WILDLIFE VETS INTERNATIONAL, TURTLES and the PLASTIC PLAGUE

1. Introduction to WVI and the plastic problem

1.1 WHO ARE WE?

Wildlife Vets International is a British charity which has been providing critical veterinary support to international wildlife and conservation projects since 2004. We currently work in South Africa, Russia, Greece, Spain, India, Mauritius and Zimbabwe.

1.2 SAVING THE MEDITERRANEAN'S TURTLES

The Mediterranean is home to three of the world's seven species of sea turtle; the green turtle (IUCN classification Endangered), the loggerhead turtle (IUCN classification Vulnerable) and the less commonly seen leatherback turtle (IUCN classification Vulnerable). An important new focus of our activities this year has been developing cooperation with two Mediterranean marine life rescue centres which treat and rehabilitate sick and injured turtles: Fundación CRAM in Spain (See 1.1.1) and ARCHELON Sea Turtle Rescue Centre in Greece (see 1.1.2)

Turtles are often considered flagship species for marine conservation, with their status in a region often reflecting wider biodiversity concerns. Their highly mobile lifestyles and typically complex life histories sadly make them especially vulnerable to the dangers posed by plastic pollution, through ingestion, entanglement, and general habitat degradation. And nowhere is the risk higher in Europe than in the Mediterranean.

1.3 A SEA OF PLASTIC

Europe is the second largest plastic producer in the world, after China. Every year we dump as much as 500,000 tonnes of macro plastics - items like bags, balloons, bottles and six pack rings - and as much as 130,000 tonnes of microplastics - including microbeads found in cleaning and cosmetic products, and fibres shed from synthetic material like fleece or lycra - into the sea. And most of that goes into the Mediterranean, which is now recognized as a global hotspot for plastic pollution[1] as a result of its enclosed nature, densely populated coastline and poor local waste management.

Plastic is estimated to be responsible for 95% of waste in the water and on the beaches. Visiting tourists are responsible for an estimated 40% increase in litter each summer.[2] The Mediterranean may only hold 1% of the world's waters but it is, for example, the source of 7% of all microplastic pollution.[3] One study was able to identify 16 different classes of synthetic polymer present

[1] Duncan, E., et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752, p744

[2] WWF, The Mediterranean at risk of becoming 'a sea of plastic': www https://wwf.panda.org/wwf_news/press_releases/?329099/The-Mediterranean-at-risk-of-becoming-a-sea-of-plastic-WWF-warns

[3] WWF, Out of the plastic trap. Saving the Mediterranean from plastic pollution, p10

in the sea's surface water.[4] Not only can plastics contain concentrations of toxic compounds as much as a million times greater than those naturally found in seawater, but plastic is known to release 30 times more contaminants once it moves into living tissue, like the intestines of a turtle.[5]

All this is very bad news for local sealife. In February 2018, some 29 kilograms of plastics were found in the internal organs of a sperm whale washed ashore in Spain, having died of peritonitis.[6] And at least one study has suggested that ingestion rates of plastic by marine turtles are particularly high in the region.

2. WHAT IS WVI DOING TO HELP?

We support vets and rehabilitation staff who work with two flagship turtle rescue centres in the Mediterranean, where the record levels of plastic in the sea are a huge threat to marine life. Read more about the work of the centres below.

2.1 CRAM Foundation of the Conservation and Rehabilitation of Marine Animals, Barcelona, Spain

Marine specialist vet Tania Monreal makes regular monthly visits to CRAM in Barcelona, where she provides expert veterinary training and advice to staff, students and volunteers. The centre is responsible for the rescue and rehabilitation of a high number of green turtles, which are typically victims of plastic pollution, toxic waste or accidental capture by fishing boats. CRAM also cares for sea birds, dolphins and whales which have become stranded on the Catalan coast. The animals treated by CRAM are often suffering from severe injuries and illnesses, most of which are a result of human activity.

CRAM also runs conservation education programmes and engages actively with the fishing industry to help promote understanding of turtles and their welfare. Changing local fishing practices is a considerable task and not one for CRAM alone but fishermen have started bringing trapped or injured turtles to the centre rather than just throwing them out to sea – a considerable step forward in terms of engaging local stakeholders. Green turtles now arrive at the centre on an almost daily basis.

The centre has to deal with a huge range of difficult and challenging cases and Tania's experience is invaluable in helping staff treat turtles and other animals successfully, gaining valuable practical knowledge in the process. Aside from giving on-the-job training, Tania is available to give advice remotely, and has already produced a series of 'How To' videos. She is also helping with the on-going development of protocols tailored to the particular needs and specifics of species, the available facilities and the experience of staff.

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4 Duncan, E. et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752 p747

5 WWF, Out of the plastic trap. Saving the Mediterranean from plastic pollution, p19

6 https://www.sciencealert.com/whale-found-dead-spain-29-kilos-plastic-stomach

Turtles which are accidentally caught by fishing boats and brought abruptly to the surface can suffer from decompression sickness and CRAM now has a decompression chamber to help combat the problem, which can affect dolphins too. Turtles can also drown. Although some species can stay underwater for many hours at a time, they do need to breathe. Drowning is most likely as a result of being caught in discarded fishing gear or other plastic waste and being unable to return to the surface. At CRAM drowned turtles are treated with acupuncture as well as more conventional techniques to remove fluid from the lungs.

All the turtles released back into the Mediterranean are tagged and some have transmitters to allow their progress to be monitored. One turtle was successfully released despite having only three flippers, following amputation and a decade in captivity, and was then tracked passing through the strong currents of the Straits of Gibraltar before crossing the Atlantic. Ten months after release, signals were still being received from the turtle. This just proves how good husbandry, veterinary care and planning can mean even the most challenging of cases can be released with a good chance of survival.

The Rescue Centre welcomes thousands of visitors a year, as well as students and scientists with an interest in marine ecology.

2.2 ARCHELON Sea Turtle Rescue Centre, Athens, Greece

In August 2019 marine specialist vet Tania Monreal and veterinary nurse Matt Rendle made the second of what we hope will be quarterly trips to train and advise the permanent staff of the ARCHELON Rescue Centre, as part of a new partnership between WVI and The Sea Turtle Protection Society of Greece. The centre is situated on the coast of the Aegean Sea, in Athens' southern suburb of Glyfada.

As a specialist in the care, rehabilitation and conservation of marine and aquatic animals, Tania lectured on appropriate veterinary protocols and techniques, while Matt shared his expertise in wound care and healing, as well as in exotic anaesthesia. Both Matt and Tania helped with practical clinical work too, focusing on anaesthetic techniques, blood testing and how staff and volunteers could get better use out of their existing equipment.

While they were there, Matt and Tania were also able to advise on diet, enrichment and pain relief, to ensure that the loggerhead turtles coming into the centre are given the best care possible in order to maximize their chances of recovery and successful release back into the wild. In particular, they were able to identify issues connected with uneven exposure to UV light, when turtles were moved frequently between indoor and outdoor tanks. The change in levels can lead to calcification of blood vessels and other problems. In

addition, Matt and Tania also advised on optimal temperatures for the tanks, as turtles which are kept in water that is too cold can experience significant slowing down of digestion and other processes, causing food to rot in the gut.

About a quarter of the turtles coming into the centre come in suffering from plastic ingestion or the consequence of collisions with boats. Another quarter will be victims of entanglement, having become caught up in fishing gear or other debris, which sometimes results in amputation. Remaining victims will typically have been injured through the deliberate actions of humans. Fishermen often feel they are in competition with turtles and will those they feel threaten their catch.

WVI's work with ARCHELON is focused on providing training and on-going support to the Rescue Centre team, with a view to reducing the time turtles typically spend at the centre before release, improving welfare and increasing overall survival rates. Going forward, Tania and Matt will be on hand to help remotely, with the aim of supporting veterinary staff and volunteers so that they can carry out procedures with increased confidence but also in the knowledge that expert advice is always at hand.

ARCHELON was founded 35 years ago and has played a crucial role in the recovery of the Mediterranean's loggerhead turtle population, which has gone from being Critically Endangered to being a species of Least Concern in the IUCN ratings for risk of extinction. (The rating for the global population of the loggerhead turtle remains Vulnerable.) ARCHELON estimates that if it were to stop its current activities the Mediterranean's loggerheads could become Near Threatened in as little as five years. It is generally acknowledged that the recovery of the population is entirely thanks to and dependent upon intensive conservation work.

In 1994, ARCHELON founded the Mediterranean's first Sea Turtle Rescue Centre, which remains the only one of its kind in Greece, treating injured animals from around the country. To date, more than a thousand sea turtles have been cared for by the ARCHELON team, and nearly 60% of these have been successfully rehabilitated and returned to the wild. Currently, the centre has the capacity to care for 40 turtles at a time, and receives a total of around 100 animals a year.

The Rescue Centre is very popular with visitors and is included in Trip Advisor's Top 20 Things to Do in Attica (the Athens region), making ARCHELON particularly well placed to disseminate information about the threats to turtles and what can be done to support their conservation. At WVI we are looking forward very much to being able to play a role in its further development.

3. Plastic Pollution – A Global Crisis

Our oceans are full of plastic. Worldwide, it's estimated that we are tipping the equivalent of one overflowing bin lorry load of plastic into the oceans every three minutes.[7] According to another estimate, there are five trillion pieces of plastic in the surface waters of our planet's seas.[8] Plastic waste is found throughout oceanic water columns and on the seabed too. Much of it is likely to take centuries to break down. Global plastic production has increased from an annual 1.5 million tonnes in 1950 to around 300 million tonnes today.[9] As a result, plastic has become the main type of marine debris, due in part to its durability and the ease with which it is dispersed in water. It is estimated that as much as 12.7 million tonnes of plastic waste may be entering the oceans every year.[10]

Current estimates suggest that by 2050 our oceans will hold more plastic than fish[11] and that 99% of seabirds will end up ingesting plastic.[12] The UN predicts that 600 marine species will be affected. Plastic debris is already impacting a wide range of taxa, from microscopic zooplankton to blue whales. Entanglement, ingestion, habitat degradation and wider impacts on the marine ecosystem are all major issues associated with plastic pollution. The scale of the threat is ever growing, especially to species already of concern to conservation, like sea turtles. With their complex life histories and highly mobile behaviour, they are particularly vulnerable to the impacts of plastic pollution.

An important emerging factor for marine turtles appears to be that the currents which transport turtle hatchings away from the beaches where they were born take them to oceanic convergence zones. These are now recognised as sinks for anthropogenic debris, where both macro and micro plastics accumulate – putting the young turtles at high risk of both entanglement (See 3.1 below) and ingestion (See 3.2 below).[13] In addition to such direct harm, the quality and quantity of food available in these areas may also at risk. Small plastic particles of plastic have already been shown to affect the reproduction and growth rates of zooplankton.[14] It is also possible that the high quantities of plastic debris present may be inhibiting gas exchange within the water column,

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[7] https://www.youtube.com/watch?v=2zrh-_pv_oY

[8] Duncan, E, et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752 (2019); p744

[9] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p165

[10] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p431

[11] https://www.earthday.org/2018/04/05/fact-sheet-plastics-in-the-ocean/

[12] https://www.ecowatch.com/seabirds-plastic-pollution-2609353767.html

[13] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p442

[14] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p174

with the potential to interfere with normal ecosystem function and alter the biodiversity of the seabed.

3.1 Macroplastics

Of the 80% of marine litter estimated to originate from the land, 80% of that in turn is believed to be composed of macroplastic waste – that is large, visible plastic objects, packing or other debris. Such visible plastic pollution clearly presents a serious threat to marine life, through entanglement (See 3.1 below) and ingestion (see 3.2 below).[15]

3.2 Microplastics

These are defined as plastic particles or beads which are less than 5mm in diameter and too small to be filtered out by water treatment plants. They have been identified in seawater worldwide and can be found in Arctic sea ice and snow. Their abundance in the marine environment and their tendency to both release and attract toxic chemicals has meant that they have come to be considered a pollutant in their own right.[16] As a result of their hydrophobic properties and large surface area to volume ratio, microplastics encourage the accumulation of contaminants like heavy metals and endocrine disrupters such as polychlorinated biphenyls (PCBs) and dichlorodiphenyldichloroethylene (DDE) from the surrounding environment. Contamination levels of microplastics can be up to a million times that of surrounding seawater.[17] Along with other chemicals used in plastic production (like plasticizers), these substances can leach into animal tissue following ingestion. Although the extent to which this is happening is not yet well researched, there is evidence that PCB's found in the tissues of Great Shearwaters originated from ingested plastic particles.[18]
In the UK, 83% of Norway lobster (typically sold as scampi) has been found to contain plastics. The same has been found to be the case for 67% of all species of fish sold for human consumption in the US, and it's been estimated that consumers of seafood in Europe could be ingesting up to 11,000 plastic particles annually.[19]

Microplastics can be divided into primary microplastics and secondary microplastics. **Primary microplastics** are most often associated with the tiny microbeads used in exfoliating cosmetic products, toothpastes and washing powders, and with the preproduction small plastic pellets or 'nurdles' used in the vast majority of plastic manufacture. They also have biomedical uses, being

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15 Flora and Fauna International (2017) Removing or Restricting Micorplastic Ingredients or "Microbeads" from Consumer and Industrial Products, Microbeads Guidance Document, Version 1; p8

16 Duncan, E, et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752 (2019); p745

17 Greenpeace, FFI, MCS, EIA (2016) Microbeads Briefing; https://www.mcsuk.org/media/ngo-microbeads-briefing.pdf:

18 Greenpeace, FFI, MCS, EIA (2016) Microbeads Briefing; https://www.mcsuk.org/media/ngo-microbeads-briefing.pdf

19 Greenpeace, FFI, MCS, EIA (2016) Microbeads Briefing; https://www.mcsuk.org/media/ngo-microbeads-briefing.pdf

added to over-the-counter medications to make them easier to swallow, for example. Estimates suggest that cosmetic microbead use in Europe alone could be adding nearly 9000 tonnes of plastic a year to the marine environment. A number of governments around the globe have now taken action aimed at prohibiting the use of microbeads in cosmetic products.[20]

Other sources of primary microplastics include acrylic, melamine or polyester microbeads used in air-blasting technology, to remove rust and paint from boats, engines and other machinery. These in particular are likely to become contaminated with heavy metals like Cadmium, Chromium and Lead.[21] Primary microplastic particles are also a by-product of the natural wear of car tyres, and of the breakdown of elastomer plastics used in products made from neoprene, lycra and silicone.

Secondary microplastics result from the break up of larger macroplastic items, when the integrity of the plastic is reduced as a result of wave action, exposure to UV radiation and physical abrasion in the sea or along shorelines. These physical, chemical and biological processes eventually result in the fragmentation of the macroplastics into microscopic particles.

It is already known that crabs which ingest microfibres exhibit changes in food consumption and energy levels, and that marine worms which ingest particles of polyvinylchloride (PVC) have reduced growth and energy reserves. Even sponges have been shown to ingest microplastics, which can also adhere electrostatically to the surface of seaweed presenting another possible pathway for their movement up the food chain.[22]

With regard to turtles, although there has not been extensive research into the effects, ingestion of microplastics has been recorded in all seven marine species.[23] In a recent study of turtles from the Atlantic, Mediterranean and Pacific basins, 100% of the turtles examined had ingested synthetic particles of less than 1mm diameter. This contrasted markedly with very variable incidence of macro plastic ingestion in the same individuals. The microplastics identified included polyethylene, ethylene propylene and polyester.[24]

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[20] Flora and Fauna International (2017) Removing or Restricting Microplastic Ingredients or "Microbeads" from Consumer and Industrial Products, Microbeads Guidance Document, Version 1; p13

[21] Cole, M., P.K. Lindeque et al. (2011) Microplastics as contaminants in the marine environment: a review. Marine Pollution Bulletin, Vol. 62 (12), 2588-97; p2589

[22] Duncan, E, et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752 (2019); p748

[23] Duncan, E, et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752 (2019); p745

[24] Duncan, E, et al. (2019) Microplastic ingestion ubiquitous in marine turtles. Global Change Biology, Vol. 25, 744-752 (2019); p746

4.0 Turtles and Plastic

There are seven marine species of turtle, all of which are threatened with extinction; loggerhead (IUCN status Vulnerable), green (IUCN status Endangered), Hawksbill (IUCN status Critically Endangered), leatherback (IUCN status Vulnerable), olive ridley (IUCN status Vulnerable), Kemp's ridley (IUCN status Critically Endangered) and flatback (status unknown).
The most obvious threats posed to turtles by plastic are ingestion and entanglement, but plastic pollution also has impacts on nesting beaches and reproduction, as well as wider eco system effects.

4.1 ENTANGLEMENT

Getting caught up in abandoned fishing equipment (known as 'ghost gear') or other rubbish – like plastic six-pack rings – is a major threat to numerous marine animals, including turtles. Discarded fishing gear is responsible for the majority of entanglements, with hundreds of tonnes being lost, abandoned or discarded annually, but other 'land-based' plastic debris can have equally devastating effects. Turtles have been found entangled in plastic sacks, twine, polythene sheeting, plastic chairs, plastic packaging straps, balloon string and six pack rings, for example.[25]

Research has revealed that entanglement affects all turtle species, at all life stages and in all ocean basins[26], but suggests that pelagic (ocean living) juveniles are particularly vulnerable. Although considered to be less of a threat than plastic ingestion, entanglement is a significant cause of turtle mortality in many areas, including the Mediterranean and northern Australia, and one which has increased substantially over the last century. Until the 1950s, the fishing industry tended to use natural fibres, like cotton, jute and hemp, but the demand for more resistant materials saw these increasingly replaced by nylon, polyethylene and polypropylene. 'Ghost' fishing nets are now usually made of non-biodegradable material like nylon and can be several kilometres long. As they drift through the ocean they accumulate marine organisms in a process known as 'bio-fouling' and consequently attract a range of grazers and predators who can then become trapped. Studies suggest that turtles are particularly vulnerable to this fate, with a 2014 study revealing that 80% of animals found in discarded nets off the coast of Australia were turtles.[27]

Entanglement can have fatal and non-fatal consequences, ranging from abrasions, serious wounds, infection and amputation, to increased drag and choking. It can constrict shell growth and limb movement, and result in drowning. A survey of experts[28] has revealed the majority believe that

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[25] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p436

[26] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p431

[27] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p173

[28] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p437

entanglement is likely to be having a population level effect on turtle species, rather than remaining an issue primarily of welfare, although there is not yet sufficient evidence available to confirm definitively that this is the case. However, it is reasonable to assume that any carcasses recovered represent only a fraction of at-sea mortalities, given the effect of factors like currents and decomposition.[29]

It can be generally assumed that entanglement in both fishing gear and other plastic waste is an under-reported and under-researched threat to marine turtles. There is an urgent need for better cooperation between stakeholders like stranding networks, fisheries and scientists in order to put effective mitigating measure in place through the targeting of ghost fishing, engagement in education and further research to bridge knowledge gaps.[30]

As a species, olive ridley turtles appear to be particularly susceptible to entanglement. This may be due to the fact that they exhibit mass nesting in the hundreds and thousands, leading to entanglement hot spots, and forage along major oceanic fronts where marine debris typically collects, as well as being generalist feeders which could encourage them to feed opportunistically on biofouled debris like ghost gear.[31]

4.1.1 WHAT CAN BE DONE TO REDUCE ENTANGLEMENT?

EDUCATION AND STAKEHOLDER ENGAGEMENT

Many local initiatives are now being put in place to help reduce the amount of fishing debris and ghost gear entering the ocean, with a focus on education and raising awareness in local communities. Examples include the Bonaire 'Fishing Line Project' in the Caribbean[32] and the Zoological Society of London's 'Net-works' project[33], which sends discarded nets from around the Philippines to a carpet manufacturing company where they are turned into high quality carpet tiles.

There is also considerable scope for better training of those involved in 'stranding networks', which respond to incidences of entangled turtles. The response can often be slow and volunteers are frequently not trained in the correct protocols for safely disentangling turtles. If they were to be properly trained to follow a standardized protocol, then such techniques could also be passed on through education training programmes to the fishing community, which would help shorten response times and establish effective reporting systems. A common database, with more detailed reporting of incidences,

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[29] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p443

[30] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p445

[31] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p442

[32] http://www.bonaireturtles.org/wp/what-we-do/fishing-line-project/

[33] https://www.zsl.org/conservation/regions/asia/net-works

along with increased collaboration between local marine resource users, could make a significant difference. In Sicily, for example, fishermen now actively volunteer to take part in turtle rescues and are aware of how to contact the relevant authorities to get the animals transferred to the nearest recovery centre.[34]

FISHING MANAGEMENT & BETTER MONITORING

Realistically, synthetic materials will continue to be used by fisheries for the foreseeable future. It would be beneficial if fisheries management plans could include action to help identify and quantify ghost gear, and to develop mitigation strategies. There is a real need for better reporting and recording of loss of gear for example. At the same time, research needs to be directed at the development of biodegradable alternatives.

There is also a need for more comprehensive post-release monitoring of turtles, in order to track any long-term chronic effects of injuries, and to evaluate the success of release protocols. This could involve satellite telemetry, for example.

Although not a result of discarded plastic, becoming bycatch is also a major issue for turtles, who can easily be trapped in 'active' fishing nets and pulled in with fish and other intended catch. The use of gillnets, longlines and trawls in the Mediterranean is another aspect of fishing management that needs to be addressed for this reason.

4.2 INGESTION

The potential effects on turtles of plastic ingestion are wide-ranging and not yet fully understood. Ingested macro plastics can cause internal injury to and obstruction of the digestive tract. Plastic fishing line can tear the intestinal wall. Partial blockage of the intestines can lead to constipation and the accumulation of hardened faecal material. The chronic effects of plastic ingestion may not present themselves until long after the items were first encountered. Although some turtles have been known to survive for a matter of months with plastic pieces in their gut, the associated reduction in stomach capacity and normal feeding stimuli can lead to malnutrition and, particularly in the smaller juveniles, starvation.

A turtle's buoyancy can also be impacted by plastic ingestion. Many plastics are less dense than water and the presence of large amounts of buoyant material in the gut may affect turtles' swimming behaviour and their ability to control

[34] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p438

their buoyancy. For deep-diving species like leatherbacks this is potentially very serious.[35]

Ingestion can be direct or indirect.

4.2.1 Direct ingestion is now very common and has been documented in all seven species. [36] It can happen when plastic debris becomes mixed up with normal food sources – e.g. young green turtles have been known to consume plastic that was attached to the macroalgae on which they feed. Turtles are primarily visual feeders so mistaken identity is also a high risk – plastic bags, balloons and sheets can be actively selected when they are mistaken for prey like jellyfish.

In one study of loggerhead turtles they were found to have consumed a notably high number of plastic bottle lids – probably due to their round shape and the fact that they float near the surface, resembling the neustonic surface-dwelling organisms on which the turtles usually prey. Studies have shown that white and transparent plastics are the most frequently consumed, though it's not clear whether this is because they resemble prey more closely or because they are simply more prevalent.[37]

4.2.2 Less is known about the effects of **indirect ingestion** – when molluscs and crustaceans which have ingested microplastic particles into their tissues are then consumed by predators, including turtles, higher up the food chain. Indirectly ingested microplastics have the potential to pass through cell membranes and accumulate in body tissues and organs, possibly leading to chronic effects, but the process and consequences are not yet well documented.

It's possible that the sublethal effects of plastic ingestion – dietary dilution, reduced energy levels and chemical contamination - could result in a depressed immune system and increased risk of disease such as fibropapillomatosis[38] – such a correlation has already been observed in stranded juvenile green turtles in Brazil.[39]

The general tendency for plastic ingestion to impact turtle health and physical condition can impair their ability to avoid predators and avoid threats such as ship strikes or accidental capture by fishermen – which already pose significant danger to many marine turtle populations.[40] Growth rates and

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[35] Duncan, E. et al. (2017) A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research, Vol. 34: 431-448: p439

[36] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p166

[37] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p166

[38] Specific to sea turtles, the disease is thought to be caused by a herpes virus and is characterised by the growth of debilitating tumours on the surface of living tissues.

[39] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p172

[40] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p172

fertility may also be adversely affected, with possible late sexual maturation another aspect which could have serious consequences for turtle numbers in the longer term. [41]

4.3 IMPACT OF INGESTION ON EARLY LIFE STAGES:

The chances of plastic ingestion and its consequences differ across turtle life stages. The life cycle of six of the marine turtle species is characterised by a period of pelagic (open ocean) drifting for young turtles – known as the 'lost year'. Ocean currents tend to transport hatchlings away from the beaches of their birth and often towards oceanic convergence zones. These areas are typically top foraging spots for many marine species, but unfortunately the advection associated with them draws in not just food but plastic waste – creating a potential ecological trap for young turtles. Their small size in early life may put them at greater risk of mortality from plastic ingestion, thanks to their less robust and smaller digestive tracts. There is little data yet available for turtles and the effect of plastic pollution during this 'lost year' phase of their lives, but it is likely that it is a particularly vulnerable stage. One study in 2015 found that just 0.5g of debris, made up predominantly of soft plastics and fibres, was enough to block the digestive tract of a juvenile green turtle, resulting in the animal's death.[42]

One study revealed that four out of five post hatchling flatback turtles (which have no oceanic dispersal phase in their life cycle) had ingested fragments of plastic.[43] Experimental evidence from post-hatchling loggerhead turtles has shown that where the turtles' natural diet is disrupted – for example because their stomachs contain plastic – they have reduced energy, may have difficulty obtaining enough nutrients for growth and can starve more quickly due to their smaller size.[44]

As they continue to mature, most turtle species then switch to benthic (bottom) foraging in neritic (coastal) areas. Some of these foraging areas also have higher concentrations of plastic as a result of physical features like discharging rivers and where this happens very high rates of plastic ingestion can occur, with one study of juvenile green turtles revealing that 90% had ingested plastic.[45]

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[41] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p172

[42] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p172

[43] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, Vol. 73(2): 165-181; p172

[44] Nelms, S., Duncan, E., et al. (2016) ICES Journal of Marine Science, Vol. 73(2): 165-181
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4.3.1 IMPACT OF INGESTION ON REPRODUCTION:

Plastic ingestion can also affect the mechanical ability of females to reproduce. A study in 2014 documented the inability of a nesting leatherback turtle to lay her eggs due to plastic blocking the cloaca.[46]

There is also a possibility that the tendency for plastic to remain in the digestive system of turtles over long periods may lead to the leaching out of contaminants such as bisphenol A (BPA) and phthalates which can then be absorbed into body tissues with the potential to disrupt normal endocrine function. In addition, the tendency of plastic fragments to accumulate heavy metals and other toxins, such as polychlorinated biphenyls (PCBs), means these can also be released during digestion. Although there is little research into this aspect in turtles, such contaminants have already been shown to cause reproductive abnormalities in other species, including eggshell thinning and delayed ovulation in birds, as well as liver issues in fish.[47]

4.3.2 POLLUTION OF NESTING BEACHES

Marine turtles rely on sandy nesting beaches in order to be able to reproduce. But sandy shorelines, which are already under threat from rising sea levels and coastal development, have become sinks for marine litter. Everything from large synthetic fishing nets to tiny microplastic particles (which have been found up to 2m below the sand surface) can threaten nesting turtles, their eggs and new hatchlings.

Large obstacles can make it difficult for females to select a nest site, sometimes forcing them to abandon the attempt and return to the sea without laying eggs. Entanglement is another possibility for the females, while larger pieces of plastic which have moved deeper into the sand can prevent hatchlings from leaving the egg chamber, effectively trapping them below the surface. Successful hatchlings must then move to the sea as quickly as possible – a process which can be made very difficult if there are plastic obstacles in their way. This potentially more arduous journey means that the young turtles are exposed to predators for longer and will likely have to expend vital extra energy to make it to the water. Some can be fatally trapped in the debris along the route.

Plastic pieces can also affect the physical properties of the nesting beaches, particularly their temperature and permeability. Sand containing plastics has been found to warm more slowly; as sex ratios of hatchlings are temperature dependent this could result in an imbalance, with more male hatchlings being

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produced as a result of cooler temperatures. The potentially increased permeability of the sand may also result in the drying out of eggs.[48] In addition, the sand can be contaminated by leached pollutants like plasticizers such as PCBs, which have also been shown to affect gonad development and consequently sex ratios in red-eared slider turtles.[49]

5. CONCLUSION:

Although there is a lack of conclusive evidence on population level impact of plastic pollution on marine turtles this does not mean there is no effect. Turtles are difficult to study because of their widespread distribution, complicated spatial ecology and highly mobile lifestyles – some of the very same reasons they are particularly vulnerable to plastic pollution. Obtaining robust statistical results can be challenging, making it harder to identify direct causal links. Nevertheless, the ways in which plastics can affect turtles have been shown by a wide range of studies to be widespread and diverse. Although not necessarily the top threat to turtles, plastic pollution is without doubt a highly significant one, given its scale and extent within the marine environment. And of course, plastic pollution of the oceans is of concern not just to biodiversity conservation but also to tourism, fisheries and human health, underlining the need for more action, cooperation and data sharing.

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