HUMAN FACTORS WITHIN SPORT DIVING INCIDENTS AND ACCIDENTS

An Application of the Human Factors Analysis and Classification System (HFACS)

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COGNITAS
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Improving Diver Safety by Challenging Current Practices and Encouraging a 'Just Culture'

Human Factors within Sport Diving Incidents & Accidents - Executive Summary

There have been many studies looking at fatalities in sport diving, and in the main what the causal factors are, but none have looked at the influence of human factors to understand 'why' incidents occurred. In 1997, a team who had developed the Human Factors Analysis and Classification System (HFACS) used it to examine a large number of US Navy and Marine Corps aviation accidents between 1991 and 1997 to understand why accidents were happening and whether pilot error or violations of rules were to blame. The study concluded that roughly a third of accidents were down to the violation of rules. Through studying these accidents, their casual factors, and the application of the HFACS, naval aviation flight safety was improved and the number of accidents reduced.

This paper takes the processes and procedures from the HFACS and applies them to incident and accident analysis with a view to improving diver safety. The paper looks at the four layers of an incident proposed by James Reason; unsafe acts, pre-condition for unsafe acts, unsafe supervision and organisational failures. These layers are then further broken down into sub-components detailing examples and mitigations.

This paper highlights that the diver, the supervisor or instructor, and the organisation or training agency each have their own level of responsibility in the prevention of incidents and accidents. Whilst individuals can drive a positive attitude upwards, there is a need for organisations to promote a culture that ensures that divers continue to follow the recommendations and procedures promoted and taught by training agencies, even years after a training course has finished; as in aviation, most incidents have their roots in violations of procedures and recommendations.

One such positive area is the introduction of a 'Just Culture', which encourages divers and instructors to report incidents or failures without fear of retribution or criticism; introducing such a culture in military and civil aviation, Air Traffic Control and medical environments has led to a marked reduction in accidents and incidents.

Sport diving by its definition is a sport and hobby, and therefore traditional supervision does not take place in the majority of diving activities. However, peer review of diving activities does occur and encouraging an attitude whereby divers can comment constructively and provide feedback on their peer's unsafe operations is needed. Addressing and encouraging this Just Culture and the application of the HFACS to diving incidents and accidents should be a high priority of the diving community at all levels; individual, supervisor and organisational levels.

Acknowledgements

This paper was produced as part of the author's drive to improve diving and diver safety by challenging current practices and encouraging a Just Culture in the sport diving (recreational and technical) world. Having experienced human factors and crew resource management training as military aircrew (as an operator, an instructor and a flying supervisor), the author believes there were many areas in accident/incident prevention, investigation and reporting that could be applied to sport diving. The author truly believes that at whatever level a diver is operating - individual, supervisor/instructor or training agency/organisation - there are lessons which can be learned and applied to improving the safety of diving and divers.

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Human Factors within Sport Diving Accidents & Incidents

Despite improvements in training standards, equipment designs, and an increased awareness of the risks involved in diving, there are still fatal incidents each year in what is largely a safe recreational sport. Diving has been considered more risky than snow skiing, but less risky than other adventurous sports such as rock climbing, bungee jumping, motorcycle racing and sky diving. Previous studies have quantified this level of risk as between 3.2-34 per 100 000 divers and 0.37 to 4 per 100 000 dives (Denoble et al, 2008). Whilst there have been many studies into diving fatality numbers (Acott, 2003; Pollock et al, 2007; Cumming, various) there have been very few looking at the causes as it is very often difficult to define the 'why' a fatality occurred for a variety of reasons (Denoble et al, 2008). However, within aviation, medicine and high-risk industries the influence of human factors on causality is a well-developed area of research, and it would seem sensible to apply these practices to diving as there are many areas which are similar. Notwithstanding this, only a few studies have applied those techniques and lessons learned to commercial and military diving (O'Conner, 2007; Tetlow & Jenkins 2005) and there are currently no referenced studies that specifically look at sport divers. Part of this might be because there is not the same commercial pressure to complete objectives whilst sport diving, but it could be argued that pressure still exists. This is especially relevant within the 'Open Water' level instructional market where time is a major pressure (Cumming, Peddie and Watson, 2010). However, it should be noted that whilst under instruction there is an extremely low level of incidence (between .300 to .482 per 100 000 dives, (Richardson, 2010)); once students leave training, the levels of incidence rise (upto 4 per 100 000 dives, (Cumming, 2010)).

'Why Do Recreational Divers Still Die?'

Unfortunately, the answer is not as simple as it might first appear to be. It is easy to blame the individual for making a mistake. However, the question still remains:, what situation were they put it in, or what caused them to make that mistake in the first place? Errors are part of human nature, and as such they need to be addressed at all levels of incident reporting and accident analysis, not just the final act of doing something 'wrong'.

The aviation industry is clearly focused on safety as the implications of something going wrong has a high cost, both from loss of life and financial perspectives. Consequently, there are many aviation related studies which look at why mistakes have occurred and, more importantly, what can be done to reduce the chain of events which lead to an accident. As shown in Reason, (1990) and Shappell & Wiegmann, (2000) 60-80% of aviation accidents can be attributed, at least in part, to human error. Professional medical organisations, such as the National Health Service (NHS), have also realised that there are numerous errors in the treatment of patients, with many dying as a result (IOM, 2000). Human Factors Error Analysis is a growing field in this area as a consequence, and it can easily be applied to all levels of the sport diving industry so that we may have a better idea, not just of why divers die, but why incidents occur in the first place.

'Human error' can mean different things to different people; however, if a lay-person were asked for a definition with regards to an aircraft accident, the first response would likely be 'pilot error'. If a group of divers was asked the same question, the response would likely be 'diver error' and that the diver died or was injured because they made an error or mistake. Currently, the British Sub Aqua Club (BSAC) Incident Reports are the only means by which the UK diving industry keeps track of recreational incidents and accidents; other reporting systems do exist - DAN, PADI & DIMS = to name a few, but these do not focus on UK diving. However, the completion of a BSAC Incident Report is not mandatory, and there are many examples of divers who have conducted dives where incidents have occurred but a BSAC Incident Report has not been completed. In addition, there is some evidence that divers believe that the reports are BSAC-specific reports and that they should only be completed by BSAC divers (Lock, 2010a). Furthermore, using previous industrial analysis, a 1:600 ratio of fatality to reportable incidents has been cited in ICAO (2006), and feedback from the British Hyperbaric Association shows that there are approximately 3.5 times as many divers recompressed as reported through the BSAC incident reporting system. Therefore, the level of reported sport diving incidents is likely to be well short of that actually encountered. Whilst the approach detailed in this paper has been based on the Human Factors Analysis and Classification System (HFACS) by (Shappell and Wiegmann, 2000), there are also many other areas within aviation and medicine which have direct application to the sport diving industry.

The Swiss Cheese Accident Model:

Reason proposed a model of human errors in 1990 and this was further expanded by Shappell and Wiegmann in their HFACS (Shappell and Wiegmann, 2000). The model describes four levels of human failure, with each level influencing the next. These failures are split between 'Latent Failures' and 'Active Failures'; the active failure, or outcome, being the actual incident or occurrence.

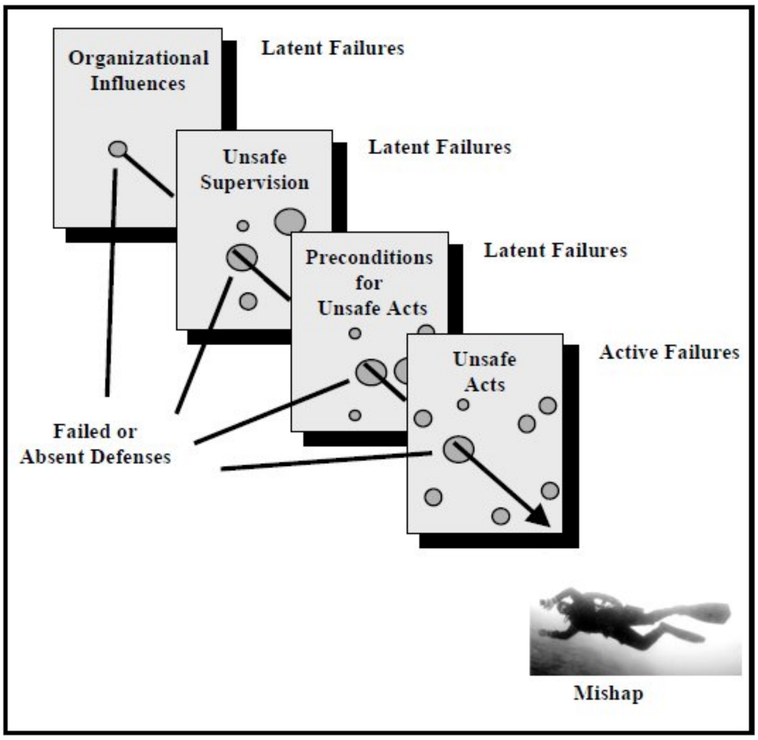

Figure 1. The Swiss Cheese Model of Human Error Causation (Reason, 1990)

This paper will describe the four layers, shown diagrammatically above, in detail and relate them to the scuba diving industry. Commercial diving, professional recreational dive instructors & guides 'At Work' and military diving are monitored in the UK by the Health and Safety Executive and the Ministry of Defence Superintendent of Diving (SOFD), respectively, and as such they will not be directly referred to in this paper.

The first layer, working back from the incident, addresses the 'Active Failures' or 'Unsafe Acts', those which ultimately led to the accident[1]. In HFACS, these are more commonly referred to as pilot error, but in this paper the actions can be thought of as "diver error". The area of unsafe acts is where most post-event investigations focus their effort and where the majority of causal factors are uncovered (ICAO, 2006). Unfortunately, active failures or unsafe acts aren't necessarily the prime causal factor, and it appears that latent factors are sometimes ignored or not investigated thoroughly. Consequently, these latent failures are likely to be present in future accidents or incidents. Using the term 'Latent Failures' describes dormant failures which lie hidden or unobserved for an unspecified period of time until they have an effect on the diver, or divers, leading to an incident or accident. These terms could also be aligned with Denoble et al's Trigger Agents, Disabling Agents or Disabling Injuries (Denoble, 2008).

The next layer, but the first of the latent failures, is *'Precondition for Unsafe Acts'* and deals with mental fatigue, poor communication or coordination procedures. In the aviation industry this is often referred to as '*Crew Resource Management'* or CRM. An example of this would be a diver who has an equipment issue or malfunction, such as a leaky regulator or hose, or a physical problem, including dehydration from sea sickness as described in Fryer (1969), and who doesn't communicate this to their buddy or to the skipper before getting in the water. By not communicating a reduction in capability or capacity, they have potentially 'laid themselves open' to a subsequent 'Active Failure'.

It would seem paradoxical that a diver wouldn't communicate a problem to the dive team prior to, or during a dive, but Reason traces the issue of poor CRM back to the third layer, *'Unsafe Supervision'*.

Supervision isn't necessarily about having a superior looking over the shoulder of the divers; supervision in this context can also mean mutual responsibility for each other when diving in a pair or team. An example of this could be two newly qualified divers paired together in marginal, but previously experienced, conditions. If these divers start a dive without discussing what they should do in the event of a problem, another link in the chain of failures is completed. They are diving within the limits to which they have been trained, but haven't necessarily made sure that they will be following a plan in the event of something untoward or different occurring, or their experiencing something that they have never encountered before.

Alternatively, a lesser experienced diver might not feel that he can comment on something wrong in front of his "superior" or more experienced buddy. The diver might hope that the problem will go away or nothing will happen to further exacerbate the issue[2]. Finally, unsafe supervision can be a situation where instructors are not teaching to approved standards or teaching something in excess of what should be taught at a particular level, sometimes just to prove a point.

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[1] Reason's original work involved operators of a nuclear power plant. However, for the purposes of this manuscript, the operators here refer to divers, supervisors, instructors and other personnel involved in diving.
[2] In aviation terms this is known as cross-cockpit gradient authority.

Reason continued to look for reasons why supervision was lacking, and found that it wasn't just direct supervision, but how the organisational influence can affect operations at all levels. Whilst evidence is hard to come by, it could be considered true where profit and human resources drive the tempo of a diving operation. Unfortunately, this level of failure is probably the most contentious as the majority of divers or staff are loyal to their primary training agency or facility, and are unlikely to want to accept positive criticism to change the way a system is run - especially if this could affect the commercial viability of their business. Agencies are also reluctant to promote the, albeit small, risks involved because that would not be good for the business model that promotes diving as a leisure/recreational activity.

In summary, a diving accident isn't normally just a case of a specific diver error; many 'holes' in the layers need to be lined up before an accident can occur (Heinrich et al, 1980). The layers and holes will be explained in more detail so that those involved in the safety of diving, from individual divers all the way through to supervisors and those in charge of organisations, are able to clearly identify them and reduce their size and consequent impact.

Reason's accident causation model has revolutionised how many industries undertake accident investigation, but it has taken time; the scuba industry is primarily recreational with limited legislature applied, and the application of more 'rules' will increase costs and potentially reduce uptake, even if it saves lives. However, rules are not necessarily the answer, a positive promotion of how to avoid the risks in the first place would be a good start.

Getting divers to realise that unsafe acts are not necessarily the reason something happened and engendering a spirit of openness and constructive criticism will help reduce the number of deaths and injuries in this sport. There is currently a reporting system managed in the UK by the BSAC which provides basic trends, details, and lessons learned. However, the author believes that this could be improved both in the type and quality of data captured, in addition to capturing more incident data to improve the statistical significance of the current data.

Unsafe Acts:

Unsafe acts can be roughly defined as either an error or a violation. In general, errors are events which occur when the outcome is not that which had been hoped for because of something the 'actor' did or did not do. Unfortunately, the published Annual BSAC Incident Report does not contain the level of detail required to ascertain the level of attribution within sport diving, but hopefully this can be improved. Changing the reporting process and system to allow more data to be actively captured, especially Human Factors, is the subject of another study by the author.

Shappell and Weigmann's HFACS classifies errors into three sub-groups; Skill-based Errors, Decision Errors or Perceptual Errors. It should be noted that there is a difference between errors and violations; errors are accidental, whereas a violation is a deliberate act to exceed the rules or guidance to achieve a specific goal. Table 1 below, describes various examples of unsafe acts and categorises them as errors (and their subsets).

Errors

Skill-based Errors:	Decision Errors:	Perceptual Errors (due to):
• Incorrect equipment assembly e.g. hose routing, octopus securing, Closed Circuit Rebreather (CCR) canister assembly • Incorrect in-water skills such as regulator clearing or Deployed Surface Marker Buoy (DSMB) launch • Omitted step in a procedure such as order in which weight belt is put on or the order for a valve shutdown • Poor finning technique resulting in silting out • Incorrect gas planning and monitoring • Incorrect or missing gas/Maximum Operating Depth (MOD) marking/analysis • Poor buoyancy control	• Wrong response to emergency such as an Out of Air (OOA) situation • Poor decision on whether to continue or end the dive • Wrong gas for depth • Continuing dive despite kit failures • Continuing dive in excessively poor visibility or strong current • Not ascending when buddy separation occurs • Not ending dive when gas minimums are reached. • Incorrect thermal protection	• Misjudged current • Misread computer or SPG • Visual illusion such as clear water and depth • Misjudged gas consumption • Disorientation due to current and particles • Lack of ascent/descent awareness due to focussing on particles or buddy who are also moving • Lost due to misjudging location

Table 1. Selected Examples of Errors of a Diver

Skill-based Errors:

Skill-based errors apply to those skills learnt during training such as buoyancy control, shutdown drills, finning techniques or bailout skills, which should be conducted without too much thought, and ultimately should be an autonomous reaction in the event of an incident. However, because they are skills that are 'subconscious', they are particularly susceptible to failures of memory or attention (Tetlow and Jenkins, 2010). Skilled performance declines with retention interval and the rate is dependent on three factors: degree of overlearning, skill type and individual differences (Wickens CD and Holland, 2000a, Chapter 7).

Within the aviation industry, attention failures have been linked to many skill-based errors (Fisk & Schneider,1981). A classic example of attention failure is where a diver, who is so task fixated photographing a subject or concentrating on the environment, does not notice their buddy has swum off[3]. Whilst this may not be a problem on its own, if there is a precondition for an unsafe act e.g. known equipment failure or missing equipment, then the diver might face an out of air (OOA) or entanglement situation without a buddy to help.

[3] This is a double failure as the second buddy hasn't noticed that he has separated from the other diver.

Memory failures, especially when stressed, often appear as omitted items in a sequence of tasks. This is especially true when conducting an emergency procedure such as remembering to drop a weight belt at the surface to achieve positive buoyancy once an emergency ascent has been conducted. Furthermore, tasks which are more complex, such as those required when assembling a CCR or conducting fault diagnosis, are even more likely to be susceptible to memory failures (Tetlow and Jenkins, 2010). Consequently, the use of checklists when assembling and checking a CCR is recommended by BSAC (BSAC, 2011) and the HSE (Tetlow, 2006) to help mitigate this problem. In addition, the reinforcement of basic training through continued skill practice is actively promoted by training agencies.

The final type of skill-based error involves technique error, and an example of this can be poor finning technique combined with poor trim[4] in a silt environment. Many divers do not realise the consequences of not being able to direct the thrust from their fins correctly, as they have not been shown properly during training - an organisational influence. Silting out[5] can, at best, ruin a dive and at worst provide an environment where the diver does not know which way to go for a safe exit leading to a fatality (Cumming, 2007). This, combined with other latent failures such as not lining off[6] in an overhead environment, adds another link to the chain of failures.

Mitigation of Skill based errors: Skill based errors can only be countered by practicing those skills which need to be second nature such as OOA drills, mask off drills or good finning techniques. This is obviously hard for "2-week summer holiday" divers (Divemasters or Guides mitigate some of the risk for this category), but those who dive regularly should get into the habit of practicing one skill on every dive like an OOA or mask remove/replace so that they are comfortable in this 'emergency' environment.

Decision Errors:

Decision errors are exhibited when intentional actions proceed as planned, but the plan proves inadequate or inappropriate options or choices were made for the given situation. Decision errors can be divided into three further subsets: Procedural, Poor choice, or Problem solving errors.

Procedural Errors:

These errors occur when a situation is either not recognised or misdiagnosed, e.g. not signalling to your buddy about a problem which might be more complex than thought, bailing out if there is a problem on a CCR, or closing the wrong post during a shutdown drill. In addition, when stress levels are elevated, the procedures are more likely to be forgotten unless they have been ingrained into the long-term memory (Tetlow and Jenkins, 2010). The only real mitigation for this series of events is to conduct regular training where multiple scenarios are experienced and honest debriefs are conducted between the divers and instructors.

[4] Good trim is where the body is flat to the surface that is being swum over. This allows the propelled water to go directly behind the diver rather than downwards into the sediment or silt.
[5] Where a diver has disturbed the silt or sediment to such an extent that they have no visibility. Normally caused by poor finning technique.
[6] In areas where visibility is reduced (disturbed sediment or rust particles dropping from the roof of a wreck) and there is a need to return to the same place, e.g. the entrance to a wreck, then a diver places a safety line marking the way out.

Poor Choice Errors:

The primary reason for 'poor choice errors' is a lack of experience, either personally gained or learned through other's experiences, and consequently applying an incorrect solution or being pressured into making the wrong decision due to reduced time scales or increased stress.

Many agencies teach divers to follow procedures which have been developed for the environment they are primarily taught, but when the problem is not fully understood and the taught procedures do not fit the situation, problem solving errors are more likely to occur (Wickens CD and Holland, 2000b). For example, a drysuit flood may mean that a diver has to end his dive early, but they have a decompression overhead which means they cannot ascend directly to the surface; the diver is unlikely to have been taught this and therefore has to use personal experience/knowledge to decide on the best strategy for ascent depending on the depth/time profile, gas choices, and environmental considerations.

Figure 2 outlines the process by which decisions are made and what cues or knowledge are applied, depending on the time available or the stress induced. As can be seen, in high stress situations skill-based rules and simple pattern matching is required to solve the problem. If more time is available, then knowledge based and analytical processes can be applied.

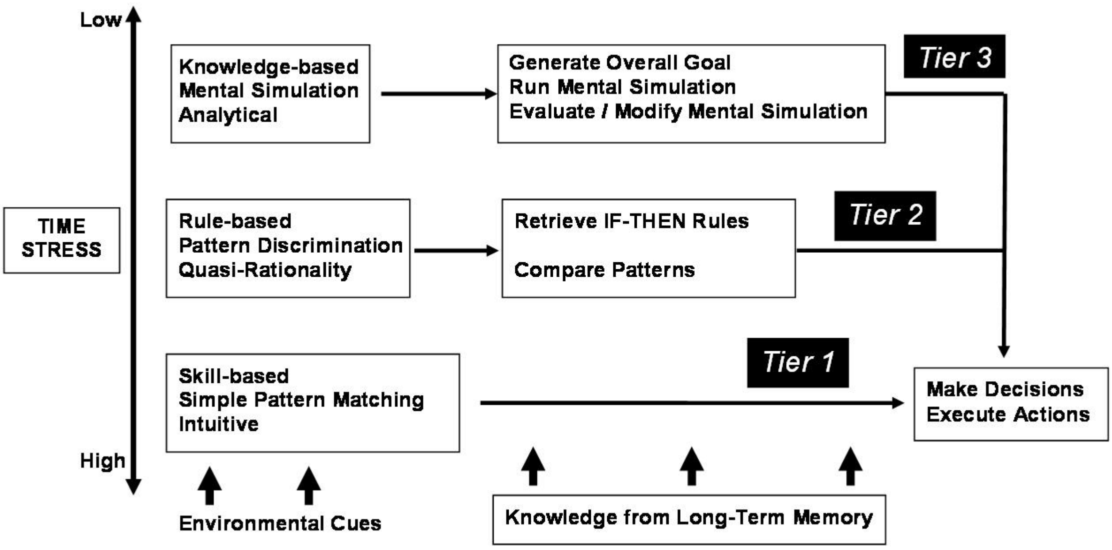

Figure 2: Naturalistic Model of Decision Making (Elgin and Thomas, 2004)

Mitigation of Decision errors: The mitigation for decision errors is to ensure that divers have experienced directly or indirectly a variety of scenarios which they are likely to encounter; even if this is not necessarily where they have been/are being trained. Exposing the diver to a multitude of different problems to solve during training or examine the 'what if' cases and carry additional equipment to compensate (within reason) can help reduce this risk. There is obviously a limit to what can be trained against, but if the diver has been exposed to a few scenarios or 'what ifs' then they are more likely to be of the mind-set to problem solve rather than panic. Ensuring that instructors have varied, relevant and current diving experience could also be considered essential if students are to get the most from their instructors. A Royal Air Force Flight Safety adage is "Learn from your mistakes, better still, learn from others"; this equally applied to the scuba diving industry.

Perceptual Errors:

The underwater world provides some interesting physiological issues which are not just limited to pressure. Depth and visual perception errors are easy to encounter because our bodies are not designed to operate in a liquid environment. A prime visual illusion or misperception occurs mainly in blue water diving locations where depth is difficult to judge as the water is clear and there are no references against which to measure depth. Disorientation can occur when descending a shotline[7] in a strong current with particles or plankton flowing through the water. This is similar to driving in a snowstorm with main beam headlights, with the added issue of weightlessness.

Perception errors are present in normal life and many activities which would be expected to be recognised are missed due to human physiology (Chabris, 2010) but these are magnified in the sub-aquatic world especially when narcosis is experienced. Nitrogen narcosis is considered by most agencies to be experienced when diving below 30m and makes reasoned judgements more difficult, thereby skewing perceptions and making problems harder to solve. Narcosis can be reduced by the use of Helium in breathing gas.

Finally, the further from the surface, the harder it is to conduct colour discrimination. Therefore, the use of colour coded items such as regulators or hoses to provide a means of safety when dealing with hypoxic or hyperoxic gas mixes is potentially a flawed methodology.

<u>Mitigation of Perception errors</u>: It can be hard to provide mitigations to perception errors other than to explain to divers what experiences they are likely to encounter. Good visibility in clear water makes it hard to judge distances and depths, so more attention needs to be paid to depth gauges and other dive team members. Experiencing the reduction in colour definition is something that is relatively easy to arrange during training dives. Finally, reduction in narcosis, through the use of helium mixes, will help in both perception errors and also skills based errors because the diver is more aware of what is going on around them.

Divers need to be honest with themselves about what they are capable of doing and adjust their diving schedules accordingly. Statistics are hard to come by because causality is not apportioned in the BSAC Annual Report (Dive Magazine, 2011), but many of the incidents at the start of the diving season could be as a result of lack of practice or reinforcement training over the winter/spring.

Violations

Violations are errors which occur when the diver is diving within the bounds of his or her training, but there is a deliberate decision to exceed these limits. There are 3 classes of violation; routine, exceptional, and situational (Ministry of Defence Joint Service Publication 551 Vol 1, Ed 1, pp103, 2003).

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[7] A shotline is a permanent or temporary line, rope or chain which is used to allow divers to descend from the surface to the wreck or reef below.

Violations

- Failure to adhere to dive brief
- Exceeding depth qualification or brief
- Conducting dive without appropriate skills/equipment (eg DSMB, Wreck penetration reels etc)
- Deliberately not preparing kit properly contrary to guidance already given
- 'It'll be alright' and 'Follow me' attitudes
- Exceeding MOD of breathing gas
- Purposely ignoring warning alarms and safety systems on a CCR.

Table 2. Selected Examples of Violations by a Diver

Routine violations are when a procedure or policy violation is systemic in a unit / setting and not based on a risk assessment – something has become 'the norm'. Looking through the accident analyses, the majority of incidents and accidents have their root causes in violations against teachings or recommendations from agencies. Cumming et al stated that if the divers carried out diving operations as per guidelines, then it is likely that 70% of fatalities would have been prevented (Cumming et al, 2010). Exceptional violations are when an individual or team intentionally violates procedures or policies without cause or need. Finally, situational violations are when the consequences / risk of violating published procedures are recognized, consciously assessed, and honestly determined by the individual or team to be the best course of action (Ministry of Defence, 2003) such as exceeding a maximum operating depth (MOD) or limited bottom time to conduct a rescue (Exley, 1995).

Mitigation of Violations: The only real mitigation for routine violations is to explain what the implications for the constant 'little bit extra' could be, especially as this extension is sometimes taken as the new "baseline". Further study is required to understand why divers complete their training and then fail to adhere to the recommendations, even when they know what they are doing is wrong. Exceptional violations are a little more difficult to spot before the event, as they are unlikely to have an indicator and they are not normally indicative of the behaviour of the diver (Reason, 1990). An example of this sort of violation could be task fixation on recovering something like an artefact from a dive site where the diver goes beyond the minimum gas reserves required, ignoring safety of life information provided by a CCR system (Nilsson, 2010), or the violation could be linked with perception errors resulting in a diver descending well beyond planned depths and encountering an Oxygen Toxicity event or severe narcosis.

Precondition for Unsafe Acts

It could be perceived that the majority of accidents or incidents within the dive industry can be attributed to 'unsafe acts' because that is what the majority of people see as the outcome. Unfortunately, there is no reliable data within the current recreational reporting system to corroborate this because the capture process does not include this area. However, knowing *why* someone did something is equally as important as what they did or did not do. Apportioning causality or blame to the diver or the agency would also make it more likely that people would be criticised for their actions leading up to the incident, and consequently would be less likely to submit future incident reports. However, providing, promoting and supporting a 'Just Culture'[8] where people are expected to make mistakes might go some way to prevent this negative attitude. Indeed, examples of introducing a Just Culture into Danish Air Traffic Control centres saw an increase in reporting and a reduction in incidents (GAIN, 2011)

Precondition for unsafe acts can be split into two areas; substandard practices of operators and substandard conditions of operators (Reason, 1990). Both of these categories can be transferred to divers and are detailed in the table below.

Substandard Conditions of Divers		
Adverse Mental States	**Adverse Physiological States**	**Physical/Mental Limitation**
• Task fixated • Complacency • Distraction • Mental Fatigue • Haste, Loss of situational awareness • Misplaced motivation • Task saturation • Stress from journey to site • Depression • Overconfidence	• Impaired physiological state, Medical illness • Physiological incapacitation (e.g. sea sickness) • Physical fatigue • Cold	• Physically unable to do the dive • Lack of physical fitness to recover another diver or themselves • Unaware or unwilling to accept their skill limitations

Table 3. Selected Examples of Substandard Conditions of Operators

Adverse Mental States. Divers are placed in an alien environment where they need to be alert to what is going on around them (equipment, environment, buddy, gas consumption. etc). As such, they need to be both mentally and physically prepared to dive. More than one training agency teaches a visualisation technique to go through the dive in detail before getting in the water to try and pre-empt any issues. Having a reduced mental capacity affects the diver's ability to understand what is going on around them and apply experience/reasoning to the

[8] A Just Culture isn't just about having a reporting system, but rather a set of beliefs and duties that should be expected from all levels in the diving operation from diver through to organisation/agency to improve diver safety.

situation; this is described as situational awareness (SA) or situational understanding (SU). Poor SA or SU manifests itself as the ease to which a diver can become distracted or task saturated (Endsley, 1995). If an individual is mentally fatigued, they are more pre-disposed to make an error (Skybrary, 2010). This could mean putting the kit on in an unsafe manner or forgetting to connect something like a BCD or drysuit feed, failure to turn on their gas supply, or not completing a buddy check.

Adverse Physiological States. Diving by its very nature places a human being in an environment when adverse physiological experiences are likely to be encountered. Diving with an injury such as a break or bruising could lead to DCI at a much lower pressure level change than a normal diver would encounter (Vann, 1989; Karlsson, Linnarson, Gennser, Blogg, 2007). Whilst DAN have stated that there is no direct correlation between the decongestant pseudoephydrin and oxygen toxicity (DAN, 2010), there might be a link with a reverse block[9] on longer dives if the decongestant wears off during the dive. Divers should be aware of the physiological implications if they do something to their body which may then be affected by pressure or enriched air diving.

Physical/Mental Limitations. Personal fitness and age is a factor which appears in the summaries of some accident reports (Cumming, various). DAN in their annual summary reports provide details of body mass index (BMI) . Whilst the body may be 'weightless' in the water, there is a requirement to be able to conduct physical activity such as finning in a current, climbing up a boat ladder wearing 10s of kgs of dive equipment[10] or divers to meet the 'physical requirements to meet any foreseeable underwater emergency' which could include a diver rescue[11]. The production of higher levels of CO2 places the diver at a higher risk of oxygen toxicity or CO2 toxicity (DAN, 2008). Placing the body under unnecessary stress through lack of physical fitness is just adding another link in the chain or making this particular 'hole' larger (Mitchell, 2010). Mentally, a diver may be under increased peer pressure to conduct a dive which they are not comfortable with, but are reluctant to say no due to cross-cockpit authority gradient[12]. In addition, there might be time and financial pressures to conduct the dive despite a diver not being physically or mentally prepared for the dive (Lock, 2010b).

<u>Mitigation of Sub-Standard diver conditions</u>: The mitigations for Sub-Standard Conditions of Divers is to again highlight the implications of diving when they are operating at a sub-standard level. Diving can be a physically and mentally challenging sport although it can be extremely enjoyable at the same time; the level of enjoyment can be directly compared to the mental and physical preparedness of the diver.

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[9] As a diver descends, they need to clear their ears due to the increase in pressure. In a reverse block, the Eustachian tubes are blocked and the pressure at depth is now trying to push the eardrum out as the diver ascends. There is no easy way to clear a reverse block other than a very slow ascent which may have gas usage implications.
[10] it is not uncommon for technical divers to enter the water with more than 70kg of dive equipment
[11] HSE Dive Medical Requirements.
[12] Cross-cockpit authority gradient is the term used to describe the reluctance of a more junior pilot/crew-member to question the decisions or actions of a more senior or experienced pilot/crew-member.

Substandard Practice of Divers

Substandard Practice of Divers	
Communication/Team Skills • Failure to plan contingencies • Failure to communicate/coordinate • Failure to conduct adequate brief • Failure to use all available resources • Failure of leadership • Misinterpretation of signals • Failure to log in/out with supervision • No dive/deco/gas plan • Unfamiliar with buddy's kit	**Personal Readiness** • Self-medicating • Inadequate rest • Too much alcohol night before • Dehydrated • Too late at dive site • Too cold/hot • Lack of preparation for dive (kit, self) • Poor condition of dive equipment (fit, service state etc.) • Denial of existing medical problem

Table 4. Selected Examples of Substandard Practices of Divers

As detailed in the previous section, it can be seen there are many situations which fall under the substandard conditions of divers, but what about substandard practices of the divers? It could be simply defined as 'those actions or things which divers directly do to stack the odds against them and allow the jigsaw of failure to be completed'.

Communication/Team Skills

Good communication and team (or buddy) skills are essential to minimise the chances of the situation deteriorating once something out of the ordinary has happened. A team, if practiced and aware of each other's responsibility/duties, is much better placed to deal with an emergency than a single solo diver. However, if these team/buddy skills do not exist, then a solo diver might be safer. Communication and team skills don't just cover the in-water phase of the dive; planning, briefs, kit checks and debriefs are all part of this strategy. Ensuring a diver knows how to get to a buddy's safety equipment or how to get them out of his BCD or harness could be considered essential in the event of an emergency. Planning for different gas consumption rates comes under this section; a diver with a good SAC[13] and small cylinder will need to end their dive much sooner if they are paired with a high-SAC rate diver to ensure that if the high-SAC diver has an OOG situation, they can both ascend safely. Debriefing a dive will allow the divers to learn from the mistakes (or the things that went well) and apply

[13] Surface Air Consumption (SAC) rate is normally expressed in litres per min and is used as a measure of a diver's gas consumption. E.g. 18l/min

those to future dives or allow others to learn from the situation. It is essential to foster an environment where a diver can comment or criticise another diver constructively.

Personal Readiness

The underwater environment is potentially a harsh one and both the body and mind need to be fit for purpose. Fortunately, attitudes are changing in the UK diving scene regarding drinking and diving; anecdotal evidence gives the impression that the "old days" used to be about going down the pub, getting drunk, getting on the boat with a hangover, being sick and consequently starting the dive in a dehydrated, tired state. This has already put the diver in a "sub-standard condition of divers". However, whilst technical divers are now much more aware of the physical risks of diving in this condition and attitudes are far more positive towards being hydrated and fit for the dive, in the sport diving world, this sub-standard attitude does seem to prevail. If a diver self-medicates, they need to be fully aware of the implications of doing so - especially if taking drugs which affect the body in hyperbaric environments, or which affect air cavities such as decongestants. Finally, motion sickness tablets can make some divers drowsy and therefore less alert for the dive. Ultimately, divers should aim to start the dive fully fit with a clear mental attitude. This should allow them to close as many of the 'holes' as possible before they start the dive, thereby reducing the risk of the dive.

<u>Mitigation of Substandard Diver Practices</u>: Divers and supervisors should not be afraid to refuse to undertake a dive if they are ill-prepared. This is sometimes hard to do, especially when divers are normally "time-limited" and want to make the most of the limited diving opportunities they have. Financial pressures sometimes provide an impetus to conduct a dive that shouldn't be done. Creating a team or group of divers who accept that a call is made without peer pressure is a great thing, and this approach and attitude should be more widely encouraged.

<u>Unsafe Supervision</u>

Reason stated that causal factors went beyond the operators themselves and that supervisory issues should be considered when conducting post-event analysis (Reason, 1990). Shappell and Wiegmann (2000) further described unsafe supervision as four sub-categories; inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations. It should be noted that supervision within the non-club[14] diving environment also covers more experienced divers diving with lesser experienced divers as they will be looked up to as the "leader" of the dive. Finally, whilst the BSAC & SAA club environments have a supervisory chain in place which should catch many of the errors from occurring in the first place, as with any environment, personalities can cloud the effectiveness of this process.

At the 2010 DAN Fatalities Conference, a presentation was made (DAN, 2010b) which examined the numbers of fatalities occurring involving PADI professionals and trained personnel, in both training programmes and whilst conducting non-training dives. The numbers of fatalities during training programs or supervised dives (between 0.300 and 0.692 per 100 000 dives) was below the norm compared to other statistics available from DAN and

[14] Club diving is considered as having a defined supervisory chain such as a Dive Manager, Diving Officer or Training Officer. Non-club diving is where dives are conducted outside of this organisational setup and normally consist of friends in a social or project-orientated context.

BSAC (0.37 to 4 per 100 000 dives[15]), which in the main covered non-training dives. It should be noted that an accurate assessment was possible because the number of divers undertaking courses or being supervised by PADI Pros was accurately known, along with the number of fatalities. It could be argued that the number of fatalities is low because there is good supervision and procedures are in place to prevent incidents becoming fatalities, such as the use of Dive Masters. What is not accurately known is what happens after the divers have finished their courses and they are left to 'dive on their own' without the safety net of a formal supervisor for two reasons; the numbers of dives is not accurately known, and neither is the number of fatalities in a certain group.

Unsafe Supervision	
Inadequate Supervision • Failure to provide guidance • Failure to provide and adhere to agency policies and principles • Failure to provide oversight • Failure to provide training • Failure to provide feedback • Inappropriate buddy pairing	Failed to Correct a Known Problem • Failed to correct document in error • Failed to identify an at-risk diver • Failed to initiate corrective action • Failed to report unsafe tendencies (to the diver themselves or higher up) • Lack of promotion of diving incident reporting process/system • Unreliable boat
Planned Inappropriate Operations • Failure to provide adequate brief time • Failure to provide adequate kitting up time • Dive not in accordance with rules/regs • Failure to check the state of emergency equipment (O2 kit, first aid, VHF etc) • No risk assessment • Failure to log in/out divers • Reluctance to modify plan for changing conditions • Failure to record Next of Kin and emergency contact details	Supervisory Violations • Promoting in-group peer pressure • Sanctioning unnecessary risk/hazard • Failure to enforce rules and regulations • Sanctioning unqualified/inexperienced diver

Table 5. Selected Examples of Unsafe Supervision

15 Large variance based on the understanding the numbers of dives taking place.

Supervisor in the context of this paper is primarily considered to be a more experienced diver or an instructor rather than a supervisor in the club environment (DM or DO), as this is considered the most common form of "supervisor" in UK diving. However, the comments below are equally applicable to a club supervisor.

Inadequate Supervision

A supervisor has a moral duty to ensure that their charge is given guidance, and is provided training opportunities (in-water and land-based skills), leadership (by direction when the junior diver is unsure), and motivation (encouragement if the diver is not confident). All of these are in addition to acting as a role model. Humans learn through a variety of methods (Visual, Auditory and Kinaesthetic – VAK) and depending on that learning style may copy what they see, even if they are told not to do it by their role model; "*don't do as I do, do as I say!*" There are many examples of an experienced diver conducting a dive with a junior diver and either passing on poor techniques/skills (either by not doing them correctly themselves, or passing on incorrect information), or not correcting poor techniques or skills by the more junior diver. In the aviation industry, lack of direction or supervision has been found to be at the cause of cockpit violations (Shappel and Weigmann, 2000). Whilst solid evidence is hard to come by in the scuba industry, anecdotal evidence would support this same theory in divers. Inadequate supervision can also manifest itself when an instructor does not have the experience to deal with the environment being faced, e.g. an instructor who has only dived at inland dives sites and never done a sea dive leads the dive in the sea[16]. Finally, in the context of mutual supervision, not conducting an honest debrief after a dive could be considered inadequate supervision. An event may have occurred which was unexpected and not dealt with satisfactorily or safely. Conversely, a problem occurred but was solved without issue. In both situations, debriefs would allow the lessons learned to be carried over to future dives and potentially to other divers when they discuss or plan their next dives. The use of internet discussion forums such as 'I Learned About Diving from That' on Yorkshire Divers and 'Incident & Accident Reports' on Rebreather World, are going some way to promoting lessons learned outside of the club environment. The aim of the Diving Incident and Safety Resource Centre[17] will be to act a central repository hosting, amongst other safety and incident related reference material, a global sport diving Lessons Learned capability.

<u>*Mitigation of Unsafe Supervision*</u>*: More experienced divers should be aware of their responsibilities and in the majority of cases they are. However, they should also be aware of their limitations and lack of experience. As divers move up the qualifications ladder within the BSAC, the position as a role model is emphasised and this is a good thing. Unfortunately, debriefs are traditionally considered to be a training course tool, however, all divers are continually learning and debriefs should take place after every dive - even if this consists of a simple "Any points from that dive?" or "How was that for you?"*

[16] This could also be considered a violation as agencies teach that divers should only conduct dives in an environment in which they have been trained.
[17] http://www.disrc.com

Planned Inappropriate Operations

Many divers spend considerable time planning dives ensuring that the majority of risk is removed before they enter the water. Unfortunately, there are divers who conduct dives knowing that what they are doing is wrong and hope that nothing else happens, as they know it will erode safety levels further. Hope is not something that should be applied to a plan before the divers enter the water. There are a variety of examples which could be applied to this error; diving with an insufficient reserve of breathing gas and hoping that a safety bottle will be dropped if things go wrong; incorrect pairing of divers by not taking into account experience levels and personalities, e.g. "cross-cockpit gradient"; ensuring that safety equipment is present and working before a dive takes place e.g. a recompression chamber or more commonly, O2 equipment on a charter boat. Many of these examples are sanctioned at the dive centre or charter boat level where profits are driving planned inappropriate operations.

<u>Mitigations of Planned Inappropriate Operations</u>: *Again, the mitigation with this is down to education. Unfortunately, the current reporting system does not capture all of the incidents and therefore divers (and agencies) do not know how often certain events are occurring; consequently they cannot assess the level of risk they are taking. A more detailed reporting and pro-active system would go someway to alleviating this problem.*

Failure to Correct a Known Problem

This concerns situations when the "supervisor" knows that something is wrong but does not correct it, and could be in documentation such as training notes or drills which have been developed but the "supervisor" spots an error but doesn't say anything. Another example might be where the "supervisor" is a more experienced diver on the boat, observing others kitting up and spotting something is wrong but not saying anything e.g. dangling regulator or reel which will snag. In both of these examples, if an accident were to occur, the supervisor has condoned the action when they could have prevented it. If a "supervisor" consistently fails to correct or discipline a diver who is not doing what they are supposed to be doing, they are also complicit in any failings which may happen in the future, with potentially fatal results. This can be linked to the routine violations in the "Unsafe Acts" subsection earlier where the baseline has moved. Unfortunately in today's society, there is a lack of confidence in standing up for oneself, but society in general need to be more responsible for their actions. In all of these examples, the difficulty is highlighting the potential problem without appearing over critical. However, if the "supervisor" can provide a real-world example with relevance, then the diver is more likely to understand and remember what was said (Wickens CD and Holland, 2000a). It should also be noted that instructors may allow a lapse in a skill to pass because there are more important lessons to be learned from a dive; this doesn't mean the mistake or lapse wasn't important, just that there were more important lessons to be applied. Emphasising this to the student can be challenging at time.

<u>Mitigation of Problem Correction Failure</u>: *The first part of this mitigation is to understand why the "supervisor" does not try to change that which is wrong; is it apathy about the system, fear of retribution for passing comment, or lack of confidence? Apathy can only be addressed at the organisational level where it is possible to request changes to the system (or explanations as to why things are as they are). Fear of retribution or adverse comment can be addressed by making the diving public more aware of the issues out there, and that everyone should be*

working towards a common goal of improving safety standards. Finally, confidence can be improved by making the number of incidents more available so that those with knowledge can speak from a position of authority citing real examples of incidents taking place. However, all of these mitigations require a mindset change in accepting that 'to err is human' and that everyone, irrespective of their experience, knowledge or aptitude, will make an error at some point.

Organisational Influences

Organisational Influences		
Resource / Acquisition Management	**Organizational Climate**	**Organizational Process**
• Human Resources o Selection o Staffing / manning o Training • Monetary / budget resources o Excessive cost cutting o Lack of funding • Equipment / facility resources o Poor design o Purchasing of unsuitable equipment o Poor/inadequate maintenance	• Structure o Chain-of-command o Delegation of authority o Communication o Formal accountability for actions • Policies o Hiring and firing o Promotion o Drugs and alcohol • Culture o Norms and rules o Values and beliefs o Organizational justice	• Operations o Operational tempo o Time pressure o Qualification quotas o Measurement / appraisal o Schedules o Deficient planning • Procedures o Standards o Clearly defined objectives o Documentation o Instructions • Oversight o Risk management o Safety programs

Table 6. Selected Examples of Organisational Influences

The influence at the organisation level is sometimes hard to specifically quantify when looking at incident or accident analysis, especially in a recreational market. Even in the best-run organisations, most latent unsafe conditions start with the decision-makers who are invariably detached from the front-line and not aware of the real world implications of their directives. These decision-makers are regularly biased by economic pressures of time, money and resources; "the fallible decisions of company management and regulatory authorities are too often the consequence of inadequate resourcing" (ICAO, 2001). Therefore, since some of these 'unsafe' decisions cannot be prevented, measures must be in place to detect them and mitigate them before they impact on the dive operation.

Although culture and operational pressures have an influence on the safety within a dive organisation, two main areas appear to influence the recreational market more than others at an operational level; financial resourcing and manpower resourcing. These are nearly always inextricably linked, e.g. a training course needs to be completed before the next course starts so corners are cut to make the time fit with the limited manpower available. Consequently, this means that the student is not necessarily getting the training required to prepare them for their post-course diving. This is equally applicable to instructor level training, but this has the added implication in that the instructor has limited opportunities (either during basic diver development or instructor development) to experience real-world environments which will help in the decision making process in either their own or their students' diving.

As an organisation grows, keeping control of the quality, knowledge and teaching standards of the instructor base becomes more difficult. As such, there needs to be a process in place to maintain those teaching standards and to maintain the instructor's own diving experience at a level commensurate at the level which they are teaching.

To understand how agencies address the problem of instructor experience, standards and consistency, all of the major agencies teaching in the UK and overseas were surveyed (Lock, 2010c) to find out: what prerequisite levels of knowledge were required before starting an instructional programme; what levels of diving and instruction are required to maintain that qualification; what checks are completed on the instructor by the agency to ensure that they are teaching to standard; and finally, what feedback mechanism is there to ensure that any concerns from students or observers can be elevated up the organisational structure. Not all of the agencies provided a response.

All responding agencies require an instructor to be qualified to or above the level to which they will be teaching, but they need not necessarily be experienced in that discipline. For example, an instructor candidate might never have dived Trimix[18] before his instructional candidate course. They could then complete a few dives on the course and then they are able to teach that discipline immediately after passing the course. It should be noted this is not the case with all agencies, and the majority require an instructor to be experienced in the skills and procedures they will be qualified to teach.

The skills with which an instructor is required to observe and teach before gaining a qualification varied from a single course in which they qualified to dive that configuration and at the same time gained their instructor qualification, to teaching the course a number of times under the watchful eye of an instructor trainer and then an instructional exam completed with another instructor trainer. This latter level of instructor development ensures that any problems encountered by the instructor candidate are corrected. It also allows the instructor

[18] Trimix is a mix of Helium, Oxygen and Nitrogen. Hypoxic trimix is where the O2 content is below 16%, Normoxic between 16% and 21% O2, Hyperoxic is above 21% O2.

trainer to introduce new problems for the instructor candidate to solve with his students thereby increasing both the instructor candidate's capability and capacity and students inferred experience.

Most agencies did not have a formal checking process for their instructors once they qualified. This means that they could qualify and then as long as they meet the required number of certifications (as low as 1 per 2 years) and no sub-standard quality control/assurance forms are received by the agency HQ, then the instructor is not assessed again. Most agencies require their instructors to update their course/teaching notes every 3-6 months following bulletins from their HQ but this is not necessarily audited. One group of agencies, all less than 10 years old, have a pro-active checking process whereby an instructor is re-examined every 3 years to ensure that teaching standards are maintained. One proposal made to the agencies from the author of this report suggested a method for ensuring standards by adopting a similar process to the military by having Standards and Evaluation (STANEVAL) units. These units conduct no-notice checks of instructional and training missions, but the issue of resourcing (financial and personnel) was cited as the main reason that this could not be employed in sport diving. Notwithstanding this, one agency has introduced such a scheme starting in Jan 2011 whereby one senior Instructor Trainer has been nominated as a standards Instructor to conduct standardisation checks (with notice).

All agencies had a feedback mechanism to ensure that any concerns a student may have about their course were sent back to the agency HQ. However, many of these forms are submitted immediately after the course when the student is potentially on a high after passing and is probably not in the frame of mind to provide critical feedback. In addition, some students do not realise what they should or should not have been taught until sometime after the course when they are speaking to another (more experienced) diver. The problem with ab initio students is that they don't know what they don't know. However, as divers move into more technically demanding diving, the choice of training tends to be biased more towards a specific instructor rather than an agency. This choice may be based on the learning style or need of the student and the reputation of the instructor. However, reputation can be a double edged sword as some instructors have a reputation for being an 'easy instructor' and therefore those potential students who want the ticket rather than want to learn something might gravitate towards this type of instructor.

Many high risk organisations such as the military, civil aviation and medicine have reporting processes to allow incident or near-miss incident reports to be submitted confidentially. Such systems include Confidential Human Factors Incident Reporting Programme (CHIRP) for Aviation and Maritime, and Aviation Safety Information Management System (ASIMS) which allow trends in practices and events to be highlighted on a regular basis thereby providing feedback on where training, practices, techniques or equipment deficiencies should be modified. The current reporting process used by the majority of diving training agencies does not allow the identification of failures *at the organisational level*, and indeed this would be very hard to quantify. In addition, only 30-40% of reports are submitted by divers themselves with the remainder coming from organisations such as the RNLI, MCGA or the Hyperbaric chambers (Cumming, 2010); only approximately 27% of DCI incidents are reported through BSAC compared to British Hyperbaric Association reports (Lock, 2010a). Finally, outside of BSAC, the incident reporting process is not actively promoted in the instructional and teaching materials of other agencies, and the specifics of reporting incidents is left to the discretion of the dive instructor.

Ultimately, it is up to the dive community as a whole, and organisations specifically, to engender a positive safety-focussed environment where issues can be raised honestly, effectively and quickly by all levels within the organisation from individual to director. It is essential that the issues should be addressed fairly and openly, especially where incidents occur following official training. However, it is accepted that introducing a safety management system has a financial cost and this will potentially reduce the profit of an organisation or instructor.

Mitigations of Negative Organisational Influence: *The only mitigation to having a negative organisational influence on safety is to ensure that everyone throughout the organisation has safety as their number one priority. Open reporting where honest and frank reports are submitted, safe in the knowledge that as long as the instructor/diver did the best they could do, with the information/skills they had, in the environment they were in, then no negative consequences are expected. Many incident reports, including reports for 'near miss' events, are not submitted because of fear of negative criticism (Lock, 2010a). These near miss incident reports will contain as much information as the 'live' incident reports and diving practices can be improved as a consequence.*

Summary and Conclusions:

As has been shown throughout this paper, there are many factors to diving incidents, and to blame a diver for making a mistake is sometimes disingenuous as the root cause of the accident or incident may have been seeded much earlier in the process. Notwithstanding this, and despite what some may say, errors cannot be completely removed from the chain of events as they are simply part of human nature; no one is perfect and accidents do happen. A positive outcome in that case is to reduce avoidable accidents to a minimum through simple practical actions.

Experience from other industries has shown that implementation of a 'just culture' for safety reporting can reduce the number of accidents occurring due to violations from 43% to 12% (Wiegmann, 2003) in conjunction with an effective safety management system.

In writing this paper, the author seeks to highlight three key points;

- To enable safety to be improved, we need to be able to measure incidents, feedback lessons learned and control the application of risk to activities; even if those activities are recreational.
- Measurement is reliant upon an open/just culture
- The aviation and medical industries have learned over many years that introducing a 'just culture' reduces the numbers of fatalities and that applying those lessons can do no harm, and because in the main a 'just culture' is attitudinal, then the costs will be minimal.

When trying to improve diver safety, the influence of human factors across the different levels - Individual, Supervisor and Organisation - all need to be recognised and addressed so that a change in attitude towards dive safety may occur and lead to a realisation that dive safety is everyone's responsibility. Mistakes that are made, if reported honestly and openly and most importantly, without fear of recourse, will allow others to learn from them and potentially stop a similar mistake from occurring in the future; this includes near misses with 'lessons learned' (Wiegmann, 2003). Whilst the effect of change is most noticeably felt at an individual level, the change should ideally be started at the organisational level with the direction and guidance given from there. Most of the problems encountered could be mitigated, or their effects reduced, by improving the educational process within current training programmes using a validated and recognised level of risk. This level of risk is currently not well defined for non-fatality incidents, but comparisons with high-risk industries such as aviation and medicine can provide some correlation.

The problem faced by the recreational dive industry is three-fold: the perception that there really isn't a problem with safety as there isn't any evidence to prove the case; there is a requirement to maintain standards at both individual and instructional level, and finally, providing an effective quality assurance process. Profit margins will always drive a company's success, but this shouldn't be at the expense of safety. If clients know the level of risk they are taking, they are probably more inclined to pay a little more for more robust training to prepare them for 'real world diving' if it reduces the overall associative risk. Maintenance of standards and providing an effective feedback mechanism are essential if improvements in decision-making and problem-solving are to be realised at the individual level.

The scale of the problem needs to be fully appreciated, and this can be achieved by fostering an environment where it is accepted as the norm to submit a report detailing an incident or a near miss and allow access to that data in an applicable timescale. This would allow divers to effect a change in their procedures or processes more quickly should a trend develop or a specific incident occurs. Engendering a 'Just Culture' will, importantly, show that making an error is not something to be ashamed of, as many people are making similar errors. Ultimately, divers need to be responsible for their actions, but for this to happen they need to be educated as to the level of risk they are taking and what can be done to mitigate it. This starts with an educational process which sits at the organisational level and should apply experiences realised through the worlds of aviation and medicine in adopting a 'Just Culture'. Although it will cost money to introduce such a process, and it will be hard to facilitate, especially as diving is perceived as a 'safe' sport, even more so at the 'holiday diving' level, the benefits to the diving community and society as a whole over the long term should not be underestimated.

Bibliography & Cited Works:

Aas, A.L.; (2010). *Industrial Application of Human Factors Safety Standards*. Available [Online] www.idi.ntnu.no/grupper/su/publ/phd/aas-final-thesis10.pdf [12 Mar 2011]

Acott C.J. (2003). *Recreational scuba diving equipment problems, morbidity and mortality: an overview of the Diving Incident Monitoring Study and Project StickyBeak*. SPUMS Journal. 2003; 33: 26-33

Blumberg Micheal A. *Human Factors in Diving. Marine Technology and Management Group*, Univeristy of California. December 1996

BSAC, *Safety Checks* Available [Online] http://www.bsac.com/page.asp?section=2672&sectionTitle=Safety+Checks [18 May 2010]

Chabris C; (2010), *The Invisible Gorilla: And Other Ways Our Intuitions Deceive Us.* Crown Archetype. ISBN 978-0307459657

Cumming B. *BSAC Incident Report Summary*; 2007

Cumming B. *BSAC Incident Report Summary*; various

Cumming B, Peddie C and Watson J. *A review of the nature of diving in the United Kingdom and of diving fatalities in the period 1st Jan 1998 to 31st Dec 2009, 2010.* Presentation to DAN Fatalities Workshop [Online] Available http://www.diversalertnetwork.org/research/conference/2010FatalityWorkshop/proceedings/pdfindex.html [1 Apr 2011]

Denoble, P.J; Caruso J.L.; de L Dear G.; Pieper C.F. and Vann R.D. *Common Causes of Open Circuit Recreational Diving Fatalities*. 2008

Dive Magazine, Letters Page (May 2011); *Incident Query*. Reply by Brian Cummings

Divers Alert Network,[Online], Available http://www.diversalertnetwork.org/medical/articles/article.asp?articleid=51 [6 Jan 2010]

Divers Alert Network [Online], Available http://www.diversalertnetwork.org/research/conference/2010FatalityWorkshop/proceedings/pdfindex.html [28 April 2011]

Elgin, P.D.; Thomas, R.P. (2004). An Integrated Decision-Making Model for Categorizing Weather Products and Decision Aids. NASA/TM-2004-212990.

Endlsey M.R. (1995). *Toward a Theory of Situation Awareness Dynamic Systems*. Human Factors, 1995,37(1),32-64

Exley, S. *Caverns Measureless to Man, Cave Books; 1995*.

Fisk A.D.; Schneider W. *Controlled and Automatic Processing During Tasks Requiring Attention: A New Approach to Vigilance. - Human Factors*, 23, 1981, pp. 737-750

Fryer, D. I. (1969). *Subatmospheric decompression sickness in man.* England: Technivision Services. pp. 343. ISBN 9780851020235

Global Aviation Information Network (GAIN) Working Group E (2004). *A Roadmap to a Just Culture: Enhancing the Safety Environment.* Available [Online] http://www.eurocontrol.int/eec/public/standard_page/safety_doc_just_culture_roadmap.html [1 Mar 2011]

Heinrich, H.W., Petersen, D., & Roos, N. (1980). *Industrial accident prevention: A safety management approach (5th ed.)*. New York: McGraw-Hill.

ICAO Doc 9589, *Safety Management Manual*, First Edition, 2006, Chapter 4.

Linda T. Kohn, Janet M. Corrigan, and Molla S. Donaldson (2000), *To Err Is Human: Building a Safer Health System*; Institute of Medicine (IOM).

Karlsson, L.; D. Linnarson, M. Gennser, S.L. Blogg, Peter Lindholm. (2007). *A case of high doppler scores duringaltitude decompression in a subject with a fractured arm."*. Undersea Hyperb Med. Abstract 34 (Supplement)

Lock, G R; (2010) *Incident Reporting in the UK Recreational Diving Industry – An Assessment of Current Practices and Potential Ways to Improve Them.* [Online] Available http://www.cognitas.org.uk/report.html [1 Dec 2010]

Lock, G.R; (2010) *Risk Management and Human Factors in Recreational Scuba Diving*; Presentation to Eurotek 2010 Advanced Diving Conference.

Lock, G.R; (May 2010). *Request for Information for an Academic Paper on Human Factors with Recreational Scuba Diving*; Correspondence between training agencies and Lock.

Alan Merry

Mitchell, S.J.; (2008) *Respiratory Issues in Technical Diving*, 2008 DAN Technical Diving Conference proceedings pp30.

Mitchell, S.J. *Cardiovascular Disease and Diving. What is the Problem?* Presentation to 2010 DAN Fatalities Workshop. [Online] Available http://www.diversalertnetwork.org/research/conference/2010FatalityWorkshop/proceedings/pdfindex.html [1 May 2011]

Ministry of Defence, JSP 551 *RAF Flight Safety Manual Volume 1 Edition 1*, 2003.

Monaghan R. (1989) *Australian diving death rates comparisons with USA and Japan*. *SPUMS Journal.* 1989; 19: 25.

Nilsson, J. *Dive accident involving a Poseidon Discovery Rebreather, in Øygarden, Norway, 2010-05-08*.

O'Connor P. *The nontechnical causes of diving accidents: Can U.S. Navy Divers learn from other industries?* Undersea Hyperb Med 2007; 34(1):51-59.

Pollock N.W., Vann R.D., Denoble P.J., Freiberger J.J., Dovenbarger J.A., et al. (2007) *Annual diving report - 2007 edition.* Durham, NC: Divers Alert Network; 2007

Reason J. *Human Error*. Cambridge: Cambridge University Press; 1990

Shappell, S., Wiegmann, D., Fraser, J., Gregory, G., Kinsey, P., and Squier, H (1999b). *Beyond mishap rates: A human factors analysis of U.S. Navy/ Marine Corps TACAIR and rotary wing mishaps using HFACS*. Aviation, Space, and Environmental Medicine, 70, 416-17.

Shappell, S.A. and Wiegmann D.A. (1997a). *A human error approach to accident investigation: The taxonomy of unsafe operations.* The International Journal of Aviation Psychology, 7, 269-91.

Shappell, S.A. & Wiegmann, D.A. (1997b). *Why would an experienced aviator fly a perfectly good aircraft into the ground?* In Proceedings of the Ninth International Symposium on Aviation Psychology, (pp. 26-32). Columbus, OH: The Ohio State University.

Shappell, S.A. and Wiegmann, D.A. (1999a). *Human error in commercial and corporate aviation: An analysis of FAR Part 121 and 135 mishaps using HFACS.* Aviation, Space, and Environmental Medicine, 70, 407.

Shappell, S.A. and Wiegmann D.A. (2000) *Human Factors Analysis Classification System (HFACS)* study, US DoT/FAA, Feb 2000.

Skybrary, *Human Factors - Fatigue Manifestations*, [Online], Available http://www.skybrary.aero/index.php/Fatigue_Manifestations_(OGHFA_BN) [1 Nov 2010]

Tetlow, *Formal risk identification in professional SCUBA (FRIPS)*; HSE; 2006

Tetlow, S and Jenkins, S, *The use of fault tree analysis to visualise the importance of human factors for safe diving with closed-circuit rebreathers (CCR), ISSN 0141 0814. International Journal of the Society for Underwater Technology, Vol 26, No 3, pp ??-??, 2005*

Vann Richard D (ed). (1989). *"The Physiological Basis of Decompression".* 38th Undersea and Hyperbaric Medical Society Workshop. UHMS Publication Number 75(Phys)6-1-89.: 437. http://archive.rubicon-foundation.org/6853

Wickens, C. D. & Hollands, J. G. (2000a). *Engineering Psychology and Human Performance (3rd ed.) Chapter 7*. Upper Saddle River, NJ: Prentice Hall. ISBN 0-321-04711-7

Wickens, C. D. & Hollands, J. G. (2000b). *Engineering Psychology and Human Performance (3rd ed.) Chapter 8*. Upper Saddle River, NJ: Prentice Hall. ISBN 0-321-04711-7

Wiegmann D.A. (2003), *A Human Error Approach to Aviation Accident Analysis*. Ashgate.