# SURVIVAL IN COLD WATER
## A Report Prepared for Transport Canada
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# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

1. Currently within Canada's internal lakes and rivers, there are numerous personnel being moved over water during the winter and spring months in vessels without the provision of liferafts. Whether this is an acceptable state of affairs is the question addressed in this research paper.

2. The facts about the dangers of immersion in cold water are as follows:

   (a) There are four clear stages of immersion in which death can occur. These are:

   1. Cold shock (kills within 3-5 minutes after immersion).
   2. Swimming failure (kills within 30 minutes after immersion).
   3. Hypothermia (kills after 30 minutes of immersion).
   4. Post rescue collapse (kills at the point of rescue or up to several hours afterward).

   (b) The cause of death associated with each stage respectively is:

   1. Drowning, heart (circulatory) and respiratory problems.
   2. Impaired physical performance leading to inability to self-help, swimming failure and drowning.
   3. Deep body cooling leading to hypothermia and drowning.
   4. Collapse of arterial blood pressure leading to cardiac arrest.

3. Up until 5-8 years ago, the problems associated with stages 1-2 and 4 have largely been considered of academic interest only. Stages 1, 2 and 4 can have a profound influence on survival probability as the water temperature falls and the sea state worsens. With regard to the condition of hypothermia, for a normally clothed "typical passenger" this is accelerated if whole body exercise is performed in the water (i.e. swimming).

4. Historically, there has been a preoccupation with hypothermia. This has been reflected in the predictive survival curves based on the time to reach hypothermia. Thus, excellent teaching and training programs, standards and equipment have been developed aimed at reducing this specific threat. However, it is now considered that the early responses to immersion (stages 1 and 2) probably account for the majority of open water immersion deaths.

5. Survival prediction curves are of limited value only. This is because they do not take into account that death may occur from cold shock, swimming failure and drowning during early hypothermia. The curves should be revised to include these factors.

6. The initial responses (stage 1) peak in water between 10-15ºC. Swimming failure (stage 2) occurs much sooner in cold water than in warm water, even in proficient swimmers. As a consequence, humans tend to grossly over-estimate their swimming capability in cold water. This is a little known, but central factor in the cause of death.

7. From all the combined research on cold water accidents and scientific research, it has become clear that sudden immersion in cold water, (i.e. below 15°C) is very dangerous. It should be avoided if at all possible. Furthermore, a conscious decision to swim (and rescue oneself) or stay floating still in the water should not be taken lightly without assessing the pros and cons. It has now been shown that a person's swimming ability in warm water bears no relationship to that in cold water.

8. These scientific findings lead to practical advice regarding the regulations requiring the carriage of liferafts and training of operators of passenger carrying vessels.

   (a) Wherever possible entry into water below 15°C should be avoided. Direct entry into a life raft should be the objective.

   (b) Transport Canada should use this philosophy in the design, development and implementation of all new legislation. All vessels operating in Canadian lakes and rivers at 15°C or below should carry liferafts that can be easily launched and boarded by the entire crew and passengers.

   (c) The only exception to this should be where it is physically or practically impossible to stow a liferaft. Under such conditions the passengers must wear inflatable lifejackets when on board.

   (d) Closeness to the shore or the carriage of EPIRB are not a reason for waiving this requirement because death from cold shock will occur within 3-5 minutes, and swimming failure in under 30 minutes. EPIRB responses have averages between 90 minutes and 2 hours.

   (e) The Marine Emergency Duties curriculum should be amended to include the two new Canadian videos on cold shock, swimming failure, hypothermia and post-rescue collapse.

   (f) Even though there are well established teaching programs, regulations and much improved life saving equipment, there are still in the order of 140 000 open water deaths each year. What has been overlooked is the significance of the first two stages - cold shock and swimming failure as a cause of death. The precise details of these are described in this report.

## Sommaire Exécutif

1. Au Canada, un grand nombre de personnes se déplacent sur les lacs et rivières pendant les mois d'hiver et de printemps dans des embarcations non munies de radeaux de sauvetage. L'étude en question vise à établir si cette situation est ou non acceptable.

2. Les faits relatifs aux dangers d'immersion en eau froide sont les suivants :
   (a) On identifie quatre stades distincts d'immersion pouvant causer la mort.

      1. **État de choc dû au froid** (*cold shock*) – le décès se produit dans les 5 minutes qui suivent l'immersion.
      2. **Épuisement à la nage** (*swimming failure*) – le décès se produit dans les 30 minutes qui suivent l'immersion.
      3. **Hypothermie** – le décès se produit dans les 30 minutes qui suivent l'immersion.
      4. **Effondrement post sauvetage** – le décès se produit au moment du sauvetage ou dans les heures qui suivent.

   (b) Pour chacun des stades susmentionnés, on attribue dans l'ordre la cause de décès suivante :
      1. Noyade, problèmes cardiaques (circulation) et respiratoires.
      2. Perturbation des capacités physiques entraînant l'incapacité de s'aider et de nager menant à la noyade.
      3. Refroidissement corporel entraînant l'hypothermie et la noyade.
      4. Chute de la tension artérielle entraînant un arrêt cardiaque.

3. Au-delà des cinq à huit dernières années, les problèmes associés aux stades 1, 2 et 4 ont été d'intérêt purement théorique. Cependant, les stades 1, 2 et 4 peuvent avoir une incidence importante sur la probabilité de survie surtout lorsque baisse la température de l'eau et que se détériore les conditions en mer. En ce qui concerne le stade 3, pour le «passager typique» vêtu de façon ordinaire, l'hypothermie survient plus vite lorsque ce dernier fait un effort considérable (comme la nage).

4. L'hypothermie (stade 3) a longtemps été au centre des préoccupations. Cela se voit aux courbes prévisionnelles de survie à l'hypothermie établies selon la température de l'eau et la durée d'immersion. Par conséquent, d'excellents programmes de formation et d'entraînement ainsi que des normes et des dispositifs de sauvetage ont été développés dans le but de réduire cette menace particulière. Toutefois, on considère maintenant que les réactions initiales à l'immersion (stades 1 et 2) comptent pour la majorité des décès dus à l'immersion en eau libre.

5. Les courbes prévisionnelles de survie ne sont pas très utiles, car elles ne tiennent pas compte du fait que le choc dû au froid (*cold shock*), l'épuisement à la nage (*swimming failure*) et la noyade dans les premiers stades de l'hypothermie peuvent également entraîner la mort. Ces courbes doivent être révisées pour inclure ces facteurs.

6. Les réactions initiales (stade 1) sont à leur maximum lorsque la température de l'eau se situe entre 10 et 15$^{o}$C. L'épuisement à la nage (stade 2) a lieu beaucoup plus rapidement en eau froide, même chez les bons nageurs. Par conséquent, les gens tendent à surestimer de beaucoup leurs capacités de nageur en eau froide. Il s'agit d'un facteur peu connu, mais primordial à la survie.

7. Selon la recherche scientifique et les études menées sur les accidents en eau froide, il est maintenant clair que l'immersion soudaine en eau froide, c'est-à-dire à des températures au-dessous de 15$^{o}$C, est très dangereuse. Elle doit être évitée autant que possible. Par ailleurs, la décision de nager (pour se secourir soi-même) ou de rester immobile dans l'eau ne doit pas être prise à la légère. Il faut absolument tenir compte de tous les facteurs. Il a maintenant été démontré que les capacités d'un nageur en eau tempérée n'ont aucun rapport avec ses capacités en eau froide.

8. Ces constatations scientifiques donnent lieu à des conseils pratiques en ce qui concerne la réglementation sur la présence de radeaux de sauvetage et la formation des opérateurs de navires à passagers.

   (a) Autant que possible, il faut éviter l'immersion en eau froide lorsque la température de l'eau est au-dessous de 15$^{o}$C. L'objectif doit être un transfert direct aux radeaux de sauvetage sans immersion.

   (b) Transport Canada doit incorporer cette philosophie dans la conception, l'élaboration et l'application de toute nouvelle loi. Au Canada, toute embarcation qui se déplace sur des lacs et des rivières dont l'eau est à 15$^{o}$C ou moins devrait être munie de radeaux de sauvetage qui peuvent facilement être mis à l'eau et accommoder l'équipage et les passagers au complet.

   (c) La seule exception admissible serait le cas d'embarcations qui ne peuvent se doter de radeaux de sauvetage pour des raisons physiques ou pratiques. Dans de telles circonstances, les passagers doivent tous porter un gilet de sauvetage à bord.

   (d) La proximité des berges ou la présence à bord d'une RLS ne justifie pas une exonération, car l'état de choc peut tuer en 3 à 5 minutes et l'épuisement à la nage, en moins de 30 minutes. L'intervention d'urgence en réponse à la RLS met en moyenne entre 90 minutes et deux heures.

(e) Le programme d’études des fonctions d’urgence en mer doit être modifié afin d’y inclure deux nouveaux vidéos canadiens sur l’état de choc dû au froid, l’épuisement à la nage, l’hypothermie et l’effondrement post sauvetage.

(f) Même s’il existe une réglementation et des programmes de formation bien établis, ainsi que des dispositifs de sauvetage très perfectionnés, les décès en eau libre sont tout de même de l’ordre de 140 000 par année. Ce qui semble avoir été négligé, c’est le rôle important que jouent des deux premiers stades – l’état de choc dû au froid et l’épuisement à la nage – dans la cause de décès. Le rapport décrit ces deux stades en détail.

# CHAPTER 1

## THE PROBLEM

Currently within Canada, there are hundreds of thousands of persons being transported for business or pleasure over inland waterways, lakes and rivers. Depending on the local climate, transportation may occur throughout the year or be limited to when the passage is ice free. Irrespective, for a large portion of the year, particularly the winter, spring, and early summer, the water is cold.

Recently, (June 2000), there has been an accident in Georgian Bay where two children drowned after the True North ll sank within two minutes (Reference 64). The question has been asked as to what steps should be taken to prevent this from re-occurring. Carriage of lifejackets is already mandatory. Should there be any change in the regulations? Carriage of liferafts within Canada's internal waterways is not mandatory when operating close to shore. Should a change of policy be made on this requirement? Finally, if there are to be any changes in policy on the wearing of lifejackets or carriage of liferafts, should it be related to the physical water temperature at the time the vessel is operating? These questions will be addressed in the following chapters with conclusions and recommendations.

## INTRODUCTION

Records of death from immersion in cold water date back to ancient times. Circa 450 BC, Herodotus (Reference 28) wrote of the sea borne expedition against Athens by the Persian general Mardonius. He clearly distinguished drowning from hypothermia, when he wrote, "Those who could not swim perished from that cause, <u>others</u> from cold." (Reference 18) In spite of hundreds of thousands of maritime disasters, the precise medical cause of death has been rarely noted. Death has commonly been ascribed to "drowning" or being "overcome by the sea". In the 18$^{th}$ and 19$^{th}$ century, James Lind (1762) mentioned the dangers of collapse after rescue (Reference 39), and James Currie (1797) observed deterioration of his subjects before improvement (Reference 9).

Loss of life at sea was accepted as an occupational hazard. Wrecking was not made illegal until 1807 and the Royal Navy's use of impressments was not abandoned until 1815. Thus, such items as lifejackets, which could be used to aid escape were not encouraged. Shipwrecked sailors had to cling to wooden spars, and water and rum barrels. With the advent of iron ships around 1850, not only did the ships sink faster, but also there was less flotsam for flotation. Consequently, there was an increase in the loss of life at sea. In 1871, it was reported that 2740 British seamen lost their lives through drowning (Reference 5).

No one paid attention to the observations by Lawrence Beesley (1912) (Reference 4). He was a survivor from the Titanic who noted that the victims wearing lifebelts and in cold, but calm water had died of cold. The official cause of death was given as drowning. Nor did the large loss of life during the First World War bring about change. Hill and Campbell's appendix to the Merchant Shipping Advising Committee Report on Life Saving Appliances in 1922 (Reference 46) is the first formal acknowledgement of the dangers of "cold". It was the inadequacies of life saving equipment during the Battle of the Atlantic in the Second World War that was the catalyst for scientific examination of the problem.

As Golden (1996) (Reference 19) clearly pointed out, official inquiries in an endeavour to prevent a recurrence, have been more interested in the cause of disaster than the cause of death of the crew and passengers. The recent issue of the Marine Investigation Report by the Transportation Safety Board of Canada on the sinking of the "True North ll" in Georgian Bay June 2000 extends to 63 pages (Reference 64). There are only five sentences assigned to the fact that two grade seven students died. One of the sentences curtly states: "The bodies were subsequently examined by the coroner who determined that the cause of death was drowning." There has been no thought put into why they drowned or even if they could swim in the first place. Thus, both funding and direction for research has sadly lagged behind the technological advances in ship design.

**THE KNOWLEDGE: PHYSIOLOGY OF THE IMMERSION INCIDENT TO 1995**

The Medical Research Committee (Reference 44) published a pamphlet in 1943 on "The Guide to the Preservation of Life at Sea After Shipwreck". This was based on the observations of naval medical officers who had treated survivors, and on 279 survivor interviews. This was the basis from which all the modern physiological research has been conducted.

Two other reports were to follow after the War that revealed the shocking loss of life at sea which could have been prevented. The first was the Talbot Report (Reference 55) published in 1946.This showed the inadequacy of the RN lifebelt and the Carley type floats. Over 30 000 men died after escaping from their ships, in other words, during the survival phase. The second was the Medical Research Committee report by McCance et al (1956) which investigated "The Hazards to Men in Ships Lost at Sea 1940 – 1944" and examined the cause of death at sea in greater detail (Reference 43).

The pioneering work post-war was conducted under the auspices of the Royal Navy Personnel Research Committee and subsequently the Royal Navy Institute of Naval Medicine. This was basically summarized in Professor Keatinge's monograph (1969) (Reference 35). As a result of all the aforementioned information, it had become clear that the human body cannot maintain its internal temperature when immersed in water below 25ºC when conscious and shivering.

The body temperature must progressively fall until death occurs. However, there was much more to the problem than this.

Golden and Hervey (1981) (Reference 18) identified four distinct stages in which a human immersed in cold water may become incapacitated and die. However, what is most important to note is that stages 1, 2 and 4 were largely regarded as of academic interest only; so they did not have a large effect on survival policy, international regulations and survival equipment. All of the effort was concentrated on predicting the onset of hypothermia. Thus, there is still no consideration given to the physiological impact resulting from the first two stages of immersion in the design of emergency equipment. For instance, flares are still vacuum packed in polythene bags and as in the Estonia accident were not usable simply because no one had the grip strength or the tactility to open the bags. The bailer in the Estonia liferaft was wrapped in polythene and after attempting to open it with his teeth, the survivor finally gave up after he had lost several teeth!!

**1. <u>Initial immersion or cold shock</u>**

On initial immersion, there is a large inspiratory gasp followed by a four-fold increase in pulmonary ventilation, i.e. severe hyperventilation. This on its own can cause small muscle spasms and drowning. Along with this, there is a massive increase in heart rate and blood pressure. These latter cardiac responses may cause death, particularly in older, less healthy people. These effects last for the first two to three minutes, just at the critical stage of ship abandonment.

**2. <u>Short-term immersion or swimming failure</u>**

Death at this stage, between three and thirty minutes after immersion, appears to affect those who try to swim. It is also known that even good swimmers may be unable to swim for more than a few minutes in very cold water. “A good swimmer aged 20 recently disappeared within 5 minutes while he was trying to swim 50 yards from an overturned dinghy in calm water of a reservoir at 10ºC-11ºC.” (Reference 36). The cause was thought to be due to the respiratory and cardiovascular responses already started in the initial immersion. An alternative theory was that the cold water contact with the nose and mouth induced the “diving response”. This causes breathing to stop (apnea), a slowing of the heart rate (bradycardia) and even cardiac arrest (asystole).

**3. <u>Long-term immersion or hypothermia</u>**

After thirty minutes or more of immersion, death may occur from hypothermia. The reason for this is that water has a specific heat 1000 times that of air and a thermal conductivity of about 25 times that of air. Thus, when a body is immersed in water below body temperature (37ºC), it will inevitably cool to hypothermic levels at a rate dependent on:

- Temperature differential
- Clothing insulation
- Rate of agitation of the water
- Body heat production produced by shivering and exercise
- Ratio of body mass to surface area
- Subcutaneous fat thickness
- State of physical fitness
- Diet prior to immersion
- Physical behaviour and body posture in the water

As the deep body temperature falls, humans lapse into unconsciousness. Death may occur in two ways – drowning through incapacitation, and cardiac arrest. Death from drowning will occur in a lightly dressed individual even wearing a lifejacket, approximately one hour after immersion in water at 5ºC, or two hours in water at 10ºC, or in six hours or less at 15ºC (Reference 19).

If the deep body temperature continues to fall, death occurs on average from cardiac arrest somewhere below a body core temperature of 24ºC. The lowest recorded survival temperature in an accidental victim is 13.7ºC (Reference 13). However, after surgical induction of hypothermia, there has been one reported incident of resuscitation from a body core temperature of 9ºC (Reference 48). Survival predictions were made from experimental data and case histories from shipwrecks.

The first classic survival curve was published by Molnar in 1946 (Figure 1, Reference 47). Included in here was the data from the Dachau prisoners (Reference 1). Survival predictions were later produced by Hall (1972) (Reference 21), and by the Canadian Red Cross from work conducted by Professor Hayward (1975, 1977, 1984) at the University of Victoria (Fig 2 Reference 23, 24, 25, 26).

A later predicted survival curve was published by Hayes et al (1987) derived from Professor Eugene Wissler's Cold Water Survival Model (Figure 3, Reference 22). From this and the combination of previous work, Tikuisis (1995, 1997) has published the latest prediction of survival time at sea level based on observed body cooling rates (Reference 57, 58).

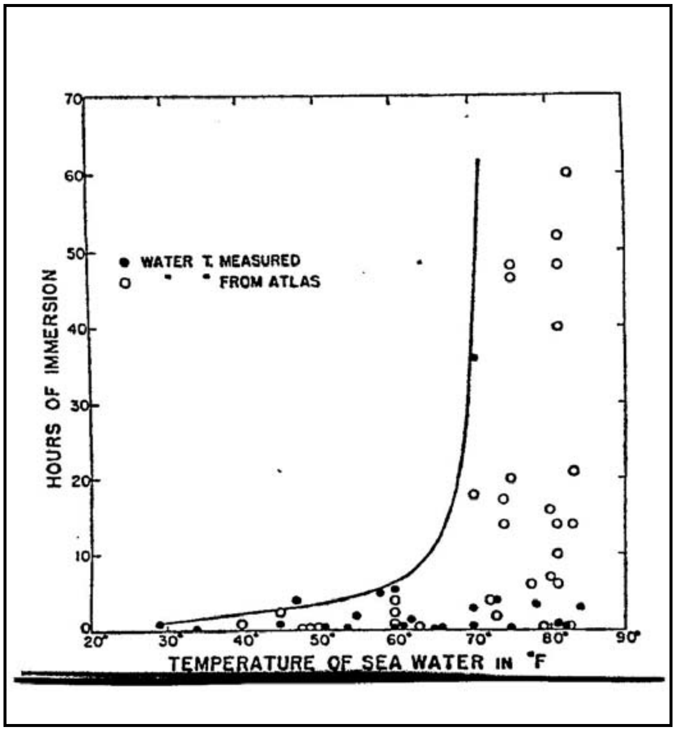


**Figure 1 (After Molnar 1946)** – Duration of immersion of shipwreck survivors in ocean waters of diverse temperatures. The data are from the files of the Bureau of Medicine and Surgery, US Navy. Open circles, sea-water temperature was measured at time of rescue. Black dots, sea water temperature was obtained from the World Atlas of Sea Surface Temperatures on the basis of date and location of shipwreck or rescue. Each point represents the survival of at least one person.

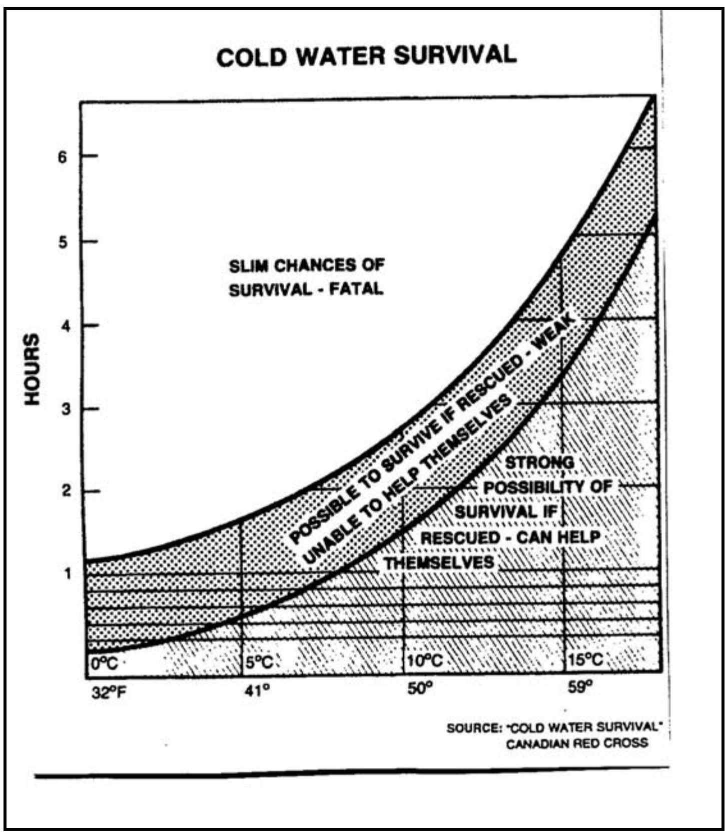


**Figure 2 – Cold Water Survival (Canadian Red Cross)**

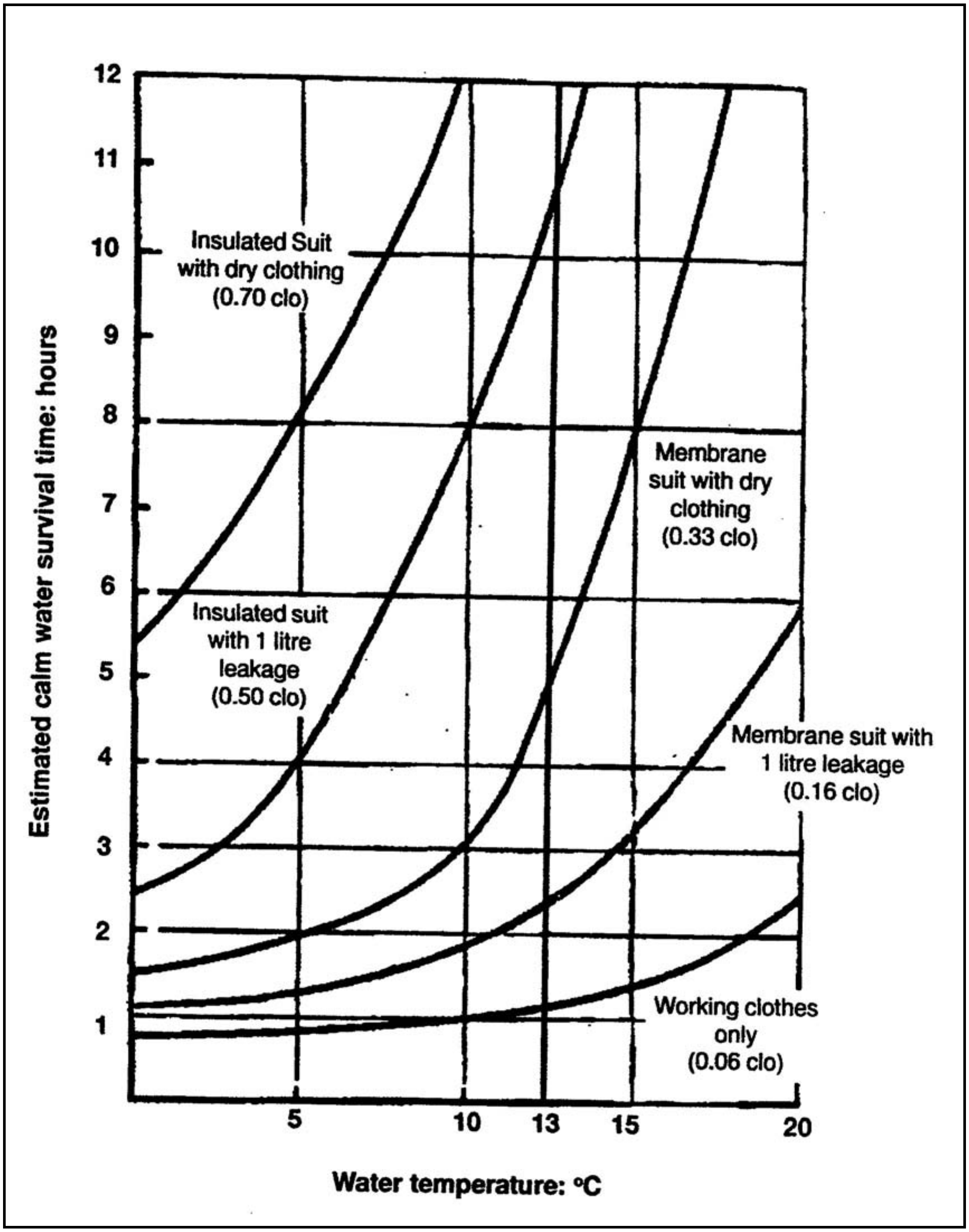


**Figure 3:** Predicted survival time against sea temperature for different levels of immersed clothing insulation – as derived from Wissler Model, Modified by Hayes, 1987.

A summary of current predictive curves is given in Oakley and Pethybridge (1997) (Figure 4, Reference 50). From this work, it became possible to give advice that survival times could be extended if the survivors stayed still in the water and did not attempt to swim to keep warm. Furthermore, adopting a fetal position with legs together and arms to the side, or folded across the chest prolonged survival time. (Reference 14, 24, 32) All of these predictive curves are premised on the fact that the person using the curves is prepared to accept the assumption that death is due to hypothermia. They are all based on time to incapacitation.

| Water temp. | Molnar, 1946[47] | Keatinge, 1969[35] | Nunnely & Wissler 1980[49] | Allan, 1983[2] | Lee & Lee, 1989[38] |
|---|---|---|---|---|---|
| 5°C | 2.3 | 0.9 | 1.1 | 1.5 | 1 |
| 10°C | 4 | N/A | 2.6 | 2.5 | 3 |
| 15°C | N/A | 4.5 | 3 | 9 | 7 |

N/A is used to indicate that the author(s) did not provide an estimate for that water temperature.

**Figure 4:** Predicted periods (in hours) of immersion at different temperatures which are expected to result in "likely death". After Oakley and Pethybridge (1997).

## 4. Post-rescue collapse

Up to twenty percent of immersion deaths occur during extraction from the water, or within hours after rescue (Reference 19). This was first noticed in 1875, by Reinke, a police surgeon in Hamburg. He recorded cases of sailors who had fallen into the canals and harbour and died within 24 hours of being rescued. (Reference 16) During the Second World War, the Germans and Allies noted that some of those who were rescued alive, died shortly afterwards. Matthes (Reference 41) noted how ditched German aircrew who had been conscious in the water and aided in their own rescue, became unconscious and died shortly afterwards. McCance et al, 1956 (Reference 42) found that seventeen percent of those shipwrecked survivors rescued from the water at 10ºC or less died within 24 hours of rescue. None of the people rescued from water above 20ºC died.

When the Wahine Ferry sank in 1969 in Wellington Harbour, Mercer (Reference 45) reported that, of the 51 lives lost, twelve were alive on rescue, but died shortly afterward. In the 1994 Estonia accident, at least one person who was noticed to be alive in the water, lost consciousness when in a helicopter hoist, fell back into the sea and died. An extensive list of post rescue collapse incidents is reported in Golden's articles on shipwreck and survival (Reference 16) and Golden and Hervey's article on the after-drop and death after rescue from immersion in cold water (Reference 18).

## THE DEVELOPMENT OF STANDARDS AND EQUIPMENT

Although the existence of the lifejacket has been known since biblical times (Reference 5), the first standard for lifesaving equipment did not appear until 1852. At this time, the United States introduced the requirement for "every (river) vessel, carrying passengers to be provided with a good life preserver…". This was followed by similar legislation in France (1884), Britain (1888), Germany (1891) and Denmark (1893). Following the Titanic accident, the International Maritime Organization formed the Safety of Life at Sea (SOLAS) committee, which required lifejackets to be carried on all passenger vessels. Most of the resolutions made in 1912 were not implemented until post-1918. Following the Vestris accident in 1928, men, women and children were noted to be lying face down and drowned in spite of wearing a life jacket. However, the second SOLAS convention precipitated by this accident ignored these facts and nothing in the lifesaving appliances regulations was changed. In the first forty-eight years of the 20$^{th}$ century, both naval and merchant navy philosophy was directed at keeping people floating in the water. Little attention was paid to whether they floated face up or face down. It was not realized that allowing people to float in cold water without protective clothing was very dangerous until (a) midway through the Second World War when the pioneering work of Macintosh and Pask established flotation angles and self-righting criteria for lifejackets (Reference 51, 52, 53); (b) the publishing of the Talbot Report (Reference 55); and (c) McCance et als' paper (Reference 43).

As a result, the SOLAS conventions of 1974, 1978, 1981 and 1983, concentrated on the prevention of hypothermia, i.e. stage three of the immersion incident (Reference 30, 31). This was done by establishing standards for life saving appliances, that is lifejackets, liferafts, and buoyant apparatus. What the international standards did not take into consideration was the effect of water temperature on the application of the standards. This has been left up to individual nations to legislate.

In summary, from 1945 until 1995 a great deal of scientific, industrial, training and legislative effort has been put into the prevention of hypothermia. As a result, in both Europe and North America, particularly Canada, there are very good survival suit regulations. There is also a very good training program on the prevention of drowning and the prevention of hypothermia conducted by the Red Cross and the Life Saving Society; this is strongly supported by the US and Canadian Coast Guard. Yet, there are still over 140 000 open water deaths worldwide each year (Reference 17). There are better international standards and education than ever before, so what is happening?

# CHAPTER 2

## THE INITIAL RESPONSES TO IMMERSION (STAGE 1 AND STAGE 2) - NEW SCIENTIFIC INFORMATION SINCE 1975

It has now become clear that over half of the immersion-related deaths occur during the first two stages of immersion, i.e. cold shock and swimming failure. However, as stated previously, investigators still concentrate on the cause of the marine accident and not the precise cause of an individual's death. It is still hard to accurately document at what stage of the immersion death occurred. This is because little history has been gathered from survivors or by investigators. It is only possible, to a limited degree, to estimate the cause of death from a newspaper report or the scant information in the accident investigation. The problem is further compounded by the fact that such a good job has been done educating people on the dangers of cold water, immersion and hypothermia, that even the pathologists now list the cause of death as hypothermia, even though the cold, wet body on their autopsy table actually died from cold shock or swimming failure and drowning.

The author was concerned about the Canadian general public's ignorance of the dangers of cold shock and swimming failure. Therefore, in conjunction with the Canadian Navy and the National Search and Rescue Secretariat, he produced, in 1998, a new training video on this topic titled "The Cold Facts – Surviving Sudden Cold Water Immersion". It is now available from Intercom Films in Toronto. As a follow on to this, he updated the knowledge on hypothermia and post-rescue collapse with the same sponsorship. The new video, "More Cold Facts – Hypothermia and Post Rescue Collapse", will be available in August 2001.

Furthermore, there has now been more research done on loss of tactility in cold water during the first 10-15 minutes of immersion (Reference 68). During this time, the cold water renders the limbs useless, and particularly the hands. It can become impossible to carry out any self-rescue procedures. This only enhances the possibility of perishing before hypothermia is established.

### STAGE 1 – COLD SHOCK

Although cold shock or an increased respiratory response to cold water has been known for many years (Falk 1884) (Reference 10), the practical significance of this response has only really been evaluated in terms of its practical importance in the last 20 years. When considering at what water temperature protection should be provided against the initial responses to cold water immersion, it is now known that the cold shock response begins at water temperatures below 25ºC (Reference 33) and peak at a temperature between 10-15ºC. (Reference 60, 61) This is in part, the explanation for deaths that occur in water as high as 15ºC long before standard survival curves would predict. It is now thought by many that the pressing threat to otherwise healthy individuals is the respiratory distress evoked by immersion and the consequent inability to control breathing and breath hold.

**Breath Holding Ability And Ability To Control Breathing Rate**

This is very critical for all who abandon ship into cold water. If they abandon dry shod into a liferaft, there is no problem. However, if they abandon ship into cold water, unless they are mentally and physically prepared for the cold shock, are protected with a survival suit, a lifejacket and a spray hood, they may drown in the immediate abandonment due to the inability to control breathing in the first three minutes of immersion. It is not just a problem of not being able to breath hold; if you are in choppy water, there is an inability to coordinate and control breathing with wave splash. This is a typical scenario for passengers on tourist vessels in Canada's lakes and rivers in spring and early summer.

Sterba et al (1979) (Reference 54) investigated breath holding capability of humans in water ranging from 15ºC-35ºC. They concluded that breath holding ability at 15ºC was approximately 30% of the non-immersed values.

Hayward et al (1984) (Reference 27) showed clearly that there is an inverse relationship between water temperature and breath hold ability. Thus, for abandonment in 25ºC water, average breath holding is 38 seconds, whereas for 15ºC, 10ºC and 5ºC water it is 28, 24, and 19 seconds respectively. They concluded that breath holding time in water below 15ºC was 25-50% of the presubmersion level. Their predictive curve was recently validated at the higher end of the scale by Cheung et al (2001) (Reference 6) in 25ºC water following a breath holding experiment. Two hundred and twenty eight subjects participated and the average breath hold time was a mean of 39.8 ± 21.1 seconds.

**Manual Dexterity**

The ability to do such tasks as activate the life jacket inflation device (if fitted), climb into a life raft, cling to a becketted line or activate a flare depends on manual dexterity and grip strength. The ability of muscle to produce force is reduced when its temperature falls below 27ºC. This can occur in as little as 20 minutes in water at 12ºC. (Reference 3) Vincent and Tipton (1988) (Reference 68) showed that the maximum voluntary grip strength (MVGS) of subjects who immersed their unprotected hands or forearms in 5ºC water was reduced by 16% and 13% respectively, and that wearing a glove significantly reduced the MVGS by 16% in air and with the hand glove and water immersion combination, the reduction was 31%. Research has also shown that hand grip strength was reduced by up to 60% (Reference 7, 8, 20, 29), manual dexterity was reduced by 30% (Reference 11, 37, 56) and speed of finger flexion was decreased by 15-25%.

The sinking of the Hudson Explorer on Christmas Day 1981 in the freezing water off the Gulf of St. Lawrence is a classic example where cold extremities contributed to the death of five seamen.

> *The raft was overcrowded. The night was pitch black. The deck lights had gone out a short time before. They could hear air escaping. They could feel freezing water coming up around them. A spirit of* sauve qui peut *seized them all. Six men made it back to the deck. They were helped by the captain and Kennedy to scramble up the ship's side. Their desperate plight may be imagined from the fact that some of them were so chilled by wind and water that they climbed the ladder using knees and elbows rather than hands and feet. Five others fell into the sea and were lost. Perhaps some of them were simply too cold to be able to climb up the ladder.*
> (Quotation from The Hudson Transport Report of Formal Investigation No. 109. ISBN 0-660-51972-0)

**<u>Practical Evidence That Cold Shock Kills</u>**

Death from cold shock is not uncommon. These are typical examples that are regularly reported in the Canadian press each year.

*Globe & Mail, April 16, 1998*

*<u>Teen drowns after lunch-hour plunge</u>*

*Toronto – A 14-year-old high-school student drowned yesterday after jumping into the frigid water of Lake Ontario.*
*Hours after the incident, police still did not know why Peter Arthur went into the water, which was only about 4 degrees. There were two other teenagers with him at the time.*
*When Peter failed to surface, his friends sought help from nearby construction workers, who called the police.*
*When they arrived they jumped into the lake, which is about 3½ metres deep at that location, and searched for the missing teen for 10 minutes, until the icy water forced them to shore Sgt. McCann said.*
*As the two officers sat on nearby rocks, huddled in blankets, members of the Toronto police marine unit arrived and took over the search. Dragging the area with a net, they located the teen, who by that time had been in the water for about 30 minutes.*
*Firefighters performed cardiopulmonary resuscitation until paramedics arrived to continue treatment. But Peter was pronounced dead at Toronto East General Hospital at 12:55 p.m.*

*Globe & Mail, January 3, 2000*

*<u>Reveller drowns after attempting polar bear swim</u>*

*A man celebrating the New Year at a party on a frozen lake drowned when he jumped into a hole cut in the ice.*

*Adrian Weber, 38, was playing hockey with 25 friends on New Year's Eve on Kingsmere Lake when he attempted a polar bear swim between two holes cut two metres apart in the ice.*

*Mr. Weber dived in at 1:30a.m. When he failed to resurface, friends jumped in but were unable to find him.*

*His body was recovered Saturday by firefighters, close to the spot where he had jumped in.*

*"The water was only about waist deep and he tried to swim between the two holes," his 44-year-old brother Christoph Weber said. "He must have got disoriented."*

*"His friends dove in right away with a rope and tried to find him. They drove a car onto the ice and pointed the headlights of the car toward the hole to get some kind of light onto the lake. It was dark and hard to see anything."*

*Mr. Weber said his brother was healthy and a good swimmer.*

*Globe & Mail, January 3, 2001*

<u>*MDs urge 'polar bear' swimmers to stop*</u>

*Doctors are urging self-styled "polar bear" swimmers across Canada to abandon their annual rite after a New Brunswick man died during a New Year's Day plunge.*

*Ringing in the New Year by jumping into freezing water is a bad idea for anyone, regardless of age or health, said Dr. Kenneth Melvin, a cardiologist at Toronto General Hospital.*

*"Even if you're in good health, this is bad for you," he said. "And if you're of middle age, and there's some question as to what your cardiac status could be, this is really playing with fire."*

*Mail Star Chronicle Herald, March 9, 2001*

<u>*Hope fades in Newfoundland for teens swept into ocean in Pouch Cove*</u>

*Hundreds of people lined the shore of this tiny coastal community Thursday night as hope faded for three teens who were swept into the ocean while playing on ice floes. Police said four males between the ages of 16 and 18 were jumping from ice cake to ice cake about 50 metres from shore when one of them fell into the frigid water and slipped under the ice. The others tried to rescue him, but two were knocked into the ocean by a wave. The fourth teen made it back to shore. A woman who didn't want to be identified said people on shore tried to rescue the teens with a rope. She said one of them tried to grab the rope, but was too weak and couldn't hold on.*

There are several common threads in these accidents:

- the victims were good swimmers
- the water was cold
- death occurred within a matter of only minutes - much too early for hypothermia to set in
- they were all healthy people
- they were all in shallow water
- the accidents occurred within feet of the shore.

Most important, there was potential help at the scene of the accident, but no one recognized the danger of sudden death from cold shock in an otherwise healthy person.

This is the precise reason why standards for wearing lifejackets and / or carriage of liferafts must not be relaxed when operating in cold water. Carriage of EPIRBs (with their 90 minute to 2 hour response time), and the fact that the vessel may be operating in a group or close to shore is not a reason for a waiver.

The clear message is that sudden entry unprotected into cold water is very dangerous and should be avoided wherever possible. This applies to everyone whether commercial operators or recreational boaters.

## STAGE 2 : SWIMMING FAILURE

It has now become apparent that much more emphasis must be put on swimming failure as a cause of death. It must also be understood that ability to swim in warm water is no indication of how well a human can swim in cold water. The classic testimony heard in the coroner's court is: "We saw him go over the side, he started to swim and by the time we had the boat turned around and tried to identify where he was lost, he had disappeared. How could that be? He was an excellent swimmer."

These are not rare events either and are commonly reported in the newspaper.

*Halifax Herald, June 18, 1996*

*A sad start – two accidents in one weekend*

*In Chester Basin, a 37-year-old woman drowned while attempting to swim across Gold River to the Goldwater Marina. About forty people including RCMP, firefighters and Coast Guard personnel undertook a search. Her body was found an hour later.*
*[In a separate incident], a 30-year-old man who apparently overexerted himself swimming in Halifax's Chocolate Lake on Sunday afternoon has a 15-year-old girl to thank for helping save his life.*

*Michelle Yetman was suntanning with a friend shortly after 5 p.m. when she heard cries for help coming from the water. At first she thought it was just children playing around, she said.*
*But then she realized it was for real. " I guess he lost his breath…so I ran in the water and swam as fast as I could to get out there," said Michelle, who happens to be a junior lifeguard. "It was so cold, I felt like I was hitting ice."*
*When she reached the man, she helped the woman he had been swimming with – who had called for help – keep him above water until another rescuer arrived in a canoe. Then she helped load the man into the canoe, which took him to shore.*

Markle (1991) in his study of life-saving appliances (Reference 41) cites a classic example of swimming failure in 15°C water.

*FISH-N-FOOL February, 1987*

*The FISH-N-FOOL capsized in a 20 ft high wave about 4 miles off the mainland of Baja California, and 2 miles from an island. Twelve people were forced into 59°F [15ºC] water. Three of them apparently died shortly afterward, directly or indirectly as a result of injuries sustained in the capsizing. One survivor – the alternate operator – managed to stay near the capsized boat hanging onto a hatch cover and a barrel. About an hour later, the boat turned in the water in such a way that its four trapped lifefloats and EPIRB were released. She lashed the life floats together and secured a board over one of them to provide a platform on which she could sit and stay relatively dry. She made sure the EPIRB was operating and then awaited rescue by a Coast Guard helicopter over seven hours later.*
*The other eight survivors became separated from the capsized boat. As a group, they decided to swim for the island. Four of them found debris including an ice chest, a bleach bottle, and a piece of plywood to provide flotation. Only one was still alive 6 hours later when he got close enough to the island to call for help from fishermen on shore.*

Tipton et al (1999) (Reference 63) studied the deterioration of swimming performance after the subjects had adapted to the stage one cold shock respiratory responses. All ten competent swimmers completed a 90-minute swim in 25ºC water; eight completed the swim in 18ºC water. In 10ºC water, five swimmers completed 90 minute swims, four were withdrawn between 22 and 50 minutes close to swim failure and one was withdrawn at 61 minutes close to swim failure. Stroke rate and length were similar in 25ºC and 18ºC water throughout the swims, but in 10ºC water the stroke rate was increased and the stroke length decreased. These changes were most pronounced in those close to swim fatigue. Stroke length decreased by 50% during the last 30 minutes for the swimmer who reached swim failure in 61 minutes.

Coincident to this, the average swimming angle increased from an average of 18ºC at the start of the swim to 24ºC at the end of the swim. The swimmer who reached swim failure finished with a swim angle of 35ºC. After 15-30 minutes in 10ºC water, swimmers' fingers were splayed and started to flex. At the end of the swims, swimmers reported that it became increasingly difficult to straighten their limbs and coordinate swimming movements. Grip strength was not altered by swimming in water at 25ºC, but in water at 18ºC and 10ºC, it was significantly decreased by 11% and 26% respectively.

Wallingford et al (2000) (Reference 69) investigated the factors which limit cold water swimming distance while wearing a personal flotation device. Five female and twelve male subjects took part in a swim in 14ºC water. The subjects swam an average of 889 metres before swim failure. There was no correlation between distance swum and percentage body fat, aerobic fitness and abdominal skinfold thickness. However, those who swum the greatest distance had a significantly larger tricep skinfold thickness.

Wallingford et al. agreed with the conclusion made by Giesbreicht (1995) (Reference 12) that the majority of the decrement in arm performance is due to the local cooling of arm tissue and not due to hypothermia. Wallingford's study did not support the assumption made by Hayward et al (1975) (Reference 23) that hypothermia could be responsible for the inability to swim in cold water while wearing a personal flotation device. If Hayward's prediction was correct, the swimmers would have covered a distance of 2058 metres before incapacitation. This was more than double the distance of 889 metres covered by the subjects long before incapacitation from hypothermia (end average core temperature of 35.8ºC).

**<u>Potential for Cardiac Arrhythmias</u>**

Tipton (1989) (Reference 59) had already documented the initial cardio-respiratory responses to immersion in cold water, i.e. the massive increase in heart rate and blood pressure within the first three minutes of immersion. Then in 1994, Tipton et al investigated the cardiac responses to submersion in water of 5ºC and 10ºC. (Reference 62). Ectopic arrhythmias (irregular heartbeats) were observed in 11 of the 12 subjects in 29 of the 36 submersions. These occurred immediately after breaking of breath hold, i.e. just at the time after jumping into the water and having to take a breath. They were benign in most cases, (i.e. they were of short duration, supraventricular in origin and producing no symptoms). However, this may not be the case for an aging population of tourists that may have to abandon a vessel in cold water, such as the St. Lawrence River or one of the Great Lakes. For those with a potential heart conduction defect, the heart is likely to be very susceptible to sudden immersion in water of 10ºC, resulting in a cardiac arrest or death. Sudden immersion in cold water to the neck makes the heart much more susceptible to arrythmias, due to an increase in output of the stress hormones (i.e. Adrenaline, Noradrenaline). The frequency of these arrhythmias is higher when the face is immersed.

## STAGE 3: HYPOTHERMIA

### Heat Balance: The Basic Physics

In order to understand the cause of hypothermia, it is important to understand the basic physics of how a human maintains heat balance.

Heat flows down a thermal gradient from high to low temperatures. Thus, in the cold, a thermal gradient is established, down which heat “flows” from the warmer deeper tissues to the cooler tissues near the surface of the body. Heat then escapes from the body to the environment. In normal circumstances in air, the body can exchange heat with the environment via four physical processes: radiation (**R**), convection (**C**), conduction (**K**), and evaporation (**E**).

**R** (Radiation). All objects possessing heat, including the body, emit thermal radiation from their surfaces.
**C** (Convection). This is the process by which heat is exchanged with the environment by the movement of air or water molecules adjacent to the skin, as they move away they are replaced by colder molecules.
**K** (Conduction). This term is used to describe heat exchange between the skin and surrounding surfaces with which it is in direct contact.
**E** (Evaporation). Evaporation is the process by which energy transforms liquid to a gas. The heat required to drive this process is removed from the surface of the object on which evaporation is occurring, and it cools.

For body temperature to remain stable in a cool environment, the heat produced by the body at rest or through exercise or shivering (**M**), must match that lost by R,C,K and E.

Several factors influence the amount of heat exchanged by R,C,K, and E. The most common are: the *surface area* involved in heat exchange; the *temperature gradient* between the body and the environment; and the *relative movement of the fluid* (air or water) in which the body is placed. This explains why someone will cool faster if: they are in colder water (*gradient*); they are partially immersed compared to completely immersed (*surface area*); they are in fast flowing as opposed to still water (*movement of the fluid*); they move about compared to staying still (*relative movement of the fluid*).

In water, heat is conducted to the molecules of water in contact with the skin (“boundary layer”), these molecules are warmed and rise (Convection), and are replaced by cooler ones. Thus, in water only two of the four primary pathways for heat exchange are available, and heat loss is principally by convective and conductive heat exchange.  Despite this, a naked individual in cold water will cool approximately four times faster than in air at the same temperature.  This is because the thermal conductivity of water is 25 times that of air, and its volume-specific heat capacity is approximately 3500 times that of air.  Therefore, water has a much greater capacity to extract heat (see Footnote).  Furthermore, when in water, unlike air, the surface area available for heat exchange with the environment comes close to 100%.  This is the reason why cold water is so dangerous.  The corollary to this is that hot water is a very good medium to rewarm hypothermic victims.

If the immersed person has survived the initial two stages of immersion, i.e. cold shock and swimming failure, then the next hurdle to face is hypothermia.  It is now known that this per se may not be the cause of death.  This was noted by Golden (1996) (Reference 19).  As previously stated in Chapter 1, the predicted 50% survival times for fully clothed men in water wearing lifejackets are 1 hour at 5°C, 2 hours at 10°C, and 6 hours at 15°C.  Yet these figures are difficult to validate in the laboratory where the body temperature only falls about two or three degrees in the equivalent time.  There must be another cause of death. Golden explained that a conscious survivor in a seaway will make the physical effort to keep his/her back against the waves, but when physically impaired through muscle cooling, semi-conscious and with a loss of determined will to survive, both of which occur after a body core temperature drop between 2-3°C, then the survivor turns into the waves and drowns.  He also emphasized the point that death will occur much quicker from drowning if a lifejacket is not worn (Figure 5, Reference 15).

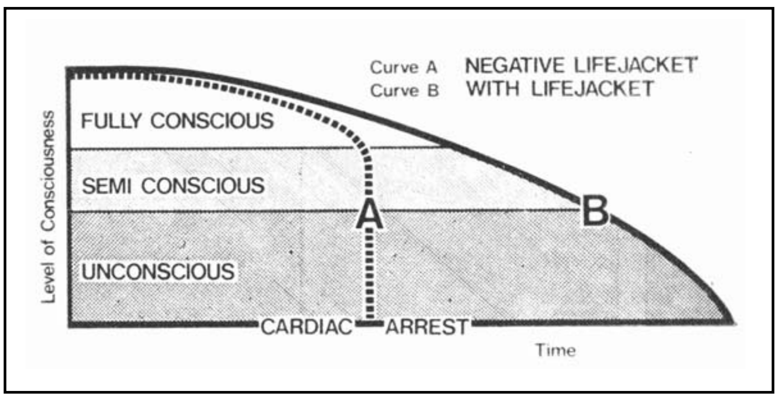


**Figure 5:** Empirical curve correlating deterioration in consciousness to time, in an immersed body with (B) and without (A) a lifejacket. Courtesy of Prof. Frank Golden.  (Reference 15)

*Footnote: The volume-specific heat capacity is obtained by multiplying the specific heat of a substance by its density.  It represents the amount of heat required to raise the temperature of a given volume of water by 1ºK.  At 37ºC the volume-specific heat capacity of water is 3431 times that of air.*

Swimming has a massive impact on the rate of body cooling and can increase the rate between 30-40% (Reference 35).

In spite of good teaching programs and regulations for lifejackets, people still die of hypothermia. The latest survival prediction curve comparison as previously mentioned, is presented by Oakley and Pethybridge in 1997 (Reference 50).

Markle provides several classic examples of death from hypothermia in water below 15ºC in his report. Again, from Markle's report (1991) (Reference 41).

*COMET, May 1973*

*The COMET had 27 persons on board and sank in Block Island Sound, Rhode Island, about seven miles offshore, in 48°F [9ºC] water. The COMET had no EPIRB and the only lifesaving apparatus was a 20-person buoyant apparatus. About 15 of the survivors held onto the buoyant apparatus at some point, including two of three who set out in a swamped dinghy to get to the buoyant apparatus. Six others were able to use an 8' X 10' piece of flotsam for partial support. Almost everyone on board had a lifejacket on when they abandoned ship. The two or three people who were not able to get a lifejacket were able to use either the buoyant apparatus or the flotsam. The first death occurred in the dinghy about ½ hour after the sinking. Deaths continued until rescuers happened on the scene 4 hours later. A total of 16 persons died in this time.*

JOAN LA RIE lll October, 1982

*The JOAN LA RIE lll had 22 persons on board and sank about 8 miles off of the New Jersey coast in 53°F [11.6ºC] water. Life saving apparatus consisted of a 7-person buoyant apparatus and a 15-person life float. Most of the passengers were resting in the deckhouse when the vessel was hit by a rogue wave, heeled over, and began to flood. Two persons are missing as a result of this casualty. They may have drowned in the deckhouse. The remaining 20 persons were able to escape into the water, but none was able to put on a life jacket. Apparently all but two persons made it to the life float and buoyant apparatus, which were secured together. Those two died. Of the remaining 18 gathered at the life float and the buoyant apparatus, 14 survived and 4 died in the 90 minutes it took for the rescue to arrive.*

The argument that liferafts are not necessary because vessels operating near shore in day time can expect other vessels to come to the rescue quickly is not supported, nor is the addition of an EPIRB going to speed up rescue to this type of response time. As already stated, death will occur within 3-5 minutes for those who have not donned a life jacket, or from swimming failure within 30 minutes if not clothed properly and supported by a lifejacket. Markle's (1991) (Reference 41) review of US lifesaving systems for small passenger vessels from 1973 – 1990 came to precisely the same conclusion.

Markle further correctly noted that persons in the water with and without lifesaving equipment died at a much higher rate than predicted by the estimated survival graph. This supports Golden’s theory that many victims drown during the cold shock and swimming failure stage of immersion, not from hypothermia per se. Even if they survive long enough to cool, cold-induced muscle incapacitation can prevent their keeping their backs to the waves, and thus their oro-nasal cavities clear of water, sometime after their body core temperature is reduced 2-3ºC.

Markle further concluded that “The present requirements for lifejackets, life floats and buoyant apparatus have proven adequate in all studied casualties where water temperature was 15ºC or more”. This might have been the case in this study, but it is still possible to die from hypothermia and post rescue collapse as in the case of the Lakonia in 1965 that sank in 17.9ºC water off Madeira (Reference 34).

The provision of a buoyant apparatus in which the survivor is basically floating with head only out of the water clinging to a becketed line in water below 15ºC is only a last ditch measure if everything else has failed. Drowning is very likely from cold shock and swimming failure, in the short term, and hypothermia and post rescue collapse in the long term. The colder the water, the greater the chance of death. Again, as Markle clearly pointed out, in the case of the Cougar accident, the two people who managed to get themselves on top of a buoyant apparatus were the two not to be hospitalized. The remainder had to remain clinging to it in water at 13ºC, three died. Similarly, in another case referred to by Markle (Zephyr ll accident), if the device had been a liferaft instead of a buoyant apparatus, the person without the lifejacket would have been able to board it and would have survived the few minutes in the water. In this accident, eight of the survivors got separated from the boat. They decided to swim to an island, only one was alive six hours later when he called for help when almost ashore.

**A Typical Case Where Death was Attributed to Hypothermia**

The Ocean Ranger sank in near freezing water on the Grand Banks off Newfoundland in February 1982 with the loss of all 84 men. No one was outfitted with a survival suit, although some wore lifejackets. The cause of death was attributed to drowning from hypothermia, yet from the testimony available, many died after only a matter of a few minutes in the water.

Quotation from the National Transportation Board Marine Accident Investigation Report NSTB-Mar-83-2, testimony from the Master of the Seaforth Highlander:

> *Probably about three minutes after sighting the first flare we visually sighted a lifeboat which at first appeared to be in good shape riding high on the water, and I maneuvered my ship very close downwind of the*

*lifeboat. The lifeboat was under power because he steamed across a swell, across my stern from the starboard side to port side, and he maneuvered his lifeboat down the port side of my vessel on to the port quarter. He came alongside us, and my men, who by this time had gone out on the deck, threw lines to the lifeboat, lines with life rings attached. One line was made fast on the lifeboat, and the other was made fast to my ship. Then some men began to come out of the enclosed boat, and they stood on the port side of the lifeboat, which was the side away from my vessel – four or five, maybe six men came out and stood on the port side.*

*Sometimes the lifeboat was just touching the Seaforth Highlander but not especially violently. At other times she was about six feet off the Seaforth Highlander. She was moving in and out a little. It was at that time that the lifeboat began to capsize to port in a very slow manner, like watching a slow motion picture. The men standing on top of the boat were thrown into the sea. The boat remained capsized. I believed during the capsize of the lifeboat the line we had made fast to it parted. After it had capsized it was approximately 12 feet maybe off the Seaforth Highlander, and I could see what I estimate to be eight or nine men clinging to the boat in the water. I could see all these men. They had lifejackets on, and there was a light on each lifejacket.*

*At about this time I was taking heavy seas in the after deck of my vessel which was stern to wind and sea. The mate and one of the seamen were washed up (on) deck, but they were both okay, although they suffered some bruising. The gangway net was washed over the side. We were still along the lifeboat, and after maybe a minute and a half or two minutes – it is very difficult to estimate – the men clinging to the boat began to let go, and they drifted down my port side. At that point I shouted down to the mate on the deck via the loud hailer system to throw over a liferaft. I saw the men running up forward on my deck to go for the liferaft, and they threw a liferaft over the side which inflated right beside the men in the water. No effort was made by any man in the water to grab hold of the liferaft. No effort was made by any of the men in the water. No apparent effort was made by any of the men in the water to reach the lines which my men had been throwing to them after the boat capsized.*

*I saw a life ring with line attached landing close to the men clinging to the boat, and they didn't make any effort to reach the life ring. At this time there were some men drifting down my port side, but the lifeboat was still off the port quarter of the ship with two or three men clinging to it. It was close to my port propeller at this time, so I had to stop my port propeller in case the men got caught in it.*

*At the time the Seaforth Highlander was forced off the location by heavy seas, and we could no longer maintain our position alongside the men in* *the water or the lifeboat. Once we were clear of all the men I was able to use the port propeller again, and I maneuvered the ship back around to an upwind position from the lifeboat and steamed down close to the lifeboat, the men and the lifejackets in the water. There was no sign of life at all. We could see all the men floating with their heads under the water, some of them with their arms outstretched, no sign of life, and the men on the deck were trying to pick up bodies.*

Death obviously in this case was caused by cold shock and possibly swimming failure, but certainly not hypothermia.

**Should Passengers Wear Lifejackets Prior To Abandonment?**

This question was raised after several rapid sinkings occurred. Particular accidents cited have been the loss of the MV George Prince (1976) (Reference 65) in the Mississippi River where 76 people died, the loss of the USCGC Cuyahoga (1978) (Reference 66) in Chesapeake Bay where 11 people died; the loss of the Marchioness (1989) (Reference 40) in the River Thames, UK, where 51 people died; and the loss of the MV Miss Majestic (1999) (Reference 67) on Lake Hamilton, Arkansas where 13 people died. The problem in each of these accidents was that many of the people were trapped between decks. The wearing of an inherently buoyant lifejacket would have further hampered their escape if it was possible. Nevertheless, for those who found themselves in the water and in the dark in two of the accidents, a lifejacket was critical to their survival.

If one is therefore going to regulate that passengers must wear a lifejacket on a passenger-carrying vessel that does not have the ability to carry a liferaft, then the lifejacket must be an inflatable one. The modern inflatable lifejacket is an excellent piece of life-saving equipment; it is comfortable, unobtrusive and very reliable. The Europeans have been using them for recreation and commercial boating operations on their lakes, rivers and canals for years. Canada has simply been slow in effecting new legislation for approval and it is only in the last five years that they have started to come into general use.

The argument from ship's operators that they are expensive to purchase and maintain is only partially true. The fact is that once operators start to use them and passengers become familiar with them, then the confidence in their merit will go up, the price (due to a higher demand) will go down, and maintenance costs will correspondingly go down due to the general public starting to respect a very good piece of equipment that will potentially save their life. The two children in the True North II accident would have likely been alive and well today if they had worn a good inflatable lifejacket as they stepped on board the boat.

# CHAPTER 3

## WHAT IS THE PRACTICAL APPLICATION OF THE CURRENT SCIENTIFIC DATA AND SURVIVOR TESTIMONY FOR LEGISLATION OF LIFE-SAVING APPLIANCES IN CANADA?

A major determinant of survival time in cold water and one that is largely overlooked is the sea state. Not only does this increase the risk of drowning because of increased frequency of immersion of the airway, it also increases convective cooling. It is concluded:

(a) That water is a very good conductor of heat.

(b) That the body immersed to the chest in a lifejacket cools principally from conduction and convection.

(c) The colder the water, the greater the thermal stimulation and heat loss. Consequently, the chance of death from cold shock, swimming failure, hypothermia, and post rescue collapse increases.

(d) The colder the water, the sooner the incapacitation of the hands very shortly after entry immersion.

(e) Grip strength and tactility is also reduced in cold water just at the critical time when it is most needed to initiate survival actions.

(f) If rescue does not occur within the first 10-20 minutes, then the ability to cling to floating debris, becketed grab lines, and do any physical self-rescue actions decreases.

(g) Even if the head is supported with a lifejacket, this is no guarantee that drowning will be prevented in cold, choppy water unless a splashguard is worn.

(h) One must avoid abandoning ship into cold water (wet shod evacuation) if possible. Whenever possible, one must leave the vessel at the last possible time and abandon directly into a liferaft (dry shod evacuation).

(i) If the abandonment occurs at dusk or in the dark, there is a high chance that the victim may become lost or drowned.

(j) Most important of all, is that once the immersion occurs in water below 15°C, the problems become worse.

Let us now consider a person who may be part of the crew, be a young child or an elderly tourist who suddenly, with little warning has to abandon ship wearing an approved lifejacket into Canadian inshore lakes or rivers. Unfortunately, there has just been such an abandonment, which ended up in tragedy, this typifies the problem and precipitated the study conducted in this report.

> *Halifax Sunday Herald, June 18, 2000*
>
> *<u>Boat mishap cause still unknown – Bodies of victims recovered</u>*
>
> *The tour boat that sank to the bottom of frigid Georgian Bay and claimed the lives of two 12 year-olds went down fast and furious after powerful waves crashed into the vessel and tore one of its doors away.*
> *None of the children was thought to have been wearing lifejackets when the 12 metre steel-hulled True North II sank Friday morning, shortly after it picked up the children following a visit to nearby Flowerpot Island.*
> *"There were other boats in the water and they were trying to get their attention. But with the waves being high, they couldn't be seen."*

[This newspaper quotation was not strictly true in the fact that there was only one US registered yacht in the area. The water conditions were too choppy for it to get close enough to assist, but it did raise the alarm.]

Unfortunately, the children had to abandon directly into the water in their street clothes, quite unprepared for such an event. This is quite typical of a marine accident – it is sudden and unexpected and, indeed, rescue was quite near at hand (20 minutes). The two children probably drowned as a result of cold shock or swimming failure. The water temperature was 10ºC and the investigators did not enquire at what stage any witnesses last saw the children, so it is speculation. The fundamental question was not reported by the Board of Inquiry as to whether they could swim. Later, at the inquest, it was established that both children could swim. They certainly did not die from hypothermia because they were not in the water long enough. As previously stated, this further supports the fact that swimming in cold water without the protection of a lifejacket is potentially very dangerous and that swimming ability in warm water bears no relationship to that in cold water. They should also all have been wearing lifejackets when there was signs that the boat was in trouble. The lifejackets were stowed in a difficult place to gain access to them, so they were never used. They should have never been allowed to abandon ship into the cold water. They should have abandoned dry shod into a liferaft, but it was impossible to launch the liferaft due to the fact that there was no hydrostatic release, nor was it able to float away free. (Reference 63)

So, could the deaths have all been prevented? Probably.

## How Should Canada Proceed with New Legislation?

Clearly, it is potentially very dangerous for any person dressed in normal street attire and particularly with no lifejacket to abandon any form of vessel irrespective of size or purpose in water below 15ºC. Even a lifejacket, if not worn properly or without a spray hood, does not guarantee the victim protection from drowning.

Transport Canada should introduce new regulations that can be implemented stepwise over a timescale of their choice. The basic principle must be that no human should be expected to abandon ship in Canadian rivers and lakes wet shod into water below 15ºC. For all newly constructed vessels it is suggested that implementation of this principle should start for the year 2003 and that by 2005 all older vessels must comply with this philosophy or be refitted. There will be some exceptions to this philosophy that will be discussed later.

By adopting this philosophy, this means that every passenger carrying vessel must carry a liferaft for a large portion of the year while the water temperature remains 15ºC. Stowage, accessibility and ease of launching is always a problem, but a particular problem for smaller vessels. Vessels that carry six to eight passengers may simply not have the space. However, these types of vessels due to the nature of their size and type of operations may be at most risk from marine accidents. The advice would be to insist that the passenger wear the most recently approved inflatable lifejackets while underway in water below 15ºC. The modern inflatable lifejacket is an excellent piece of safety equipment, it is light weight, comfortable to wear, unobtrusive, cool even on hot days and does not limit physical movement.

Insisting on inherent buoyant lifejackets causes the potential risk of someone being trapped between decks due to the buoyancy. For school trips, Scout camps, etc., it would be prudent to insist that everyone wears an inflatable lifejacket and irrespective of this, all schoolchildren under age 13. (The teachers and leaders would then be showing an example to their students and also many of them are non-swimmers.) For rapid capsizements, such as the True North II there is still merit in carrying seat cushions and buoyant apparatus for those who cannot swim.

Certain catastrophic conditions will be faced by the passengers at the point of abandonment into cold water:

- Very rapid sinking with little warning – life jacket donned
- Very rapid sinking with little warning – no lifejacket donned
- A slower, more orderly evacuation where the majority of people will don lifejackets

For the first two conditions the passengers may find that they have simply been washed over the side or physically ejected from the deck. This is the worst possible scenario.

The primary level of protection from drowning especially in cold water from cold shock will be their lifejackets if donned. To improve the likelihood that they are wearing lifejackets, the Masters need more education in ordering the donning of lifejackets when conditions start to get rough, not when it's too late. This is what happened in the case of the True North ll. The two new Canadian videos on cold shock, swimming failure, hypothermia and post-rescue collapse should be introduced into the curriculum of the Marine Emergency Duties Course as soon as possible.

The secondary level of protection will be the liferaft and buoyant apparatus. Hopefully, if there is a slower, orderly evacuation, they can abandon dry shod into a liferaft. The victims who find themselves suddenly in the water, and particularly non-swimmers will require some immediate flotsam, jetsam or buoyant apparatus to cling to in order to control respiration and make their way to a liferaft. In theory, if all the new, regulated liferafts have automatic hydrostatic releases, then even in the dark it should be possible for the survivors to stay afloat long enough to locate the raft and board it, likely with assistance. For those already wearing a lifejacket, they will be able to swim a short distance to the liferaft.

For all victims, if the water is cold and they are dressed in street clothes only, they should not swim unless within metres of shore or a safe refuge, the likelihood of death from swimming failure is always present, hence the requirement for carriage of liferafts when the water temperature is below 15ºC.

The argument that liferafts are not necessary because vessels operating near shore in day time can expect other vessels to come to the rescue quickly is not supported, nor is the addition of an EPIRB going to speed up rescue to this type of response time. The Canadian response to an EPIRB ranges from 90 minutes to 2 hours. Death will occur within 3-5 minutes for those who have not donned a life jacket, or from swimming failure within 30 minutes if not clothed properly and supported by a lifejacket.

# CONCLUSIONS

1. Up until fifty years ago, no one really understood the reason why people immersed in cold water died. It was attributed to an inability to stay afloat and vague terms such as “exposure”.

2. The massive loss of life at sea during the Second World War noted in the Talbot Report and McCance et al’s paper for the Medical Research Council initiated a lengthy and extensive research program to investigate the cause, in which hypothermia became recognized.

3. Subsequently, a whole series of survival prediction curves have been produced, in different temperatures of water, the objective being to predict when death occurs from hypothermia.

4. Survival prediction curves are of limited value only. This is because they do not take into account that death may occur from cold shock, swimming failure and drowning during early hypothermia. The curves should be revised to include these factors.

5. Regulators, teaching establishments and survival suit manufacturers all concentrated their efforts on protecting the person from hypothermia. Indeed, in this regard they have done a very good job.

6. By the early 1980’s, it became clear that there were four stages of the immersion incident in which a person could die: Stage 1 - cold shock (3-5 minutes); Stage 2 - swimming failure (30 minutes); Stage 3 - hypothermia (greater than 30 minutes); and Stage 4 - post rescue collapse (on or shortly after rescue).

7. Swimming ability in warm water bears no relationship to swimming ability in cold water.

8. Manual dexterity is severely degraded in water below 15°C particularly at the time when it is required to do essential survival tasks.

9. For those passengers with a potential heart conduction defect (middle-aged and elderly tourists), immersion in cold water increases the chance of fatal cardiac arrythmia (irregular heart beat).

10. Even given the above, the layperson, is often still surprised that some people do not survive a lengthy immersion even though they are theoretically within the “safe” boundaries of the current, predicted survival curves. These people do not die of hypothermia per se, but from a variety of problems included in which is moderate hypothermia where a lowering of the body core temperature is enough for them to lose their physical

ability and mental determination to keep their backs to the waves. They thus inhale the next wave and die from drowning in spite of wearing a life jacket.

11. Even though there are well established teaching programs, regulations and much improved life saving equipment, there are still in the order of 140 000 open water deaths each year. What has been overlooked is the significance of the first two stages - cold shock and swimming failure as a cause of death. The precise details of these are described in this report.

12. Research within the last ten years and documentation of witness testimony and boards of inquiry have confirmed that cold shock and swimming failure are indeed a very significant cause of death.

13. From all the combined research on cold water accidents and scientific research, it has become clear that sudden immersion in cold water, i.e. below 15°C is very dangerous, it should be avoided if at all possible. Furthermore, a conscious decision to swim (and rescue oneself) or stay floating still in the water should not be taken lightly without assessing the pros and cons. It has now been shown that a person's swimming ability in warm water bears no relationship to that in cold water.

14. The severity of the effects of cold shock is directly proportional to the water temperature peaking between 10-15ºC.

15. These scientific findings lead to the practical advice regarding the regulations requiring the carriage of liferafts and training of operators of passenger carrying vessels.

    (a) Wherever possible, entry into water below 15°C should be avoided. Direct entry into a life raft should be the objective.

    (b) Transport Canada should use this philosophy in the design, development and implementation of all new legislation in a step wise fashion. All vessels operating in Canadian lakes and rivers at 15°C or below should carry liferafts that can easily be launched and boarded by the entire crew and passengers.

    (c) The only exception to this should be where it is physically or practically impossible to stow a liferaft. Under such conditions the passengers must wear inflatable lifejackets when on board.

    (d) Operating a vessel close to the shore or in groups or the carriage of EPIRB are not a reason for waiving this requirement because death from cold shock will occur within 3-5 minutes, swimming failure in under 30 minutes, and darkness only hampers escape and rescue.

(e) The Marine Emergency Duties curriculum should be amended to include the two new Canadian videos on cold shock, swimming failure, hypothermia and post-rescue collapse.

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