species. This knowledge revealed four primary themes: 1) immature sea turtles are most commonly found in local estuaries, suggesting hawksbills exhibit an estuarine developmental stage, 2) hawksbills are found in estuary waters year-round, 3) food and safety are the primary mechanisms for hawksbill habitat associations, but their location can also be influenced by "turtle happiness", and environmental factors (e.g. tides, water temperature), and 4) when/if hawksbill hatchlings stay within estuaries after a release, their dispersal is likely influenced by currents. We then reframed the themes as research questions that may guide future conservation science and practice. This study demonstrates the rich data FEK provides, generates directions for future studies, and urge the further integration of the social sciences in conservation.

Key words: habitat use, mangrove estuary, social-ecological systems, local ecological knowledge

INTRODUCTION

Traditional ecological knowledge is critical to conservation science (reviewed in Haggan et al., 2007). One type of traditional ecological knowledge is fisher's ecological knowledge (FEK; Johannes et al., 2000). This combination of fishers' experiential and culturally transmitted knowledge, is rich in multidimensional data, and provides several advantages when incorporated

into conservation science (Johannes et al., 2000; Haggan et al., 2007; Hind, 2014, Chapter 1). FEK is intrinsically integrated into the lives of fishers, making it a strong data source. As Haggan et al. (2007, P. 14) state, "Fishers rely on their knowledge for their livelihood, . . . Fishers' knowledge is not just an academic exercise – it is a way of life that evolves continuously to address changes in fisheries and fishers." Knowledge of these wild species and ecosystems they inhabit has been refined through years of personal and community experiences; and is particularly deep in areas where people have developed cultural affinity with wildlife. In such areas, FEK extends beyond livelihood; it is integral to local culture (Garibaldi and Turner, 2004; Butler et al., 2012). Sea turtles are one example of an animal with which humans have forged strong cultural ties (Hart et al., 2013; Liles et al., 2015a; Barrios-Garrido et al., 2018), and have even been classified as "cultural keystone species" in Australia (Butler et al., 2012).

A study by Liles et al. (2015a) focused on Salvadoran fishers' and *tortugueros'* (turtle egg harvesters) perceptions of local conservation initiatives and their connections to the local population of critically endangered hawksbill sea turtles (*Eretmochelys imbricata)*. Through naturalistic inquiry and an ethnographic approach, Liles et al. (2015a) developed an understanding of local community realities and how they relate to hawksbill conservation. They found that while the economic value of hawksbill turtle eggs is of primary importance to local residents, a deeper connection between sea turtles and the local culture exists (Liles et al., 2015a). For the current study, we explored this connection and the long history of sea turtle use in the area. We used informant-directed(Peterson et al., 1994), semi-structured interviews (McCracken, 1988) with fishers in the same region to explore the FEK on eastern Pacific (EP) hawksbill sea turtles and offer our results as a demonstration of how FEK can contribute directly to conservation science. Specifically, this study provides a thematic analysis of the FEK regarding EP hawksbills near their two primary rookeries: Bahía de Jiquilisco, El Salvador (Bahía), and Estero Padre Ramos (EPR) in Nicaragua. FEK at both sites developed through an emergent analysis. Through this process four themes emerged:

(1) Immature sea turtles are most commonly found in both estuaries, suggesting hawksbills exhibit an estuarine developmental stage.

(2) Hawksbills are found in estuary waters year-round, not just during nesting season.

(3) Food and safety are the primary drivers for hawksbill habitat associations, but their location can also be influenced by "turtle happiness" (defined in section RQ 3, "Turtle comfort and happiness") and environmental factors (e.g. tides, water temperature).

(4) Hawksbill hatchlings and yearlings, the youngest sea turtle life stages, stay within the estuaries after a hatchling release.

We reframed these themes as four research questions (RQs):

(1) Are immature hawksbills the most commonly found sizes in both estuaries?

(2) Are hawksbills found in estuary waters year-round, rather than just during nesting season?

(3) Do food, safety, environmental factors, and "happiness" drive habitat use?

(4) Do the youngest sea turtle life stages stay within the estuaries after a hatchling release?

Conservation context

The EP hawksbill population was thought to be ecologically extirpated from the 1960s to 2008 (Vásquez and Liles, 2008; Gaos et al., 2010). For many years, biologists dismissed FEK in the region as anecdotal, thinking fishers were mistaking green sea turtles (*Chelonia mydas*) for hawksbills (Gaos and Yañez, 2012). It was not until 2008, when conservationists working throughout the region came together to compile their knowledge of EP hawksbills. This insight from those working within communities throughout the region led scientists to find a viable population, one that could return from the brink of extirpation (Vásquez and Liles, 2008; Gaos et al., 2010).

Since the re-discovery of EP hawksbills, FEK and local community involvement have been paramount to the conservation of this population (Gaos et al., 2010; Gaos and Yañez, 2012; Liles

et al., 2015a). Research has focused on adult movement and genetics (e.g., Gaos et al., 2012b; Liles et al., 2015b; Gaos et al., 2018), with a few studies focusing, in part, on immature turtles (Carrión-Cortez et al., 2013; Torres Gago et al., 2016; Liles et al., 2017; Llamas et al., 2017), with Llamas et al. (2017)focusing almost exclusively on juveniles. Together, this research led to the pivotal finding that adult EP hawksbills nest and forage within mangrove estuaries. Two estuaries have emerged as the primary rookeries for this population that ranges from Mexico to Peru, hosting >70% of the nesting of the ~800 nesting turtles in the population: Bahía de Jiquilisico, El Salvador (Bahía), and Estero Padre Ramos in Nicaragua (EPR). In two recent studies, Wedemeyer-Strombel (Chapters 1, 3) incorporated FEK from both sites to generate baseline data and corroborate stable isotope analysis. These studies revealed critical scientific knowledge: EP hawksbills exhibit an oceanic developmental stage and then, while still young, recruit back into the Bahía and EPR mangrove estuaries to continue development until, and perhaps beyond reaching adulthood. These findings directly connect hawksbill developmental and nesting grounds, and report EP hawksbills size at recruitment into these estuarine habitats – information that will improve how we conserve these turtles.

In this exploratory study, we explore the extent and applicability of FEK to research and conservation initiatives in the region. First, we record the FEK of hawksbill habitat use within the mangrove estuaries of Bahía and EPR. Further, we analyze how FEK revealed this information. We argue that hawksbill conservation in the eastern Pacific highlights the importance of integrating FEK into conservation studies to better understand imperiled species and to improve conservation.

METHODS

Study sites

We conducted interviews 7 May – 8 June 2016 in fishing communities surrounding Bahia (13°13'N, 88°32'W) and EPR (12°48'N, 87°28'W), the two primary nesting areas for EP hawksbills. Both sites are mangrove dominated ecosystems, house artisanal fishing communities throughout, and are threatened by the conversion of mangrove forest to shrimp farms. These

communities were chosen because they have been crucial in the scientific re-discovery of this population (Vásquez and Liles, 2008; Gaos and Yañez, 2012), the conservation initiatives that have been implemented over at least a decade (Gaos et al., 2010; Liles et al., 2015a), and have strong cultural connections to hawksbill sea turtles(Liles et al., 2015a).

Informant directed semi-structured interviews

A total of 69 people were asked for an interview, and 68 total interviews were conducted (38 in Bahia, 30 in EPR). All informants gave verbal consent prior to being interviewed, 62 informants gave additional verbal consent to be recorded (34 in Bahia, 28 in EPR). The 62 recorded interviews were then translated, transcribed and used for analysis. For more specifics of the interview process please see Chapter 1. All interviews were conducted in the informant's primary language, Spanish, following the long form interview (McCracken, 1988) and adapted to enable informant direction per Peterson et al. (1994). All interviews started with the general question, "please tell me about your experiences with hawksbill turtles in the estuary". To maintain consistency regarding hawksbill sizes across interviews, we used cardboard cutouts to represent different hawksbill shell sizes, measured from the top of their dorsal shell to the point at the bottom of their dorsal shell (curved carapace length in cm, CCL). Sizes of the cutouts were: A (4cm, recently hatched turtle), B (15cm, post hatchling life stage), C (30cm, neritic juvenile), D (65cm, large subadult), and E (84cm, adult nesting turtle). All transcripts were translated from Spanish to English, with a subset double-translated to ensure that original meanings were not lost in translation (Marín and Marín, 1991). Transcription and translation were done by Salvadorans skilled in English. All informants gave verbal consent prior to being interviewed; some give additional verbal consent to be recorded. The University of Texas at El Paso Institutional Review Board approved all interview practices (IRBNET ID 896427-1).

Creating research questions

A partially emergent thematic analysis (Kincheloe and McLaren, 2005) was used to analyze the translated transcriptions of the 62 recorded interviews. During initial interview processing, author KRWS organized translated interviews into single units of meaning labeled as

"utterances". Through this process, and in combination with field notes taken while conducting the interviews, KRWS' ecological knowledge of EP hawksbills (Chapter 3), and the FEK explored in Chapter 1, distinct themes emerged (Peterson et al., 1994; Peterson et al., 2010). Using these themes, data were categorized into four categories (C) with C1 and C4 broken down further into sub-categories (Table 4.1; Corbin and Strauss, 1990; Kincheloe and McLaren, 2005). Later, the FEK that emerged from these categories was translated into our four research questions (RQs1–4).

Table 4.1 Categories and subcategories used for the thematic analysis of interviews (n = 62; 34 Bahía; 28 EPR)

Category	**Subcategory**	**Definition**
C 1: Which hawksbill size(s) are seen more often than others within the estuary?	A B C D E Unspecified	When a size is mentioned, it must have quantifying information along with it (e.g., more, only, always, often, mostly, etc.). Cannot refer to temporal (e.g., we mostly see E during nesting season)
C 2: Are hawksbills found in the estuary outside of nesting season?		Direct reference to seeing hawksbills year round, or mentions of, "it's all the same, we can always see them, she stays". Responses such as "more during nesting season" indicate you can see them outside of nesting season.
C 3: Why are hawksbills found in certain areas?		Must answer *why* not just *where* hawksbills are found (e.g., "they feed, they're safer, during the high tide, there are mangroves")
C 4: After a release, where do hatchlings and yearlings go?	Stay in estuary Go out to sea We don't know /needs research Other	Must be referring specifically to A or B sized turtles and must say directly where the turtles go (e.g., they develop in the estuary, tide takes them out to sea, I don't know where they go)

Coding

Once the data were organized into utterances, authors KRWS and NH developed a codebook which defined the four research questions (RQs) and their respective subcategories (Appendix C), and used it to train themselves and assess intercoder reliability (Krippendorff, 2013). KRWS and NH independently coded ~20% of utterances, and calculated intercoder reliability across all RQs and subcategories with weighted Cohen's kappa (Cohen, 1968; .9886). Coding was done using NVivo 10.0 qualitative software (QSR International, Doncaster, Victoria, Australia). Depending on fit, individual utterances were coded into zero, one, two, three, and/or four categories according to the categories and their respective subcategories (Table 4.1). Each utterance was additionally coded as prompted or unprompted. Prompted utterances directly answered a question. Alternatively, unprompted utterances occurred when informants addressed a category without explicit direction. In these cases, informants volunteered information that went beyond direct response to interview questions. We used a frequency analysis to enumerate the times fishers uttered prompted and unprompted responses for each question.

The four categories were used to frame further exploration of the interview transcripts, also using NVivo 10.0 qualitative software (QSR International, Doncaster, Victoria, Australia). Matrix coding queries were used to identify number of utterances per category and subcategories, and advanced coding queries were done to further pull out prompted vs unprompted responses for specific categories and subcategories..

RESULTS AND DISCUSSION

We translated the four themes that emerged from the categories into four RQs. Each RQ emerged out of an especially salient strand of FEK. This information includes details pertinent to the conservation of EP hawksbills and provides corroboration for recent studies (Torres Gago et al., 2016; Gaos et al., 2018). These data also suggest new directions for future research. We discuss the four RQs that emerged in detail below, using informants' language whenever possible to describe their FEK.

RQ 1: Are immature hawksbills the most commonly found size in both estuaries?

Most informants identified immature hawksbills of size C (~30cm CCL,) as the most common size seen within Bahia and EPR, with 92/207 utterances. Examples include:

> They [hawksbills] can start to be seen when they are already medium sized or when they are of this size [C]. (Response J004.04).

> [We see] this young [immature; C] always more than anything. (Response B025.01)

The sea turtle life-history literature (Bolten, 2003) identifies size C as an immature sea turtle that would be returning to a neritic (near-shore, shallow water) feeding zone from a oceanic (open ocean) state – as FEK here confirms. Unique to this study, the sea turtle life-history ascribed by these fishers differs from that specified by Bolten (2003) in that they identify mangrove estuaries as the neritic habitats. This foraging ground has typically been described as disconnected from the nesting ground of adults in the same species, and is usually distinct from adult foraging grounds (Bolten, 2003). However, resident fishers reported that after immature turtles (size C), adults (E), were the second most reported size at both sites, followed by the largest immature turtles (D). This FEK suggests an alternative life history where the same habitat simultaneously provides developmental and foraging grounds for immature turtles, and foraging grounds and rookeries for adult turtles.E being commonly reported is expected, as Bahia and EPR serve as the primary rookeries for this region (Liles et al., 2015b). Most often sizes were mentioned independently of one another, but occasionally fishers associated sizes together. Fishers' reported:

> The adult [E] and that one of 30 [C] [are the most common]. (Response B020.03)

> Talking about adult ones right because the young ones [juveniles], I mean this one [C] and this one [D] [we see] all the time. (Response C042.03)

> Well we go around; fishing and that's when we catch them of all sizes. Yes, like this [C]. Like this [D] and like this bigger one [E]. (Responses A041.01–.03)

The sightings reported by fishers at both locations posit a change to the presumed life history of hawksbill sea turtles: they experience a mangrove developmental stage, suggesting further departure from their long-accepted coral reef associations. This mangrove developmental stage for EP hawksbills has been corroborated through participatory action research (Chapter 1) and stable isotope analysis (Chapter 3) and is consistent with the few studies within the EP that found immature and adult turtles foraging within the same estuaries (Gaos et al., 2012a; Torres Gago et al., 2016). This information challenges the currently accepted life-history patterns for sea turtles, where developmental habitat is separate from rookery adjacent waters and adult foraging grounds (Bolten, 2003). Additionally, immature and adult turtles foraging in the waters directly adjacent to the population's primary rookies reveals the interconnectedness of these habitats: they are one in the same. These findings directly answer calls for a better understanding of the connections between rookeries and foraging grounds (Hamann et al., 2010; Rees et al., 2016; Gaos et al., 2018) as well as providing data regarding immature EP hawksbill habitat use more generally (Liles et al., 2017; Wildermann et al., 2018).

The shared nature and multiple functions of these estuarine habitats highlight the importance of broadening our conservation efforts beyond nesting turtles to include multiple life-history stages and conservation of the mangrove estuary ecosystems. These conservation programs could build upon the strong foundations that already exist in both of these estuaries (Gaos and Yañez, 2012; Liles et al., 2015a; Liles et al., 2015b; Liles et al., 2017).

The deep connections between fishers and turtles emerged as a related theme to RQ 1: on a few occasions, informants mentioned size C sightings in conjunction with successful conservation initiatives in both Bahia and EPR. One fisher is Bahia explained:

> But, speaking frankly we have definitely seen the change with the hatchery, the change has been seen because before it was very rare to see a small Hawksbill like this one[C]. Yes, it was very rare and now, well since we work there in the, here in the Bahia and we can see that size [C] very often. (Response G007.05–.06)

While a fisher in EPR reflected:

> Well for example nowadays, to say it like that, one has seen a better influence of the Hawksbill. Because the truth is to be honest with you that some years ago; 12 or 13 years ago. You could only see a few. A few; and the majority of the ones you saw were only the adults [E]. And even more and the time when you could see them more was only in the mating season. They went around mating and then after that you couldn't see them anymore. But now I have about 4 years; 5 years on this area that you can see the… you can see the impact that has happened with the reproduction of the Hawksbill turtle. Because now almost in the majority of the estuaries that I go inside to fish, I fish almost daily. And almost in the majority of the estuaries that I go in to fish there is a lot of Hawksbill. The majority of them between lets say; 2 years, 3 years. It’s this one [C].There is a lot of the C; for example very close to here I tell them that it (turtle) has taken that little estuary of La Tiburona. They have taken it as a place to grow; there are so many turtles there. (Responses A043.01–.13)

Another EPR fisher shared a similar story of seeing the change in the hatchery:

> Those medium ones like that one have already been seen; more of them have been seen… before only the big ones could be seen. Now you can see of… of different sizes there. (Response F066.02–.03)

As indicated in these responses, fishers go beyond reporting sizes. They explicitly use size as a springboard for discussing both life history of the turtles and programmatic conservation efforts.

RQ 2: Are hawksbills found in estuary waters year-round, rather than just during nesting season?

Most fishers reported seeing hawksbills year round in both estuaries, supporting the idea of an estuarine residency by some turtles. Some respondents built upon the emerging results from RQ 1, mentioning specifically that they see size C year-round:

> Like that one [C] all year round; you can see them all year round and if its summer or winter you can see those little animals go. (Response D022.15)

Another fisher shared the same sentiment, but added that the adults come and go, since they are more often seen during nesting season.

> Ok, in the case of the young of 30[C] I think that all year round you can see but as far as the adults[D][E], I think that she comes, you can see her more often when the nesting season approaches. (Response I003.01)

Some informants provided more details, and ventured explanations as to why turtles may stay in the estuary year round:

> So, I think that some do stay here in the Bahia because when the nesting season has passed for them you can always see them frequently. And if they would leave [the bay] then you wouldn't see them, right? Only the other species would be seen, the green turtle (*prieta*), the olive ridley turtle (*golfina*). But the Hawksbill can be distinguished when they float, right. Because they[hawksbills] have a yellow little head so you can tell her apart. And you

can see her all the time; yes all the time. All year round, whether it is season; she [hawksbill] is over there floating. (Responses O004.02–.08)

These differences in habitat use by different sized hawksbills are consistent with genetic (Gaos et al., 2018) and stable isotope analyses (Chapter 3). Gaos et al. (2018) showed that EP rookeries are the primary contributors to proximal foraging grounds. Chapter 3 takes this further to estimate that hawksbills return to the estuaries after ~37cm CCL (immature, size C), and remain within the estuaries, increasing their dependence on estuarine resources through ~65cm (size D, early adulthood). They then exhibit a mixed strategy as adults – foraging in both the estuary and out in coastal waters. As in RQ 1, these data supports the need for further conservation of the estuary habitat. Future studies should dive further into the mechanisms driving the year round use of these estuaries, investigate how turtles are using these habitats year round, and what impacts this may have on fecundity and other measures of fitness for this population.

RQ 3: Do food, safety, environmental factors, and "happiness" drive habitat use?

RQ 3 reveals possible mechanisms driving the use of the estuary habitat, with food, safety, environmental factors, and "happiness" emerging as the strongest drivers. Understanding the mechanisms that drive estuary use by hawksbills of all sizes is important so we can better identify and prioritize the factors critical to their survival, and further understand the connections between rookeries, developmental ground, and foraging grounds (Rees et al., 2016; Gaos et al., 2018; Wildermann et al., 2018).

Food

Food availability is thought to drive habitat use for flatback sea turtles (*Natator depressus)*, leatherbacks (*Dermochelys coriacea)*, EP olive ridleys (*Lepidochelys olivacea)* (Bolten, 2003), and now EP hawksbills. FEK revealed that feeding is the strongest driver of habitat selection by hawksbills within the estuary. Some fishers provided straightforward responses:

> That she likes it because there she can find her food source. (Response F043.08).

> There is a lot of food, that is what attracts them more to the place too; the food, that there is good food. (Response I044.04)

> Because I know that is where the turtles feed from. (Response 047.03)

Others offered information about the types of food hawksbills eat, with barnacles and mangroves being the most common. Some offered first-hand accounts, like this fisher who has witnessed hawksbills eating barnacles:

> But almost always it is like that, well in my point of view it is that they like it more because the mangrove has more barnacle, it has a lot of barnacle. We call a little thing (inaudible) barnacle, and they eat it. Because we have already seen that they do eat that. Because we would be washing ourselves and all of a sudden there is a branch in the water and it has a lot of those little things [barnacles] and the turtles come and makes (noise) and you can hear when she bite…We say: "look the turtle is eating the barnacle". (Responses G035.06–.10)

Others reported what they've heard from others:

> Someone came to tell them and it [hawksbill] was stuck in the mangrove there and was eating barnacle. (Response E002.03)

Another shared that hawksbills return to the estuary when they know food is available:

> Yes they return and they also say that they [hawksbills] know the date when there is food in the Estero which is the seed of the mangrove. (Response C039.05)

This coordination of migratory behavior by hawksbills in response to food availability, and how this could relate to the estuarine developmental stage and year-round use of these estuaries by hawksbills, deserves further investigation. While hawksbills are traditionally thought to feed primarily on coral reefs (Jones and Seminoff, 2013; IUCN, 2018), our findings support others who have found hawksbills foraging with in mangrove estuaries throughout the EP (Torres Gago et al., 2016; Llamas et al., 2017; Gaos et al., 2018, Mendez et al. in review). Fishers mentioned algae, barnacles, fish, and sea grass as other diet items preferred by hawksbills, and future studies should use this knowledge to craft diet content analyses at these sites, similar to Mendez et al. (in review).

Safety

Safety also emerged as a driving force for estuarine use by hawksbills. This is consistent with known functions of mangrove estuaries (Nagelkerken et al., 2008). Fishers shared:

> I imagine that they go to the [artificial] reefs, to the big rock where the rocks are because that's where they are a little bit safer (Response G040.01).

> In those areas, I say that they feel safer. It has to be. (Response H002.05, 07)

Some provided more context:

> I have not seen them but I have been told that in those streams there is an abundance of them, I can imagine that is where they can escape and that is why there is an abundance (Response C013.02)

Others mentioned specific predators by name:

> Hmmmmm my idea is that if they are not eaten by the predators, well they look for refuge in the little stream that go inside of the mangrove, yes that's my idea, which is the only way that they can save themselves from the predators because a blowfish like this would eat them. (Response G022.01).

> Further up for the small extensions of the estuaries because if they [A] stay in the deepest end there are bigger fish like that *robalo*, the *pargo*, *menton* that we call it here, which is a type of big *pargo* that lives here in the Estero and that eats them [hawksbills]. (Response G042.02)

Turtle safety was also associated with lack of fishers' nets in some instances:

> …Also in the Estero to the places where they [E] don't, don't throw the nests as much. Yes where the nets aren't thrown as much (Response C045.01)

Hawksbills adjusting their habitat use in response to where they avoid humans, feel more secure, or "happier" is explored below under "turtle comfort and happiness". Rocks were also mentioned several times as potential hiding spots for turtles and were also mentioned in association with food availability. Rocks as drivers of habitat use by hawksbills is further explored below under environmental factors.

Environmental factors

Rocks were the most prominent environmental factor mentioned, and were mentioned in association with feeding, predator avoidance, and among other reasons why hawksbills prefer certain habitat:

> There are algae that grows there on the rocks. So that's where they have their food. (Response E040.03–04)

One fisher shared that finding rocks are innate to hawksbills:

> She has that focus in mind from when she is born she knows that her release; from the moment of her release she is going to look for shelter like the rocks are for her. (Response D043.05)

Others, reported vegetation or artificial reefs as safe spaces for hawksbills:

> It could be due to the vegetation; yes more likely it is because of the vegetation and may it feels a little bit more protected (Response E009.01)

> I imagine that they go to the reefs, to the big rock where the rocks are because that's where they are a little bit safer (Responses G040.01).

Rocks, artificial reefs, and mangrove vegetation make sense as preferred habitat for turtles as both provide food sources and predator avoidance (Nagelkerken et al., 2008) – similar to coral reefs, the preferred habitat for hawksbills in other regions (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013; IUCN, 2018). This is plausible to posit, since EP sea turtles species are known to have specifically adapted to the unique environments of the EP (Seminoff et al., 2012).

Other environmental factors included tides and currents, particularly when fishers were talking about where the smallest (sizes A and B) turtles go immediately after they hatch. Many responded that tides and currents take small turtles to certain areas, a facet further addressed under RQ 4. Additional environmental factors included depth, temperature, salinity, and substrate. All

of these factors are variables often measured in habitat suitability analyses. KRWS has unpublished data on these environmental factors that corresponds to where hawksbills within Bahia and EPR were caught; this FEK supports the need for a future habitat suitability analysis.

Turtle comfort and happiness

In addition to empirical answers by fishers, some included more anthropomorphized explanations as to why turtles are in some areas rather than others, giving the turtles feelings. Responses included:

> I supposed that is because they like the area maybe they like it here. They find a way to accommodate themselves, here right. (Responses E006.04, .05, .08)

Some were more specific, and mentioned turtles like where they are not bothered:

> It might be because no one bothers them and they feel at ease (e008.03)

> That there is someone in other parts that throws bombs, throw nets so in the sea they throw nets and in those cases the animals, what they do is that they leave to another area where they are not bothered, they find more danger maybe in other areas. (Response H023.03)

One fisher drew a direct parallel between human actions and turtle decisions:

> We move away from danger and we find where to shelter so it's the same with those little animals those species. (Response G045.03)

Another fisher combined many of the other fishers' sentiments:

> She stays [in the estuary] because it is a part almost in all of the estero here that the people don't bother her they don't kill her for food. And there are a lot of places that they have to feed themselves. So she feels good and she stays. (P042.11–.13)

This apparent deeper connection to the turtles – understanding their feelings – and strong cultural connections to hawksbills was found in a previous ethnographic study in Bahia (Liles et al. 2015). The theme of "turtle happiness" and the connections the fishers feel towards turtles should be further explored. These connections could provide deeper insight into FEK, as well as the most mutually beneficial conservation solutions that address the human and turtle needs in the region.

RQ 4: Do the youngest sea turtle life stages stay within the estuaries after a hatchling release?

Since few fishers reported ever seeing hatchlings or young turtles (<30cm CCL, sizes A–B) outside of a release, we asked, "if we don't see A or B in the water, where do they go?" On several occasions, local fishers were as perplexed by this question as we were, and many said they had not thought about it before (KRWS field notes, May 2016). Some fishers responded that they did not know and we should research this more, one fisher said specifically:

> … I think that it needs to be researched where do they go, because that is how we can control if it is true that they go to the mangrove or they go somewhere else."(Response L001.07–.08)

Some fishers mentioned the currents could be pulling the hatchlings deep into the mangroves, which is why they did not see them. Others suggested that the currents serve the opposite purpose, pulling at least some of the hatchlings out into the open ocean. One fisher proposed:

> Some [hatchlings] must go to the sea and other ones must stay here in the estuary because of the current right. It [current] must throw some of them to the sea. Some others it must

> leave them there when it goes inside there, how do I say this, to the Bahia [estuary], when there is not too much current in the estuary I imagine that they stay there. And when we see that the big current grabs them it brings them down and leaves them who knows where. (Responses G031.02–.04)

The overwhelming majority of fishers believe that hatchlings stay in the estuaries, with 174/242 utterances supporting this thought, with going out to sea being the second most mentioned option for newly hatched hawksbills at only 36 utterances. These results alone merit future studies focused specifically on hatchling dispersal, mechanisms of dispersal (e.g., tides, currents, timing of releases). Chapter 3 revealed that young hawksbills (<30cm CCL, size C) exhibit pelagic stages, and Liles et al. (2017) found that ~30cm CCL turtles were bycaught in artisanal fisheries in ocean waters outside the mouth of the estuaries. It could be possible that initially, small turtles (e.g., hatchlings, size A; <15cm CCL, size B) are riding the currents, or moving deep within the estuaries, and then move out to the sea at a size between 15–30cm CCL, before coming back into the estuary. Currents are known to influence loggerhead (*Caretta caretta)* hatchling dispersal in the Atlantic (Mansfield et al., 2014; Mansfield et al., 2017) and to influence immature (>30cm CCL) and adult EP hawksbill habitat use within Bahia and EPR (Torres Gago et al., 2016). As such, currents affecting hatchling dispersal should be a research priority for this population.

When asked where small turtles are dispersing to, many offered where and why hatchlings would be found in certain areas, linking the knowledge of *where* turtles are (RQ 4) closely with *why* they are in certain areas (RQ 3). Specifically, many mentioned habitat use, driven by food and protection, kept the youngest hawksbills in the estuary. One fisher explained:

> To the extremes of the canals, the small extensions of the estuaries is what I imagine because if they go to the sea, because there are birds that you can see doing like this (pazz makes sound), grabs them and takes them. And the fish as well, the little fish gets the little turtle, he eats her. (Responses B039.02–.04)

Another postulated similarly:

> So they [hatchlings, size A] stay there, they stay there looking for a way to escape from the predators. Yes because you know that for example there are a lot of fish here in these estuaries that would eat them. So they look for places where they can hide. (Responses D045.05–.07)

One fisher stated that the hatchlings associate with the mangroves for food availability:

> [You can find hatchlings] in those oldest trees on the mangrove over there. Since in there you can find bigger, oldest trees on the mangrove, [the turtles are] more nourished there." (responses G007.02–.03)

One fisher responded more holistically, emphasizing that hawksbills are adapted to life in the estuary:

> Because I don't think that all the turtles go only to the sea, they have to live in the mangrove the ones that are already adapted to the estuary area because its calmer than the sea." (response H001.08)

Data on these small turtles are deficient for most sea turtle populations worldwide, so much so that sea turtle biologists deem these years as "the lost years"(Carr, 1952; Wildermann et al., 2018). Fishers' expert knowledge in this study provides insight on where the youngest hawksbills may be dispersing to, and should be used to guide future qualitative and quantitative studies focused on EP hawksbills lost years. Of special consideration for future studies should be to identify how the tides and currents play into the dispersal of hawksbill hatchlings within Bahia and

EPR, as these factors have been found to impact older immature (>30cm CCL) and adult hawksbill movement within these estuaries (Torres Gago et al., 2016), and in "lost years" dispersal of other sea turtle species (e.g., Mansfield et al., 2017).

CONCLUSION

In this exploratory study, RQs were allowed to emerge from the FEK, illuminating several themes important to the conservation of an imperiled population. This study's RQs focus on critical gaps in hawksbill knowledge, specifically: how they use mangrove estuaries near their primary rookies, Bahia and EPR, throughout their lives. FEK revealed that these estuaries provide crucial developmental habitat for EP hawksbills (RQ 1, 2), habitat use is primarily driven by food availability and safety (RQ 3), and some adults use these estuaries year-round (RQ 2). The "lost years" remain elusive, but FEK strongly suggests that the influence of currents on hatchling dispersal warrants further investigation (RQ 4).

This study directly answers calls for more data on sea turtles, specifically to identify links between foraging grounds and rookeries (Rees et al., 2016), the identification of habitat use by immature EP hawksbills (Liles et al., 2017; Gaos et al., 2018; Wildermann et al., 2018), and the integration of social science methods into sea turtle conservation (Rees et al., 2016; Chapters 1-3). These methods and information sources provide powerful data for improved conservation. Obtaining these data can be a relatively efficient and low-cost endeavor that simultaneously enables researchers to build partnerships with local residents. Further, this study supports the recent calls for the social sciences to be used in conservation science (Bennett et al., 2017; Teel et al., 2018) and provides further support for the value of FEK for conservation (Johannes et al., 2000; Haggan et al., 2007). Finally, incorporating FEK into the lexicon of conservation may breathe new life into the scientific process by challenging scientists to open their minds to diverse knowledge cultures (e.g., local knowledge), even when that knowledge contradicts accepted scientific norms.

Conflict of interest

The authors declare they have no conflict of interest.

Author contributions statement:

KRWS conducted all interviews, data analysis, and drafted the manuscript. NH aided in study design, coding, and data analysis. RS, SC, MV assisted with all interviews conducted in El Salvador. ML coordinated fieldwork, provided logistical support in the field, and facilitated translation of interviews. EA, VC provided logistical support in the field. SS provided logistical and writing support. TRP helped design the study, methods, and writing support.

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Conclusion

The four chapters of this dissertation provide important insight into the life history and conservation of EP hawksbills. They highlight the value of integrative approaches that blend the social science with SIA approaches. They demonstrate the value of FEK, provide an opportunity for local fishers to be heard and given the influence their knowledge deserves. Chapter 1 generated 301 baseline data points in one month, creating the first ever detailed in-water habitat use map for hawksbills in Bahia and EPR. This multi-dimensional FEK led to the invention of a new tool (Chapter 2), and guided our in-water sea turtle capture, so we could survey and sample the turtles living within the estuaries. This chapter revealed four advantages of incorporating PAR to engage FEK in conservation. Chapter 3 fully integrates the social and natural sciences, and uses SIA to quantify the transition of hawksbills into estuarine habitat from pelagic waters. SIA and FEK corroborate and strengthen one another, highlighting the effectiveness and power of a social-ecological systems approach. In Chapter 4, a thematic analysis of FEK is consistent with information identified throughout this project and provides insight to where future conservation research and management should be focused.

The critical new information discovered herein is that hawksbills are experiencing a mangrove estuarine developmental stage, and rely on the mangrove estuaries throughout their lives. The size of EP hawksbills at recruitment into these two estuaries is a critical detail, as the SIA revealed that hawksbills experience a pelagic stage prior to recruitment back into the estuaries. This movement from the ocean into the estuary at ~37cm CCL may mean that EP hawksbills are regularly interacting with artisanal fisheries just outside the mouths of the estuaries. Liles et al. (2017) found that these artisanal fisheries are the top threat to turtles in this region, so our new knowledge underscores the need to focus conservation efforts beyond just estuarine habitats. We should engage with open ocean fishers, and in a way similar to this study, collaborate with them so that their FEK can help us expand our conservation reach, and help us to create mutually beneficial conservation priorities and management practices (Liles et al., 2015).

Our findings fit within the context of sea turtle evolution, as the sea turtle common ancestor is thought to have moved into the water and remained within estuaries in order to stay close to shore (Bolten, 2003). Flatback sea turtles (*Natator depressus)* remain in neritic waters throughout their lives, so they are within foraging grounds and close to nesting beaches (Bolten, 2003). Additionally, hawksbill aggregations are known to be influenced not only by food availability, but also by shelter availability and predator avoidance (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). Our interdisciplinary data together, reveal that food availability and safety (e.g., predator avoidance) are likely driving estuarine habitat use by EP hawksbills.

Our data show that some adult hawksbills exhibit polymodal foraging strategies, some remaining true to estuaries waters, while others forage in pelagic waters (Chapter 3). Polymodal foraging within sea turtle populations has been identified in loggerheads, green sea turtles, leatherbacks, (Hatase et al., 2002; Hatase et al., 2006; Caut et al., 2008), and in Caribbean hawksbills (Bjorndal and Bolten, 2009) through SIA. Satellite tracking studies within the EP further support our results of a mixed adult foraging strategy. Our findings are further supported by Gaos et al. (2012), which found two distinct patterns of habitat use by tracked inter-nesting female EP hawksbills: some inhabited in-shore estuarine bays, and other inhabited waters off the coasts of El Salvador, Nicaragua and Ecuador. Additionally, the most recent species review states that hawksbills have a mixed migratory strategy, even within rookeries, with some remaining as residents close to their rookery and others migrating long distances (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). In addition to corroborating the adult mixed strategy, our data provide critical information: habitat use of Bahia and EPR by immature EP hawksbills.

We report that immature EP hawksbills experience a pelagic stage before recruiting into Bahia and EPR for an estuarine developmental stage (Chapters 1, 3–4). These findings are supported by recent studies that report preliminary genetic structuring between open beach and estuary nesters (Gaos et al., 2015), and have proposed "natal foraging philopatry" (NFP), where foraging grounds are closely connected to rookeries (Gaos et al., 2017; Gaos et al., 2018). NFP is

consistent with our findings that in addition to serving as the primary rookeries for EP hawksbills, the waters of Bahia and EPR also serve as critical foraging and developmental grounds (Chapters 1, 3–4).

Overall, this research addresses top priorities for sea turtle research: for studies to go beyond tag-recapture and satellite telemetry to understand spatial ecology of sea turtles by incorporating multiple approaches (Hamann et al., 2010; Rees et al., 2016), understanding connections between foraging grounds and rookeries, and identifying size at recruitment and habitat use by immature turtles (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013; Liles et al., 2017; Gaos et al., 2018; Wildermann et al., 2018). We have answered calls specifically for this population (Wallace et al., 2011, Mendez et al., in review; Rees et al., 2016; Gaos et al., 2017; Liles et al., 2017; Gaos et al., 2018; Wildermann et al., 2018), and recent calls to integrate the social sciences in conservation (Haggan et al., 2007; Rees et al., 2016; Bennett et al., 2017; Ban et al., 2018; Teel et al., 2018). This dissertation demonstrates that a social-ecological systems approach can efficiently generate high quality quantitative and qualitative data.

While this dissertation used EP hawksbills as a case study, the methods explained throughout have broader impacts. Knowledge comes in diverse forms, each with its own power and potential, and deserving of respect in its own right. The findings of this dissertation highlight that when we open our minds to different knowledge cultures, it allows us to broaden our understandings of natural systems and how humans interact with them (Drew and Henne, 2006; Haggan et al., 2007; Hind, 2014; Marchio, 2018). Working together with fishers, or other subsistence resource users, is critical to the future of conservation where our social-ecological systems are intrinsically linked. We show that when we integrate these different knowledge sources, we can increase commitment of local stakeholders to conservation initiatives, expand academic knowledge, and collaboratively generate knowledge of a revolutionary nature.

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Glossary

Bahía: Bahía de Jiquilisco, El Salvador

Broca Nefta: drill bit attachment invented to take carapace samples from marine turtles

EP: eastern Pacific

EPR: Estero Padre Ramos, Nicaragua

FEK: fishers' ecological knowledge

PAR: participatory action research

TOV: trinity of voice

SIA: stable isotope analysis

RQ: research question

Appendix A: IRB Supporting Documents

INFORMED CONSENT FORM (ENGLISH)

University of Texas at El Paso (UTEP) Institutional Review Board
Informed Consent Form for Research Involving Human Subjects

Protocol Title: Local perspectives towards the feeding ecology of hawksbill turtles in El Salvador and Nicaragua
Principal Investigator: Kathryn R. Wedemeyer-Strombel and Michael J. Liles
UTEP: K.R.W-S, Environmental Science and Engineering; M.J.L, Biological Sciences

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1. Introduction
You are being asked to take part voluntarily in the research project described below. Please take your time making a decision and feel free to discuss it with your friends and family. Before agreeing to take part in this research study, it is important that you read the consent form that describes the study. Please ask the study researcher or the study staff to explain any words or information that you do not clearly understand.

2. Why is this study being done?
You have been asked to take part in a research study to understand where within the estuary waters local marine resource users, like yourself, have encountered hawksbill sea turtles. This project will increase our capacity to, and efficiency in, protecting hawksbills and their critical habitat and will highlight the importance of local knowledge in conservation.

Approximately, 100 people will be enrolling in this study from the communities surrounding Bahía de Jiquilisico, El Salvador and Estero Padres Ramos, Nicaragua.

You are being asked to be in the study because you work on or near the water and are an adult resident (over the age of 18) of a community surrounding Bahía de Jiquilisco, El Salvador or Estero Padre Ramos, Nicaragua. If you decide to enroll in this study, your involvement will last about 30 minutes to 1 hour.

3. What is involved in the study?
If you agree to take part in this study, the research team will conduct a personal face to face interview, led by either Kathryn Wedemeyer-Strombel or Michael Liles. No identifiable information will be collected. Your participation in this study will last up to 1 hour per interview. If you agree to participate you will have the opportunity to direct the interview, talking as you'd like and stopping when you feel it necessary. You will be asked open-ended questions (see Interview Questions document), and you will decide if you answer them and in how much detail. Interviews will take place at a location of your choosing, where you feel most comfortable. If you give permission, the researcher will make an audio recording during the study in order to assist with the data collection process. The researcher will ask whether or not you give

permission for audio recordings to be made during your participation. You may also ask to stop the audio recording anytime during the interview.

4. What are the risks and discomforts of the study?
There are no known risks associated with this research.
You do not have to answer anything you do not want to. Aside from your time, there are no costs for taking part in the study.

5. What will happen if I am injured in this study?
The University of Texas at El Paso and its affiliates do not offer to pay for or cover the cost of medical treatment for research related illness or injury. No funds have been set aside to pay or reimburse you in the event of such injury or illness. You will not give up any of your legal rights by signing this consent form. You should report any such injury to Kathryn R. Wedemeyer-Strombel (1-915-747-5913) and to the UTEP Institutional Review Board (IRB) at (915-747-7693) or irb.orsp@utep.edu.

6. Are there benefits to taking part in this study?
There will be no direct benefits to you for taking part in this study. This research may help us to understand the habitat use of hawksbill sea turtles and their accidental interactions with fishing gear.

7. What other options are there?
You have the option not to take part in this study. There will be no penalties involved if you choose not to take part in this study.

8. Who is paying for this study?
External funding:
UTEP and Kathryn Wedemeyer-Strombel are receiving funding from the National Science Foundation to conduct this study.

9. What are my costs?
There are no direct costs. You will be responsible for travel to and from the research site and any other incidental expenses.

10. Will I be paid to participate in this study?
You will not be compensated for taking part in this research study.

11. What if I want to withdraw, or am asked to withdraw from this study?
Taking part in this study is voluntary. You have the right to choose not to take part in this study. If you do not take part in the study, there will be no penalty or loss of benefit.

If you choose to take part, you have the right to skip any questions or stop at any time. However, we encourage you to talk to a member of the research group so that they know why you are leaving the study. If there are any new findings during the study that may affect whether you want to continue to take part, you will be told about them.

The researcher may decide to stop your participation without your permission, if he or she thinks that being in the study may cause you harm.

12. Who do I call if I have questions or problems?
You may ask any questions you have now. If you have questions later, you may contact the Principal Investigator, Kathryn Rose Wedemeyer-Strombel, to tell her about a concern or complaint about this research at (915)747-5913 or krwedemeyer@miners.utep.edu. You may also contact the faculty adviser, Dr. Tarla Rai Peterson at (915)747-5913 or trpeterson@utep.edu. If you have questions or concerns about your participation as a research subject, please contact the UTEP Institutional Review Board (IRB) at (915-747-7693) or irb.orsp@utep.edu.

13. What about confidentiality?
Your part in this study is confidential. No identifiable information will be collected. Research records will be stored securely and only Kathryn Rose Wedemeyer-Strombel (PI), Dr. Michael J. Liles (Co-PI) and Dr. Tarla Rai Peterson (faculty advisor) will have access to the records. Information will be stored in locked file cabinet; computer files protected with a password. All interview data and other project related information will be encrypted and stored on computers in the PIs' office (Quinn Hall, Room #210). These computers are protected by passwords that meet UTEP security requirements. Confidentiality will be ensured by coding and secure storage of results. The interview data and all other project related data will be destroyed after they have been transcribed and coded. The results of this research study may be presented at meetings or in publications. No identifiers will be used in publications or presentations.

14. Mandatory reporting
If information is revealed about potentially dangerous future behavior to others, the law requires that this information be reported to the proper authorities.

15. Authorization Statement

We will not request written consent of these informants. A verbal consent will be obtained from respondents.

I have read each page of this paper about the study (or it was read to me). I know that being in this study is voluntary and I choose to be in this study. I know I can stop being in this study without penalty. I will get a copy of this consent form now and can get information on results of the study later if I wish.

INFORMED CONSENT FORM (SPANISH)

University de Texas en El Paso (UTEP) Comité Institutional de Revisión
Consentimiento informado para la investigación que involucra sujetos humanos

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Título de Protocolo: Perspectivas locales sobre la alimentación ecológica y captura incidental de tortugas carey en El Salvador y Nicaragua
Investigador Principal: Kathryn R. Wedemeyer-Strombel y Michael J. Liles
UTEP: K.R.W-S, Ciencias Ambientales e Ingeniería; M.J.L, Ciencias Biológicas

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1. Introducción
Se le solicita formar parte de manera voluntaria del proyecto de investigación descrito abajo. Por favor tómese su tiempo decidiendo y siéntase en libertad de discutirlo con sus amigos y familiares. Antes de aceptar formar parte de este estudio de investigación, es importante que lea el formulario de consentimiento que describe el estudio. Por favor pregúntele al investigador del estudio o al personal del estudio que le explique cualquier palabra o información que no entienda claramente.

2. ¿Por qué se está realizando este estudio?
Se le ha solicitado ser parte de un estudio de investigación para entender a donde dentro de las aguas del estero los usuarios de recursos marinos locales, como Usted, han encontrado tortugas carey y que interacciones accidentales pueden tener las carey con pescadores. Este proyecto aumentará nuestra capacidad y eficiencia para proteger a las carey y su hábitat critico y resaltará la importancia del conocimiento local para la conservación.

Aproximadamente, 210 personas participaran en este estudio de comunidades aledañas a la Bahía de Jiquilisco, El Salvador y Estero Padre Ramos, Nicaragua. Se le ha solicitado ser parte de este estudio porque, ya sea trabaja en la costa o cerca de ella y es un adulto (mayor de 18 años) que reside en una comunidad en los alrededores de la Bahía de Jiquilisco, El Salvador o Estero Padre Ramos, Nicaragua. Si decide participar en este estudio, su participación durará aproximadamente de 30 minutos a 1 hora.

3. ¿De qué se trata el estudio?
Si acepta formar parte de este estudio, el equipo de investigación va desarrollar una entrevista en persona, dirigida ya sea por Kathryn Wedemeyer-Strombel o Michael Liles. No se recopilará ninguna información identificable. Su participación en este estudio durará hasta una hora por entrevista. Si acepta participar tendrá la oportunidad de dirigir la entrevista, hablando como prefiera y parando cuando sienta que es necesario. Se le harán preguntas abiertas (vea el documento con Preguntas de la entrevista), y va poder decidir si las quiere contestar y con cuanto detalle. Las entrevistas se van a realizar en el lugar de su preferencia, donde se sienta más cómodo. Si Usted lo autoriza, el investigador hará una grabación de audio durante el estudio para asistirle en el proceso de recopilación de datos. El investigador le preguntará si le brinda permiso de hacer una grabación de audio durante su participación. Usted también podrá solicitar que se detenga la grabación en cualquier momento durante la entrevista.

4. ¿Cuáles son los riesgos e incomodidades asociados con el estudio?
No existen riesgos conocidos relacionados con esta investigación. No tiene que contestar nada que no quiera. Además de su tiempo, no hay costos asociados con el estudio.

5. ¿Qué sucederá si me accidento durante este estudio?
La Universidad de Texas en El Paso y sus afiliados no ofrecen pagar o cubrir costos asociados con tratamientos médicos para investigaciones relacionados con enfermedades o accidentes. No se han destinado ningún tipo de fondos para pagarle o reintegrarle en caso de algún accidente o enfermedad. Al firmar este formulario de consentimiento no renunciaran a sus derechos legales. Debe reportar cualquier accidente a Kathryn R. Wedemeyer-Strombel (1-915-747-5913) o a Michael J. Liles (1-915-747-5913) y al Comité Internacional de Revisión (IRB por sus siglas en Inglés) de UTEP al (915-747-7693) o irb.orsp@utep.edu.

6. ¿Hay beneficios relacionados con participar en este estudio?
No habrán beneficios directos por participar en este estudio. Esta investigación puede ayudarnos a entender el hábitat utilizado por las tortugas carey y su interacción accidental con equipos de pesca.

7. ¿Qué otras opciones hay?
Tiene la opción de no participar en este estudio. No habrán penalidades si decide no participar en este estudio.

8. ¿Quién esta pagando por este estudio?
Financiamiento externo:
UTEP y Kathryn Wedemeyer-Strombel están recibiendo fondos de la Fundación Nacional de Ciencias para desarrollar este estudio.

9. ¿Cuáles son mis gastos?
No hay gastos directos. Usted se responsabilizará por su llegada al sitio donde se realizará la entrevista y cualquier otro gasto imprevisto.

10. ¿ Se me pagará por mi participación en este estudio?
Usted no será compensado por participar en este estudio de investigación.

11. ¿Qué si quiero retirarme del estudio, o se me solicita retirarme del estudio?
Su participación en este estudio es voluntaria. Usted tiene el derecho de escoger no participar en el estudio. Si no participa en el estudio, no habrá penalidad o perdida de algún beneficio.

Si decide participar, Usted tiene el derecho de saltarse cualquier pregunta o detenerse en cualquier momento. Sin embargo, lo animamos a que hable con un miembro del equipo de investigación para que sepan porque decidió dejar el estudio. Si se dan descubrimientos nuevos durante este estudio que puedan afectar su deseo de continuar, se le dejará saber sobre ellos.

El investigador puede decidir detener su participación sin su autorización si el o ella piensa que formar parte del estudio pueda causarle algún daño.

12. ¿A quién le puedo llamar si tengo preguntas o inconvenientes?
Puede hacer cualquier pregunta en este momento. Si tiene preguntas más adelante, puede contactar a la Investigadora principal, Kathryn Rose Wedemeyer-Strombel, para decirle sobre su inquietud o queja sobre esta investigación al (915)747-5913 o a krwedemeyer@miners.utep.edu. También puede contactar al Co Investigador, el Dr. Michael J. Liles al (915)747-5913 o a mjliles@utep.edu. Si tiene preguntas o inquietudes sobre su participación como sujeto de investigación, por favor contacte al Comité Internacional de Revisión (IRB por sus siglas en Inglés) de UTEP al (915-747-7693) o a irb.orsp@utep.edu.

13. ¿Qué hay de la confidencialidad?
Su participación en este estudio es confidencial. No se recopilará ninguna información identificable. Los expedientes de investigación serán guardados de forma segura y solo tendrán acceso a ellos Kathryn Rose Wedemeyer-Strombel (IP), el Dr. Michael J. Liles (Co-IP) y la Dra. Tarla Rai Peterson. La información será guardada en un archivador bajo llave; los archivos de las computadoras protegidos con una contraseña.

Toda la información de la entrevista e información relacionada con el proyecto será codificada y guardada en las computadoras de la oficina de los IPs (Quinn Hall, Aula #210). Estas computadoras están protegidas por contraseñas que cumplen con los requisitos de seguridad de UTEP. Se asegurará la confidencialidad codificando y guardando los resultados de manera segura. La información de la entrevista y toda otra información relacionada al proyecto será destruida después de haber sido transcrita y codificada. Los resultados de este estudio de investigación pueda que sean presentados en conferencias o en publicaciones. No se usará información personal en publicaciones o presentaciones.

14. Obligación de informar
Si se descubre alguna información sobre algún comportamiento posiblemente peligroso hacia otros, la ley obliga que esta información sea reportada a las autoridades.

15. Declaración de autorización

No requeriremos de un consentimiento escrito de estos informantes. Un consentimiento verbal se obtendrá de los encuestados.
He leído (o me fue leído) cada pagina de este documento. Sé que formar parte de este estudio es voluntario y yo escojo ser parte de el. Sé que puedo dejar de estar en este estudio sin ninguna penalidad. Obtendré una copia de este formulario de consentimiento y más adelante si quiero puedo obtener información sobre los resultados del estudio.

WAIVER OF WRITTEN DOCUMENTATION OF THE CONSENT PROCESS FOR THE USE OF HUMAN SUBJECT RESEARCH

Title of Project: Local perspectives towards the feeding ecology of hawksbill turtles in El Salvador and Nicaragua

Investigators (co-investigators): Kathryn Wedemeyer-Strombel, PhD Candidate (Principal Investigator); Dr. Michael J. Liles, PhD (Co-Principal Investigator); Dr. Tarla Rai Peterson, PhD (Faculty Advisor)

The applicants request a **waiver of written documentation of the consent process** for the use of human subject research.

Protocol-specific explanation: A verbal consent will be obtained from respondents. Participants will be asked to give a verbal consent if they agree to take part in the research study. K. Wedemeyer-Strombel or M. J. Liles will read out the informed consent document (see separate submitted "Informed Consent Document") in Spanish, and will seek verbal consent from respondents. It is not culturally appropriate to have rural participants sign a consent document. For an illiterate population, an inability to sign can cause embarrassment. The socio-political situation in Latin America could also make potential participants uneasy if required to sign a document, even though no risk is expected from the study, a signed document would be the only personal identifier that could lead back to the participant. Participants will be informed that they do not have to answer any question they do not wish to. Both M. Liles and K. Wedemeyer-Strombel are fluent in Spanish and have spent enough time within these cultures to understand social cues and will be able to identify if a participant feels uncomfortable. Additionally, some of these community members have willingly participated in a previous interview study done by M. J. Liles and T.R. Peterson.

INTERVIEW QUESTIONS TO BE USED DURING INFORMANT-DIRECTED, OPEN-ENDED INTERVIEWS

Title of Project: Local perspectives towards the feeding ecology of hawksbill turtles in El Salvador and Nicaragua

Investigators (co-investigators): Kathryn Wedemeyer-Strombel, PhD Candidate (Principal Investigator); Dr. Michael Liles, PhD (Co-Principal Investigator); Dr. Tarla Rai Peterson, PhD (Faculty Adviser)

<u>Open ended question:</u>
Please discuss your experiences encountering hawksbills within the estuary.

Por favor, cuentame usted sobre sus experiencias con tortugas carey dentro del estuario.

<u>Prompts, as needed:</u>
How often do you encounter hawksbills within the estuary?

¿Con qué frecuencia ve las tortugas carey dentro del estuario?

Where do you encounter hawksbills within the estuary?

¿Dónde ve las tortugas carey dentro del estuario?

Why do you think they are found in certain areas?

¿Por qué cree que las tortugas carey se encuentran en ciertas areas?

What sizes do you see? Are different sizes found in different areas?

¿De qué tamaño son las tortugsa carey que ha visto? Ha visto diferentes tamaños de tortugas carey en diferentes áreas?

Appendix B: Raw stable isotope data not shown and/or used in chapter 3

Bulk $\delta^{13}C$ and $\delta^{15}N$ of potential hawksbill estuarine prey

Sample ID	Tray #	Tray ID	Weight	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C:N	Type
BP 15	2	A1	0.476	-23.5	8.7	53.7	13.3	4.0	barnacle
BP 16	2	A2	0.460	-21.5	6.8	42.8	11.1	3.9	barnacle
BP 17A	2	A3	0.497	-23.4	8.0	46.3	13.1	3.5	barnacle
BP 17B	2	A4	0.528	-23.3	9.3	43.0	13.8	3.1	barnacle
BP 17C	2	A5	0.520	-23.5	8.7	42.9	13.2	3.3	barnacle
BP 17D	2	A6	0.499	-23.8	10.9	52.7	14.5	3.6	barnacle
BP 17E	2	A7	0.487	-23.8	9.7	43.7	12.6	3.5	barnacle
BP 17F	2	A8	0.535	-23.8	10.1	44.8	12.2	3.7	barnacle
BP 18	2	A9	0.508	-23.1	9.3	47.9	14.9	3.2	barnacle
BP 19	2	A10	0.486	-23.7	10.3	45.8	12.4	3.7	barnacle
BP 20	2	A11	0.463	-22.3	7.5	46.9	10.5	4.5	barnacle
BP 22	2	B1	0.447	-21.7	8.8	46.3	12.1	3.8	barnacle
BP 23	2	B2	0.536	-20.9	9.6	52.1	13.2	4.0	barnacle
MP 69	2	B7	7.197	-28.6	-1.4	44.1	0.8	51.9	mangrove
MP 70	2	B8	7.259	-27.8	1.7	37.7	1.6	23.9	mangrove
MP 71	2	B9	7.186	-27.6	1.1	42.1	0.6	72.8	mangrove
MP 72	2	B10	6.993	-27.6	1.6	42.7	1.4	31.5	mangrove
MP 73A	2	B11	6.925	-27.4	-0.9	43.4	0.7	62.4	mangrove
MP 73B	2	B12	5.352	-25.6	0.0	44.4	0.6	74.4	mangrove
MP 74A	2	C1	7.072	-29.7	3.2	49.6	2.4	20.6	mangrove
MP 74B	2	C2	7.088	-28.1	1.6	44.7	1.2	38.0	mangrove
MP 74C	2	C3	6.921	-28.1	1.1	44.4	1.1	40.5	mangrove
MP 75	2	C4	7.046	-27.6	-1.2	44.8	0.8	55.6	mangrove
MP 76	2	C5	7.203	-27.9	-1.0	45.1	1.0	46.7	mangrove
MP 77	2	C6	7.057	-30.3	0.8	47.7	1.4	34.5	mangrove
MP 78A	2	C7	7.135	-30.5	1.8	47.3	1.4	33.1	mangrove
MP 78B	2	C8	6.730	-30.3	-1.4	45.5	0.9	50.9	mangrove
MP 78C	2	C9	6.884	-30.7	-1.4	47.1	1.0	48.6	mangrove
MP 78D	2	C10	6.978	-29.3	-2.7	46.4	1.9	24.6	mangrove
MP 78E	2	C11	7.027	-31.4	-5.3	53.6	1.0	51.5	mangrove
MP 79	2	C12	7.009	-27.3	-3.0	47.7	0.8	58.2	mangrove
MP 80	2	D1	6.908	-26.2	1.5	45.0	1.2	37.2	mangrove
MP 81	2	D2	7.077	-27.5	2.6	40.1	1.2	34.5	mangrove
MP 82	2	D3	6.930	-29.2	0.9	45.6	1.1	41.9	mangrove
MP 83	2	D4	6.978	-30.8	0.3	46.8	0.8	58.4	mangrove
MP 84A	2	D5	6.846	-30.0	-0.6	52.9	0.5	103.3	mangrove
MP 84B	2	D6	6.889	-30.5	-1.0	53.5	0.5	109.2	mangrove
MP 85	2	D7	6.965	-27.8	-1.2	47.9	0.5	100.0	mangrove
MP 86	2	D8	6.795	-27.7	-0.5	46.7	0.9	50.4	mangrove
MP 87	2	D9	7.035	-26.7	-3.0	46.4	0.5	98.3	mangrove

SP 44	2	D11	2.979	-23.0	8.1	10.3	2.4	4.2	sponge
SP 45	2	D12	2.947	-19.0	10.9	8.9	2.8	3.2	sponge
SP 48	2	E3	2.952	-23.1	8.1	14.1	3.4	4.2	sponge
SP 49	2	E4	3.322	-21.6	9.9	7.1	1.3	5.3	sponge
SP 50	2	E5	3.130	-24.2	8.2	28.6	5.4	5.3	sponge
SP 51A	2	E6	3.482	-19.1	10.0	11.4	3.4	3.4	sponge
SP 51B	2	E7	3.290	-18.2	10.2	10.6	3.2	3.3	sponge
SP 51C	2	E8	3.001	-20.1	9.7	11.3	2.9	3.9	sponge
SP 52	2	E9	3.098	-26.5	7.1	25.1	5.0	5.0	sponge
SP 53	2	E10	3.360	-19.0	11.6	10.9	3.5	3.1	sponge
SP 54	2	E11	3.297	-26.3	7.1	13.8	3.1	4.5	sponge
SP 55	2	E12	2.995	-26.2	7.0	14.2	2.8	5.1	sponge
SP 56	2	F1	2.990	-25.3	7.8	19.1	3.3	5.9	sponge
SP 57	2	F2	3.021	-25.3	7.9	6.9	1.3	5.5	sponge
SP 58	2	F3	3.111	-24.9	7.8	17.4	3.3	5.3	sponge
SP 59	2	F4	3.469	-26.0	7.5	18.5	4.1	4.5	sponge
SP 60	2	F5	3.491	-22.4	8.4	13.7	3.4	4.0	sponge
SP 61	2	F6	3.677	-24.9	9.1	9.7	1.8	5.4	sponge
SP 62	2	F7	3.017	-24.8	8.9	14.7	2.8	5.3	sponge
SP 63	2	F8	3.489	-24.9	8.0	15.9	3.0	5.3	sponge
SP 64	2	F9	3.239	-23.7	9.4	10.3	2.1	4.9	sponge
SP 89	2	F10	3.000	-20.6	8.9	20.7	3.8	5.5	sponge

BULK δ^{13}C AND δ^{15}N OF SKIN SAMPLES FROM HAWKSBILLS THROUGHOUT THE EASTERN PACIFIC

These samples were provided by Jeffrey Seminoff at NOAA Southwest Fisheries Science Center (SWFSC), they were prepared and analyzed for bulk δ13C AND δ15N by Kathryn R. Wedemeyer-Strombel in December 2015 at SWFSC following Lemons et al. (2011).

LabID	YR	M	Turtle_ID	Location	Country	CCL	CCW	Capture_Type	Sex	d13C	d15N	wt %C	wt %N	C:N
125843	2009		99076	Punta Coyote, Guan	COSTA RICA			BYCATCH	U	-22.4	12.1	46.0	15.3	3.01
116601	2013	3	115972	Osa - Golfo Dulce	COSTA RICA	63.0	53.7	IN-WATER	U	-16.4	12.0	45.2	16.9	2.68
116602	2011	3	115973	Osa - Golfo Dulce	COSTA RICA	58.0	51.0	IN-WATER	U	-16.9	8.6	47.3	14.3	3.31
116603	2012	1	115974	Osa - Golfo Dulce	COSTA RICA	59.4	49.5	IN-WATER	U	-16.6	10.5	45.5	16.6	2.74
116605	2012	3	115976	Osa - Golfo Dulce	COSTA RICA	66.5	49.6	IN-WATER	U	-15.8	10.9	44.8	15.8	2.84
116607	2013	3	115978	Osa - Golfo Dulce	COSTA RICA	34.8	29.0	IN-WATER	U	-15.3	12.0	45.2	15.7	2.88
116608	2012	3	115979	Osa - Golfo Dulce	COSTA RICA	76.9	72.0	IN-WATER	U	-14.0	10.8	44.7	15.0	2.97
116611	2012	10	115982	Osa - Golfo Dulce	COSTA RICA	75.5	61.0	IN-WATER	U	-16.6	9.9	45.4	15.7	2.89
116612	2012	10	115983	Osa - Golfo Dulce	COSTA RICA	61.5	51.4	IN-WATER	U	-16.7	9.4	43.2	14.2	3.05
116614	2013	1	115985	Osa - Golfo Dulce	COSTA RICA	73.0	62.2	IN-WATER	U	-15.8	11.4	45.4	15.9	2.86
116614	2013	1	115985	Osa - Golfo Dulce	COSTA RICA	73.0	62.2	IN-WATER	U	-16.9	11.1	47.4	15.0	3.17

116615	2013	1	115986	Osa - Golfo Dulce	COSTA RICA	53.0	45.2	IN-WATER	U	-14.6	11.6	44.7	15.8	2.82
116621	2010	12	115991	Osa - Golfo Dulce	COSTA RICA	46.0	36.5	IN-WATER	U	-15.5	13.9	42.7	15.1	2.83
116623	2013	2	115993	Osa - Golfo Dulce	COSTA RICA	79.8	66.7	IN-WATER	U	-16.5	10.3	43.0	14.7	2.94
116625	2012	1	115995	Osa - Golfo Dulce	COSTA RICA	45.1	38.1	IN-WATER	U	-15.3	13.4	44.5	15.6	2.84
116626	2012	7	115996	Osa - Golfo Dulce	COSTA RICA			IN-WATER	U	-15.8	13.9	47.1	14.9	3.17
116631	2010	10	116001	Osa, Golfo Dulce, San Josecito	COSTA RICA	55.0	45.5	NESTING	F	-17.4	10.0	45.0	14.9	3.02
116633	2010	9	116003	Osa, Golfo Dulce, San Josecito	COSTA RICA			NESTING	U	-20.1	15.0	44.5	12.9	3.46
116634	2010	9	116004	Osa, Golfo Dulce, San Josecito	COSTA RICA			NESTING	U	-19.8	14.8	35.1	10.6	3.30
116635	2010	11	116005	Osa, Golfo Dulce, San Josecito	COSTA RICA			NESTING	F	-15.6	12.6	44.1	15.0	2.93
116644	2010		116014	Osa, Golfo Dulce, Rio Claro/San Josecito	COSTA RICA			NESTING	U	-16.2	14.3	44.6	13.5	3.31
116627	2010	6	115997	Playa Curu	COSTA RICA			STRANDING	U	-13.8	15.7	46.4	14.7	3.17

116628	2010	10	115998	Playa Naranjo	COSTA RICA			STRANDING	U	-18.4	11.9	50.5	15.4	3.29
116629			115999	Santa Rosa	COSTA RICA			STRANDING	U	-16.4	13.5	45.1	14.5	3.12
116630			116000	Santa Rosa	COSTA RICA			STRANDING	U	-16.8	13.3	40.8	13.4	3.04
116643	2010	8	116013	Osa, Golfo Dulce, San Josecito	COSTA RICA			STRANDING	U	-15.9	12.4	47.0	14.9	3.16
105633	2003	8	108447	Santa Cruz, Punta Nunez	ECUADOR			FORAGING	U	-12.2	12.4	46.9	15.4	3.04
102289	2010	1	97587	Isla Plata	ECUADOR	45.0		IN WATER	U	-13.2	13.7	39.9	14.4	2.77
102294	2010	3	97592	Pto. Lopez	ECUADOR	91.0		IN WATER	U	-14.6	14.3	45.0	16.1	2.80
102270	2009	6	97568	Pto. Lopez	ECUADOR			STRANDING	U	-15.7	12.8	37.3	12.6	2.96
102271	2009	6	97569	Pto. Lopez	ECUADOR			STRANDING	U	-17.2	13.0	40.0	12.5	3.19
102272	2009	7	97570	Frailes	ECUADOR			STRANDING	U	-17.0	13.0	48.0	15.0	3.20
102274	2009	10	97572	La Playita	ECUADOR	46.0		STRANDING	U	-16.9	12.9	48.3	15.2	3.19
100587	2007	6	96448	San Lazaro	MEXICO			BY-CATCH	U	-16.8	14.7	46.5	15.7	2.97
100589	2007	11	96450	Lopez Mateos	MEXICO			BY-CATCH	U	-16.6	16.1	49.4	15.8	3.12
100600	2007	12	96461	Agua Amarga	MEXICO			BY-CATCH	U	-14.6	13.9	43.8	16.8	2.61
100607	2007	12	96468	Ramaditas	MEXICO			BY-CATCH	U	-15.6	14.6	37.3	13.0	2.86

100611	2008	1	96472	Bahía de los Angeles	MEXICO			BY-CATCH	U	-14.7	14.8	38.7	14.3	2.70
100622	2008	1	96483	Loreto	MEXICO			BY-CATCH	U	-14.1	15.5	42.5	16.1	2.64
100623	2008	1	96484	Loreto	MEXICO			BY-CATCH	U	-15.5	14.7	32.6	11.4	2.86
100659	2009	8	96520	Acuario Mazatlan	MEXICO			CAPTIVE	U	-14.9	14.9	40.5	13.2	3.06
100624	2008	6	96485	Quemado	MEXICO			IN-WATER	U	-13.8	16.4	45.0	16.8	2.67
100626	2008	6	96487	Quemado	MEXICO			IN-WATER	U	-14.3	17.9	34.1	12.4	2.75
100628	2008	7	96489	Isla El Pardito	MEXICO			IN-WATER	U	-13.6	16.7	34.3	12.5	2.75
100629	2008	7	96490	Isla El Pardito	MEXICO			IN-WATER	U	-14.3	15.3	38.0	13.8	2.75
100631	2008	8	96492	Boca del Alamo	MEXICO			IN-WATER	U	-13.3	17.4	34.4	11.5	2.99
100644	2009	8	96505	La Manzanilla (Las Animas)	MEXICO			IN-WATER	U	-15.0	14.7	40.2	13.3	3.03
100646	2009	8	96507	Careyes	MEXICO			IN-WATER	U	-15.5	15.1	42.7	14.7	2.91
100647	2009	8	96508	Careyes	MEXICO			IN-WATER	U	-15.0	14.4	40.8	13.9	2.93
100651	2009	8	96512	Punta Mita	MEXICO			IN-WATER	U	-16.8	15.1	39.3	13.8	2.85
100636	2009	6	96497	San Lazaro	MEXICO			STRANDING	U	-15.2	17.7	36.9	14.0	2.64
100637	2009	7	96498	San Lazaro	MEXICO			STRANDING	U	-15.3	17.7	34.4	12.7	2.71

100664	2008	10	96525	Playa Miramar, Puerto Penasco	MEXICO			STRANDING	U	-15.5	16.1	41.9	14.6	2.87
114568	2012	8	114634	B JALTEM BA	MEXICO			STRANDING	U	-16.3	15.7	46.2	16.1	2.87
114569	2010	10	114635	CHILA	MEXICO			STRANDING	U	-15.3	13.0	41.1	14.2	2.90
114570	2010	11	114636	CHILA	MEXICO			STRANDING	F	-14.7	15.1	44.2	16.6	2.67
114570	2010	11	114636	CHILA	MEXICO			STRANDING	F	-15.0	14.5	37.0	13.1	2.82
114571	2012	9	114637	CAREYE ROS	MEXICO			STRANDING	F	-14.3	14.7	48.3	15.9	3.05
114571	2012	9	114637	CAREYE ROS	MEXICO			STRANDING	F	-13.9	13.9	39.4	13.2	2.98
114573	2012	11	114639	EL NARANJ O	MEXICO			STRANDING	U	-15.0	14.7	37.6	13.4	2.81
114573	2012	11	114639	EL NARANJ O	MEXICO			STRANDING	U	-14.8	14.2	36.8	12.5	2.95
114575	2013	2	114641	LAS GLORIA S	MEXICO	33.0	31.0	STRANDING	U	-15.0	15.6	45.0	16.4	2.75
114575	2013	2	114641	LAS GLORIA S	MEXICO	33.0	31.0	STRANDING	U	-15.0	15.4	40.9	14.2	2.87
114576			114642	LAS GLORIA S	MEXICO	43.0	39.0	STRANDING	U	-15.1	15.5	44.4	16.4	2.71
114576			114642	LAS GLORIA S	MEXICO	43.0	39.0	STRANDING	U	-15.4	15.5	37.4	12.7	2.95
114624	2011	11	114690	P MITA	MEXICO			STRANDING	U	-15.6	14.8	33.7	11.2	3.00
114624	2011	11	114690	P MITA	MEXICO			STRANDING	U	-15.6	14.3	42.5	14.3	2.97
114783	2007	5	109000	ISLAND SAN LAZARO	MEXICO	42.0	37.0	STRANDING	U	-16.4	14.4	42.1	14.0	3.02
114796	2010	4	114861	TEOPA	MEXICO			STRANDING	F	-13.5	17.6	44.3	14.7	3.01
114796	2010	4	114861	TEOPA	MEXICO			STRANDING	F	-13.8	16.9	40.4	13.6	2.96

114566	2012	7	114632		MEXICO			UNKNOWN	U	-16.1	14.7	43.4	15.5	2.81
114609	2011	11	114675	LUCENIL LA	MEXICO	40.1	32.4	UNKNOWN	U	-15.0	14.9	44.5	16.5	2.70
114609	2011	11	114675	LUCENIL LA	MEXICO	40.1	32.4	UNKNOWN	U	-15.1	14.6	41.2	14.1	2.91
114610	2012	11	114676	MAZATL AN	MEXICO	39.0	35.0	UNKNOWN	U	-14.5	14.4	44.3	16.7	2.65
114610	2012	11	114676	MAZATL AN	MEXICO	39.0	35.0	UNKNOWN	U	-14.8	14.6	39.0	13.2	2.96
114620	2009	11	114686	MEZCAL ES	MEXICO			UNKNOWN	M	-15.0	15.8	45.4	16.2	2.81
114620	2009	11	114686	MEZCAL ES	MEXICO			UNKNOWN	M	-16.4	15.8	43.5	13.0	3.34
114621	2011	6	114687	MEZCAL ES	MEXICO			UNKNOWN	F	-15.6	16.3	43.9	16.1	2.73
114621	2011	6	114687	MEZCAL ES	MEXICO			UNKNOWN	F	-15.0	15.2	40.8	14.2	2.88
125845	2009		99078	Muerto Viejo, Veraguas	PANAMA			HAND CAPTURE	U	-15.4	13.0	35.8	12.7	2.83
146290	2014	9	133639	Coiba	PANAMA	64.3		IN-WATER	U	-14.8	11.6	44.3	14.3	3.11
146291	2014	9	133640	Coiba	PANAMA	61.4		IN-WATER	U	-14.6	10.9	45.4	14.1	3.21
146292	2014	9	133641	Coiba	PANAMA	48.0		IN-WATER	U	-14.6	11.1	46.3	16.3	2.84
146293	2014	9	133642	Coiba	PANAMA	44.6		IN-WATER	U	-15.0	12.3	43.6	14.6	2.99
146294	2014	9	133643	Coiba	PANAMA	39.6		IN-WATER	U	-14.9	12.5	44.8	16.7	2.69
146296	2014	9	133645	Coiba	PANAMA	44.4		IN-WATER	U	-15.6	13.3	44.0	14.7	2.99
146297	2014	9	133646	Coiba	PANAMA	47.0		IN-WATER	U	-15.1	11.4	45.8	16.8	2.73
146298	2014	9	133647	Coiba	PANAMA	38.7		IN-WATER	U	-15.5	11.5	43.7	13.8	3.16

146300	2014	9	133649	Coiba	PANAMA	51.1		IN-WATER	U	-13.9	10.2	43.7	15.5	2.82
146302	2014	9	133651	Coiba	PANAMA	44.5		IN-WATER	U	-15.1	11.6	45.3	16.3	2.78
146303	2014	9	133652	Coiba	PANAMA	54.0		IN-WATER	U	-13.0	10.8	45.8	17.0	2.69
146304	2014	9	133653	Coiba	PANAMA	41.0		IN-WATER	U	-15.3	12.4	40.8	13.7	2.97
146305	2014	9	133654	Coiba	PANAMA	35.0		IN-WATER	U	-15.4	12.7	44.0	14.5	3.04
146307	2014	9	133656	Coiba	PANAMA	45.5		IN-WATER	U	-15.4	11.7	44.5	14.0	3.17
146309	2014	9	133658	Coiba	PANAMA	41.0		IN-WATER	U	-15.3	11.8	43.5	15.5	2.81
146310	2014	9	133659	Coiba	PANAMA	50.0		IN-WATER	U	-14.5	11.2	44.9	15.8	2.83
146311	2014	9	133660	Coiba	PANAMA	43.0		IN-WATER	U	-15.1	11.8	44.6	15.4	2.89
146312	2014	9	133661	Coiba	PANAMA	55.0		IN-WATER	U	-14.6	11.8	44.2	15.7	2.82
146313	2014	9	133662	Coiba	PANAMA	72.4		IN-WATER	M	-16.7	12.2	46.1	15.6	2.96
114376	2010		114581	PLAYA MATA OSCURA	PANAMA			NESTING	U	-17.7	14.3	42.4	14.4	2.94
114377	2010		114582	PLAYA MATA OSCURA	PANAMA			NESTING	F	-16.3	12.5	40.1	14.1	2.85
114378	2011		114583	PLAYA MALENA	PANAMA			NESTING	U	-16.9	14.7	42.5	14.1	3.02
146314	2014	7	133663	Mata Oscura	PANAMA			NESTING	F	-13.6	11.0	44.5	15.8	2.81

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COMPOUND SPECIFIC ANALYSIS OF AMINO ACIDS OF $\delta^{13}C$ OF EP HAWKSBILL SKIN

Samples were prepared and run for compound specific analysis of amino acids of $\delta^{13}C$ following University of New Mexico Center for Stable Isotopes protocols.

SampleID	RunID	RunDate	STD	STD.t	N.inj	Ala13C	Ala13C .SD	Gly13C	Gly13C. SD	Thr13C	Thr13C .SD	Ser13C	Ser13C. SD
KWS-Ei-115	492	2/2/2018	53	UCM	2	-18.68	0.05	-13.39	0.13	-14.44	0.25	-9.97	0.18
KWS-Ei-17	492	2/2/2018	53	UCM	2	-19.06	0.15	-14.64	0.11	-6.59	0.04	-6.41	0.11
KWS-Ei-18	492	2/2/2018	53	UCM	2	-24.54	0.31	-18.85	0.09	-19.58	0.14	-16.9	0.03
KWS-Ei-217743	389	7/12/2017	52	UCM	2	-20.59	0.04	-19.29	0.04	-17.07	0.08	-18.12	0.31
KWS-Ei-217759	389	7/12/2017	52	UCM	2	-20.73	0.05	-19.68	0.04	-17	0.03	-20.14	0.09
KWS-Ei-217783	389	7/12/2017	52	UCM	2	-13.47	0.26	-12.43	0.43	-7.92	0.06	-9.25	0.3
KWS-Ei-217787	390	7/13/2017	52	UCM	2	-24.11	0.09	-21.93	0.03	-20.51	0.09	-21.67	0.15
KWS-Ei-217805	390	7/13/2017	52	UCM	2	-16.22	0.21	-16.18	0.06	-14.08	0.21	-15.45	0.06
KWS-Ei-217811	390	7/13/2017	52	UCM	2	-18.25	0.1	-19.1	0.23	-15.67	0.48	-13.39	0.04
KWS-Ei-217841	389	7/12/2017	52	UCM	2	-16.4	0.04	-14.87	0.04	-13.04	0.03	-12.06	0.09
KWS-Ei-217857	390	7/13/2017	52	UCM	2	-16.9	0.16	-16.17	0	-13.97	0.43	-12.44	0.22
KWS-Ei-217925	390	7/13/2017	52	UCM	2	-13.53	0.25	-13.97	0.21	-10.38	0.23	-10.42	0
KWS-Ei-217981	389	7/12/2017	52	UCM	2	-15.51	0.69	-11.44	0.01	-9.7	0.01	-9.47	0.39
KWS-Ei-33	492	2/2/2018	53	UCM	2	-20.32	0.22	-15.68	0.05	-14.98	0.14	-13.14	0.25
KWS-Ei-35	492	2/2/2018	53	UCM	2	-21.04	0.03	-16.49	0.15	-12.84	0.14	-5.75	0.55

KWS-Ei-57	483	1/23/2018	53	UCM	2	-18.96	0.43	-12.1	0.05	-19.57	0.15	-16.25	0.25
KWS-Ei-60	483	1/23/2018	53	UCM	2	-19.39	0.04	-9.71	0.16	-20.49	0.41	-16	0.35
KWS-Ei-63	494	2/4/2018	53	UCM	2	-20.59	0.75	-5.75	0.18	-9.59	0.59	-6.6	0.49
KWS-Ei-66	482	1/22/2018	53	UCM	2	-14.53	0.09	-7.9	0.16	-13.16	0	-5.76	0.02
KWS-Ei-68	483	1/23/2018	53	UCM	2	-15.86	0.56	-8.23	0.18	-19.06	0.23	-15.01	0.14
KWS-Ei-72	482	1/22/2018	53	UCM	2	-18.46	0.03	-10.7	0.14	-15.92	0.17	-9.06	0.07
KWS-Ei-88	494	2/4/2018	53	UCM	2	-18.59	0.35	-6.32	0.09	-6.38	0.18	-5.6	0.07

SampleID	**Val13C**	**Val13C.SD**	**Leu13C**	**Leu13C.SD**	**Ile13C**	**Ile13C.SD**	**Pro13C**	**Pro13C.SD**	**Asp13C**	**Asp13C.SD**	**Met13C.SD**
KWS-Ei-115	-25	0.02	-27.24	0.02	-19.16	0.17	-19.43	0.19	-19.34	0.04	NA
KWS-Ei-17	-21.53	0.08	-24.21	0.05	-16.84	0.19	-15.96	0.07	-18.09	0.09	NA
KWS-Ei-18	-28.07	0.18	-30.2	0.11	-23.33	0.16	-22.65	0.07	-21.14	0.08	NA
KWS-Ei-217743	-26	0.65	-30.45	0.07	-22.61	0.01	-17.24	0.07	-22.57	0.05	NA
KWS-Ei-217759	-24.73	0.15	-30.23	0.07	-22.56	0.32	-19.1	0.14	-22.67	0.09	NA
KWS-Ei-217783	-19.07	0.48	-24.63	0.1	-17.46	0.36	-10.43	0.5	-14.75	0.29	NA
KWS-Ei-217787	-25.57	0.14	-31.11	0	-20.56	0.3	-19.18	0.32	-24.28	0.03	NA
KWS-Ei-217805	-21.62	0.4	-26.56	0.27	-16.43	0.06	-13.7	0.4	-20.13	0.01	NA
KWS-Ei-217811	-22.87	0.22	-28.43	0.09	-17.28	0.04	-15.27	0.93	-21.22	0.26	NA
KWS-Ei-217841	-21.56	0.02	-27.06	0.13	-18.24	0.04	-12	0.25	-18.43	0.1	NA
KWS-Ei-217857	-22.14	0.11	-27.74	0.28	-16.97	0.16	-12.53	0.21	-20.01	0.16	NA
KWS-Ei-217925	-17.94	0.23	-25.08	0.23	-17.88	0.55	-10.43	0.03	-16.52	0.12	NA
KWS-Ei-217981	-16.89	0.43	-23.74	0.16	-13.32	0.65	-9.5	0.44	-15.12	0.02	NA
KWS-Ei-33	-23.1	0.05	-26.67	0.56	-19.66	0.1	-19.06	0.03	-16.46	0.21	NA
KWS-Ei-35	-24.13	0.12	-27.94	0.04	-20.59	0.12	-19.56	0.07	-19	0.11	NA
KWS-Ei-57	-17.43	0.14	-26.45	0.34	-19.28	0.22	-16.54	0.51	-15.55	0.21	NA
KWS-Ei-60	-15.39	0.45	-24.8	0.28	-18.44	0.01	-16.78	0.1	-12.93	0.09	NA
KWS-Ei-63	-21.34	0.2	-24.87	0.76	-17.29	0.61	-15.39	0.64	-15.88	0.02	NA
KWS-Ei-66	-19.81	0.19	-26.46	0.06	-17.69	0.49	-13.91	0.18	-15.25	0.11	NA
KWS-Ei-68	-14.71	0.11	-25.45	0.16	-18.46	0.05	-13.69	0.13	-11.51	0.16	NA
KWS-Ei-72	-21.64	0.21	-26.7	0.03	-20.04	0.08	-18.62	0.05	-14.22	0.12	NA

KWS-Ei-88	-20.79	0.11	-24.47	0.03	-17.25	0.21	-14.73	0.51	-16.18	0.16	NA

SampleID	Glu13C	Glu13C.SD	Phe13C	Phe13C.SD	Tyr13C	Tyr13C.SD	Lys13C	Lys13C.SD	Arg13C	Arg13C.SD
KWS-Ei-115	-17.48	0.02	-26.38	0.67	-31.08	1.66	-22.26	0.24	-13.38	0.3
KWS-Ei-17	-17.17	0.05	-25.82	0.02	-25.8	0.22	-19.81	0.09	-14.75	0.31
KWS-Ei-18	-21.08	0.07	-30.39	0.36	-31.03	0.06	-33.08	0.09	-18.1	0.38
KWS-Ei-217743	-22.39	0.02	-45.7	0.47	-31.79	0.37	-22.12	0.2	-15.54	0.05
KWS-Ei-217759	-22.52	0.07	-29.43	0.08	-31.42	0.05	-23.36	0.25	-16.91	0.36
KWS-Ei-217783	-15.57	0.18	-24.77	0.62	-24.49	0.07	-15.91	0.45	-10.28	0.3
KWS-Ei-217787	-24.46	0.09	-31.15	0.18	-31.45	0.38	-23.62	0.05	-19.66	0.21
KWS-Ei-217805	-20.46	0.04	-28.12	0.09	-28.86	0.38	-20.27	0.13	-15.28	0.19
KWS-Ei-217811	-21.47	0.23	-28.51	0.02	-30.35	0.27	-20.25	0.07	-15.76	0.11
KWS-Ei-217841	-18.73	0.14	-27.2	0.54	-28.69	0.13	-19.09	0.03	-13.97	0.14
KWS-Ei-217857	-19.4	0.06	-28.08	0.42	-28.52	0.47	-19.58	0.27	-15.45	0.12
KWS-Ei-217925	-16.69	0.14	-25.61	0.25	-26.4	0.01	-15.44	0.02	-12.84	0.01
KWS-Ei-217981	-15.28	0.03	-24.52	0.07	-25.21	0.49	-16.04	0	-12.29	0.02
KWS-Ei-33	-17.44	0.19	-29.75	0.56	-29.71	0.31	-28.56	0.12	-14.62	0.63
KWS-Ei-35	-17.57	0	-32.15	0.24	NA	NA	-22.68	0.06	NA	NA
KWS-Ei-57	-17.64	0.22	-27.53	0.36	-25.65	0.4	-22.49	0.5	-13.45	0.01
KWS-Ei-60	-16.14	0.04	-23.68	0.3	-24.25	0.08	-20.92	0.07	-13.58	0.11
KWS-Ei-63	-14.7	0.46	-25.87	0.78	-26.68	0.17	-18.04	0.18	-13	0.15
KWS-Ei-66	-14.49	0.04	-27.89	0.37	-28.87	0.4	-19.18	0.04	-11.12	0
KWS-Ei-68	-13.26	0	-28.56	0.01	-25.29	0.04	-19.52	0.08	-11.07	0.04
KWS-Ei-72	-15.44	0.21	-27.5	0.48	-27.39	0.03	-21.37	0.12	-14.36	0.12
KWS-Ei-88	-13.54	0.1	-27.13	0.19	-26.23	0.31	-17.92	0.39	-12.6	0.31

Appendix C: Codebook for thematic analysis

CODING PROTOCOL

The unit of analysis is the individual sentence. Each sentence can be coded more than once. To code:

1. Read the transcript sentence by sentence.
2. On every .01 (first utterance after a question):
    a. check the question to see what RQ is being answered
    b. check for interjections and clarifications, which may indicate that whatever follows is prompted. This will be indicated by PROMPTED: before .03 "interviewer interjection/prompt"
3. Determine if the sentence pertains to RQ 1, RQ 2, RQ 3, or RQ 4 (e.g. has to pertain to one of the four criteria).
4. If sentence does not pertain, indicate no code. A sentence does not pertain if it does not fit our RQ coding OR is incomprehensible due to unintelligible content. [If hesitant on sentence, check 1 sentence prior and after. If still hesitant, check to see if sentence triggers any codes; if not, then indicate no code and consult with other coder].
5. Compare sentences indicated as no-code with other coder (once ICR has been achieved, this step is not necessary)
6. Read the sentence.
7. Use one RQ code at a time for each sentence (i.e., read the sentence)
8. Code sentence with a RQ code.
9. Code sentence with unprompted or prompted (see below).
10. If coder cannot determine the code (needs context), check previous sentence.
11. If additional context is needed, then check the sentence after.
12. Each sentence can be coded more than once (e.g., RQ1 and RQ2).

Notes

- No more than 25% of the time should you need to go to another sentence for context.
- If a sentence contains summary transition words (and so, so, therefore, such as, thus, like) look to prior sentence for context.
- If the sentence could have been part of the previous sentence due a simple punctuation change, look to another sentence for context.
- If a sentence does not contain any of these elements, the sentence should be coded as a stand-alone unit.
- Assume that references to nets refer to in estuary fishing
- If RQ answer is negative (e.g. RQ 3 no) we make it a no-code
- Default to nets referring to fishing in the estuary. If there is any question, look back two utterances to see if they're talking about the estuary or the sea.
- If they say they see turtles every time they fish, then they see turtles outside of nesting season. The time of year they wouldn't be fishing would be during nesting season so we can extrapolate that if they see turtles every time they fish, that includes outside of nesting season.

- If in the transcript I interject with "of the C" (or another size letter), I am clarifying which turtle size cut out they were pointing to, and thus is not a prompt.
- If too vague, go back to Spanish translation

FRAMEWORK

The specific, appropriate analytic framework will be allowed to emerge through the interview process (Kincheloe and McLaren 2005). This emergent framework stresses the importance of context (Kincheloe and McLaren 2005). Just as different populations of sea turtles develop with different influences and resources that must be considered, the knowledge of the local marine resource uses is shaped by the context in which they live and have developed their knowledge. Therefore, it is important to have plastic qualitative methods to account for the different contexts that could provide new themes to be analyzed that may otherwise be missed by rigid methods (Kincheloe and McLaren 2005). Partially emergent thematic analysis – we allowed the salient RQs to appear upon first examination of the data, and then used those emergent themes to create framework to guide further analysis. During preliminary analysis of the data, four research questions were allowed to partially emerge, which provide the more targeted framework for NVIVO analysis. These research questions will allow for targeted analysis of the interviews, to pull the Fishers' Ecological Knowledge (FEK) on these four topics.

Definitions

Hawksbill size classes A, B, C, D, E:

CCL = Curved Carapace Length (cm), length of the back shell from tip to tip measured using a sewing measuring tape.
[A]: Hatchling
[B]: Yearling
[C]: Juvenile, ~30cm
[D]: Subadult, ~65cm
[E]: Adult, ~84cm (this is the size of nesting hawksbills), nesting, nester
Sizes between C and D (transcribed as [C]-[D] or between [C] [D]).

RESEARCH QUESTIONS (RQ) TO ELUCIDATE FISHERS' ECOLOGICAL KNOWLEDGE (FEK)

RQ 1: Are some hawksbill sizes seen more often than others within the estuary waters? If so, which ones? Which ones they see most of. Which sizes are seen most commonly in the estuary?

RQ 1 is subdivided into 6 categories:

- [A]
- [B]
- [C]
- [D]
- [E]
- [unspecified]

RQ 1 refers to mentions of sizes being seen more often, several of a size being seen, multiple of a size (e.g. “we go fishing we see 3 or 4 30cm [C] floating”), usually see these, see more of these than others.
Only interested WITHIN the estuary. This can be articulated by “the most common size is [C]”, “it used to be rare to see a small hawksbill like this one [C], but we can see that size very often…”. “You can see several of them [C] floating”.
Default to nets referring to fishing in the estuary. If there is any question, look back two utterances to see if they’re talking about the estuary or the sea.
NO-CODE examples:
B001.03:It would have been good, this one of 30 also. We have also found ones of 30 centimeters [C].

RQ 2: Are hawksbills found in the estuary outside of nesting season (winter/rainy)?
Are the juveniles there when “not meant to be”? Are the nesting turtles [E] also there when “not meant to be”?

RQ 2 refers to hawksbills, of any size [A] [B] [C] [D] [E], being observed in the estuary year round. Some responses may include that there are times when the hawksbill are more present in the estuary than others, but what we are looking for are statements that indicate we can find them outside of the nesting season. They don’t have to be in abundance year round, just as long as they have been observed year round.
Default to nets referring to fishing in the estuary. If there is any question, look back two utterances to see if they’re talking about the estuary or the sea.
If they say they see turtles every time they fish, then they see turtles outside of nesting season. The time of year they wouldn’t be fishing would be during nesting season so we can extrapolate that if they see turtles every time they fish, that includes outside of nesting season.

RQ 3: Why are hawksbills found in certain areas, rather than others?
RQ 3 refers to hypotheses about why hawksbills are found in certain areas, rather than others. For example, due to development, feeding, predator avoidance, and/or tides (among other reasons). These will be indicated by responses like, “E015.02:So and as opposed to I have always noticed that wherever you can find artificial reefs there is always an abundance of Hawksbills.” Or, B022.06: “You can see several of them[C] floating on the mangroves, more frequently she remains while the tide is high, they are very tame.”
This is not, “do they like certain places” but WHY are they in certain places. It must answer the WHY in order to be coded

RQ 4: After a hatchling release, where do the hatchlings [A] and yearlings [B] go?
RQ 4 relates specifically to mentions of sizes [A] and [B] and where they go after a release/liberation (liberacion in Spanish). This includes calls for future research, or answers such as “we don’t know”.
RQ 4 is subdivided into four subcategories:

- Stay in estuary
    - Mentions may include, “they must grow here, I believe they have to grow here in the estuary”, or “hawksbills are natives because they may find what to eat…”.

    - C024.01:Hmmm I don't think they go too much to the sea because they grow there in the Estero since you can see them go around and they are this size like this[C], it means that they grow there. That is my idea, who knows if…"
    - C024.02:They must grow here, I believe that they have to grow here in the Estero.
- Go out to sea
    - Leave to develop/migrate: mentions of hawksbills leaving the estuary to develop, feed, due to tides, etc. This includes mentions of migration, and of going out to open sea.
- We don't know / need future research
- Other

All RQs can be further sub-divided into prompted or unprompted

Prompted: Prompted is when the informant directly responds to a question. That is, they only reveal specific information pertaining to one of the RQs because they were asked specifically about it. For example, if they are asked, "why do we find hawksbills in one area, instead of another?" and they respond, "because of where they eat" → RQ 3 Prompted.
Unprompted: Unprompted is when the informant provides the answer to a RQ without guidance. That is, they offer up information such as why hawksbills are in certain areas when only asked if they see hawksbills. For example, if they are asked, "tell me about your experiences with hawksbills in the estuary" and they respond, "we see size C most often and in xyz canal because that is where they feed." → RQ 1 Unprompted, and RQ 3 Unprompted.

Research Questions
RQ 1: Which hawksbill sizes seen more often than others within the estuary waters? If so, which ones? Is their size mentioned? Estuary and size together = RQ 1 Must include a qualifier like, "mostly, mainly, more often, commonly" Can NOT be temporal i.e., "I see a lot in this season, or after a release" Subdivided into size categories: • A • B • C • D • E • unspecified If they talk about [A] in relation to a release – i.e. "just after a release I see a lot of A" it is a NO CODE. Examples for coding: B025.01:This young (juvenil) [C] **always more than anything**.

C032.04:Seems like maybe when they are a little bit bigger they look for the deepest part or I don't know how but here in the estuaries you will **only** find of this size [C][D].

A025.08:In the (tapadas) when the nets are left for an extensive time you can catch D and young (juvenil)[C] **more than anything**.

C053.06:Ehhh I don't know really where they [E] go to but the **one you can see often** is the small one [C].

C053.03:But once the seasons ends the **one that you see a lot** is this one [C].

RQ 2: Are hawksbills found in the estuary outside of nesting season (winter/rainy, May-Oct)?

All year round / it's the same
More often during nesting season (implies presence outside of nesting season)
You see them more when the rain comes, because they like the fresh water
When answering a directed RQ2 question – "she stays" triggers year round / all the time.

When they mention the rainy season, if it is not exclusive to the rainy season – then it qualifies for RQ2.

C053.03:But once the seasons ends the one that you see a lot is this one [C].

C053.04:Because this C [C] goes around floating, yes, almost all of the time [year], she goes around floating.

I003.01:Ok, in the case of the young (juveniles) of 30[C] I think that all year round you can see but as far as the adults[D][E], I think that she comes, you can see her more often when the nesting season approaches.

D053.01:Well its because it's the same [C], its the same all year round, I have not seen that it drops nor that I see more.

RQ 3: Why are hawksbills in certain areas, rather than others?

Causality/hypothesis for why turtles are where they are : because, since, so, to (to feed, to be safe), it means
"they feed"
"they're safer"
"during the high tide"
"there are mangroves"

This is not, "do they like certain places" but WHY are they in certain places. It must answer the WHY in order to be coded If the turtle is associated with something, for example, "it wouldn't move from the artificial reef" we can infer that the turtle is in that area because of the reef. Not just a WHERE but a WHY Not A CONDITION of where humans can find them, but the reason why the hawksbill itself is in an area "And they return, yes because they are migratory." RQ 3 because hawksbills are in the estuary because they are migratory. E001.03:We,the idea always is that the fishermen is that we see a small one it's because the larger one is around, yes,the larger one is near. C024.01: Hmmm I don't think they go too much to the sea because they grow there in the Estero they grow there in the Estero since you can see them go around and they are this size like this[C], it means that they grow there. F033.02:And yes; no since we go around harpooning we go under and we go searching for them and there are times when they are eating roots, barnacle like that [D]. A035.17:Sometimes we would find some that were stuck because we have even gotten a lot of them unstuck that you find, since they go inside the mangrove to eat barnacle . Q053.04:She didn't keep ehhh, there is also this area that they also go around but that one there there is a rock there that is where the fishermen stay mainly. J054.02:Some [A] migrate and others stay there feeding themselves there. J057.03:yes they stay here in the Estero, they (encojoyan) because in those, in the (cojoyales) like that there are rocks and there in the rocks is where they maybe stay. B059.06:Yes right now they are very scarce but there are a lot in the rocks; there are a lot.

RQ 4: After a hatchling release, where do the hatchlings [A] and/or yearlings [B] go?
Just because they haven't been seen in one place does NOT mean they are in the other. For example, "we don't see them in the sea" does NOT mean they are in the estuary.
 	
Double check that the question is specifically referring to lost years and/or the answer is specifically referring to lost years. If it is not, then it is not RQ 4.
 	
• Stay in estuary
  o J054.02:Some [A] migrate and others stay there feeding themselves there.
  o J057.01:Well all that I can imagine is that they (encojoyan) inside.

- J057.03:yes they stay here in the Estero, they (encojoyan) because in those, in the (cojoyales) like that there are rocks and there in the rocks is where they maybe stay.

- Go out to sea
  - J054.02:Some [A] migrate and others stay there feeding themselves there.

- We don't know / need future research
  - I054.01:Hmmm I don't know where they [A] could go.
  - L001.07:Yes because I think that that it needs to be researched where do they go

- Other
  - Any other hypothesis or reason that does fit into the other categories.

Possible trigger words:
They develop within the estuary
Some go to the sea with the tide, some stay in the estero

Prompted and Unprompted	
Prompted	**Unprompted**
Check for interjections and clarifications in the properties of response.01 for each question (e.g. A001.01), which may indicate that whatever follows is prompted. • This will be indicated by PROMPTED: A.001.03 "interviewer interjection/prompt" **Recites part of question back:** • What size do I see most? • Why are turtles in certain areas?	**Offers information beyond scope of the question.** • If question is "tell me about your experiences seeing hawksbills", and response is**:** o "I see them when I fish in Cojon because that is where they eat" >>they were not asked about why turtles were in certain places, so it is unprompted. • If questions asks about where do the hatchlings [A] go after a release and the response talks about any other size turtle and where they go.

Appendix D: Other publications by K.R.Wedemeyer-Strombel

PEER-REVIEWED PUBLICATIONS

Ross et al. 2018

Ross AD, Struminger R, Winking J. and **KR Wedemeyer-Strombel**. (2018). Science as a Public Good: Findings From a Survey of March for Science Participants. Science Communication. 40(2), pp.228-245. DOI: 10.1177/1075547018758076

Abstract: On April 22, 2017, millions of people marched for science in response to a growing sense of urgency for preserving scientific funding and knowledge, both perceived as threatened by the Trump administration. This research note highlights data collected at three marches: Washington, D.C.; Los Angeles, California; and Austin, Texas. We examine marcher motivations for participation, finding the environment, current administration, and science funding were most prevalent. Furthermore, we find the majority of marchers support stances that position science as public good, including the belief that science informs responsible government policies and the support of government investments in science.
Keywords: March for Science, public goods, science activists, Trump administration,
climate change

Rees et al. 2016

Rees AF, Alfaro-Shigueto J, Barata PC, Bjorndal KA, Bolten AB, Bourjea J, Broderick AC, Campbell LM, Cardona L, Carreras C, Casale P, Ceriani SA, Dutton PH, Eguchi T, Formia A, Fuentes MMPB, Fuller WJ, Girondot M, Godfrey MH, Hamann M, Hart KM, Hays GC, Hochscheid S, Kaska Y, Jensen MP, Mangel JC, Mortimer JA, Naro-Maciel E, Ng CKY, Nichols WJ, Phillott AD, Reina RD, Revuelta O, Schofield G, Seminoff JA, Shanker K, Tomás J, van de Merwe JP, Van Houtan KS, Vander Zanden HB, Wallace BP, **Wedemeyer-Strombel KR**, Work TM, and BJ Godley (2016). Are we working towards global research priorities for management

and conservation of sea turtles? Endangered Species Research, 31, 337-382. DOI 10.3354/esr00801

Abstract: In 2010, an international group of 35 sea turtle researchers refined an initial list of more than 200 research questions into 20 metaquestions that were considered key for management and conservation of sea turtles. These were classified under 5 categories: reproductive biology, biogeography, population ecology, threats and conservation strategies. To obtain a picture of how research is being focused towards these key questions, we undertook a systematic review of the peer-reviewed literature (2014 and 2015) attributing papers to the original 20 questions. In total, we reviewed 605 articles in full and from these 355 (59%) were judged to substantively address the 20 key questions, with others focusing on basic science and monitoring. Progress to answering the 20 questions was not uniform, and there were biases regarding focal turtle species, geographic scope and publication outlet. Whilst it offers some meaningful indications as to effort, quantifying peer-reviewed literature output is obviously not the only, and possibly not the best, metric for understanding progress towards informing key conservation and management goals. Along with the literature review, an international group based on the original project consortium was assigned to critically summarise recent progress towards answering each of the 20 questions. We found that significant research is being expended towards global priorities for management and conservation of sea turtles. Although highly variable, there has been significant progress in all the key questions identified in 2010. Undertaking this critical review has highlighted that it may be timely to undertake one or more new prioritizing exercises. For this to have maximal benefit we make a range of recommendations for its execution. These include a far greater engagement with social sciences, widening the pool of contributors and focussing the questions, perhaps disaggregating ecology and conservation.

Key words: Sea turtle · Marine conservation · Evidence-based conservation · Systematic review Research prioritisation

Schuyler et al. 2015

Schuyler, Q., Wilcox, C., Townsend, K.A., Wedemeyer-Strombel, K.R., Balazs, G., Sebille, E., and B.D.Hardesty (2015). Risk analysis reveals global hotspots for marine debris ingestion by sea turtles. Global Change Biology. DOI 10.1111/gcb.13078

Abstract: Plastic marine debris pollution is rapidly becoming one of the critical environmental concerns facing wildlife in the 21st century. Here we present a risk analysis for plastic ingestion by sea turtles on a global scale. We combined global marine plastic distributions based on ocean drifter data with sea turtle habitat maps to predict exposure levels to plastic pollution. Empirical data from necropsies of deceased animals were then utilised to assess the consequence of exposure to plastics. We modelled the risk (probability of debris ingestion) by incorporating exposure to debris and consequence of exposure, and included life history stage, species of sea turtle and date of stranding observation as possible additional explanatory factors. Life history stage is the best predictor of debris ingestion, but the best-fit model also incorporates encounter rates within a limited distance from stranding location, marine debris predictions specific to the date of the stranding study and turtle species. There is no difference in ingestion rates between stranded turtles vs. those caught as bycatch from fishing activity, suggesting that stranded animals are not a biased representation of debris ingestion rates in the background population. Oceanic life-stage sea turtles are at the highest risk of debris ingestion, and olive ridley turtles are the most at-risk species. The regions of highest risk to global sea turtle populations are off of the east coasts of the USA, Australia and South Africa; the east Indian Ocean, and Southeast Asia. Model results can be used to predict the number of sea turtles globally at risk of debris ingestion. Based on currently available data, initial calculations indicate that up to 52% of sea turtles may have ingested debris.

Keywords: *Caretta caretta, Chelonia mydas*, debris ingestion, *Dermochelys coriacea*, *Eretmochelys imbricata, Lepidochelys kempii Lepidochelys olivacea*, marine plastics, *Natator depressus*, risk analysis

Wedemeyer-Strombel et al. 2015

Wedemeyer-Strombel, K.R., Balazs, G., Johnson, J.B., Peterson, T., Wicksten, M., and P. Plotkin. (2015). High frequency of occurrence of anthropogenic debris ingestion by sea turtles in the North Pacific Ocean. Marine Biology 162: 2079-2091. DOI 10.1007/s00227-015-2738-1. W-S et al. 2015_FactSheet; W-S et al 2015 message box

Abstract Ingestion of anthropogenic debris can have deleterious effects on sea turtles. To study diet content of sea turtles, four species were opportunistically collected as deceased bycatch over 18 years (1993–2011) from pelagic longline fisheries based in American Samoa and Hawaii (North Pacific between 140°–170°W and 20°S–50°N). Diet contents were analyzed from 71 sea turtles: 45 olive ridleys (*Lepidochelys olivacea*), 22 greens (*Chelonia mydas*), 2 loggerheads (*Caretta caretta*), and 2 leatherbacks (*Dermochelys coriacea*). This study reports some of the highest frequencies of anthropogenic debris ingestion documented for sea turtles, with 83 % of all the sea turtles sampled ingesting anthropogenic debris. Within species, 91 % of greens and 82 % of olive ridleys ingested anthropogenic debris. This is the first published report of anthropogenic debris ingestion by olive ridleys outside of the Atlantic Ocean. Neither of the leatherbacks ingested anthropogenic debris. The average dry weight of anthropogenic debris ingested by individual olive ridleys and individual greens was 4 and 7 g, respectively. The total dry weights of anthropogenic debris ingested by the two loggerheads were 9 and 120 g. Plastics were the most prominent anthropogenic debris ingested, making up 95 % (405 g dry weight) of the total 427 g ingested. Increased ingestion of anthropogenic debris was found in olive ridleys collected during the winter, which corresponds with the wintertime increase in anthropogenic debris accumulated in the North Pacific Subtropical Convergence Zone. This study highlights the need to better understand the factors affecting anthropogenic debris ingestion and its sublethal effects.

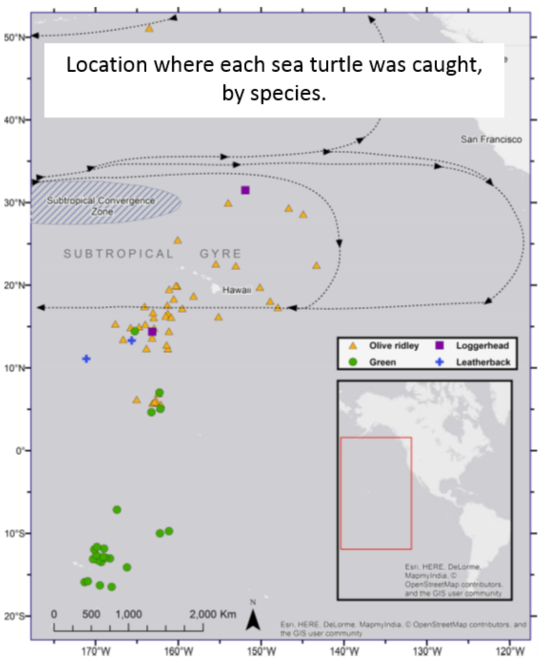
Wedemeyer-Strombel et al. 2015 Fact Sheet

High frequency of occurrence of anthropogenic debris ingestion by sea turtles in the North Pacific Ocean

Wedemeyer-Strombel, K.R.*, Balazs G.H., Johnson, J.B., Peterson, T.D., Wicksten, M.K., Plotkin, P.T

Correspondence to Kathryn R. Wedemeyer-Strombel, email: krwedemeyer@gmail.com.

Hair comb, toothbrush, plastic bottle necks, caps & bags found in sea turtles' stomachs.



Anthropogenic (human-generated) debris is a growing problem in our marine ecosystems, negatively impacting nearly 700 species worldwide.

To investigate the frequency in which sea turtles are ingesting human-generated debris, we evaluated the stomach contents of 71 sea turtles that were accidently caught, and deceased, in longline fisheries in the North Pacific ocean. US fisheries have legal limits of this accidental catch that we call bycatch. Fisheries work with government officials so when an animal is caught and found deceased, we are able to learn from them.

What we found: Of the 71 sea turtles we sampled, 83% had ingested human-generated debris. The majority (95%) of this debris by weight was plastic. **We highlight the need to better understand the factors affecting human-generated debris ingestion and its sublethal effects.**

- We report some of the highest documented values for frequency of occurrence of human-generated debris ingestion by sea turtles worldwide with 91% of greens and 82% of olive ridleys ingesting human-generated debris.

- Plastic was the most prominent human-generated debris ingested. It accounted for 94% of the dry weight of human-generated debris ingested by green turtles and 93% for olive ridleys, 99% for one loggerhead, and 93% for the other loggerhead.

- Sea turtles had ingested items such as: a black hair comb, a red tooth brush, plastic bottle caps, plastic bottle necks, plastic bags, fishing line, polystyrene, rope, and small unidentified plastic pieces.

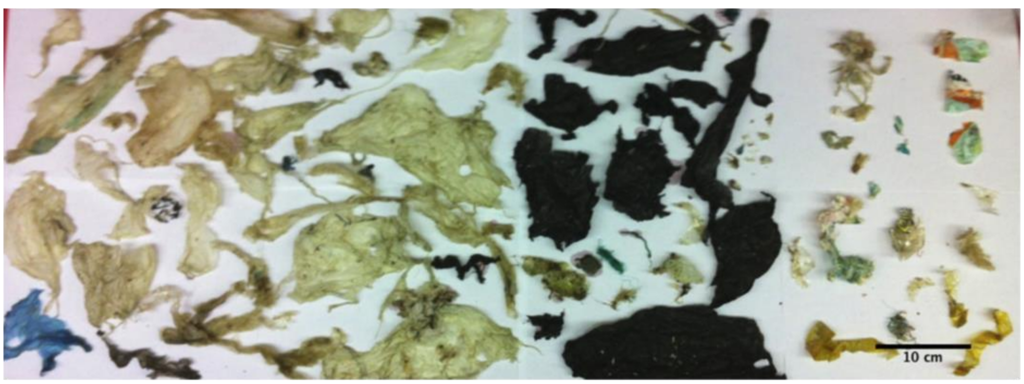
- This is the first published report of human-generated debris ingestion by olive ridley sea turtles outside of the Atlantic Ocean.

Wedemeyer-Strombel, et al. *Marine Biology* 162.10 (2015): 2079-2091. doi:10.1007/s00227-015-2738-1

What we did: We dissected, identified, categorized and quantified the stomach and gastrointestinal tract contents from 71 sea turtles. All sea turtles were collected as deceased legal bycatch. No sea turtles were harmed for this study. This included 45 olive ridley, 22 green, 2 loggerhead and 2 leatherback sea turtles, which were collected between 1993-2011. Percent frequency of occurrence was calculated as follows: [# of sea turtles ingesting human-generated debris/ # of sea turtles analyzed] *100

Left: Human-generated debris ingested by **one** loggerhead, which made up 78% of its diet. Debris includes**: A red toothbrush, 16 plastic bottle caps, and 2 plastic bottle necks.** For scale, this picture shows four sheets of A4 letter paper.

Below: Human-generated debris ingested by **one** green turtle, which made up 75% of its diet. This picture shows **eight sheets of A4 printer paper covered in plastic bags and small plastic pieces.**



Why is this important?

- The sublethal effects of human-generated debris ingestion by marine animals is not well known, but can have adverse effects such as: perforation or obstruction of gastrointestinal tract, nutrient dilution, and toxin absorption which may lower the animal's overall fitness. This is especially of concern for threatened and endangered species, like all animals in this study.

- Human-generated debris ingestion, especially that of plastic, by marine animals can likely transfer bioaccumulated pollutants throughout the marine food web, and potentially onto our plates.

Wedemeyer-Strombel, et al. *Marine Biology* 162.10 (2015): 2079-2091. doi:10.1007/s00227-015-2738-1

POPULAR MEDIA PUBLICATIONS AND APPEARANCES

The PhD identity crisis

Wedemeyer-Strombel, K.R. (2019, March). The PhD Identity Crisis. The Chronicle of Higher Education. https://www.chronicle.com/article/The-PhD-Identity-Crisis/245805

Last month on Twitter, I opened up about one of the side effects of doctoral study that I hadn't anticipated: the Ph.D. identity crisis. With the date of my dissertation defense looming in four months, I'd begun to realize that I couldn't answer two rather important questions:

Who am I outside of "Ph.D. Candidate"?
What do I want out of life and this degree?

I talk a good game on Twitter – about staying true to yourself in graduate school, about being more than your research, about being a whole person. All of that talk is often fueled by my failure to do any of those things well. I have written in these pages before about how graduate school, and the toxic aspects of academic culture, can strain your personal relationships. But honestly, the relationship it has strained the most is the one with myself.

I was nervous to admit any of that publicly, afraid that maybe I was alone in these feelings. Ever since I did, however, the response on Twitter has been humbling and huge. Turns out the "Ph.D. identity crisis" resonates with thousands.

When I entered my doctoral program I had a really strong sense of self. Before starting graduate school, I had worked for a few years in the outside world – as a lead educator at a small zoo and aquarium and as an intern for a federal research lab. Fascinated and inspired by sea turtles, I was determined to better understand science so I could better communicate it, creating connections between people and nature, and between people through nature. I worked full time, interned for free, played soccer two days a week, went to the beach, and had friends and a love life.

I felt so prepared for graduate school. But right from the start of my program, I gave in to one of the most common and toxic pressures of graduate study: the idea that my Ph.D. had to be everything – the only thing I talked or thought about, the one thing to rule them all. I let it consume me.

At times, I tried to fight that pressure and burned bridges in my program along the way. But mostly I bought into the unnecessary competitiveness and the kudos I got for spending 12 to 17 hours a day in the lab. We all did that every day – except for Fridays, when we would leave the lab early to binge drink (something that was oddly encouraged, presumably to help us "blow off steam" or "bond").

I lost connections to my life outside of my lab and my doctoral cohort. Pursuing a doctorate became this strange, surreal experience in which I kept waiting for "real life" to begin. I would tell myself, "If I focus really hard this semester, then I can be me again during winter break." But somehow I never did. I kept putting off life, and the people who were important to me, until "after this grant, after this exam, after this meeting, after my fieldwork is done." It was a never-

ending cycle of goals and expectations that weren't even mine anymore, yet I measured my self-worth by whether I achieved them.

Certainly I loved the occasional praise from a professor or a colleague. It felt good, even if only for a second, even if I was losing myself and changing in ways I didn't like. The momentary high meant I belonged in academe and it fueled me – until it didn't.

By the time I reached out for advice via Twitter, I realized I'd forgotten why I was in graduate school in the first place.

Yes, doctoral study should change you. It should be challenging. After all, that's why we're here – to learn new things, to change. But it feels like graduate school is very different from other life-changing experiences I've had, such as studying abroad for 18 months as an undergraduate. In those cases, my identity took on new layers. It wasn't ripped away and stripped down to "Hi I'm Katie, Ph.D. candidate." And nothing else.

Don't get me wrong: I've enjoyed fieldwork and met wonderful people throughout my studies. I am so fortunate for the many amazing experiences I've had in pursuing my Ph.D. I just wish I would have lived them in the context of my "real life" – and not the weird extended no-man's land of doctoral study. Unable to turn off my inner academic, I let my work dictate how I would live.

And it turned out, I was not alone. After I tweeted, I heard from many A.B.D.s and Ph.D.s who said their own identity crisis had hit either just before their dissertation defense, or shortly after. Among the hundreds of replies:

> "The 'It's over! I should feel great! But actually I just feel very tired and empty!' thing is something I've seen very often – and it usually seems to catch people unawares (I know it did that to me)."
>
> "I'm a few months (hopefully) from handing in, and this resonates so much with me. When people ask me 'What's next?," I still feel like a little kid being asked what I want to be when I grow up. … And I still don't know!"
>
> "As the toxicology saying goes: The dose is the poison. I have allowed [academe] to consume my life, out of a fear of poverty and because that's what the environment pushes. Recently, I resolved to work less and reclaim other parts of my aca-squashed soul."
>
> "It's OK. Many of us have been there. It gets better!"
>
> "With the help of great advisers, I was able to view it as a transformation. One adviser even talked about emerging from a cocoon – kind of silly maybe, but it was a powerful mental construct. You have so many possibilities, where are you going to fly to now that you have new wings?"

> "And if you don't feel you belong in academia – or you feel you do but can't get paid enough to stay – the identity crisis is worse. You're no longer a student or an academic. Gotta sort out what's left, and that required a lot of self-reflection on my part. It's ongoing, really."

So, what comes next for me? Who will I be when my degree is in hand and I am no longer "Katie, Ph.D. Candidate"?

To answer those questions, I have spent a lot of time trying to find my passions and rebuild my life outside of graduate study. Thankfully, my university has accessible mental-health support, which has been critical in helping me accept how I have changed and grown, while filtering out the toxicity I've picked up along the way.

Departments and graduate professors have a major role to play in helping us through this transition. They can:

- Encourage doctoral students to take time off, guilt-free.
- Support students who pursue hobbies and interests outside of academe and alcohol.
- Normalize mental-health care and offer accessible, affordable services - and not just for those times when students are in crisis, but for the day-in, day-out pressures of graduate-level work.
- Hold faculty members who abuse their academic power accountable.

Students, you can also take steps on your own, or with peers, to set boundaries in your academic life:

- If it's an option, go to therapy early and often.
- Pursue hobbies unrelated to your field or work.
- Talk about something other than your research.
- If you have to formally schedule calls with friends and family outside of academe to maintain those relationships, do it. Put them in your calendar.
- Every week take some "me time" and ignore that nagging voice in your head whispering "you should be writing."
- Surround yourself with people, peers, and mentors who honor that.

I'm taking my own advice. With my defense approaching, I am going to therapy. I am taking time for hikes and walks with my dog and my husband. I am protecting my "me time" fiercely. I am working hard – on my dissertation and on myself.

Graduate school should be challenging, not traumatic

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As a doctoral student, I have at times found the culture of graduate school to be toxic. When I've mentioned that – in conversations in person or on Twitter – some professors and fellow students rush to contradict me. "You're just complaining because you don't want to work hard," they say. Or, somewhat more politely, "a Ph.D. should be challenging."

Yes, graduate school should be challenging – but it shouldn't be traumatizing. There is a difference.

I recently created a Twitter thread to share my views on the difference between intellectually demanding hard work and a toxic or hostile work environment. The response was astounding: In 24 hours there were more than 1,000 likes and 300 retweets. Even two weeks later, the thread was still getting traffic. Clearly, this topic resonates.

I am open and honest – some may think too much so – about the struggles I have experienced as a doctoral student. Hearing on Twitter from hundreds of people who can relate makes me feel less alone, but it also angers me that these struggles are widely relatable yet not talked about nearly enough. So let's talk about them.

What are the differences between a challenging graduate-school culture and a traumatizing one? I've experienced both and, in fact, got myself out of a toxic situation. Here are some key differences that I have either observed myself or heard from other graduate students.

Challenging is:

- Long hours spent understanding a complicated concept, improving a course plan, arranging a remote fieldwork trip, coordinating international collaborators, or writing efficient academic prose.
- Research setbacks, grant and publication rejections, and "revise and resubmit" decisions.
- Disagreeing with your advisers or colleagues on methods and having a healthy debate about options.
- Hard, focused studying for candidacy exams, but in an environment that prepares you well for those tests.
- Failing at some task but being encouraged to keep going and to ask for help when you need it.

Toxic is:

- Being yelled at – told you are awful and that you need to "pull up your big-girl panties and deal with it."

- Dreading going into meetings with passive-aggressive or outright abusive supervisors.
- Taking time off to attend a family event and being told that "seeing family is a childish excuse for a vacation."
- Promoting extreme competition among doctoral students.
- Being told to your face that everything is fine, but hearing from others that the same person is saying just the opposite about you to peers, future collaborators, and potential employers.
- If those abusive behaviors sound familiar, take them as warning signs: This is not "just how graduate school is" – you are likely in a toxic environment.

I do not shy away from challenging work. I enjoy it and I am good at it. I do loudly dismiss noxious environments because I felt trapped in one – and it took me years to undo the damage. I know that I was not the perfect graduate student then (or now). I made mistakes and I will own them. But in graduate school, making mistakes should be OK. That’s why we are students – to learn.

My goal here in sharing all of this is to help other graduate students understand: You don’t get a special commendation on your doctorate just because you survived a traumatic environment. You’re not stuck in a toxic program or with a toxic adviser. You can make a change. Extricating yourself will be difficult, and some situations (e.g. visa requirements, dependents) provide more obstacles than others, but you can break free and start again elsewhere.

Your task: Find an adviser who creates and promotes a challenging yet healthy work environment – someone who pushes you but knows when you need a break, someone who sees you as a whole person and emphasizes your health above your research. Such advisers do exist and they make all the difference. If you are one of those advisers, thank you. If you have or had one of these advisers, please thank them.

I do not have exact answers here. I am not a psychologist – just a graduate student who has struggled and recognizes the power in being transparent about those struggles. But I do have some suggestions on how students and their advisers can best navigate the academic environment. If you have suggestions, I hope you will share them, too.

For professors and graduate-program directors looking for ways to promote a healthy, challenging culture in your department, here are some ideas:

- Provide graduate students with links and phone numbers to campus counseling services. Normalize seeing a therapist in graduate school for your students.
- We all know that a Ph.D. program means long hours of reading, writing, research, and stress. Recognize that your students are more than research robots. Encourage reasonable work hours, mental and physical health, and time with family.

- Encourage your students to pursue hobbies unrelated to the degree program. For students new to the area, recommend local sports leagues, book clubs, and the like. Support their having a life outside of the intense focus of graduate study.
- If you notice a student in your department who appears to be stuck in an unhealthy, toxic relationship with an adviser, reach out to that student. Or find someone in your department who can. Struggling students may not know whom they can trust – you can at least let them know they have options (including the three I suggest below). If they decide to change labs or switch advisers, support them however you can, even by just being an advocate and a positive reference as they search for a new adviser.
- Especially if you have tenure, work to resolve problems in your own department. Or find someone who can in the departmental or institutional leadership. Do not put that onus on the student.

For current graduate students feeling stuck in an environment that seems more toxic than challenging, here are some suggestions:

- Talk to a psychologist. I was nervous at first to use my university's counseling services, but I realized I needed help to deal with a situation that felt overwhelming. Counseling helped me tremendously, and I wish I would have started sooner. Almost every graduate student I know has, at one point, talked with a psychologist and, honestly, I think every graduate student should. I cannot recommend it more. I do realize this is not always affordable, but check with your university and see what is available to you.
- Do some serious self-study. Why are you in graduate school? What do you want out of your program? Are you happy? If not, why not? If you decide you want to stay in graduate school, great. If not, that is OK, too. Leaving does not equal failure. Doing what's best for you is the most important consideration.
- Talk to an ombudsman. This is an impartial observer, either in your department or in the office of graduate studies, who will talk with you confidentially. You can speak candidly to this person about your situation, and he or she can help you figure out what you need to do to move forward.

If you are in a position of power to help create a positive, challenging culture for doctoral students, please do so. Or at least start talking about these problems openly. Your graduate students need to know they have options.

Why does graduate school kill so many marriages?

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The longer I have been in my Ph.D. program, and the more colleagues I have met, the more frustrated I have become with the fact that so many of my friends have lost their marriages to graduate school.

My nearly 6.5 years of doctoral study have included two labs, two departments, and two universities. I have connected with graduate students from other campuses at the usual places: cohort gatherings, workshops, Twitter, conferences. We have a variety of things in common, but the one I wish we didn't share is the negative effect of graduate school on our partnerships.

Doctoral training is hard. And relationships are hard. They're both long-term, serious pursuits. But the quest for knowledge should not mean sacrificing your relationship.

Certainly some people have had great marriages through graduate school and beyond. I truly love to hear the success stories – specifically, how they made it work. But I know many other doctoral students, of different backgrounds and genders, whose relationships fell apart or struggled to survive as a direct result of their doctoral study. When my own marriage nearly collapsed, graduate school was a main factor. We have had to fight hard to stay together, and I have had to unapologetically realign my priorities to what works better for both of us, and not just for my work.

Clearly we are not alone. When I posted these thoughts on Twitter last month, I received dozens of responses like these:

- One Ph.D. tweeted that she had "underestimated" the "psychological investment necessary for grad school. Academic ability is not enough. Grad school is a crucible that strengthens relationships and can expose unknown cracks in [the] foundation."
- Another academic wrote: "Doing a Ph.D. nearly destroyed my marriage – luckily we are tenacious and pulled out of the nose dive."
- And yet another: "Mine was a neverending feedback loop of grad school causing marriage issues and marriage causing grad-school issues."

I have heard many accounts from women who got married in graduate school and said they were told not to change their names since the relationship wouldn't last, anyway. I have been told myself, by multiple senior professors, that my work should outweigh my marriage when making decisions about our lives.

Marital hardships are easily traced to academe's toxic work culture – one in which your research must be everything, you are praised for working 17 hours a day in a lab, and you are reprimanded and told you're not dedicated enough for visiting your long-distance partner or (gasp!) taking a vacation.

For many overachievers, i.e., most graduate students, the work-is-everything environment becomes a trap that bleeds you of your emotional capacity. You stop being present in your daily personal life. You live to get through this one class, this one semester, this one grant proposal, this one field season, this one short course, this degree. Only when you get through those accomplishments can you start your life. Even then, you are encouraged to chase the next goal. It's a never-ending cycle.

Trouble is, your life is happening – even as you push through all the work. When you stop being present in your own life, however, it is easy to lose connections to those who matter most to you. And you may not even notice for a while because graduate school has depleted your emotional reservoir.

Most of the graduate students and Ph.D.s who have shared their stories with me say that they didn't realize they were neglecting their partners. How did we not notice? Why didn't anyone talk about this until crisis struck? Why wasn't this covered in our "welcome to grad school" orientation? Why don't doctoral programs give you all of the information when you sign up about what a Ph.D. may truly cost you, besides money? Most important, why aren't academics more transparent with each other about these struggles?

In talking with a friend and fellow graduate student, who has received prestigious grants and accolades in a science field, we both agreed that had we known we would have to put up our marriages as collateral, we would have reconsidered our decision to pursue a doctorate.

My partner was a successful professional chef for several years, until we really saw what longevity in that profession looked like for marital, and family, success. We decided together that he would pursue a different path because what we knew, saw, and were told about that industry did not match with sacrifices we were willing to make. Little did we know – because nobody talked about it – that my pursuit of a Ph.D. would provide pressures and work-life imbalances similar to those in my partner's previous career path.

As a community, we need to do better. We need to be transparent about work-life challenges in doctoral study – and not just talk about it but provide concrete support and actual suggestions. I do not have exact answers, either. I am not a marriage counselor or a marriage researcher. I am just a married graduate student who has struggled on this front. But I can share some realizations and strategies that have helped me be more present in my personal life in the hope that they may prove useful to you, too.

Only you can decide how to prioritize your time, and which comes first: your doctoral program or your relationship. I realized before it was too late that the only correct answer for me was that work had to depend on what was right for my partner and me.

- A marital crisis, in whatever form, does not have to be an end. It can be a new beginning.
- Therapy works. My partner and I did individual therapy to work on ourselves, and then used those skills to work on us. We are considering couples therapy, and many have said this has greatly helped them, others has said it did not. Here, too, you must decide what is best for you.

- If your marriage does not work out, you are not a failure. Leaving does not equal failure, whether the departure is from academe or marriage. Sometimes things don't work out as you'd hoped. That is OK.
- It's also OK to say no to things – to wait a day to respond to emails, to go a day without checking messages, to do less. I decided to do less and work less and be more diligent with my time when I am working. Seriously, say "no" more often to unnecessary extra "opportunities." It is so freeing.
- You are not alone in experiencing a relationship crises. Talk to other partnered friends in your field. Knowing it is not "just us" can be so powerful.
- Talk with your spouse/partner. Really talk. Most important: Listen. Check in, ask how your partner is doing, then listen and allow the information to sink in. If necessary, designate a meeting time during the week where you do this, so you know you have a protected time and space to have these conversations.
- Reinstate date night. The first five years of my Ph.D. program, my husband and I went on maybe four dates. For much of that time we had a long-distance relationship but, even when we were in the same city, we didn't set aside enough time or energy to actually be together. Now, we make it a point to have designated date nights where we don't text, scroll, call, or be present with anyone but each other. It doesn't have to be fancy, expensive, or complex – just time solely dedicated to the two of you connecting, and preferably not talking about work. Melissa Cristina Márquez has some great, affordable, suggestions for easy date nights on her blog.
- Find and maintain hobbies outside of graduate school. They can be things you each do on your own or things that you do together. We are all better when we are whole people, when we are more than our schooling, our research, and our teaching.

The more I share stories with my fellow academics about my struggles in graduate school, the more I realize they are not mine alone. The more we share our coping strategies, the stronger and better off we will all be. Marriage and graduate school do not, and should not, have to be mutually exclusive.

PODCAST APPEARANCES

Wedemeyer-Strombel, K.R. "It's Something That I Do, But Not Who I Am (Part 1)." Audio blog post. WeatherHype. 2018. http://www.weatherhypepodcast.com/episode-51.html

Wedemeyer-Strombel, K.R. "We Should be More Than Research Robots (Part 2)." Audio blog post. WeatherHype. 2018. http://www.weatherhypepodcast.com/episode-52.html

Vita

Kathryn R. Wedemeyer-Strombel, B.S., National Science Foundation Graduate Research Fellow, published four peer-reviewed papers during her PhD, one as first-author. She developed and taught "Grant Writing & Professional Development" for graduate students; co-developed and taught "Environmental Communication" for graduate students, and "Communication and Organizational Leadership, an Environmental Focus" and "Methods of Research and Communication" for undergraduate students in the Department of Communication at UTEP. She was a teaching assistant for the Department of Biology at Texas A&M. Kathryn was hired to develop and teach three graduate-level science storytelling workshops, the audience at one included members of the National Academy of Science. She is contracted to write for the Chronicle of Higher Education, and is the 2019 Keynote Speaker at the University of Ohio's Graduate and Professional School Appreciation Week Celebration.

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