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CHAPTER 8

The role of conservation physiology in mitigating social-ecological traps in wildlife-provisioning tourism: a case study of feeding stingrays in the Cayman Islands

Christina A.D. Semeniuk

➲ Take-home message

Effective selection and communication of physiological metrics of animal health in wildlife-provisioning tourism can minimize problem-causing and problem-enhancing feedbacks in social-ecological systems.

8.1 Introduction

Wildlife tourism is the most rapidly expanding sector within the tourism industry, generating billions of dollars globally (Meyer et al. 2019), and contributing substantially to the gross domestic products (GDPs) of both developed and developing countries (World Travel and Tourism Council, 2015). This growing demand to interact with wildlife, with between 80–440 million estimated participants, is projected to double over the next 50 years (Moorhouse et al. 2015; Trave et al. 2017) and has given rise to a wide range of wildlife tourism activities that can be both educational and entertaining (Reynolds and Braithwaite 2001; Pratt and Suntikul 2016). When managed for sustainability, the ultimate benefit of wildlife tourism is in its potential to create a positive feedback between resource persistence and tourism demand that results in a common incentive to protect the natural environment (Wilson and Tisdell 2003). Presently, it is unclear whether wildlife tourism is succeeding in its conservation objectives, with several studies examining whether the direct and indirect negative impacts of wildlife tourism on the environment outweigh the positive (see Abrantes et al. 2018).

Coastal and marine wildlife tourism is a growing tourism subsector of wildlife tourism that has become one of the leading sources of economic earnings for countries with coastlines (Garrod and Wilson 2004). Defined as ‘non-consumptive’ tourism (Burgin and Hardiman 2015), it encompasses ‘any tourist activity with the primary purpose of watching, studying or enjoying marine wildlife—flora and fauna that live in the coastal and maritime zone and are dependent on resources from the marine environment’ (Masters 1998, p. 6). Increasingly popular is the feeding (provisioning) of marine

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wildlife to increase the chances of viewing animals up close. This activity is frequently used by nature-based tour operators to attract visitors to marine destinations and enhance tourist satisfaction as it greatly improves the chance of sighting animals at close range (Patroni et al. 2018). Allowing visitors to feed target species can permit enhanced interactions and consequently positive visitor experiences (Brookhouse et al. 2013). Provisioning tourism therefore has the potential to significantly impact conservation directly by providing economic benefits, and indirectly through social benefits (Gallagher and Hammerschlag, 2011; Cisneros-Montemayor et al. 2013; Lowe and Tejada 2019). Nonetheless, the practice is controversial (Meekan and Lowe 2019; Ziegler et al. 2019) with concerns being raised about what long-term impacts feeding marine wildlife might have on the target animals, and is restricted or banned in some marine protected zones; however, assessment of the biological effects on marine fauna is limited, and results from different areas and taxa are frequently contradictory (Burgin and Hardiman, 2015). One reason is that the indicators used do not necessarily reflect morbidity or mortality of the target species.

8.2 Conservation physiology—a call to arms

Traditional ecological indicators used in assessing marine wildlife-provisioning effects centre on: (1) modified behaviours—foraging patterns and diel movements, habituation, aggression and other social behaviours, and parental investment; (2) morphology—injury and parasites; (3) breeding responses—reproductive success; (4) target species population dynamics; and (5) community ecology—assemblages and species composition (Bateman and Fleming 2017). With the exception of very few indicators, none outwardly reveals impacts that can be interpreted as detrimental on individual fitness (e.g. growth, reproduction, survival), or population persistence (i.e. a decline in population size can be attributable to emigration, not increased mortality rates). And yet it is these types of indicators that could serve to more definitively contribute to policy and regulation discussions. One reason why estimating provisioning impacts is so divisive is that many studies lack the long-term monitoring that would reveal any positive or negative implications over time (Burgin and Hardiman 2015). This shortcoming is two-fold: the relative immaturity of the industry itself, and debate over what constitutes ‘harmful impact’ (Bateman and Fleming 2017). A category of indicators that can address both these issues can be found in physiological responses. Physiological measurements have the potential to reveal mechanistic cause-and-effect relationships and can be translated and scaled from the individual level to population levels (Illing and Rummer 2017). In wildlife provisioning, such indicators can be related to (1) stress (e.g. heartrate, circulating levels of cortisol/corticosterone and epinephrine); (2) immune response and function (e.g. humoral or cell-mediated, white blood cell parameters, parasite loads, oxidative stress); (3) metabolism/respiration rates; (4) development, growth, body condition and survival; (5) impaired responses to injuries/healing wounds (e.g. pH, partial pressure of CO_2, lactate, glucose); and (6) nutritional status (e.g. lipid profile, stable isotopes, triglyceride concentrations, essential vitamins and minerals) (Knapp et al. 2013; Burgin and Hardiman 2015; Barnett et al. 2016; Bateman and Fleming 2017). These metrics not only represent increased sensitivity to health status, but also have a greater capacity for predicting future change (Bergman et al. 2019). Physiological indicators measured at a discrete time point can thus simultaneously reflect the state of the organism and deliver critical information about the current and future state of the tourism activity.

Despite the call to action of incorporating physiology into conservation science (Wikelski and Cooke 2006; Madliger and Love 2015), very few published examples exist where physiological findings have led to improved management practices for marine wildlife in general (Cooke et al. 2017), and fewer still in regard to provisioning tourism (Madliger et al. 2016). In other words, evidence-based *ecological* results of feeding marine wildlife do not translate into adaptive management strategies for long-term sustainability of this tourism activity, despite findings being indicative of positive or negative impacts on the target species. To address this barrier, it is absolutely imperative that conservation biologists consider marine wildlife-provisioning tourism within the context of a complex socio-ecological system. It is well understood how tourism can have positive conservation outcomes by financing marine reserves and their regulation, providing alternative livelihoods, and contributing to overall socio-economic capital. But at its core, it is both wildlife and tourists that are the critical players in wildlife tourism settings, and are the ones responsible for determining the success of any tourism management plan. Too often, the visitor experience is overlooked (Patroni et al. 2018) in how it contributes to the degradation of wildlife resource, and how it can be managed so that resultant impacts on wildlife are mitigated. Human-dimensions research has found that within and across attractions, experience is influenced by ethics, values, motivations and expectations, levels of specialization, and desired wildlife interactions (i.e. typologies). Moreover, visitors themselves are not homogeneous groups, making a 'one-size-fits-all' management plan problematic (Martin 1997; Moscardo 2000; Higham and Carr 2002; Scott and Thigpen 2003; Curtin and Wilkes 2005; Dearden et al. 2006). It is perhaps no wonder that physiological evidence of detrimental effects of wildlife feeding can have little to no impact on its management: health biomarkers are not often directly linked to impacts on visitor experience (only their actions), findings typically go uncommunicated to the visitors themselves, tourists are not informed how their actions and behaviours can impact wildlife health, and direct tourist input on alternative management plans is not always considered. Being able to translate physiological biomarkers into both animal health and visitor experience can mitigate potential negative impacts on wildlife and preserve

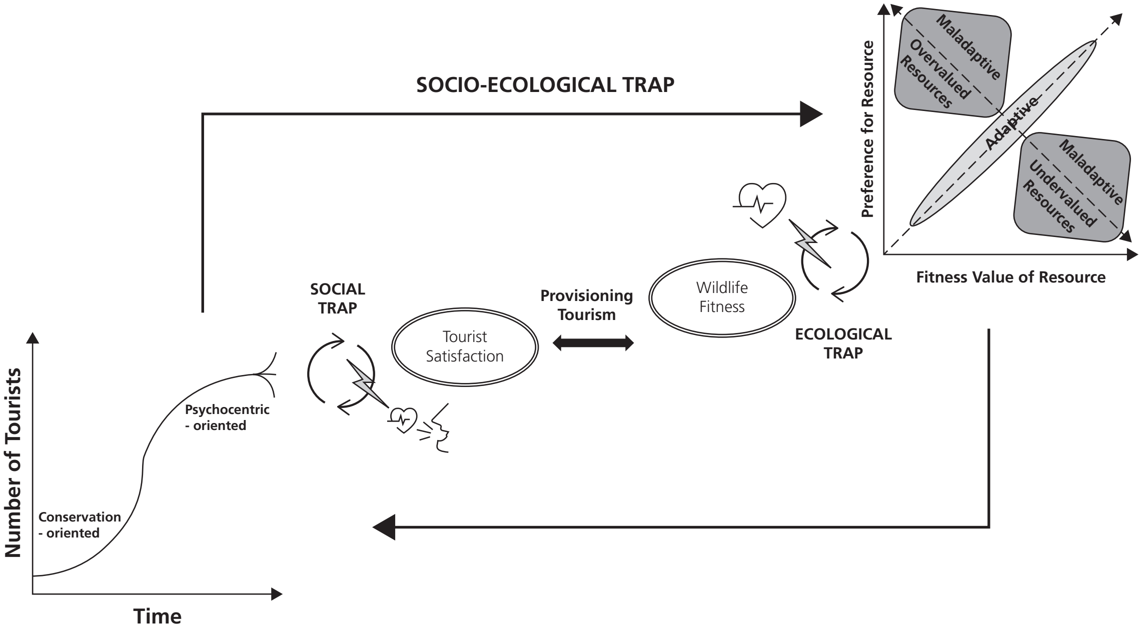

Figure 8.1 Schematic diagram of socio-ecological trap theory for marine wildlife provisioning: tourists, in their pursuit to maximize satisfaction, may engage in activities that negatively affect the tourism system, which then progresses through life-cycle characteristics that end in collapse (i.e. a social trap). Wildlife, in their quest to maximize fitness may prefer and overvalue resources with few beneficial returns, thus making maladaptive decisions that can affect their health and survival (i.e. an ecological trap). A socio-ecological trap occurs when tourist activities such as feeding wildlife directly cause an ecological trap, and as the wildlife system declines, it further exacerbates the social trap, resulting in the exhaustion of the tourist site at an accelerated rate. The careful selection of physiological indicators can uncover health impacts of fed wildlife and hence mitigate an ecological trap from occurring. Communication of physiological indicators to tourists can reveal impacts of their feeding activities, help improve the visitor experience, and prevent the progression of a social trap. Ecological trap diagram modified from Robertson et al. 2017; tourist life-cycle diagram adapted from Duffus and Dearden 1990.

or even enhance the tourist experience. Without this careful and deliberate consideration, the wildlife-tourism system may fall into a social-ecological trap (Figure 8.1). This chapter serves to argue how effective communication of physiological metrics of wildlife health can bridge the gap between science and practice and contribute to minimizing impacts of provisioning as a wildlife tourism activity. As such, I provide a framework that outlines steps that can be undertaken to achieve an enhanced understanding of wildlife feeding as a coupled human–natural system, and demonstrate with a case study on feeding stingrays how physiological indicators play a role in socio-ecological research and resultant management success.

8.3 Socio-ecological traps in wildlife-provisioning tourism

8.3.1 Ecological traps explained

Social-ecological traps (SESs) are lose–lose situations where the pressure imposed by the social system (tourist expectations, revenue) has costs for the ecological system (animal health, maladaptive behaviours, site degradation), which in turn feed back into the social system (loss of tourist satisfaction, loss of revenue), resulting in the demise of both systems (exhaustion). Social-ecological systems become embroiled in problem-causing and problem-enhancing feedbacks (Cumming and Peterson 2017), and to better understand the mechanisms driving SESs, one must look at each component as an integrated whole to help guide the selection of relevant indicators to study. In an ecological context, a trap occurs when human-driven environmental change decouples the cues that animals use to assess habitat quality from the true quality of the environment (Schlaepfer et al. 2002). When animals mistakenly rely on false or altered environmental cues to maximize their fitness, but do not immediately receive the necessary feedback of impending fitness costs, this maladaptive habitat selection leads to reduced survival or reproduction, compared with the probable outcome if the true, high-quality habitat had been selected or remained unchanged (Battin 2004). In a wildlife-tourism setting, the focal animal's natural habitat is being altered, and these changes can create the potential for an ecological trap, as animals may be misinterpreting the cues in their environment as representing either a good-quality resource when it is not, and vice versa. Examples of ecological traps can include: birds switching to less profitable breeding sites as they believe these alternatives to be higher in quality due to human presence at traditional sites (Higham 1998); sharks attracted to feeding stations may be prone to inbreeding if they experience a reduction in dispersal (Clua et al. 2010); and dolphins with high exposure to tour vessels that choose not to leave the vicinity suffer reduced reproductive success (Higham and Bejder 2008). In provisioning tourism, marine wildlife are attracted to supplemental food sources that can result in an ecological trap should the animal's nutritional or reproductive health be affected, the food attracts predators, or if the higher congregation of competitors results in increased injury rates and/or parasite or disease transmission. In these circumstances, wildlife are making suboptimal, maladaptive decisions of where to forage, using cues that no longer maximize fitness.

8.3.2 Social traps explained

A social trap is any situation in which the short-term, local reinforcements guiding individual behaviour are inconsistent with the long-term, global best interest of the individual and society (Platt 1973; Cross and Guyer 1980). Fundamentally, the apparent short-term gains do not translate into longer-term sustainability (Costanza 1987). Moreover, while any single individual's actions may have negligible environmental consequences, the actions of many individuals damage the environment of the collective, including the individual players (Kilbourne and Pickett 2008). In wildlife tourism, a social trap arises when tourists, in their quest to maximize satisfaction with their wildlife experience, possess values, motivations, and actions that unwittingly cause impacts to the system (Higginbottom et al., 2003). Tourists do not receive the immediate feedback of the costs of their actions, and through resultant repercussions at the tourist site, a social trap occurs when tourist satisfaction becomes negatively affected, or equally, does not reach the maximum it could have under more favourable conditions (Moyle et al. 2013). Indeed, the evolution of the tourist product—a theoretically and empirically represented S-shaped growth pattern of tourist volume over time (Butler 1980, based on the economic product life-cycle concept), culminates in a fatigue of the site due to lifted restrictions to encourage greater visitation, a shift in tourist typology (e.g. conservation-oriented to psychocentric values), socio-economic factors, the appearance of other tourism competitors, and/or the reduction of environmental quality (Duffus and Dearden 1990; Catlin et al. 2011).

8.3.3 The use of physiological indicators for the prevention of social-ecological traps

What makes provisioning tourism unique to other types of wildlife tourism is that each subsystem is vulnerable to its own specific type of trap (ecological, social) independent of the other's direct influence. For example, social traps can occur when sites become overcrowded, and ecological traps can arise should the activity attract predators. However, given the importance of close proximity to and interacting with animals, marine wildlife provisioning is especially prone to both ecological and social traps inexorably linked through food. In the absence of exploring how feeding wildlife can impact both animal health and tourist satisfaction, there is a credible chance the site will become a social-ecological trap from which recovery will be a challenge (Boonstra et al. 2016). Considering provisioning tourism within the SES trap perspective has the advantage of outlining the appropriate types of questions to ask and guiding the inventory of suitable indicators which can then be translated into effective management strategies that can prevent the progression of SES traps. For instance, wildlife tourism activities can be identified that could potentially directly precipitate an ecological trap, thus providing insight into which proxies of animal fitness should be investigated. Similarly, the importance of these activities can be examined in relation to the tourist experience, satisfaction and management support, and the potential to trigger a social trap.

Physiological measures have the advantage of being informative indicators when inventorying the health status of wildlife as they can provide crucial information on the immediate status of organisms and predict long-term consequences without the need for actual long-term monitoring of population dynamics (Cooke and O'Connor 2010). The information derived from physiological indicators on the stress, immune function, metabolism, body condition, responses to injuries, and nutritional status can then best be translated to policy makers and tourists if these indicators are further linked to tourist activities, thus playing the dual role of cause–effect–cause for both wildlife health *and* tourist satisfaction. Simply stated, tourists made aware of the impacts of their actions may be more willing to alter their activities (Moorhouse et al. 2017), and decision makers will thus be more informed about the limits of acceptable change the tourist system can undertake. While changes in tourist behaviour have been documented in other types of marine wildlife tourism (e.g. whale-watching, shark-diving, sea turtle interactions) (Trave et al. 2017), no case studies have been recorded for using physiological metrics as the driver for tourist change in marine provisioning tourism (although see the case study in Section 8.5). The ability to inform policy decisions therefore cannot be performed without an integrated, coupled model of natural and human systems (Costanza and Voinov, 2001). In a resource-management context, coupled models are used to collectively assess the impacts of policy actions from both biological and social perspectives, and can assess the importance of precaution in decision making, acceptable levels of additional risk, estimates of how long it may take for mitigating measures to take effect, whether effects are reversible, and efficient allocation of conservation resources (Thompson et al. 2000; Faust et al. 2003). Most notably, modelling can be used to build consensus among science, policy, and the public by building mutual understanding and maintaining a substantive dialogue between members of these groups (van den Belt et al. 1998).

8.4 Scenario-planning coupled systems for the management of wildlife-provisioning tourism

By coupling human- and natural systems from the outset, strategies effective in managing visitors and wildlife can be deduced much more readily, and be used to predict support for management alternatives within a scenario-planning framework (Pizzitutti et al. 2017). Scenario planning is an investigative and decision-making tool that offers managers a method for creating more resilient conservation policies by contrasting plausible scenarios to explore the uncertainty surrounding the future consequences of a decision (Peterson et al. 2003). Benefits of using scenario planning include increased understanding of key uncertainties, the incorporation of alternative perspectives and human choice into conservation planning, and greater resilience of decisions to surprise (Ceauşu et al. 2019). To successfully manage wildlife tourism, one must consider the factors that can affect both animal and tourist population persistence, and explore the differential effects alternative management scenarios can have on their respective population dynamics (Cinner et al. 2011). Within a tourism-provisioning context, scenario planning should begin, as a first step, by incorporating the tourist experience, resultant wildlife health impacts, and management actions with associated management costs (e.g. tourist fees; Burgin and Hardiman 2015) to gauge level of support and find an optimal solution for all involved (including wildlife). The crafted scenarios should be evidence-based (e.g. based on findings provided by conservation physiology research), and hence, reliant on measures indicative of population decline.

As an example, Bach and Burton (2016) employed a stated preference choice experiment—a non-market evaluation tool used to understand tourist consumer behaviour under hypothetical scenarios—to quantify preferences of visitors towards potential changes in their dolphin-feeding experience. The authors developed their survey based on the mounting evidence of negative reproductive and behavioural impacts experienced by habituated dolphins in Shark Bay, Western Australia (e.g. Mann et al. 2000). The majority of tourists felt their experience would remain the same if they were no longer able to feed the dolphins themselves, but importantly, their satisfaction would decrease should dolphin reproduction be compromised. Visitors were therefore willing to trade off management aspects should they improve dolphin welfare. What this study demonstrates is that without physiological evidence of health impacts (if they indeed exist), the acceptance of tourist and regulators for any type of ongoing management and monitoring may be difficult to achieve, especially in the absence of noticeable, easily monitored indicators (survival- and reproductive rates) typically lacking in wildlife-tourism encounters.

8.5 Case study: feeding stingrays as a marine tourism attraction in the Cayman Islands

The case study presented here synthesizes the research conducted on the feeding of southern stingrays (*Hypanus americanus*) at 'Stingray City Sandbar' in the Cayman Islands as a wildlife-tourism attraction within the framework of SES traps. The most popular tourist site in the Cayman Islands is Stingray City Sandbar (SCS), a warm, shallow-water (1.6 m maximum depth) sandbar in the North Sound, approximately 7740 m^2 in area and located roughly 300 m inside the fringing reef. Although the southern stingray is a solitary inhabitant of all shallow bays around the Cayman Islands, only in the vicinity of SCS can stingrays be found year-round in a dense mixed-sex aggregation of individuals. This amassment results from the unregulated quantity of provisioned squid (*Illex* and *Loligo* spp.), a non-natural diet item shipped in from the North Atlantic and North Pacific (Semeniuk, pers. obs.; Gina Ebanks-Petrie, director, Cayman Islands Department of Environment, pers. comm.). The feeding routine (daily, except during the off-season, when weekends are excluded in summer) lasts from early morning until mid-afternoon as tour boats continuously deliver mainly cruise line tourists for an average 45-min visit. Due to its massive popularity, SCS supports over 50 local snorkel and dive tourism operations and hosts over 1 million visitors per year, almost half of all visitors to the island, with tourist numbers having more than doubled since 2000 (CI MoT 2002).

A day-long activity that first began in the early 1980s (Shackley 1998), by the mid-2000s, a maximum of 2500 tourists could be present at a given time at the shallow sandbar, engaged in feeding, touching, and holding of stingrays as part of their marine tourism experience. Some tour operators provided only the most rudimentary information, while others delivered an informative in-water session. The organized trip also provided photo opportunities, with some tour operators holding the ray in or out of the water or placing it on people's backs and heads while the picture is taken. Conservatively, stingray-related revenue for the local economy is estimated to be as high as US$50 million annually (Vaudo et al. 2018).

A lack of management or codes of practice since the SCS's inception in 1984 had resulted in significant tourist congestion, with stakeholders (government officials, tour operators, tourists, and locals) expressing concern about the long-term sustainability of the attraction (G. Ebanks-Petrie, C.A.D.S., pers. obs.). In 2003, Cayman Island stakeholders convened a committee to agree upon a set of detailed rules for stingray protection and crowding alleviation for SCS. While each proposed regulation considered alone could be expected to redress the known problems (e.g. limits on boat density would be likely to reduce the risk of boat-related injuries for stingrays and/or reduce congestion), the outcome of the simultaneous application of these and other regulations was uncertain, and faced opposition from some locals and tour operators fearing economic fallout as well as the inherent uncertainty in this little-studied system. As such, the potentially progressive process was in danger of being derailed by the lack of an integrative plan designed to consider both visitor satisfaction and stingray fitness. Consequently, given the tight human–animal interdependence of SCS, proposed management scenarios necessitated a true optimization of human–wildlife needs rather than simple unidirectional decisions (e.g. stingray–human interaction rules could reduce stingray injuries but also dissuade visitors from returning or promoting the site to others).

8.6 SES Trap theory and stingray tourism

8.6.1 Stingray ecological trap

At SCS, there are two human activities that have the potential to cause SES traps (i.e. affect wildlife fitness and tourist demand): feeding stingrays and 'handling' stingrays (either through direct interaction or indirectly through collisions with boats). For an ecological trap to occur (maladaptive decision making), habitat alteration must first simultaneously alter the cue set with which the animal assesses habitat quality (i.e. increase its attractiveness), and decrease the suitability of the habitat. Next, the ability of the animal to adjust to and persist in these novel conditions must be compromised (Robertson and Hutto 2006). The ecological indicators thus chosen for study were selected to provide information on the general, physiological, and immunological health of the tourist-fed population and reveal whether these animals were being exposed to conditions of an ecological trap (Table 8.1).

Initial research into the system contrasted non-esterified fatty acid profiles between tourist- and non-tourist stingrays as a marker of diet composition, lipid requirements, and nutritional status (using non-fed stingrays as baseline). Results revealed multiple findings, with the first being non-random habitat use: stingrays at SCS were incorporating the tourist-supplemented food as the major item in their diet (Semeniuk et al. 2007), becoming habituated to the constant supply of provisioned food. This behavioural diet shift, in combination with very high yearly recapture rates (Corcoran 2006; Corcoran et al. 2013; Vaudo et al. 2018), suggested strong site fidelity, and hence, an attraction to the site. Second, this physiological indicator revealed the provisioned stingrays exhibited essential fatty acid ratios, specific to both species and habitat, comparable with those of elasmobranchs from cold-water environs, implying that the provisioned food did not provide a similar nutritional lipid composition required in tropical habitats (Semeniuk et al. 2007). The cue (provisioned food) was acting as a false attractor of a 'good-quality' foraging site. Third, an additional study demonstrated that the novel grouping behaviour that stingrays exhibited at SCS imposed significant costs in the form of increased aggression, parasite load, and injury, when compared with stingrays from control, non-tourist locations around the island (Semeniuk and Rothley 2008). What was still lacking, however, was definitive evidence of long-term costs that would reveal the occurrence of an ecological trap.

Using stingrays from non-tourist sites about Grand Cayman as a basis for comparison, findings

Table 8.1 List of ecological indicators examined between tourist-fed stingrays at Stingray City Sandbar and stingrays at three non-tourist control sites around Grand Cayman, Cayman Islands.

Wildlife fitness indicator category	Indicator	Description	Ecological condition
General health			
	Parasite load (virulence transmission)	Parasitic ectodermal isopods (*Gnathia* sp.) located in stingray spiracles	Atypical grouping
	Conspecific bite marks (aggression)	Fresh and scarred semi-circular bite marks on stingray pectoral fin margins	Atypical grouping/ non-natural diet
	Collision injuries	Fresh and scarred boat-propeller and anchor chain wounds on body	Human contact
	Predator injuries	Missing stingray tails, fresh and scarred triangular (shark-tooth) wounds on body	Atypical grouping
Physiological health			
	Serum essential fatty acids (EFAs)	Preformed long-chain fatty acids important for normal growth, development, and reproduction; relative and absolute amounts linked to metabolic demands of disease resistance and immune response	Unnatural diet
	Haematocrit	Relative amount of red blood cells in total blood volume; reflects intensity of oxygen transport. Low values indicative of bacterial or parasite infections, starvation, or scarcity of micronutrients	Unnatural diet
	Serum protein concentration	Circulating proteins in peripheral blood used as an index of total protein reserves; can be used to assess dietary inadequacies and other vital biological functions	Unnatural diet/ human contact
	Total antioxidant capacity (TAC)	Total concentration of endogenously produced enzymes, low-molecular-weight molecules, and exogenous and food-derived antioxidants (e.g. vitamin K, urea, and glutathione) used to protect against damage from reactive oxygen species	Unnatural diet/ human contact
Immunological health			
	Leukocrit	Fraction of white blood cells in total blood volume; if values are high can suggest possible pathogen infection; if low, stress-induced immunosuppression	Human contact/ atypical grouping
	White blood cells	Differential counts of lymphocytes (L), granulocytes (heterophils [H] and eosinophils [E]), monocytes (M), and thrombocytes (T). Low L, M, and T can be indicative of compromised cell-mediated immunity and antibody production; high H, E and T increase with infection, disease, and stressful conditions	Human contact/ atypical grouping
	Total oxidative status (TOS)	Reactive oxygen (and nitrogen) species as a result of cellular metabolism. Excess concentrations can damage cell structures, deplete energy, and cause early apoptosis. A low TAC:TOS ratio is sign of oxidative stress	Human contact/ atypical grouping

showed in this natural experiment that tourist-exposed stingrays exhibited haematological changes indicative of physiological costs of wildlife tourism in the form of suboptimal health and attenuation of the defence system (Semeniuk et al. 2009). More specifically, stingrays displayed lower haematocrit, total serum protein concentrations, and oxidative stress (i.e. lower total antioxidant capacity combined with higher total oxidative status). Moreover, they showed evidence of attenuation of the defence system: for provisioned stingrays only, animals possessing both injuries and high parasite loads also exhibited lower leukocrit (packed white blood cells), serum proteins, and antioxidant potential, as well as differing proportions of differential leukocyte cell types indicative of immunosuppression (lymphocytes and heterophils) and down-regulation (eosinophils), suggesting that the

Figure 8.2 Stingray City Sandbar. (A) Stingrays and tourists. (B) Health assessment. (C) Drawing blood sample from underside of tail. (D) Performing blood smears for cell counts. Photo (A) courtesy of Matthew Potenski. Photo credit for (B), (C), and (D): Christina Semeniuk.

physiological changes of tourist stingrays were in partial response to these stressors. Although direct evidence of reduced reproductive success (e.g. measures of fecundity) and survival (e.g. observed mortality) would have been definitive evidence of an ecological cost, this was not logistically feasible. Nevertheless, the physiological indicators integrated multiple stressors: altered social behaviours, non-natural diet, and interactions with tourists and tour boats. These significant responses to provisioning tourism indicated that the long-term health and survival of tourist stingrays were being compromised, revealing the occurrence of an ecological trap (Figure 8.2).

8.6.2 Tourist social trap

To understand whether tourists were prone to a social trap—reduced satisfaction followed by tourist population declines—intercept surveys were conducted on cruise ship passengers upon their immediate return from SCS, as ship passengers comprise over 85 per cent of tourists compared with stay-over visitors at SCS (G. Ebanks-Petrie, pers. comm.). The human-dimensions indicators surveyed were chosen to reflect tourist expectations, wildlife-tourism values, and tourist preferences for management activities at SCS (via a stated-preference discrete choice experiment, similar to Bach and Burton 2016; Louviere and Timmermans 1990). These indices provided information on the conditions at SCS that would (1) have the greatest potential to add to, or detract from, tourist experiences; (2) establish whether education/interpretation would be required in promoting stewardship and awareness among tourists of the types of interactions that affect wildlife fitness; and (3) determine which management options could garner the most (or least) support by visitors. While tourists were very satisfied overall with their wildlife interaction at SCS, the majority were willing to have activities regulated to a certain extent and were willing to pay a conservation access fee to the site. However, key indicators from the data suggested that a social trap was in development: just over one half of the tourists expressed only 'mild' concern for potential negative wildlife impacts arising at the attraction and almost one quarter felt 'low' concern (Semeniuk et al. 2008). In addition, one third of the surveyed tourist population was vociferously against any management of the tourist–wildlife interaction, believing their actions caused no harm. These differences were revealed when using a decision-support tool to calculate their respective market shares of support for alternative management strategies.

The decision-support tool was created as a forecasting tool to estimate which management scenario (and its subsequent potential ecological outcome) would garner the most and least support among respondents. Despite the differences between the two tourist population typologies (i.e. 'pro-management' and 'no-management'), both exhibited a preference for the continuation of feeding and handling the stingrays (albeit at different levels of intensity). Further evidence from the decision-support tool revealed that neither tourist typology was currently experiencing maximized satisfaction from their provisioning experience—this would only be realized if crowding conditions were ameliorated and the risk of harm to stingrays was low. Indeed, tourist realization of the high risk of stingray injury would result in significant diminishment of trip experience coupled with an unwillingness to return for two thirds of the respondent population, again intimating that a social trap, in which reduced satisfaction is followed by tourist population declines, is a distinct possibility. What the collective results revealed were that visitors at SCS, in their quest to maximize their satisfaction, were in fact engaging in activities that were harmful to the health of the animals. Taken together, both ecological and social research revealed that SCS, if not adequately managed, would not be sustainable, and the use of appropriate physiological indicators was instrumental in grounding this realization.

8.7 Scenario planning for management: integrating ecological and social traps

While the survey decision-support tool was key in determining tourist support for different proposed management plans, it was not able to predict future outcomes for the makeup of the resultant tourist-population typology (i.e. proportion of tourists identified as 'pro-management' versus 'no-management'), stingray population dynamics (immigration rates, mortality), nor stingray life expectancy for individuals that choose to remain at SCS. A scenario-planning model was therefore developed using system dynamics modelling to provide illustrative results of how tourist numbers, stingray population size, and stingray life expectancy would change over time under different restrictive management plans (Figure 8.3). The development of the model was guided by the belief that sound ecological management occurs only when social values, preferences, and their resultant ecological effects are equally integrated. Essentially, plans aimed at optimizing wildlife fitness must also be acceptable to tourists. In specific, the model allowed for the ability to evaluate the impacts of alternative management plans on the sustainability of the wildlife tourism attraction by simultaneously exploring the effects of policies on both wildlife health and the tourist experience, governed by evidence-based ecological and social research at SCS. The model then outputted data on stingray population size, stingray life expectancy, and tourist visitation rates (for each tourist typology) over a future time span of 25 years. The model's main structural component was two population submodels: an ecological model of stingray population dynamics (recruitment and mortality estimates based on mark–recapture data, and subjected to sensitivity analyses) and tourist population trajectories (based on the Cayman Islands Department of Tourism's Port Authority of cruise ship tourist numbers). Each submodel was assumed to be affected by management scenarios, and data fed into the model's parameterizations were informed by previous research findings—that is, how management plans were assumed to affect (1) stingray survival and life expectancy (via research on stingray health as

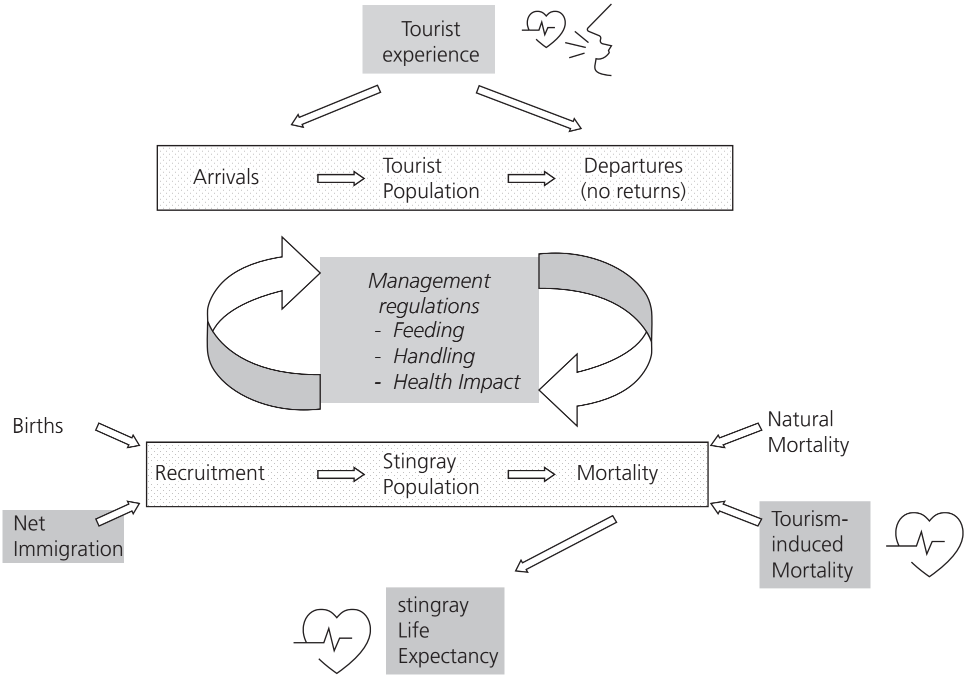

Figure 8.3 Conceptual system dynamics model of Stingray City Sandbar to investigate plausible management options within a scenario-planning framework. The aim is to find optimal plans that address both visitor experience and stingray health. The two population submodels are linked via impacts of management of tourist activities—feeding and handling stingrays—that affect both tourist satisfaction and wildlife health. These management scenarios in turn impact the tourist experience and subsequent visitation rates, stingray immigration rates due to limiting amount of provisioned food, and stingray mortality, morbidity and life expectancy (grey boxes), all of which are integral to the sustainability of the tourism system. Physiology metrics and their communication are indicated where evidence-based results were used to guide research and build realistic conservation models.

revealed by the physiological indicators), and (2) tourist visitation rates (via tourist preferences for management that was assumed to link with behavioural intentions regarding future visitation rates). Importantly, the two submodels were dynamically linked since tourist surveys indicated the extent to which the stingray population and stingray individual fitness influenced tourist experience (and hence visitation), and how tourist actions (feeding and handling) impacted stingray health (informed by the physiological indicators) and influenced stingray immigration rates (via the attraction by unnatural foods).

Scenario modelling confirmed both an ecological and a social trap in the absence of any management (business as usual option): the model predicted lower tourist numbers of both tourist typologies, a larger stingray population size (mainly through immigration), but poorer overall health—all classic hallmarks of social and ecological traps. The model also indicated that under certain management plans, tourists possessing psychocentric values and no willingness to curtail their activities with stingrays would eventually replace the more conservation value-oriented visitors. Again, the model predicted this unsustainable outcome in the long run due to the detrimental effects of these tourist-type-driven activities on stingrays. The optimal management action was one in which there was a reduction in visitor density, mild restricted stingray interactions, and an imposition of a small conservation fee. Over time, although fewer stingrays were predicted to remain at SCS, they would live longer and experience fewer stochastic disease events; the desirable tourist segment was predicted to predominate; the fee could recoup costs imposed either by on-site supervision or management actions; and model simulations were still sustainable after the allotted 25-year time span (Semeniuk et al. 2010). By understanding how management will affect tourist activities and their subsequent impacts on both wildlife health and visitor satisfaction, it was possible to explore the management alternatives that would optimize both, under the edict of preventing a social-ecological trap: a social trap (handling and feeding stingrays) triggering an ecological one (maladaptive attraction to a provisioned food resource).

8.8 Management outcomes at Stingray City Sandbar

SCS stakeholders (e.g. tour operators, general public) believed prior to this research that the tourist-fed stingrays were still foraging predominantly naturally, and that if any negative repercussions were to exist, fed stingrays—being wild and not captive—were free to leave the area. The fact that they were remaining could only be indicative of no harm. Moreover, the belief was also that access to a virtually unlimited food supply would compensate for any ill-effects of the tourism activities (e.g. via increased fecundity). The use of physiological indicators was instrumental in demonstrating these beliefs to be incorrect. Instead, provisioning stingrays was creating unsustainable conditions for the wildlife—stingrays would continue to be attracted with negative repercussions. Further, careful management was required since, if evidence of any stingray harm was unavailable, unrestricted feeding and handling stingrays would continue to influence tourist satisfaction. However, findings also revealed that, despite the importance of direct interactions with stingrays, a large majority of tourists were willing to accept some form of management should there exist a risk of injury to the rays. This management would further translate into *increased* satisfaction with the tourist experience. Again, the physiological evidence was critical during discussions with Caymanian policy makers and dissemination to the public, with research results publicized in local newspapers.

Tourist management recommendations thus emerged from the collective SCS studies to assist Caymanian resource managers charged with the responsibility of protecting the environment and providing satisfactory recreational opportunities. These are summarized as: (1) the heterogeneity of tourist types visiting SCS would require various management practices; (2) communication and education through various forms of media would play a key role in resolving behaviours or actions that prove harmful to stingray health; and (3) the wildlife tourism attraction would need to undergo marketing and promotional restructuring to implement the desirable changes, as most visual and written advertisements for SCS promote the feeding and holding of stingrays. Ecological management measures recommended were to alleviate stingray crowding conditions at SCS by limiting the number of people and boats, or by expanding the site into nearby areas to accommodate the current level. Less food provisioned to the rays would also alleviate stingray competition and subsequent aggression injuries, and ensure that the animals resumed foraging naturally and solitarily, further away from the tourist site. If food was still to be provisioned, care was to be taken to ensure that as natural a diet as possible was provided, either through locally caught food or a formulated diet that could be monetarily compensated for by the conservation access fee. Restriction of handling to the tour operator only was also recommended and safety devices on boat propellers, such as cages and guards, would also aid in reducing injuries.

Since the inception of the North Sound Committee in 2003, charged with the planning and management of SCS, new developments have transpired. Recently enacted legislation based on research findings presented here has resulted in the creation of Wildlife Interaction Zones, including the North Sound of Grand Cayman where SCS is located. This zoning act contains a regulation that no marine life may be taken out of the water, including the stingrays, and the Department of Environment will be enforcing the new regulation. Also, while feeding is allowed within these designated zones, the food must be approved by the Marine Conservation Board. Recent plans have a permanent officer for the Wildlife Interaction Zones, with a vessel purchased specifically for that role, as well as the hiring of an officer whose main responsibilities will be to patrol these areas. A campaign was also initiated to produce interpretive materials for visitors at SCS to enhance and inform their stingray experiences (Cayman Compass 2009). Lastly, continuous monitoring of SCS stingray population size and physiological health has been endorsed and participated in by the Cayman Island's Department of Environment (Corcoran et al. 2013; Vaudo et al. 2018).

8.9 Conclusions and future directions

Physiology on its own is an important tool in the conservation toolbox. In situations where impacts are revealed to be occurring at the physiological level but will still incur long-term consequences at the individual and population level, these findings must go beyond simple reporting. When translated into the human dimensions context with social science and scenario planning, it can become an exceptionally important instrument that can effect change (Kittinger et al. 2012). This change can be realized because among the diversity of situations and species involved in human–wildlife interactions, the one common thread is that the thoughts and actions of humans ultimately determine the course and resolution of any conflict (Manfredo and Dayer 2004). Effective communication of physiological metrics of wildlife health will therefore greatly contribute to minimizing problem-causing and problem-enhancing feedbacks in social-ecological systems since tourists made aware of the impacts of their actions may be more willing to alter their activities; and decision makers will thus be more informed about how much of a change a tourism system can sustainably undergo.

The socio-ecological trap theory presented here has wide applicability to other tourist–wildlife interactions, from directed ecotourism to incidental wildlife tourism, and can serve as a guiding framework for scenario-planning directives. Specifically, one should examine within a 'trap' context: (1) the motivations and behaviours of people that have the potential to simultaneously affect their own needs/livelihoods *and* wildlife fitness; and (2) the behavioural decisions of animals affected by human actions that can in turn reduce wildlife population numbers. Critically, the selection of appropriate physiological indicators reflecting this relationship between humans and wildlife can then inform management options (and explore the alternatives) to prevent both interlinked traps from occurring in wildlife tourism attractions, thus increasing the probability of a sustainable outcome for all.

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