Reducing the fatal entrapment of marine turtles in towed seismic survey equipment

1. INTRODUCTION

Seven species of marine turtle occur worldwide, five of which are found throughout tropical and subtropical waters while a further two species have more restricted geographical ranges (Table 1). The IUCN classifies three species as Critically Endangered, a further three as Endangered and a single species as Data Deficient. All marine turtle species are therefore of conservation concern due to declining worldwide populations and increasing anthropogenic impacts both offshore and at their nesting beaches and adjacent coastal zones. Identified threats to marine turtles include deliberate hunting for meat, exploitation of eggs, high levels of accidental capture in fishing nets, trawls and on long-lines, loss of nesting habitat, loss of foraging habitat, marine litter, pollution and disease.

Table 1. Status of marine turtles worldwide (**IUCN** = International Union for Conservation of Nature and Natural Resources)

English name	Scientific name	Distribution	IUCN status
Leatherback turtle	*Dermochelys coriacea*	Worldwide in tropical / subtropical / temperate waters	Critically endangered
Loggerhead turtle	*Caretta caretta*	Worldwide in tropical / subtropical / temperate waters	Endangered
Green turtle	*Chelonia mydas*	Worldwide in tropical / subtropical / temperate waters	Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Worldwide in tropical / subtropical / temperate waters	Critically endangered
Flatback turtle	*Natator depressus*	Northern Australia and southern Papua New Guinea	Data deficient
Olive ridley turtle	*Lepidochelys olivacea*	Worldwide in tropical / subtropical / temperate waters	Endangered
Kemp's ridley turtle	*Lepidochelys kempii*	Primarily Gulf of Mexico (and warm Atlantic Ocean)	Critically endangered

One impact that has been undocumented to date, is the accidental entrapment and mortality of turtles within geophysical seismic survey equipment. Marine turtles are frequently encountered during seismic surveys conducted in tropical/subtropical waters (Figure 1), for example off Brazil (de Gurjão et al., 2005), the Canary Islands (Pierpoint and Fisher, 2003) and Angola (Weir, 2007).

Figure 1. Olive ridley and leatherback turtles photographed from 3D seismic survey vessels off Angola

In recent years, the increased presence of Marine Mammal Observer's (MMOs) onboard seismic survey vessels has raised awareness of marine fauna amongst seismic crews and oil companies. However, one conservation issue that has become apparent over this period is that of turtles becoming caught in seismic tail buoys and other towed equipment. Marine seismic surveys are usually conducted using specialised vessels that tow up to 16 seismic cables, each of up to 10 km in length, with a typical separation of 50 to 100 m between the cables. Maintaining the cable separation and monitoring their position requires a considerable amount of equipment to be towed astern of seismic ships, including paravanes (or 'doors'), mono-wings, dilt floats (located at the head of each cable) and tail buoys (at the end of each cable) (Figure 2).

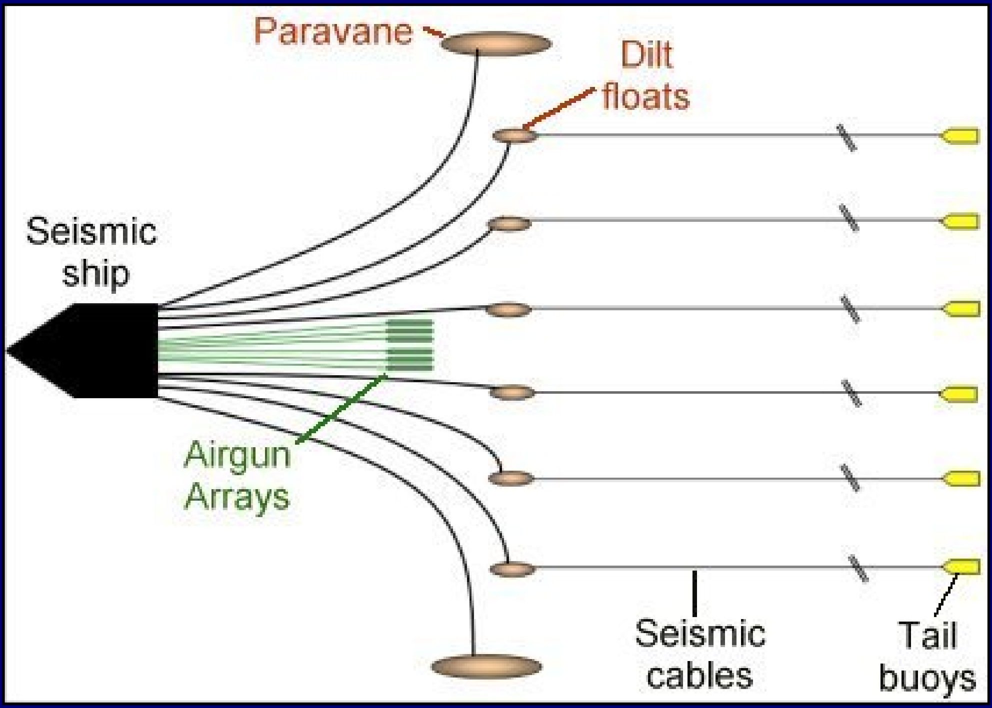


Figure 2. Schematic (not to scale) showing a simplified configuration for a 3D marine seismic vessel towing six cables

2. THE ISSUE: TURTLE ENTRAPMENT IN SEISMIC TAIL BUOYS

2.1. MECHANISM OF TURTLE ENTRAPMENT

2.1.1. ENCOUNTERS BETWEEN TURTLES AND SEISMIC EQUIPMENT

A marine turtle must obviously have to come into very close proximity with seismic equipment in order to become entrapped. While regular contact between turtles and seismic equipment might initially seem unlikely, in particular geographic areas and at specific times of the year high densities of marine turtles can be present in the vicinity of a seismic survey. For example, off West Africa large numbers of turtles have been noted during offshore seismic surveys prior to the turtle nesting season (Weir et al., 2007), and proximity of animals to the seismic vessel and towed equipment is frequently noted (e.g. Figure 3). Weir (2007) reports 'near miss' collisions between basking turtles and dilt floats (Figure 3). The same potential for collision occurs with tail buoys.

Figure 3A. A basking turtle (beneath arrow) passing within a few metres of a seismic dilt float off Angola

Figure 3B. Basking turtle on a direct collision path with a dilt float. The turtle 'startle dived' immediately prior to contact

2.1.2. SEISMIC TAIL BUOYS

The piece of seismic equipment that almost all reported turtle entrapments have been associated with is the tail buoy. A tail buoy is a large float attached to the end of each seismic cable (Figure 4), which is used to monitor the location and direction of the cables. The upper surface of the tail buoy is fitted with radar reflectors and Global Positioning System (GPS) receivers, and some designs also have solar panels for powering the equipment. Tail buoy designs vary, and not all seismic contractors utilise the same type. However, in the more commonly used buoys the subsurface structure ('undercarriage') usually consists of a 'twin-fin' design (Figure 5), which is used for: (a) counter-balancing the upper structure to ensure stability in the water; and (b) facilitating easy upright storage on deck. A propeller unit is housed within the undercarriage of some buoy designs to provide additional power to the unit. Towing points are located on the leading edge of each side of the undercarriage, and these are attached by chains to a swivel which leads to the stretch at the end of the seismic cable.

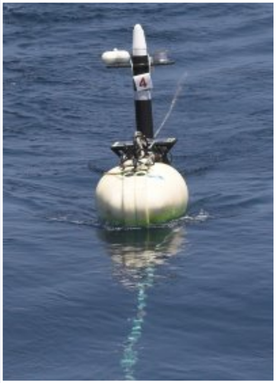


Figure 4. A seismic tail buoy with the cable visible subsurface

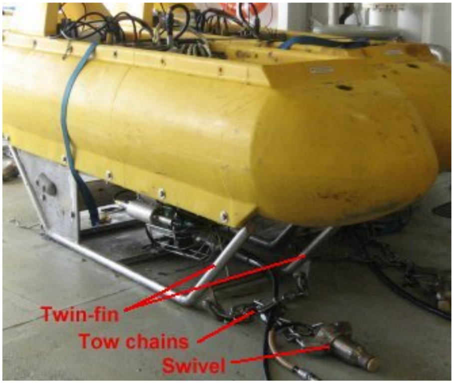


Figure 5. A tail buoy on deck, showing the twin-fin design, swivel and tow chains

Figure 6. Two dilt floats on deck (upside down) showing the twin-fin subsurface structure

2.1.2. HOW DO TURTLES BECOME ENTRAPPED?

It is not clear exactly how turtles become trapped within tail buoys. However, two potential theories are: (a) as a result of 'startle diving' in front of towed equipment, and (b) as a result of foraging along seismic cables.

Startle dives are usually observed when a turtle is basking at the water surface for metabolic purposes during hot, calm weather. Basking behaviour appears to make turtles slow to react to approaching threats, with startle dive reactions occurring only at close range (often within a few metres) to approaching objects and apparently based principally on visual detection. Turtles have been observed startle diving in reaction to towed seismic equipment (paravanes and dilt floats) and to seismic vessels themselves (Weir, 2007). A turtle that startle dives in response to an approaching tail buoy will be in a prime position for entrapment (Figure 7).

It is also possible that turtles become trapped in tail buoys as a result of foraging along the seismic cables. There is evidence from seismic crews that turtles feed on barnacles and other organisms growing along seismic cables. In tropical areas turtles are regularly observed swimming immediately over seismic cables by crews out in the workboat. Furthermore, 'noise' on the hydrophones within seismic cables has been attributed to turtles sliding along the cables while foraging. It is plausible that a turtle feeding along a seismic cable may travel to the end of the cable and along the stretch, before surfacing to breathe. At that point it would be immediately in front of the tail buoy giving rise to a possible entrapment situation. Not all species of turtle feed on barnacles and other invertebrates. Loggerhead, olive ridley and Kemp's ridley turtles would be the main species likely to be attracted to seismic cables for foraging purposes.

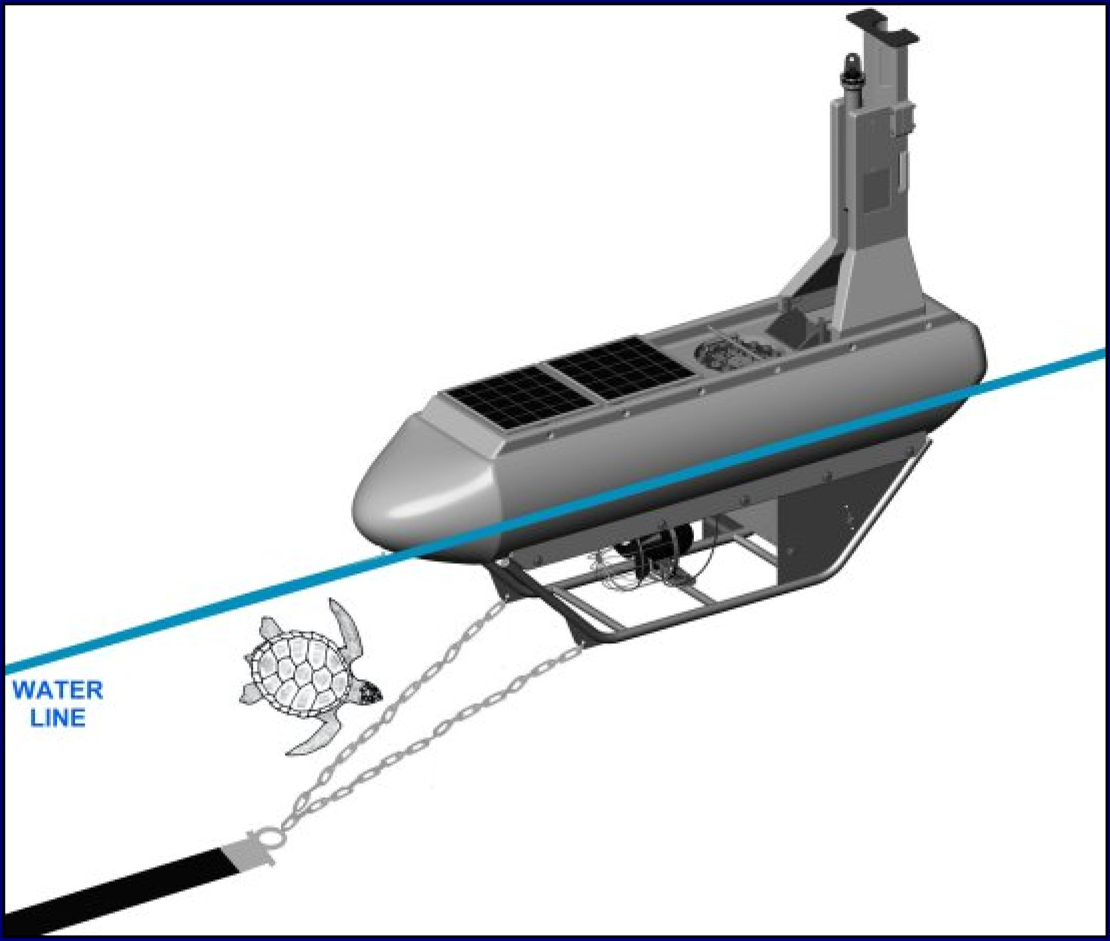
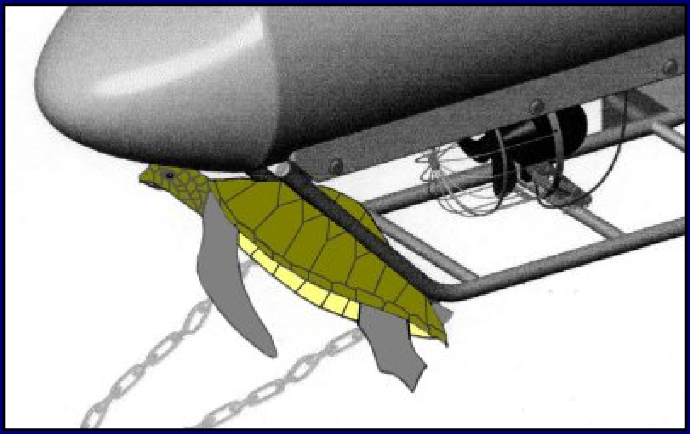


Figure 7. Schematic of a turtle that has startle-dived in response to an approaching tail buoy

2.1.3. WHERE DO TURTLES BECOME TRAPPED?

Seismic personnel have reported two areas of a tail buoy where turtles become trapped:
(A) in front of the undercarriage in the area between the buoy and the towing chains; and
(B) between the 'twin-fin' undercarriage structure:

(A)



(B)

The attachment of the tow chains to the tail buoy undercarriage results in the creation of an angled gap between the chains and the underside of the buoy. Seismic crew have reported large turtles becoming stuck within this angle, lying across the top of the chains and underneath the float. Often, these turtles are trapped with their ventral (under-) surface facing the oncoming water, resulting in considerable drag and causing the turtle to be held firmly in position and the tail-buoy to tow awkwardly.

The gap below a typical tail buoy (e.g. Figure 5) extends to 0.8 m below water level, and is approximately 0.6 m in width. The potential for a turtle to become stuck within this gap will therefore depend on the size of the animal. It would need to be small enough to enter the gap, but too big to pass all the way through the undercarriage.

The presence of the propeller in some buoy designs prohibits turtles that have entered the undercarriage from travelling out of the trailing end of the buoy. It is unclear at this stage in what position turtles trapped here are orientated, i.e. whether they enter the structure head-first or tail-first and whether they are upright or upside-down.

Unfortunately no photographs are currently available to confirm these potential entrapment sites. Since the twin-fin design is also used as the undercarriage of some dilt floats (Figure 6), entrapment is also a possibility in that equipment. However, on dilt floats the twin-fin is positioned towards the rear of the float rather than at the front, and turtles probably have sufficient time to move out of the way and avoid becoming trapped.

2.1.4. FOLLOWING ENTRAPMENT

Once stuck inside or in front of a tail buoy, a turtle would be unable to escape due to the angle of its body in relation to the movement of the buoy. The 4–5 knot water speed of a seismic vessel would result in considerable water pressure against a trapped turtle, acting to hold the animal inside the buoy with little chance of manoeuvring away.

For a trapped turtle this situation is almost certain to be fatal, since marine turtles are reptiles meaning that they have lungs and must regularly reach the surface to breathe oxygen. Although resting turtles may remain submerged for several hours due to their inactivity and the large stores of oxygen maintained in their blood and muscle tissues, eventually they must return to the surface to breathe. It is likely that the added stress of being trapped subsurface would also result in the turtle's oxygen supplies diminishing more rapidly than usual, and suffocation would potentially occur quite soon after entrapment.

2.2. GEOGRAPHICAL AREAS AND REGULARITY OF TURTLE ENTRAPMENT

The frequency and distribution of turtle mortality within tail buoys is mostly unknown at present due to lack of a rigorous reporting of these events by seismic contractors (see Section 4). However, informal discussions with seismic personnel indicate that turtle entrapment is certainly not uncommon, and happens with frequency in some areas (*pers. comms*.). For example a survey off West Africa in 2004 caught '*numerous turtles*', and a survey off India in 2007 was reported to have killed '*several turtles every week*'. Seismic personnel have also indicated that turtle entrapment has occurred in the Gulf of Mexico and off Australia, and it is likely to be a problem whenever 2D/3D/4D seismic surveys and turtles co-occur.

Clearly, this problem is far less likely to impact significantly upon turtle populations than other threats such as the hundreds of thousands of marine turtles caught incidentally in trawls, on long-line hooks and in fishing nets every year. It is also recognised that some seismic crews take the opportunity to rescue turtles entrapped in fishing gear (Figure 8), therefore making a positive contribution to turtle conservation.

Figure 8. A seismic crew cut free six turtles entangled in fishing net off Congo (© M. Unwin)

However, in contrast to the far larger issue of fisheries bycatch the entrapment of turtles in tail buoys is relatively straightforward to prevent and seismic contractors, tail buoy manufacturers and oil/gas companies could eliminate this mortality completely without expending significant time or resources. The following pages describe some potential solutions.

3. POTENTIAL SOLUTIONS

It should be emphasised that not all tail buoy designs will trap turtles. According to seismic personnel no turtles used to become trapped using older designs of tail buoys that had single keels. In the long-term, the solution to turtle entrapment probably requires alterations to the design of seismic tail-buoys. In the short-term, the fitting of 'turtle guards' to existing tail buoys could help to alleviate the problem.

3.1. 'TURTLE GUARD' DEVELOPMENT

'Turtle guards' were developed at the request of one oil company following a seismic survey in which many turtles became trapped within tail buoys. The guards are simple devices that act to physically exclude turtles from the gap at the front of the tail buoy undercarriage. To date, two designs of turtle guard have been implemented by different contractors and are described briefly below.

3.1.1. DESIGNS USED TO DATE

Design 1. On this tail buoy three simple exclusion bars have been welded across the large gap between the twin-fins and the horizontal joining stiffener to exclude turtles from entering the gaps.

Figure 9. Simple exclusion 'turtle guard' design (the added structures are circled in red)

This design is simple to produce, and does effectively address one of the known sites of turtle entrapment. However, this design may not eliminate the possibility of turtle entrapment between the tow chains and the undercarriage as has been reported to occur in some surveys (Section 2.1.3).

Design 2. This turtle guard projects forward from the tail buoy undercarriage to push turtles out of the way before they can enter the gap between the twin-fins or get stuck in the angle between the tow chains and the buoy.

Figure 10. Forward-projecting turtle guard design (the added structure is circled in red)

This design is slightly more complex to produce but is potentially more effective since it addresses both locations of turtle entrapment described in Section 2.1.3. The gun mechanics also indicated that this design made at-sea maintenance of the tail buoy more efficient, due to being able to lift the extended front portion of the buoy on to the stern of the workboat.

3.1.2. MANUFACTURE OF TURTLE GUARDS: SIMPLICITY AND COST

Manufacturing and fitting turtle guards could be done either onboard a seismic vessel (as occurred in Figures 9 and 10), or the guards could be pre-fabricated onshore and subsequently sent to the ship for fitting to tail buoys during survey mobilisation. The metal rods that have been used to create turtle guards are inexpensive and are either already present onboard a seismic vessel or can be easily ordered. The tools required to create and fit the turtle guards shown in Figures 9 and 10 are already present as standard equipment onboard the vessel. Seismic personnel estimate that the manufacture and fitting of turtle guards takes a few hours for each tail buoy, with ten tail buoys being easily fitted in two days. Turtle guards could be fitted either during the regular transits of seismic vessels between survey prospects, or during the mobilisation of a survey. The manufacture of turtle guards is therefore simple, cost-effective and easily carried out by the crews onboard a seismic vessel.

3.1.3. FUTURE DEVELOPMENT

The 'turtle guard' designs presented here represent the attempts to date by two seismic contractors to develop a solution for their tail buoys at the request of an oil company. Incentives from seismic contractors and oil companies would doubtless result in the development of more-effective turtle guard designs. For example, it has been suggested that something as simple as a series of chains running directly from the swivel (see Figure 5) to a bow-mount around the front of the tail buoy would effectively exclude turtles from the whole area at the front of a tail buoy and prevent the animals from entering any of the known entrapment sites.

3.2. TAIL BUOY DESIGN MODIFICATION

The long-term solution to preventing turtle entrapment within tail-buoys is likely to require modifications to tail buoy design. Tail buoy manufacturers should consider the possibility of turtle entrapment when designing new buoys, and particularly consider reducing the occurrence of gaps at the front of the buoy, the necessity for the undercarriage and the positioning of tow chains in relation to the buoy undercarriage. Some possibilities that have been suggested include:

- Removing or reducing the subsurface undercarriage. This would be the most obvious solution to prevent turtle entrapment. However, it is recognised that some subsurface structure is needed to counter-balance the otherwise top-heavy design of tail buoys. The possibility of designing a buoy with a single keel should be explored, particularly since the presence of solar panels on most buoys now reduces the need for the underwater propeller unit. The advantage that the twin-fin design offers for upright storage is considered surplus since it is not utilised on many ships (see Figure 6)

- Re-locating the towing chains to the front of the buoy undercarriage to remove the tight angle between the chains and the undercarriage where turtles are known to get caught (Section 2.1.3). Ideally, the use of a single tow chain would greatly reduce the potential for turtle entrapment. However, gun mechanics indicate a strong preference for having two tow chains for the reasons of logistical handling and for safety should one of them fail. Effort should be made to consider alternative mechanisms of towing that would present less danger for turtles

- Removing surplus parts of the tail buoy undercarriage (e.g. the horizontal joining stiffener, Figure 9) which have no obvious role and create extra gaps where turtles could become trapped

- Incorporating 'turtle guards' as an integral part of new tail buoy designs

4. FUTURE REPORTING OF TURTLE ENTRAPMENT

The reporting by seismic crews of turtle entrapment in seismic equipment should be strongly encouraged both by contractors and oil/gas companies, and the data compiled to facilitate the development of effective solutions to the issue. The type of information that is required is indicated in Box 1.

Many of these questions could be addressed simply by asking seismic crews to photograph turtles trapped within tail buoys, and to photograph the turtle's carapace and head once the animal is removed. This would allow species identification, and offer insights into how the animals are becoming trapped. Simple records of turtle entrapment events, including associated data on their size, species (when known), position (GPS), sea state, tail buoy type and presence/absence of turtle guards would provide some indication of the scale of the problem and the effectiveness of various designs of turtle guard. At present it is unclear whether turtle guards work effectively for all sizes and species of turtle. For example, does reducing the size of the tail buoy gaps through the use of turtle guards reduce the entrapment of adults but increase the capture of juvenile turtles or smaller species? This information is vital if an effective solution is to be developed.

It is crucial to emphasise that accurate and open reporting is viewed as a constructive action. Many seismic personnel are currently reluctant to report turtle mortality in case it is viewed negatively by the environmental sector.

The potential implementation of 'turtle guards' by industry is discussed on the next page.

Box 1. Key data to acquire from seismic crews

Turtle species involved:
- Which species are becoming trapped?

Size range of turtles involved:
- What size are the trapped turtles? This information is vital for designing effective 'turtle guards'

Method of entrapment:
- How do turtles become trapped? It is important to understand the mechanism of entrapment in order to design effective solutions

Geographic areas where turtle entrapment occurs:
- Is turtle entrapment restricted to particular geographic areas, or is it widespread?

Frequency of turtle entrapment:
- How often does entrapment occur?

Tail buoy designs where entrapment occurs:
- Do all types of tail buoy trap turtles or is it a result of particular designs?

Effectiveness of installed 'turtle guards':
- Does the presence of 'turtle guards' prevent (or significantly reduce) the entrapment of turtles within tail buoys?

5. IMPLEMENTATION OF 'TURTLE GUARDS' BY INDUSTRY

Given their endangered/critically endangered species status, the issue of turtle entrapment in seismic equipment should be acknowledged and addressed by offshore industry. In addition to potentially reducing turtle mortality, the implementation of turtle guards confers several further advantages to industry (Box 2), and it is recommended that their implementation is adopted worldwide as HSE 'best practice'. The use of turtle guards is particularly important in tropical and subtropical waters, and in documented feeding and breeding habitat for marine turtles.

The implementation of 'turtle guards' or the use of 'turtle friendly' tail buoys (meaning those buoys with designs where there is no possibility of turtles becoming trapped, i.e. no subsurface gaps and appropriately positioned tow chains) should occur at three levels:

(1) Regional licensing bodies
The issuing of licences for seismic surveys in areas known to be inhabited by turtles should include the requirement for turtle guards or 'turtle friendly' tail buoys

(2) Seismic contractors
Contractors who operate seismic vessels should voluntarily adopt turtle guards or 'turtle friendly' tail buoys throughout their seismic fleet as a responsible HSE measure

(3) Oil and gas companies
Companies that charter seismic vessels to conduct surveys should include the requirement for turtle guards or 'turtle friendly' tail buoys in the tender process. It should be a requirement of survey mobilisation that the survey does not commence until all tail buoys are appropriately fitted to avoid/reduce turtle mortality

A further form of implementation is via the tail buoy manufacturers who should be encouraged by industry to consider turtle entrapment during buoy design and manufacture:

(4) Tail buoy manufacturers
Manufacturers should focus on modifying future tail buoy design to create 'turtle friendly' tail buoys where there are no gaps in the undercarriage, and where the tow chains are located in a position that does not create tight angles relative to the float in which turtles could become trapped (see Section 2.1.3).

Box 2. Why choose to implement turtle guards?

1. Conservation relevance:
- Six of the seven marine turtle species are endangered or critically endangered and avoidable mortality should be eliminated

2. Environmental credibility

3. Cost-effectiveness:
- The problem is very simple and cheap to solve

4. Health and Safety:
- Workboat operations are required to remove entrapped turtles, thus subjecting seismic personnel to increased risk exposure

5. Seismic survey production:
- The entrapment of large turtles within a tail buoy can cause the buoy to tow/track to one side, risking taking the survey out of spec

6. CONCLUSIONS AND RECOMMENDATIONS

- Mortality of endangered/critically endangered marine turtles within seismic tail buoys currently occurs worldwide but could easily be addressed by the seismic industry

- The long-term solution to the issue is to modify the design of tail buoys to eliminate the potential for turtle mortality

- In the shorter-term, 'turtle guards' should be fitted to existing tail buoys to reduce turtle mortality. However, it is important to assess the effectiveness of turtle guards for different species and sizes of turtles, and the relative effectiveness of different designs

- The implementation of both 'turtle guards' and 'turtle-friendly' tail buoy designs should be adopted as HSE 'best practice' at all levels of the seismic industry, including by the licensing bodies, seismic contractors and oil & gas companies

- Contractors and oil & gas companies should provide incentives to seismic crews and to tail buoy manufacturers to improve the design of turtle guards and tail buoys and to develop other potential solutions to the problem

- Open reporting of turtle entrapment by seismic crews should be strongly encouraged by contractors and oil & gas companies in order to better document the mechanism of turtle entrapment and develop effective solutions

7. ACKNOWLEDGEMENTS

The information presented on these pages is the result of consultation with many seismic personnel including gun mechanics, seismic observers, boat drivers and client representatives. Sincere gratitude is owed to each and every one of them for their input, for allowing the use of their images and for providing advice on potential practical solutions.

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All information is available online at:
www.ketosecology.co.uk/Turtle-Guards.htm