'TURTLE GUARDS': A METHOD TO REDUCE THE MARINE TURTLE MORTALITY OCCURRING IN CERTAIN SEISMIC SURVEY EQUIPMENT

During 2007 Ketos Ecology released a document entitled 'Reducing the fatal entrapment of marine turtles in towed seismic survey equipment' (Ketos Ecology, 2007), which outlined the issue of accidental mortality of endangered marine turtles occurring in seismic tail buoys. The document contained information on the mechanism of turtle entrapment in this equipment and made recommendations for minimising the problem via the use of 'turtle guards' that could be fitted to the front of seismic tail buoys to prevent turtles from becoming trapped. During October 2007, this document was distributed to the IAGC, the OGP and various seismic regulatory authorities with the aim of raising awareness and finding a long-term solution to the problem.

During 2008/09, it has become apparent that the turtle guards designed and implemented by certain seismic contractors do not eliminate turtle mortality in tail buoys. It also became apparent that not all designs of seismic tail buoy trap turtles; the problem is restricted to particular designs used by certain seismic contractors. Consequently, an industry-wide review of this situation is required to assess which designs of tail buoy and turtle guard are effective in reducing mortality and to exchange information on appropriate design and implementation of turtle guards. Updated information on the turtle guards used to date, problems encountered and recommendations for future implementation has been added to the existing 2007 document and is presented as this 2009 version.

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 anthropogenic 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 waters	Endangered
Green turtle	*Chelonia mydas*	Worldwide in tropical/subtropical waters	Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Worldwide in tropical/subtropical 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 waters	Endangered
Kemp's ridley turtle	*Lepidochelys kempii*	Primarily Gulf of Mexico (and warm Atlantic Ocean)	Critically endangered

One impact on marine turtles 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. 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 (located at the end of each cable) (Figure 2).

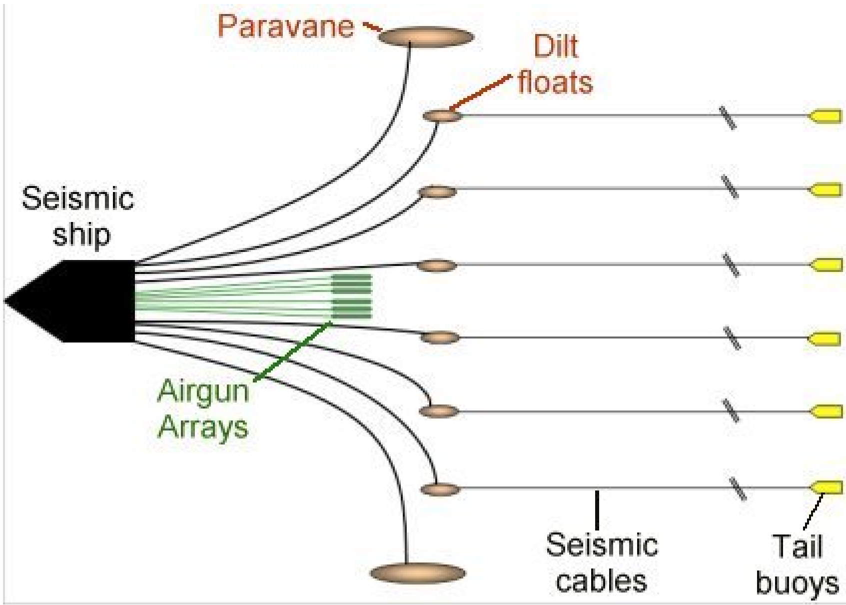


Figure 2. Schematic (not to scale) showing a simplified configuration for a 3D marine seismic vessel towing six cables

The following pages provide information on the fatal entrapment of turtles within seismic tail buoys, aiming to raise awareness of this issue and provide some potential solutions to the problem.

2. MECHANISM OF TURTLE ENTRAPMENT

2.1. ENCOUNTERS BETWEEN TURTLES AND SEISMIC EQUIPMENT

Clearly, a marine turtle must have to come into very close proximity with seismic equipment in order to become trapped. 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 close 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, although these are usually located several kilometres astern of the ship where such interactions cannot easily be monitored.

Figure 3. Basking turtle on a direct collision path with a seismic dilt float off Angola. The turtle ‘startle dived' immediately (<1 m) prior to contact

2.2. 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 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, the tail buoys used by several of the main seismic contractors have a subsurface structure ('undercarriage') consisting 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.

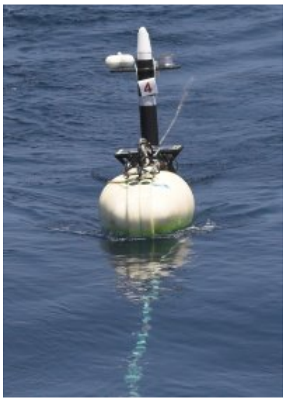


Figure 4. A seismic tail buoy with the tow cable visible subsurface

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

2.3. HOW DO TURTLES BECOME ENTRAPPED?

It is not clear exactly how turtles become trapped within tail buoys. 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.

(A) 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 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 at the bow of seismic vessels themselves (Weir, 2007), usually when less than 1 m from the approaching object.

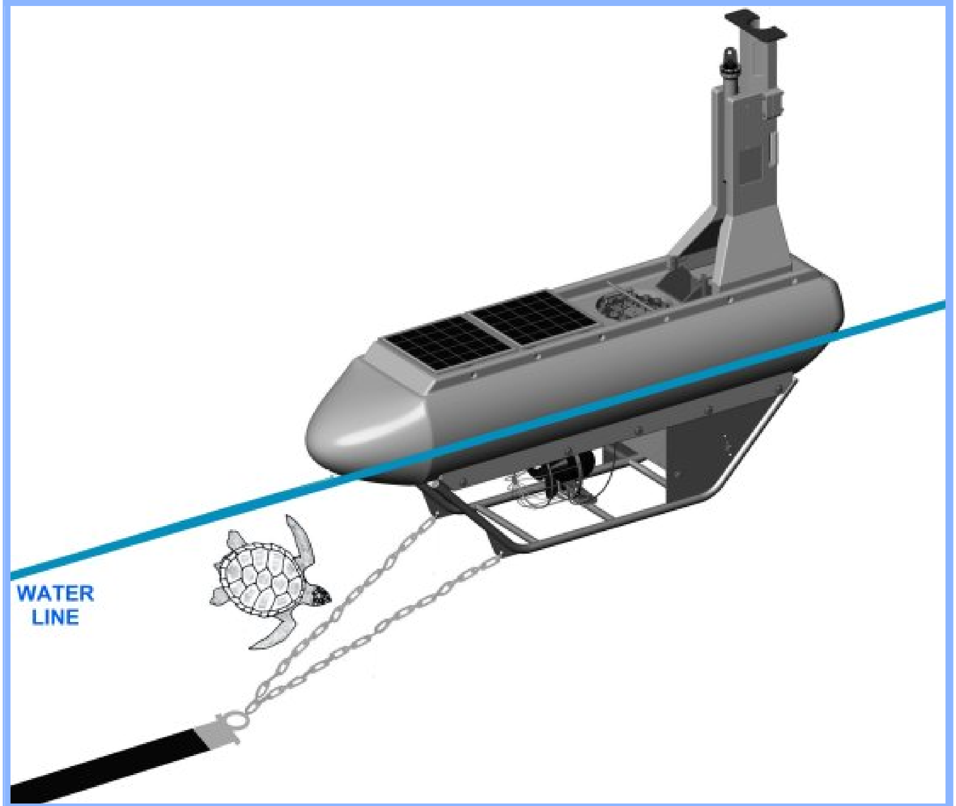


Figure 7. Schematic of a turtle that has startle-dived in response to an approaching tail buoy

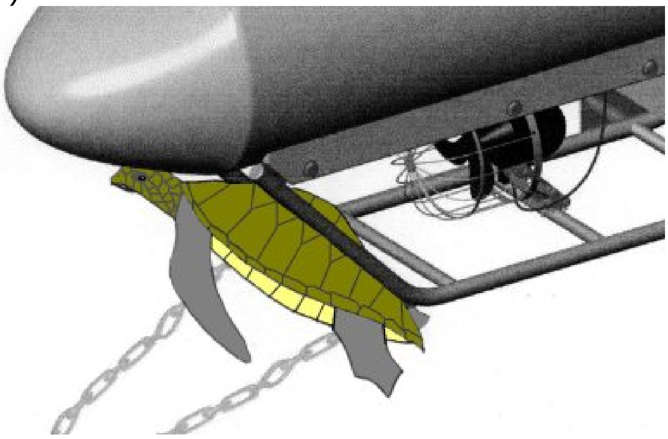
A turtle that startle dives in response to an approaching tail buoy will be in a prime position for entrapment (Figure 7).

(B) Foraging by turtles on barnacles and other organisms growing along seismic cables is suggested by the frequent observations reported by workboat crews of turtles swimming immediately over seismic cables. 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.

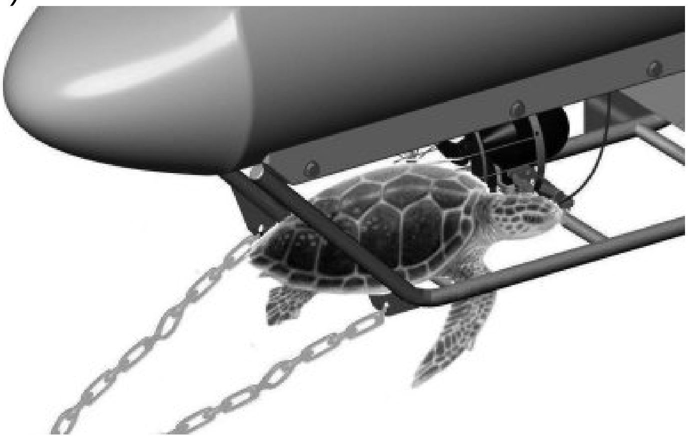
2.4. WHERE DO TURTLES BECOME TRAPPED?

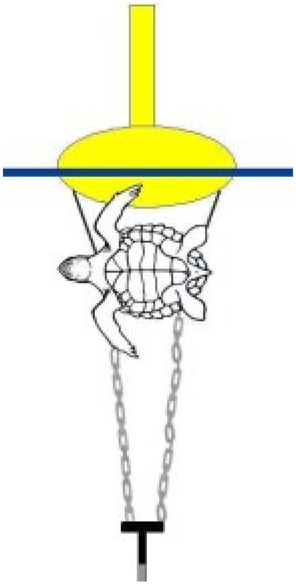
Seismic personnel have reported two areas of a tail buoy where turtles become trapped: (A) in front of the undercarriage in the area between the buoy and the towing chains; and (B) inside the 'twin-fin' undercarriage structure:

(A)

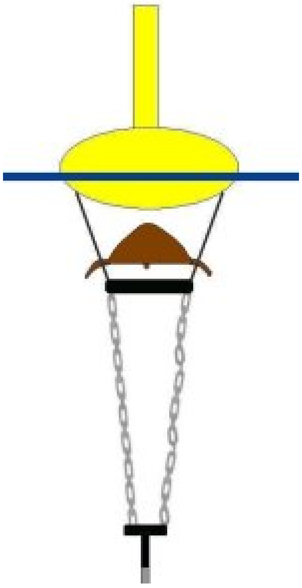


(B)





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 turtles becoming stuck within this angle, lying across the top of the chains and underneath the float. In all reported cases these turtles have been trapped on their sides, 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. However, workboat crews using underwater cameras have reported that most turtles are trapped in position A above, i.e. across the tow chains and in front of the tail buoy undercarriage.

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.

2.5. 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 forward 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 against/inside the buoy with little chance of manoeuvring away.

For a trapped turtle this situation will be fatal, since marine turtles are air-breathing reptiles with lungs and must regularly reach the surface to breathe. 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 result in a turtle's oxygen supplies diminishing more rapidly than usual, and suffocation would potentially occur quite soon after entrapment.

3. 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 5). 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 2003 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.

Figure 8A. Several olive ridley and green turtles trapped in fishing net, photographed from a seismic vessel off Equatorial Guinea (© C. Weir). This situation is fatal for turtles.

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

Clearly, this problem is far less likely to impact significantly upon turtle populations than other anthropogenic threats such as the thousands of marine turtles caught incidentally in trawls, on long-line hooks and in fishing nets every year. For example there have been many sightings of turtles trapped in discarded fishing gear offshore of West Africa, and it is recognised that certain seismic crews do take the opportunity to rescue turtles entrapped in fishing gear (Figure 8) therefore making a positive contribution to turtle conservation.

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.

4. 'TURTLE GUARDS'

4.1. 'TURTLE GUARD' DEVELOPMENT

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 tail buoy designs that had single keels. The modern tail buoys used by certain seismic contractors also have minimal likelihood of trapping turtles (see Design 3 below). However, the tail buoys used by other seismic contractors do cause turtle mortality and in the long-term the solution requires either alterations to the design of those tail buoys or replacing them completely with ‘turtle-friendly’ tail buoys. In the short-term, the fitting of 'turtle guards' to existing tail buoys could help to alleviate the problem.

'Turtle guards' were developed at the request of one oil company following a seismic survey off Angola in 2003 during which many turtles became fatally trapped within the 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, the author is aware of several different designs of turtle guard that have been implemented by different seismic contractors and these (plus potential other solutions) are described briefly below.

4.2. DESIGNS USED TO DATE

To date turtle guards have been designed in two different ways:

1. As **'Exclusion Turtle Guards'** which aim to simply prevent turtles from entering gaps in the subsurface structure of the tail buoy (see Section 2.4, B).

2. As **'Deflector Turtle Guards'** which aim to both exclude turtles from gaps in the subsurface structure and additionally to push turtles away from the angled gap between the tow chains and the buoy (see Section 2.4, A and B).

Some examples of the designs currently fitted to seismic tail buoys are provided below.

Design 1. Exclusion turtle guard

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

This design is simple to produce, and does effectively address one of the known sites of turtle entrapment. However, it does not address the possibility of turtle entrapment between the tow chains and the undercarriage as has been reported to more frequently occur (Section 2.4).

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

Design 2. Exclusion turtle guard
This tail buoy has been fitted with a pre-fabricated exclusion turtle guard that was shipped out and welded into place onboard the vessel. The guard consists of a series of closely-spaced vertical bars that prevent turtles from entering the gap between the twin-fin undercarriage.

This design does exclude turtles from entering the gap in the undercarriage. However, it does not prevent turtles from becoming trapped above the tow chains and in front of the turtle guard, as illustrated in Section 2.4.A.

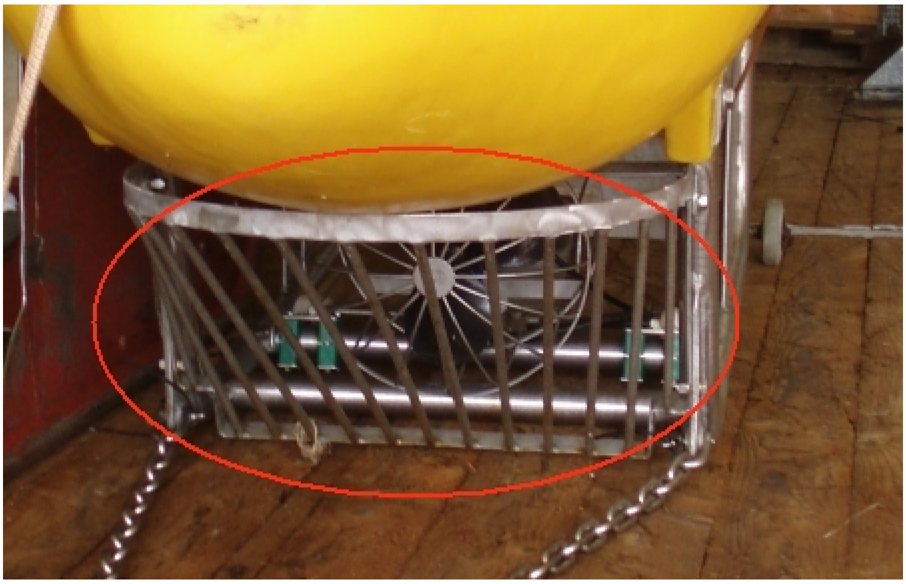


Figure 10. Exclusion 'turtle guard' design (the added structure is circled in red)

Design 3. Exclusion turtle guard
The tail buoy shown here (Figure 11A) is of a design highly unlikely to trap turtles. The tail buoy lacks the prominent 'twin fin' of some other designs, having instead a front end that slopes backwards at a shallow angle to the under-carriage and would not cause turtles to be pinned against the front. Metal bars across the front also mean that turtles could not enter the under-carriage. Rather than having two tow chains across which turtles could become stuck, there is a single towing point. Turtles encountering this tail buoy should simply slide down the front of the buoy and move away without becoming stuck. There are no known instances of turtle mortalities using these buoys, and they are considered to be a **'turtle friendly'** tail buoy design.

However, as an extra precautionary measure a simple turtle exclusion guard has been welded across the gaps on either side of the tail buoy (Figure 11B) to exclude turtles in the unlikely event that they come into contact with the buoy from the side.

(A)

(B)

Figure 11. (A) A tail buoy design unlikely to cause turtle Mortality; and (B) an exclusion 'turtle guard' added along the side to prevent turtles entering the buoy (the added structure is circled in red)

Design 4. Combined deflector and Exclusion turtle guard

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.

This design is slightly more complex to produce but is potentially more effective as it addresses both of the potential locations for turtle entrapment outlined in Section 2.4. 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.

Figure 12. Forward-projecting deflector turtle guard design (the added structure is circled in red)

4.3. 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, 11 and 12), or the guards could be pre-fabricated onshore and subsequently sent to the ship for fitting to tail buoys during survey mobilisation (as during Figure 10). 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 the above figures 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 gun mechanics onboard a seismic vessel.

4.4. DO TURTLE GUARDS WORK?

The efficacy of the turtle guards currently in place on seismic tail buoys is largely unknown, due to a lack of feedback and reporting from seismic personnel (see Section 5). Ideally, turtle guards should be fitted on a trial basis and all incidents of turtle mortality should be openly reported so that the guards can be evaluated and re-designed where necessary. It is unclear how many seismic vessels currently have turtle guards fitted to their tail buoys, or whether those tail buoys have continued to cause turtle mortality following the implementation of turtle guards.

However, anecdotal information to date indicates that some turtle guard designs do not eliminate turtle mortality. At least two turtle mortalities occurred off West Africa during 2008/09 using tail buoys fitted with an Exclusion Turtle Guard. Although disappointing, the reporting of these mortalities has provided valuable information that indicates that a simple exclusion turtle guard design is not sufficient to protect turtles. In both of the above mortality incidents the workboat crews reported that turtles became trapped above the tow chains, and were lying horizontally across the front of the turtle guard with their ventral (under-) surface facing the water current, as shown in Section 2.4.A. This evidence strongly suggests that turtle guard designs need both a Deflector and an Exclusion element, and that simply blocking the undercarriage gap will not effectively address the issue.

Proper field testing, feedback and reporting of turtle guard design and subsequent mortality events are essential to understanding which designs are effective.

4.5. OTHER OPTIONS

There are several possible alternatives to welding metal turtle guards to tail buoy undercarriages, and these include:

- Re-locating the tow point on the tail buoy so that the tow chains attach higher up and do not create the subsurface angle where turtles become trapped between the chains and the buoy. However, gun mechanics have indicated that this might make a tail buoy tow awkwardly by pulling the front end lower in the water, and it may not therefore prove a viable option
- Fitting a series of chains (or ropes) running directly from the swivel to a bow-mount around the front end 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. However, these would have to be fitted at a precise tension so as to remain taut at all speeds/angles which may be problematic to achieve. Crews have also expressed reluctance to trial this method due to the increased potential for entanglement with floating debris such as fishing gear
- Fitting Norwegian buoys ahead of each tail buoy, so that basking turtles react to the Norwegian buoy and have already startle-dived and moved away prior to encountering the tail buoy. This method was used during one survey off West Africa when high levels of turtle mortality were unexpectedly recorded. The Norwegian buoys were deployed as a stop-gap measure since it was not feasible to retrieve all of the tail buoys and fit turtle guards. The rope attached to the Norwegian buoy was clamped on to a streamer connector at the tail end of the stretch section so that the buoy floated at the surface 2–3 metres ahead of the tail buoy. While this method was not 100% successful in reducing turtle mortality (perhaps due to misalignment of the Norwegian buoy with the tail buoy during strong surface currents and turns between lines), it did result in a marked decrease in incidence (based on anecdotal evidence) and should be considered as a feasible temporary measure for any survey incurring turtle mortality

However, it should be noted that none of these methods have been stringently field tested and their efficacy is therefore unproven. Feedback is encouraged from all parties trialling these methods.

- Perhaps the most straightforward solution to turtle entrapment is for all seismic contractors to swap to tail buoy designs that are 'turtle friendly' and have minimal potential to catch turtles (e.g. Figure 11 above)

4.6. FUTURE DEVELOPMENT

The 'turtle guard' designs presented here represent the attempts by some seismic contractors to develop a solution at the request of client oil companies. Further incentives from seismic contractors and oil companies would doubtless result in the development of more-effective turtle guard designs and other options. Collaboration between the different sectors of the offshore seismic industry is encouraged, to maximise the field trialling of turtle guard designs, exchange of information on design success, and ultimately to ensure that the best possible solution is identified as soon as possible.

5. 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 describe or 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.

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? Inside the buoy? Across the tow chains? 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?

It is crucial to emphasise that accurate and open reporting of turtle mortality events is viewed as a constructive action. Many seismic personnel are understandably reluctant to report turtle mortality in case it is viewed negatively by the environmental sector. However, given that we now know this problem is widespread and frequent in some areas, seismic contractors and oil/gas companies should encourage open reporting of all turtle mortalities as a standard HSE requirement.

It is suggested that two types of reporting should be implemented to better understand the turtle mortality problem, and these are described below.

5.1. TURTLE MORTALITY INCIDENT REPORT

A report should be filed every time a turtle mortality occurs in a tail buoy, to answer the questions posed in Box 1 and to maximise the efficiency of future turtle guard development. These reports should be submitted to the client at the end of the survey. An example **Turtle Mortality Incident Report Form** can be downloaded for electronic or written completion.

5.2. SEISMIC SURVEY TURTLE MORTALITY FEEDBACK REPORT

A simple one-page report should be completed at the end of every seismic survey, outlining the type of tail buoys used and the number of turtle mortalities that were recorded. Note that this information is equally important for surveys where no turtle mortalities were documented, as this suggests effective tail buoy designs and/or turtle guards were used. An example **Turtle Mortality Seismic Survey Feedback Form** can be downloaded for electronic or written completion.

5.3. WHERE TO REPORT TO

In the first instance these reports should be submitted to the client and to the regional licensing body (and submission of these data should become a survey requisite for both of those parties). However, it is recommended that the seismic survey industry identifies a central independent contact point to compile these forms, analyse the resulting data and produce advice/recommendations.

6. 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/adjacent to documented feeding and breeding habitat for marine turtles.

Box 2. Why choose to implement turtle guards or 'turtle-friendly' tail buoy designs?

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 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 turtles within a tail buoy structure can cause the buoy to tow/track to one side, risking taking the survey out of spec
- The faulty tracking caused by turtle entrapment could potentially lead to tail buoy tangles, causing streamer damage and streamer fluid leaks and potentially causing increased tension on streamers causing them to break. Such events can result in several days of lost production

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, see Figure 11) 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 and reporting on any turtle fatalities in towed equipment should be a mandatory requirement

(2) Seismic contractors
Contractors who operate seismic vessels should voluntarily adopt turtle guards or 'turtle friendly' tail buoys

(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 minimise turtle mortality

7. IMPLEMENTATION OF 'TURTLE FRIENDLY' TAIL BUOYS BY MANUFACTURERS

A further form of implementation is via the tail buoy manufacturers who should be encouraged by industry to consider turtle entrapment during future 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 (at least in the sub-tropical and tropical waters where the highest turtle densities occur). 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 2.4). Ideally, the use of a single tow chain would greatly reduce the potential for turtle entrapment and is already used in some tail buoy designs (Section 4.2)
- 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 effective 'turtle guards' as an integral part of new tail buoy designs when an undercarriage and/or twin-fin design is necessitated

8. CONCLUSIONS AND RECOMMENDATIONS

- Mortality of endangered/critically endangered marine turtles within seismic tail buoys is under-reported by seismic personnel but based on anecdotal evidence it apparently occurs in warm and tropical waters worldwide
- This mortality could be readily addressed and reduced/eliminated by the seismic survey industry
- The long-term solution to the issue is to modify the design of tail buoys to eliminate the potential for turtle mortality, or for those seismic contractors whose tail buoys are known to cause turtle mortality to adopt the 'turtle friendly' tail buoy designs already used by other contractors
- In the shorter-term, 'turtle guards' of a combined Deflector and Exclusion design should be fitted to existing tail buoys to reduce turtle mortality. Evidence to date suggests that the simple Exclusion designs implemented so far by certain seismic contractors are not effective in preventing turtle mortality
- It is important to assess the relative effectiveness of different turtle guard designs via scientific study, field trials and implementation of an industry-wide feedback report system
- The implementation of both 'turtle guards' and 'turtle-friendly' tail buoy designs should be adopted as HSE 'best practice' whenever seismic surveys are operating in warm/tropical water regions, 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 seismic contractors and oil & gas companies in order to better document the scale and mechanism of turtle entrapment and to develop effective solutions

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10. REFERENCES AND FURTHER INFORMATION

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Feedback on this issue and suggestions for further developments for turtle guards would be greatly welcomed. To provide feedback or for more information please contact Caroline Weir (Email: Caroline.Weir@ketosecology.co.uk)

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