DIVING POPULATIONS AND EQUIPMENT IN CANADA

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Level 1 Fitness to Dive Course
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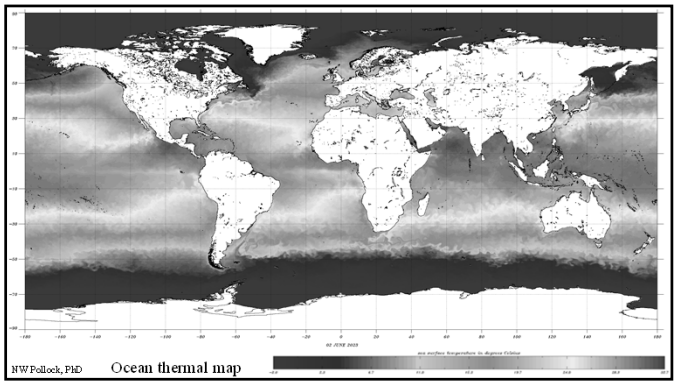
OBJECTIVES

- We will discuss
  - the range of applications of diving and the activities of divers



Ocean thermal map

CANADA
- longest coastline at <202,000 km
- 3 oceans, many rivers and lakes
- highly variable

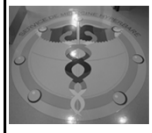
HYPERBARIC CENTRES

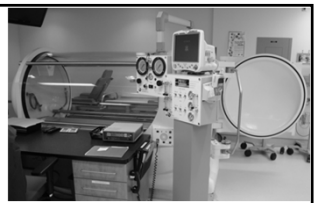
- ~22+ fixed units

▲ Civilian
● Military

LEVIS HYPERBARIC CENTER

- Established in 1999
  - with one mono-/duo-place chamber

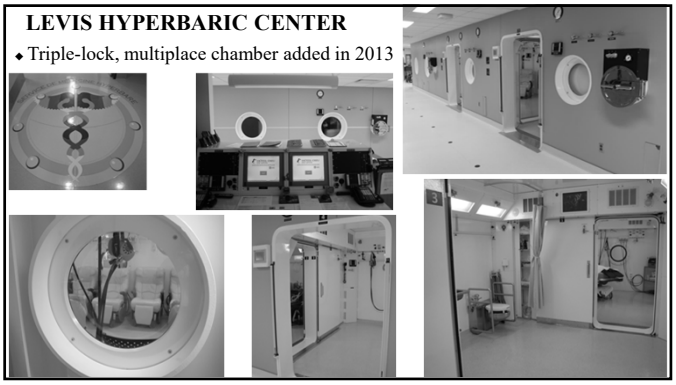




Perry Sigma Plus
3 ATA capability

LEVIS HYPERBARIC CENTER

- Triple-lock, multiplace chamber added in 2013



UNDERWATER DIVING

DISCIPLINES
- Recreation
- Instruction/Guiding
- Scientific
- Public safety
- Inland commercial
- Inshore commercial
- Offshore commercial
- Military
- Harvesting/Aquaculture
- Photo/Cinematography

ENVIRONMENTS
- Seawater/Freshwater
- Warm-Cold water
- Confined/Open water
- Shallow/Deep
- Cave/Wreck/Ice
- Boat/Shore
- Current/Drift
- Wall
- Blue water
- Low visibility/Night
- Altitude
- Aquarium
- Contaminated

MODES
- Breath-hold/Freediving
- Open-circuit scuba
- Semi-closed-circuit scuba
- Closed-circuit scuba
- Surface-supplied
- Saturation
- Atmospheric pressure

Operational distinctions do not alter the physiological impacts of diving

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MAJOR DIVING GROUP CLASSIFICATIONS

RECREATIONAL
- depth range typically max 18-40 m (60-130 ft)
- training modest
- decompression none to modest
- activity dependent to independent
- medical evaluation requirements none to modest

PROFESSIONAL/TECH
- depth range typically 0-120+ m (0-400+ ft)
- training variable
- decompression highly variable
- activity independent or partially controlled
- medical evaluation requirements from minimal to major

COMMERCIAL
- depth range highly variable 0-200+ m (0-660+ ft)
- training variable
- decompression variable
- activity generally controlled
- medical evaluation requirements stringent

- Variability and overlap between groups can be substantial
  - in some cases the need for assessment can be greater than regulatory requirements

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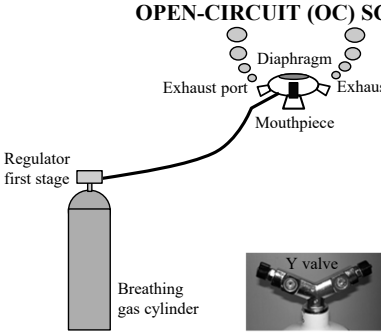
OPEN-CIRCUIT (OC) SCUBA*



*self-contained underwater breathing apparatus

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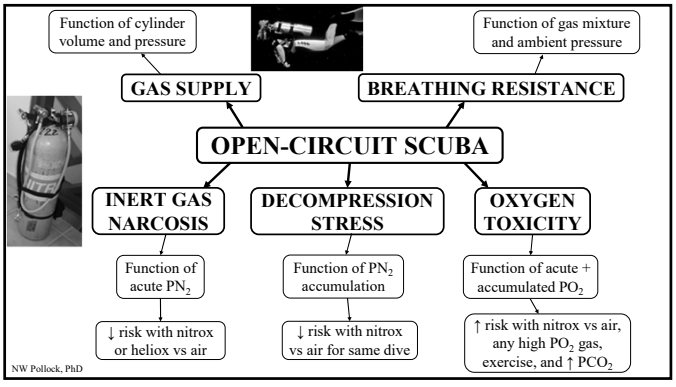

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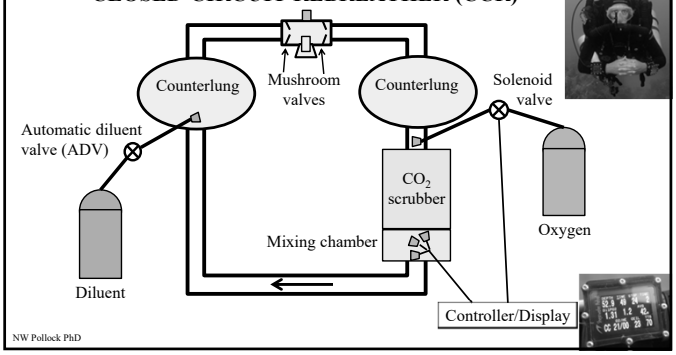
CLOSED-CIRCUIT REBREATHER (CCR)



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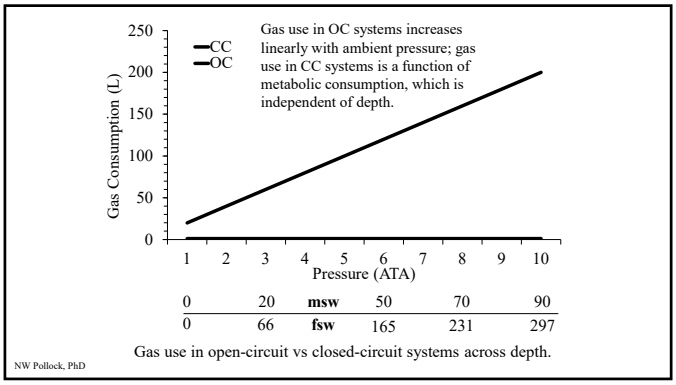

Gas use in open-circuit vs closed-circuit systems across depth.

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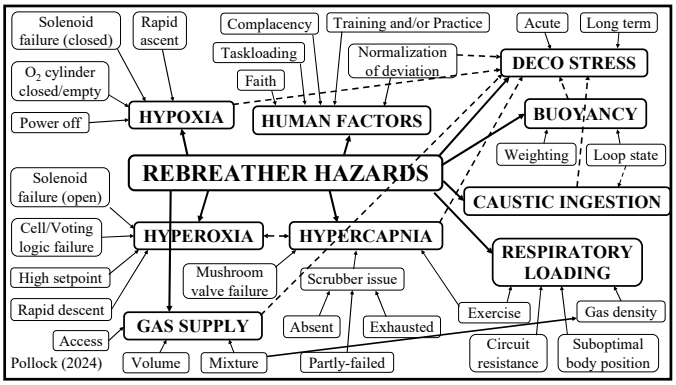

Pollock (2024)

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SURFACE-SUPPLIED DIVING

- Umbilical serves multiple purposes
  - breathing gas
  - voice communications
  - depth measurement (pneumofathometer)
  - strength member
- Typically employs solo diver with backup not in water

Helmet and neutrally buoyant umbilical

Portable surface diver control center

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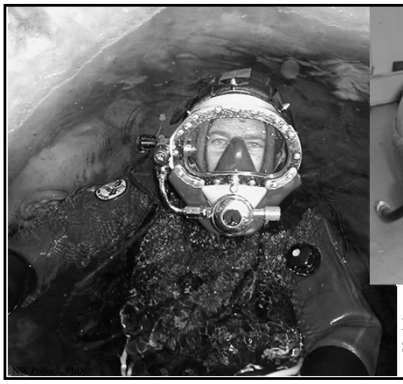

Kirby Morgan weights
Band mask - 6.2 kg (13.6 lb)
SuperLite 17 helmet - 13.2 kg (29.0 lb)

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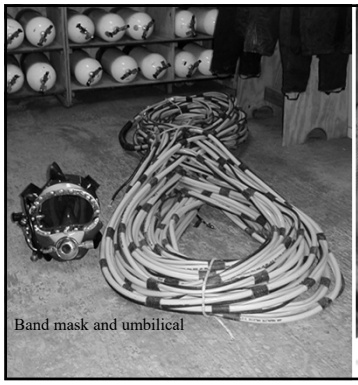


Band mask and umbilical

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- Umbilical plumbed into helmet sideblock (l) and attached to body harness (r)

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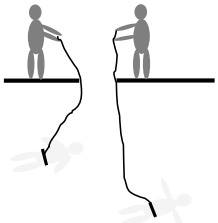

SEPARATE TETHER DIVING

- Each diver is tended on a single line
  - communication with surface via line signals
    - standard 1-4 count coding
    - full deflection pulls with pauses for clear signals
      - 1 - "OK?" / "I'm OK"
      - 2 - "Give me slack"
      - 3 - "Take up slack"
      - 4 - "Bring me in fast"

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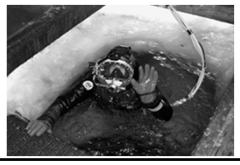
OBSTACLES

- Common obstacles include overhead barriers and structural elements
  - eg, boat traffic, underwater pilings, structures, garbage, ice
- Obstacles may alter many access issues
  - site ingress/egress/risk of entanglement
  - communications
    - line
    - through water systems
- Mode used may need to be changed

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OPERATIONAL HAZARDS - TASK LOADING

- Task burden in diving environments high even before 'job' considered
  - equipment bulk
  - monitoring life support equipment
  - maintaining buoyancy control
  - effective communication (with dive partner and/or surface)
  - navigation/spatial awareness
  - depth and decompression schedule management
  - current/surge/obstruction/low visibility management
- Simple tasks may become very complicated underwater
  - eg, securing tools/equipment (dexterity and anti-loss issues)
  - eg, anchoring self to gain leverage
- Complexity may create safety hazards that would be much greater than in dry land situations

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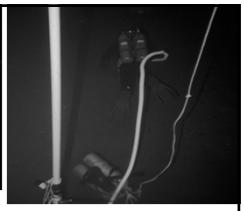
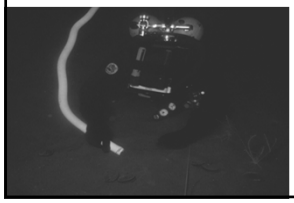

- A standard range of tasks can be conducted even during polar scientific diving
  - challenges include -2°C (29°F) water temperature, overhead ceiling, darkness, and extreme isolation
    - Pollock (2007)

WATER HAZARDS OVERVIEW

Environmental
- Weather/Water state
  - visibility (0-30+m)
  - temperature (-40 to +40°C)
  - currents/tides
  - wind/sea state
  - barometric pressure
  - dams ('delta P' risk)
- Pollution/Contamination
  - native or introduced
- Worksite
  - accessibility (ingress/egress)
  - obstacles
- Animal/Plant interactions

Operational
- Equipment
  - surface support
  - life support
  - gas supply
  - backups
- Procedures
  - communications
  - dive profile
  - task loading
  - pre-/post-dive

Human factors
- Individual
  - predisposition
  - training
  - activity
- Team
  - training
  - activity
- Miscellaneous
  - trauma/crush
  - sound
  - electrical shock
  - explosions

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MARINE VESSELS

- Diving may be conducted from tenders deployed from mother ships
  - there are many opportunities for shipboard accidents to occur





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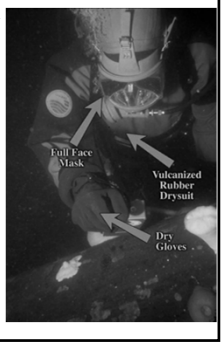
- Dive operations can sometimes require helicopter support
- Isolation and delay to transport issues arise if helicopters do not remain on station
- Flying after diving issues
  - Freiberger et al. (2002)

POLLUTED WATER PERSONAL PROTECTIVE EQUIPMENT

- Full facemask mated to drysuit offers some protection from dermal, ingestion, inhalation sourcing
  - unknown circumstances should dictate use of at least a full-face mask, dryhood, drysuit, drygloves
- Decontamination
  - progressive, initiated before any gear is removed
    - both tenders and divers require protection
  - potable water rinse is very effective for microbes with decontamination-compatible equipment
    - slick rubber materials
      - neoprene materials cannot be cleaned effectively
  - boats or access areas need to be divided into zones
    - hot
    - contaminant reduction
    - clean



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CONTAMINATED WATER DIVING (Z275.2-15; USN 2019)

- **CAT 1 - Grossly contaminated**
  - extreme risk; fully encapsulated diver with surface return exhaust or positive pressure freeflow helmet
  - diving not recommended
- **CAT 2 - Heavily contaminated**
  - commonly encountered during occupational diving in industrial environments
  - fully encapsulated diver; considered baseline (default) condition
- **CAT 3 - Moderately contaminated**
  - routine diving with some risk, primarily biological, of contamination
  - minimum standard
    - full face mask with integrated second stage regulator
    - second stage with separate inhalation and exhalation channels
    - drysuit
    - hood
    - gloves
    - two-way communication

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ANIMAL HAZARDS

- Diver-animal interactions have the potential to end badly
  - but most marine animals typically do not initiate aggressive contact with humans
    - eg, killer whales attacking boats?
      - no recorded cases of human harm
  - many diver injuries are passively induced or incited by diver actions
- Review papers are available
  - eg, Todd and Edsell (2019); Krzyżak and Korzeniewski (2021)

ANIMAL HAZARDS

Biting

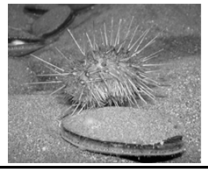
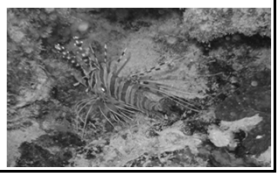
- Eg, sharks, crocodiles, alligators, barracuda, grouper, moray eels, octopus, squid, marine mammals (killer whales, seals, sea lions, walruses)
- Eg, 30 of 350 shark species have reportedly attacked humans
  - 25% of attacks involving divers (nearly half of these involving freedivers)
    - common risks are surface swimming and spear/line fishing
      - Lippman (2018)



ANIMAL HAZARDS

Venomous

- Eg, sea urchins, cone shells, sea snakes, blue ringed octopus, coelenterates (eg, jellyfish, corals, anemones)
- Eg, several fish species - pufferfish, scorpionfish, lionfish, stonefish, stingray
- tetrodotoxin (neuromuscular block = paralytic) secreted by both blue ringed octopus and pufferfish
  - eg, Lau et al. (2020)

OPERATIONAL HAZARDS - SOUND

Anthropogenic (man-made) ocean noise increasing

- Gisiner (1998)
  - eg, sonar, pile driving / other construction noise, explosives
    - influence of low frequency sonar on marine mammals is a concern
      - Bohne et al. (1985), Jepson et al. (2003)
    - limited studies on divers report generally modest aversion scores by recreational divers exposed to low frequency underwater sound
      - Fothergill et al. (2001)

Sound known to cause injury will generally be

- 1) relatively close; and 2) high energy

Prevention

- maintain awareness of all activity in the region
- develop and enforce lockout procedures and monitor for compliance

ELECTRICAL SHOCK

Various Sources

- eg, underwater tools (cutting and welding), electric cables, television cameras, active heating systems

Electrical Shock

- an electric field gradient of 0.2 $V \cdot ft^{-1}$ in saltwater gives a current flow of 5 mA through the chest
- a 2 $V \cdot ft^{-1}$ gradient in saltwater could cause paralysis

Types of Current

- low frequency (1 Hz - 100 kHz) alternating current (AC) most dangerous
  - 50-60 Hz AC can cause tetany (ie, sustained muscle contraction)
  - 400 Hz AC can cause ventricular fibrillation
  - risk of cardiac arrhythmia high for up to 24 h

Hz = hertz; frequency in $cycles \cdot s^{-1}$

EXPLOSIVES HAZARD

- Various sources
  - eg, ordnance, construction, seismic survey, fishing, equipment failure (eg, welding)
- Underwater explosions
  - pressure wave is propagated in all directions
  - water absorbs less energy than air so effects felt further
  - pressure waves can be reflected off different surfaces
    - soft substrates dampen effects
    - hard substrates amplify effects

Use of explosives to open dive hole in Antarctica


TAKE HOME MESSAGES

- Diving is conducted with wide ranges of
  - purpose/motivation
  - environments
  - equipment
  - individuals
- Diving physics and physiology apply regardless of purpose
  - the most challenging element is often the diver
- Solid foundations are important for safety
  - medical fitness
  - health fitness
  - knowledge base
  - training and practice
  - readiness

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