



Health implications associated with exposure to farmed and wild sea turtles

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DECLARATIONS

Competing interests

None declared

Funding

This study was funded by the World Society for the Protection of Animals

Guarantor

CW

Contributorship

All authors contributed equally

Acknowledgements

WSPA

Reviewers

Fred Frye and Ray Greek

Summary

Exposure to sea turtles may be increasing with expanding tourism, although reports of problems arising from interaction with free-living animals appear of negligible human health and safety concern. Exposure both to wild-caught and captive-housed sea turtles, including consumption of turtle products, raises several health concerns for the public, including: microbiological (bacteria, viruses, parasites and fungi), macrobiological (macroparasites), and organic and inorganic toxic contaminants (biotoxins, organochlorines and heavy metals). We conducted a review of sea turtle associated human disease and its causative agents as well as a case study of the commercial sea turtle facility known as the Cayman Turtle Farm (which receives approximately 240,000 visitors annually) including the use of water sampling and laboratory microbial analysis which identified *Pseudomonas aeruginosa*, *Aeromonas* spp., *Vibrio* spp. and *Salmonella* spp. Our assessment is that pathogens and toxic contaminants may be loosely categorized to represent the following levels of potential risk: *viruses* and *fungi* = *very low*; *protozoan parasites* = *very low to low*; *metazoan parasites, bacteria* and *environmental toxic contaminants* = *low or moderate to high*; and *biotoxin contaminant* = *moderate to very high*. Farmed turtles and their consumable products may constitute a significant reservoir of potential human pathogen and toxin contamination. Greater awareness among health-care professionals regarding both potential pathogens and toxic contaminants from sea turtles, as well as key signs and symptoms of sea turtle-related human disease, is important for the prevention and control of salient disease.

Introduction

Exposure to sea turtles may be increasing with expanding tourism, although reports of problems arising from interaction with free-living animals appear of negligible human health and safety concern. However, exposure both to wild-caught and captive-housed sea turtles, including consumption of turtle products (for example, meat,

eggs, organs, adipose tissue and blood), raises several health concerns for the public, including: *microbiological* (bacteria, viruses, parasites and fungi), *macrobiological* (macroparasites), and *organic and inorganic toxic contaminants* (biotoxins, organochlorines and heavy metals).^{1,2,3,4,5}

According to the Cayman Island Government during the five years from 2007 to 2011 approximately 1.2 million visitors (average 240,000

people per year) have attended the turtle farm, making the facility an important interface for both direct and indirect contact with potential turtle-associated human pathogenic agents. The subsequent distribution of visitors exposed to turtle-farm conditions may also involve opportunities for further dissemination of contaminants into established tourist hubs including cruise ship and airline carrier contactees.

Awareness of potential threats may be modest among health-care professionals and low among the public. One study conducted interviews with 134 residents and 37 physicians in a region where consumption of sea turtle meat was high in order to assess comparative perceptions on turtle meat as a healthy or unhealthy diet.⁵ The researchers found that 32% of physicians had treated patients for sea turtle-related consumption illnesses, and believed that sea turtle products were unhealthy foods, although they were largely unaware of specific risk factors.

The prevalence of sea turtle-associated human disease is not known. As with other reptile-borne human disease, ascertainment in general is difficult due to diagnostic failure rates.^{6,7} Also, because the taking and slaughter of sea turtles is widely illegal there may be a general reluctance to report some known associations.²

We conducted a review of sea turtle associated human disease and its causative agents and compiled descriptive tables outlining biotic and abiotic pathogenic agents as well as guidance regarding relevant signs and symptoms. We also conducted a case study of the commercial sea turtle facility known as the Cayman Turtle Farm, located in Grand Cayman, including the use of water sampling and laboratory microbial analysis.

Methods

For this analysis we conducted a dedicated literature search, reviewed original visual materials partly gathered under our direction, and evaluated laboratory microbiological data (compiled by Greendale Veterinary Diagnostics Limited, Woking, UK) which was also acquired under our direction.

Microbial pathogens and macroparasites

Zoonotic (animal-to-human) pathogens (for example, bacteria, viruses, fungi and micro-

macroparasites) may be considered potential health risks whether consumed in products or manifesting from direct or indirect contact with turtles or their (especially captive) environment.⁷ However, while viruses have some association with other (non-sea turtle) reptile-borne human disease,⁸ sea turtle viruses as well as fungi and some parasites are not significantly linked to human disease.⁴ Sea turtle-related zoonoses have not been studied in great detail, although several zoonoses and other human health issues are known to occur.² Table 1 lists potential zoonotic and other sea turtle-associated pathogenic agents, as well as typical signs and symptoms.

Contaminants and toxins

Sea turtle marine environments are subject to a variety of contaminant sources including oil spills, chemical waste and other debris.⁹ Most data available on sea turtle contaminants appear to refer to studies of free-living animals, although as mentioned elsewhere, there is negligible concern about human contamination from interactions with turtles in their natural environment.

Organic and inorganic toxic contaminants (biotoxins, organochlorines and heavy metals) are notable agents in disease,^{1,2,3,4,5} with the turtle-endemic biotoxin, chelonitoxin, constituting a primary health concern.² Table 2 lists potential toxic contaminants and sources as well as example signs and symptoms.

Consumption of raw and cooked products

The consumption of sea turtle products involves both raw and cooked items. Raw items present a persistent health hazard because microbes, macroparasites and environmental toxic contaminants are unmodified and viable. Intuitively, products that are thoroughly cooked pose a greatly reduced risk of transfer to the consumer.

However, it has to be emphasized that it is difficult to rule out that consumption of any product carries zero risk to health. This is because viable organisms may reside in areas that are not thoroughly cooked, and also toxins from the presence of former live microbes may yet remain potential health hazards. Where chelonitoxin is involved, thorough cooking may offer little or no

Table 1
Known and potential pathogens, zoonoses and sources, and typical signs and symptoms of human disease associated with green, Kemps ridley and hawksbill sea turtles

| Pathogen | Type | Zoonosis/condition | Source | Signs and symptoms | References |
|--|-----------|---|---|---|------------|
| <i>Vibrio mimicus</i> , <i>V. vulnificus</i> , <i>V. alginolyticus</i> | Bacterial | Vibriosis | Eggs, meat, water, organs | Gastrointestinal, pain, vomiting, fever, septicaemia, otitis | 4,7,8 |
| <i>Chlamydomphila abortus</i> | Bacterial | Pelvic inflammatory disease, chlamydiosis | Exposure to infected animals | Abdominal pain, fever, anaemia, abortion, flu-like, pneumonia, septicaemia | 9,10 |
| <i>Salmonella</i> spp. | Bacterial | Salmonellosis | Eggs, meat, water, organs | Gastrointestinal, nausea, vomiting, pain fever, septicaemia, meningitis | 6,11 |
| <i>Mycobacterium</i> spp. | Bacterial | Mycobacteriosis/cutaneous nodular disease | Open wound exposure to water, infected animals | Dermatological, other | 4,11 |
| <i>Aeromonas hydrophila</i> | Bacterial | Aeromonal gastroenteritis | Eggs, meat, water, organs, exposure to infected animals | Gastrointestinal, cellulitis, nausea, vomiting, pain, fever, septicaemia, colitis, meningitis | 4 |
| <i>Pseudomonas fluorescens</i> | Bacterial | Bacteraemia | Eggs, meat, water, organs, exposure to infected animals | Fever, dermatitis, urinary, diarrhoea, respiratory, meningitis, corneal ulceration, otitis, endocarditis, bacteraemia | 4,12 |
| <i>Pseudomonas aeruginosa</i> | Bacterial | Bacteraemia | Eggs, meat, water, organs, exposure to infected animals | Fever, dermatitis, urinary, diarrhoea, respiratory, meningitis, corneal ulceration, otitis, endocarditis, bacteraemia | 13 |
| <i>Flavobacterium</i> spp. | Bacterial | Bacteraemia | Eggs, meat, water, organs, exposure to infected animals | Pain, fever, septicaemia, meningitis, carditis | 4 |
| <i>Bacillus</i> spp. | Bacterial | Bacteraemia | Eggs, meat, water, organs, exposure to infected animals | Fever, dermatological, septicaemia, peritonitis, respiratory, meningitis, ophthalmitis, endocarditis, otitis | 4 |
| <i>Escherichia coli</i> | Bacterial | Enteritis | Eggs, meat, water, organs, exposure to infected animals | Acute gastrointestinal, nausea, vomiting, pain, fever, acute renal failure | 4 |
| <i>Leptospira</i> spp. | Bacterial | Leptospirosis | Eggs, water, urine, organs, open wound exposure to infected animals | Flu-like, vomiting, icterus, telangiectasia, uveitis, splenomegaly, meningitis | 4 |
| <i>Cryptosporidium parvum</i> | Parasitic | Cryptosporidiosis | Water, organs | Acute gastrointestinal, nausea, vomiting, pain, fever | 4,14 |
| <i>Schistosoma</i> spp. | Parasitic | Schistosomiasis/bilharzia | Eggs, meat, water, organs, exposure to infected animals | Flu-like, splenomegaly, hepatomegaly, gastrointestinal, pain, itching, dysuria, haematuria | 15,16 |
| <i>Entamoeba invadens</i> , <i>E. histolytica</i> | Parasitic | Amoebiasis | Water, organs, exposure to infected animals | Gastrointestinal, pain, vomiting, fever, hepatic abscessation | 4 |

Table 2
Known and potential environmental toxic contaminants and sources as well as typical signs and symptoms of human disease associated with green, Kemps ridley and hawksbill sea turtles

| Contaminant | Type | Disease | Source | Signs and symptoms | References |
|---|----------------|---------------------------------------|---|---|------------|
| Chelonitoxin | Biotxin | Chelonitoxinism/ seafood poisoning | Eggs, meat, adipose tissue, organs | Gastrointestinal, nausea, vomiting, pain, polyarthralgia, flu-like, coma | 19 |
| Chloride/dichlorodiphenyl- trichloroethane (DDT)/ dichlorodiphenyldichloroethylene (DDE) | Organochlorine | Organochlorine poisoning | Meat, adipose tissue, organs | Neurological, neuropathy, nephropathy, hepatopathy cancer, anaemia, immune compromise, fatigue, subfertility, fetal and child abnormalities | 4 |
| Chlordane | Organochlorine | Chlordane poisoning | Eggs, meat, adipose tissue, organs | Gastrointestinal, immune deficiency, neurological, dizziness, muscle dysfunction, convulsions | 4 |
| Polychlorinated biphenyls (PCBs) | Organochlorine | PCB poisoning | Adipose tissue, meat, organs | Gastrointestinal, endocrine, immune compromise, cancer, subfertility, fetal and child abnormalities | 4 |
| Dieldrin | Organochlorine | Dieldrin poisoning | Adipose tissue, meat, organs | including behavioural effects Cancer, Parkinson's and other neurological disease, immune compromise, reproductive dysfunction | 4 |
| Hexachlorobenzene | Organochlorine | Hexachlorobenzene poisoning | Adipose tissue, meat, organs | Hepatic, renal, and thyroid cancer, porphyric neurological and dermatological sequelae, photosensitivity, alopecia, fetal and child abnormalities | 4 |
| Cadmium | Heavy metal | Cadmium poisoning | Eggs, meat, organs | Neurological, neuropathy, nephropathy, hepatopathy cancer, anaemia, fatigue, osteoporosis, fetal and child abnormalities | 4 |
| Mercury | Heavy metal | Mercury poisoning | Eggs, meat, organs | Neurological, neuropathy, nephropathy, hepatopathy cardiovascular, immune compromise, vision loss, desensitization, cancer, anaemia, fatigue, subfertility, fetal and child abnormalities | 4 |
| Lead | Heavy metal | Plumbism | Eggs, meat, organs | Neurological, delirium, nephropathy, hepatopathy, cardiomyopathy, anaemia intestinal disease, reproductive dysfunction | 4 |

protection against ingestion of harmful material.¹⁰ It is reasonable to assume that similar health risks remain associated where other toxic contaminants are concerned, regardless of how well cooked a product may be.

Relatedly, freezing of sea turtle products (for example, meat) may aid to control some but not all potential health threats. For example, freezing may kill certain macroparasites but will not kill bacteria.⁴

Sea turtles, like other reptiles, are a regular reservoir of certain human pathogenic bacteria such as *Salmonella*.² Some adult sea turtles, for example, are dominant in the food chain and consume a wide variety of prey, including other key predators. Certain species, for example green sea turtles (*Chelonia mydas*), are omnivorous as juveniles and manifest a dietary shift to vegetation as they mature. Broadly speaking, this means that these animals consume diverse foods leading to environmentally acquired organisms and toxins accumulating in their organs and tissues.²

Certain of these acquired organisms and toxic agents, in particular inorganic contaminants including organochlorines and heavy metals, may be notable human health risks where turtle products (for example, meat, eggs) are consumed. While the consumption of, or contact with, sea turtle products are the typical routes for human contamination, the sea turtle associated toxin, chelonitoxin, may also be transferred to infants and fetuses via breast milk and transplacental introduction.¹⁰

Accordingly, it would be highly speculative at least to presume that any sea turtle product, no matter how well prepared, presents no risk to human health. The precautionary principle favours a presumption that some potentially harmful content may reside in any sea turtle product.

Case study: the Cayman Turtle Farm

The Cayman Turtle Farm (CTF) is an island-based commercial sea turtle production facility that has operated since 1968. According to CTF promotional information, the facility holds approximately 8000 turtles, the vast majority of which are green sea turtles (*C. mydas*). In 2010 the facility

reportedly produced 25,000 eggs of which over 1400 hatched.¹¹ CTF sells farmed turtle meat, including to the public and local restaurants, exclusively on the island. Anecdotal evidence suggests that customers are typically tourists rather than the local human population because CTF meat is expensive.¹²

The facility is serviced by coastal seawater. This water cannot be regarded as purely local as tidal and other forces imply an oceanic exchange. This seawater matrix should be presumed to harbour biotic and abiotic contaminants from a far greater (global) environment than may be immediately apparent to the casual observer.

Relatedly, contaminants that are established for wild sea turtle populations are probably also local to CTF-utilized water. A number of these contaminants are more likely absorbed into sea turtle organs and tissues due to their relative longevity and diet. In addition, sea turtles are resilient when diseased and may not indicate their contamination status.²

People potentially infected or infested with pathogens from direct or indirect contact with CTF turtles or the facility in general or from consuming farm produce may be asymptomatic at departure from the Island thus 'blurring' possible links. Because both direct and indirect transmissions are well established routes for reptile-borne pathogens, the entire publicly accessible arena of the farm environment should cautiously be regarded as potentially contaminated.

Furthermore, numerous turtle-associated human diseases symptomatically superficially resemble conditions including gastrointestinal disorders, influenza and malaise,^{6,7} and thus they may go undiagnosed as turtle-related in the human population.

As part of this assessment water samples were obtained from turtle occupied ponds at the CTF facility. Table 3 presents the results of laboratory microbiological investigation for the following target bacterial zoonotic organisms: *Vibrio* spp., *Chlamydophila* spp., *Salmonella* spp., *Mycobacterium* spp., *Aeromonas* spp., *Pseudomonas* spp., *Flavobacterium* spp., *Bacillus* spp., *Escherichia* spp., *Leptospira* spp.

The established presence of these turtle-associated zoonotic microorganisms, while not unexpected, is concerning both because their presence was importantly noted in only a relatively

Table 3**Microbiological analysis of water samples from turtle tanks at Cayman Turtle Farm**

| Sample no. | Source | Bacteria isolated | Zoonotic (Yes/No) | Zoonosis |
|------------|---------------|-------------------------------|-------------------|---------------------------|
| 1 | Touch tank 1 | <i>Pseudomonas aeruginosa</i> | Yes | Bacteraemia |
| 2 | Touch tank 2 | Negative | – | – |
| 3 | Adult tank 1 | Negative | – | – |
| 4 | Adult tank 2 | <i>Aeromonas</i> spp. | Yes | Aeromonal gastroenteritis |
| 5 | Juvenile tank | <i>Vibrio</i> spp. | Yes | Vibriosis |
| | | <i>Salmonella</i> spp. | Yes | Salmonellosis |
| 6 | Lagoon | <i>Vibrio</i> spp. | Yes | Vibriosis |
| 7 | Outflow 1 | Negative | – | – |
| 8 | Outflow 2 | Negative | – | – |

Note: Commensal organisms were isolated in: 1; 2; 3; 4; 5; 6. Commensal organisms are typically benign microbial associates of hosts, for example, 'good/positive' intestinal, mucosal or dermal bacteria (samples analysed by Greendale Veterinary Diagnostics Limited, UK)

small sampling exercise and because the public had regular access to all the water sources showing these pathogens.

Conclusions

Human contact with and consumption of wild-caught and captive-housed sea turtles and their products present a recognized potential threat to health from a variety of pathogenic sources of biological and contaminant toxin origin. It is probably prudent to adopt a precautionary approach and presume that both the potential pathogens and toxic contaminants (Tables 1 and 2) and established pathogens (Table 3) are relevant to both wild and captive sea turtle environments.

Significantly, the captive farming of turtles arguably draws on some of these potential threats, in particular from bacteria, and exacerbates these risks due to the practice of housing many turtles in a relatively confined space and under intensive conditions – both of which act to concentrate potential pathogen density and raise the potential threat from the microbial reservoir. As stated previously, these and other concerns appear to focus on captive farmed animals and not free-living turtles.

Some potential disease-causing agents such as *Pseudomonas* spp. and *Bacillus* spp. are essentially opportunistic pathogens while others, for example, chelonitoxin are invasive and may affect otherwise healthy people.

Our assessment is that pathogens and toxic contaminants may be loosely categorized to represent the following levels of potential risk: *viruses and fungi* = very low; *protozoan parasites* = very low to low; *metazoan parasites, bacteria and environmental toxic contaminants* = low or moderate to high; and *biotoxin contaminant* = moderate to very high.

Conceivably, many potential pathogens and toxins not thought to be associated with sea turtles may nevertheless be consumed and harboured by them. For example, while giardiasis (causal agent *Giardia intestinalis haplotypes*) is a microbial parasite generally associated with marine animals other than sea turtles, the fact that sea turtles may consume other marine life theoretically allows opportunities for this atypical sea turtle zoonotic pathogen to enter the human food chain.

Given the potential long lifespan of sea turtles, it is reasonable to hypothesize that their exposure to microbial, macroparasitic and abiotic environmental challenges is proportionately great and that their immune competence and coping mechanisms are correspondingly robust. Relatedly, natural longevity offers sea turtles a special opportunity to accumulate organisms and toxins in organs and tissue over a long period.

We agree with other investigators that where animal seafood is to be consumed, people should avoid food derived from sea turtles and perhaps also other relatively long-lived species regardless of their role in the food chain as all

these animals potentially have more time in which to accumulate hazardous organisms and toxins and present an increased risk of animal-linked human pathology.

Farmed turtles may constitute a significant reservoir of potential human pathogen and toxin contamination, and visitors attending a facility may be exposed to artificially raised risks of acquiring disease as a result both of captive sea turtle and human population densities, proximity to turtles and their water, intermediary surfaces, and the available consumable products.

Greater awareness among health-care professionals regarding both potential pathogens and toxic contaminants from sea turtles, as well as key signs and symptoms of sea turtle-related human disease, is important for the prevention and control of salient disease.

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