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An essay on the hazards of human life in the ocean

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Abstract
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This essay is a personal view of the attraction that many humans have to being in the ocean, both with respect to the drivers of that attraction and to its related hazards, which persist despite years of attention. There is no doubt that the pursuit of food, riches and military conquest can explain much of human behaviour both in and out of the ocean but, as is true for any complex human behaviour, a singular gain explanation is limited in applicability. The converse argument that much human activity in the ocean occurs independently of gain is also true. It is a physiological fluke (the low perfusion pressure of the pulmonary arteries and the consequent trapping of venous bubbles) that enables any form of prolonged human hyperbaric exposure without significant neurological injury, and decompression illness remains an enigma. The human attraction to being in the ocean is ancient and is almost certain to continue, providing countless hours of pleasure, reward and disease.

Introduction

This essay addresses the attraction that many humans have to being in the ocean, both with respect to the drivers of that attraction and to its related hazards, which persist despite years of attention. The sub-theme of the essay could be the Latin phrase, 'e mare, a mare', which translates literally to 'from the sea, to the sea'. The associated hypothesis here would be that humans are engaged in a costly reverse evolution for reasons that remain elusive.

What are the drivers for the human attraction to being in the ocean?

The human attraction to being in the ocean is ancient. This essay is not a historical treatise, but Alexander the Great's employment of divers in various military roles could be used to both illustrate the antiquity of diving and to argue that the main driver in this context is primary and secondary gain (gain). There is no doubt that the pursuit of food, riches and military conquest can explain much of human behaviour both in and out of the ocean but, as is true for any complex human behaviour, a singular gain explanation is limited in applicability.

The converse argument that much human activity in the ocean occurs independently of gain is true for some archeological and scientific diving and for almost all recreational diving. Indeed, given the reality of the hazards that humans experience in the ocean, and even allowing for the perceptual inflation of the risks associated with some of these hazards and the deflation of others, this pre-occupation occurs despite many negative influences and often at considerable financial cost.

Jacques Cousteau proposed through the medium of his anthropocentric documentary movies and television programmes that humans are attracted to the ocean in a form of reverse evolution. His romantic theory was based on an analogy of the ocean to the womb and the return of adult humans to the uterine environment. It is easy to parody this by absurdly extrapolating the tides to the ebb and flow of uterine blood flow.

There are several more poignant reasons why Cousteau's hypothesis is flawed. The most important of these are that humans are a 'long evolutionary distance' from the primeval swamp and ocean, are essentially terrestrial, and have little or no residual and/or new adaptation to life underwater. Indeed, with the exception of some concurrent adaptations, such as neuronal and cerebrovascular responses to hypoxia, humans have little or nothing in common with marine mammals in the context of the so-called diving reflexes. This is even true for accomplished diving societies such as the Japanese and Korean Ama, who are well acclimatised but poorly adapted to being in the ocean.

In the context of this argument about any human predisposition to being in the ocean, it is worth noting that it is a physiological fluke (the low perfusion pressure of the pulmonary arteries and the consequent trapping of venous bubbles) that enables any form of prolonged human hyperbaric exposure without significant neurological injury.

For my generation, much of the appeal can be attributed to our heroes and anti-heroes, and to the media that maintained their imagery; Lloyd Bridges as Mike Nelson in *Sea Hunt*, and Hans Hass as himself are obvious examples. It is amusing in this context to recognise that Hass's favourite closed-circuit diving equipment and the oxygen that he used to dive with would be lethal for many mere-mortals.

During World War II, Ken Donald, later Emeritus Professor of Medicine at Edinburgh University, visited this variability in oxygen tolerance; lessons seemingly unknown to many contemporary and consequently temporary technical divers. Donald's navy frogmen are part of the legend of diving that inspired so many of us, as were the mysteries such as Buster Crabb's disappearance without trace during an underwater reconnoitre on a Russian warship in Portsmouth Harbour. Hass himself was considered to be so important that he had considerable freedom of movement during World War II despite being an Austrian behind enemy lines (he was in the Caribbean when war broke out).

The media have been a mixed blessing for the recreational diving industry. Movie characters such as James Bond in *Thunderball* inspired would-be aquanautic 007's, whereas, the anxious were greatly troubled by the mechanical shark that starred in the *Jaws* series. The recreational diving industry has probably been a victim of its own success. The popularity of such diving increased rapidly during the last decade, in large part due to the careful media portrayal of diving as being avant-garde, somewhat dangerous and 'sexy'.

This, of course, was in conflict with the claimed safety record for sports diving, but the spin doctors managed this very well. By the end of the decade, divers had become so commonplace that the social image consequently suffered; other 'out-there' sports were readily available and recruitment and retention suffered. The response has been to develop new forms of recreational diving and to debate the lower age at which it is appropriate to teach children to dive. Although the suggestion is cynical, both of the latter can be interpreted as a direct commercial response to declining markets.

Commercial and military diving has also suffered a recent fall off in interest due to robotics, although not to the extent predicted by the United States Navy in 1983, the collapse of the Soviet Union and the general fall in real terms of the price of oil. Stricken submarines, mine countermeasures and Special Forces operations remain the stimulus to military attention to diving.

This current decline in popularity is probably best seen as cyclic and as a correction to the extraordinary growth of recreational diving in the previous decade, a growth that involved many individuals poorly suited to working and playing in a dense, mobile, non-respirable and unpredictable marine environment. The human attraction to being in the ocean has survived for millennia and is almost certain to continue, albeit with socially influenced troughs and peaks of interest.

The hazards of human life underwater

In general terms, there has been a progression from breath-holding techniques for being in the ocean, to diving using surface supplied breathing apparatus (SSBA), to diving using self-contained breathing apparatus (scuba), and a concurrent attempt to avoid hyperbaric exposure by the use of armour.

Breath-hold diving is accessible and rich in hazard. As cited above, even societies of breath-hold divers may be well acclimatised but are poorly adapted. Immersion causes a centralisation of blood volume and a consequent contraction of blood volume, which can have deleterious effects during and after any subsequent rescue, and loss of lung compliance. Hypothermia is common. Ambient pressure is transmitted through body fluids such that gas volumes change and cause a plethora of barotraumata. Dangerous marine animals are encountered, divers become entangled and for these, and many other reasons, they drown. One of the most important of these reasons is hypoxia of ascent, an event that is made more likely by pre-dive hyperventilation and by hard work while underwater. The onset of hypoxia is unlikely until the diver returns to the surface, as the relevant gas tension is a product of ambient pressure and alveolar oxygen fraction.

Breath-hold diving was also used to salvage sunken sailing ships, a process facilitated by firing of the ships. The advent of bells to assist the diver resulted in breath-hold diving from a compressed gas source; this resulted in even more barotrauma and the increased duration of hyperbaric exposure caused tissue and venous bubble-induced decompression illness (DCI).

Early attempts to armour the diver were naive to the transmission of pressure through fluids and also frequently flooded. Later attempts have become very sophisticated and have enabled very deep exposures. However, to date the robotics industry has not found an effective substitute for the human hand, which has the highly desirable and functional properties of proprioception and torque. Although remote-operated vehicles have replaced divers for many occupational and military tasks, there remain many that are still the province of the diver.

Armoured suits have intrinsic problems in maintaining oxygen and carbon dioxide levels, and in the waste products of additional equipment for propulsion, etc. This is best exemplified by submarines, which are (hopefully) normobaric, sunken, steel cylinders replete with every known industrial environmental hazard.

The recent sinking of the *Kursk* has also highlighted the associated problem of escape and rescue from a stricken submarine. There has been much debate about the likely morbidity and mortality of such events. While the traditional approach to support of a sunken boat has been based on the infrequent occurrence of lung injury and arterial gas embolism in training (about 0.05% of training ascents), it is probable that, in most situations, almost all submariners escaping and/or being rescued from a stricken submarine will be sick or injured.

The ongoing reliance on commercial and military divers and the growing number of recreational divers has been responsible for the development of both SSBA and scuba diving. The invention of effective SSBA quickly increased the depth and duration of underwater exposure. The former resulted in increasing problems with nitrogen narcosis and gas density, and the work of breathing. The latter was manifest mainly as DCI.

Helium and then hydrogen were seen as alternatives to nitrogen; the United States Navy developed oxygen-helium diving schedules more than 60 years ago and hydrogen was used by the Swedish to dive to 500 fsw during World War II. Both gases have advantages and disadvantages (e.g., thermal stress) compared with nitrogen as a diluent gas in diving. Although the various inert and metabolic gases have a differing propensity to bubble formation, relatively if $N_2 = 1$, then He = 0.7 and $O_2 = 0.3$, neither helium nor hydrogen has resolved the problem of DCI. Liquid breathing could, but remains very experimental.

Buhlmann and Keller developed oxygen decompression schedules for a 1,000 fsw dive, which Hannes Keller carried out 40 years ago with lethal outcome for his co-diver and for one of the standby divers. Media pressure and the threat to his funding may have been the major reasons why he embarked on the dive despite a cracked bell and leaking helium supplies. However, this is mere anecdote and rumour. What is clear is that Keller encountered the High Pressure Neurological Syndrome. This syndrome appears to be hydrostatic in nature, such that it could not be prevented by liquid breathing, and may well be the hazard that limits human underwater exploration in the absence of submarines.

The time taken to compress divers to a work site and the very long times needed to decompress to avoid DCI, e.g., 10 days from 300 msw, resulted in an economic incentive to develop saturation diving. Despite the bizarre physiology and predictable psychology of such diving, this development has had health benefits for working divers as the long-term health problems of diving (e.g., deafness, bone infarction, brain injury) appear closely linked to the number of decompressions that a diver performs in their career. The techniques of saturation diving and the current standard operating procedures represent a record of trial and, usually, error. It is not surprising that an escalation of diving in society would involve the antithesis of such equipment-dependent diving, that is, scuba diving; although technical divers seem 'hell bent', literally, on reversing that trend.

Although scuba well pre-dates Cousteau and Gagnon, their invention of a breathing regulator was the stimulus for the still current scuba domination of diving. Three phases of the modern scuba epidemic can be identified. The first was that of untrained, male hunter-gatherers. Mortality and morbidity were relatively high. Equipment was blamed, but then, as now, most underwater accidents were the result of human error. The second was characterised by the expansion of diving training agencies, the adoption of conservative diving practice and by increasing numbers of women and 'environmentalists'. Mortality and morbidity fell dramatically.

The third phase is current and is technologically and not intellectually driven. There are signs that morbidity and mortality are increasing again, but, despite the financial growth of the recreational diving industry in the broadest sense, the denominator of exposure is still unknown such that incidence data are not available. Wreck diving appears more dangerous than cave diving, largely due to the conscientious behaviour of cave-diving organisations in response to earlier alarming death rates.

The use of closed and semi-closed diving apparatus by recreational divers will acquaint this community with the problems of hypoxia, oxygen toxicity and carbon dioxide toxicity so well known to the commercial and military divers who have been using such equipment for more than a century. Few lessons learnt by the latter appear to have been understood by the former.

The mystery of decompression illness

Decompression illness remains an enigma. Although the physical explanations for bubble formation are at variance with observation, it is probable that bubbles form in tissues and venous blood after nearly all dives below 4 msw. Unless there is intra-pulmonary or intra-cardiac shunting and/or pulmonary barotrauma, the arteries remain relatively free of bubbles. The role of the pulmonary arteries in filtering venous bubbles has already been cited.

The result of bubble formation is mechanical, biochemical and vascular disease, which varies from no discernable change in health status for the individual, to death, and everything in between. Research on the subject and especially on the prevention of DCI has been bedevilled by an arbitrary threshold category outcome imposed on this spectrum of disease, which results in a binomial outcome, DCI versus no DCI, where one outcome, DCI, is relatively rare.

Factors such as anxiety, hypochondriasis, insurance, litigation, and proximity to a treatment facility will shift the threshold of reporting to the healthy end of the spectrum, for which the natural outcome remains uncertain. Conversely, the nonsensical concept of safety, which literally means freedom from risk, in diving, the paranoia that accompanies this and consequent denial behaviour will shift the threshold in the other direction. The number needed to treat (NNT) and harm (NNH) for all the conventional modalities used to treat DCI are unknown; dogma and anecdote rule. A shift in emphasis to altering the vascular effects of bubbles has some support. Using cardiac surgical patients as a facsimile for divers, the NNT for lignocaine to prevent brain injury from arterial gas embolism in comparison to placebo one month after the event is about five.

The hazards of human life in the ocean

I am unable to answer simply the question of what are the drivers for the human attraction to being in the ocean. Nevertheless, I am sure that singular theories of gain do not provide an adequate explanation any more than does reliance on theories of media-influenced societal fashions. Certainly, these drivers operate in the context of a rich environment of hazards and despite the limited adaptations that humans have for being in the ocean. What I am sure of is that human activity in the ocean will persist and provide countless hours of pleasure, reward and disease.

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