DECOMPRESSION STRESS - BEYOND THE ALGORITHM

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DISCLOSURE

- I will include reference to commercial devices but I have no financial relationships or conflicts to disclose

MOTIVATION FOR TALK

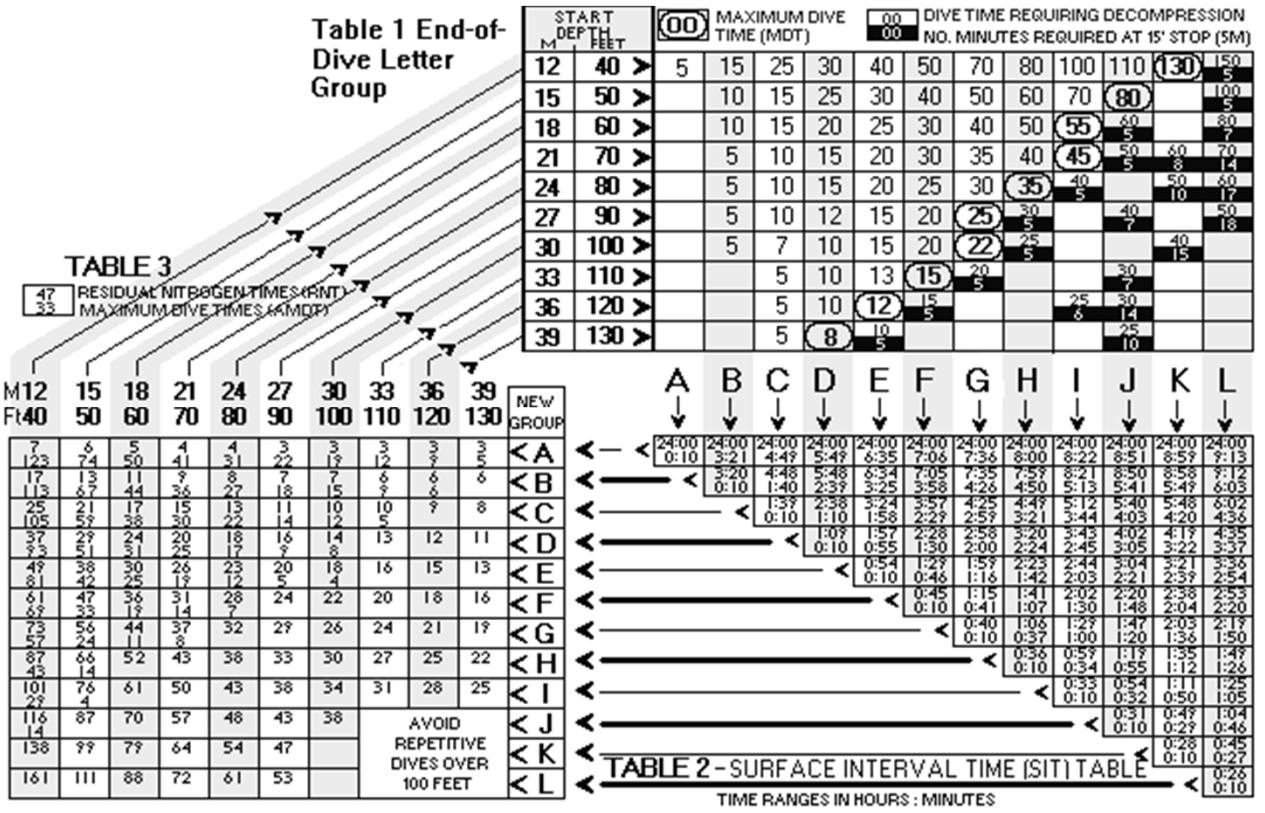
- Need to combat unrealistic expectations of divers
  - faith in the computer screen
  - intense drive to redirect 'blame'
- Need to orient those dealing with injured divers

OBJECTIVES

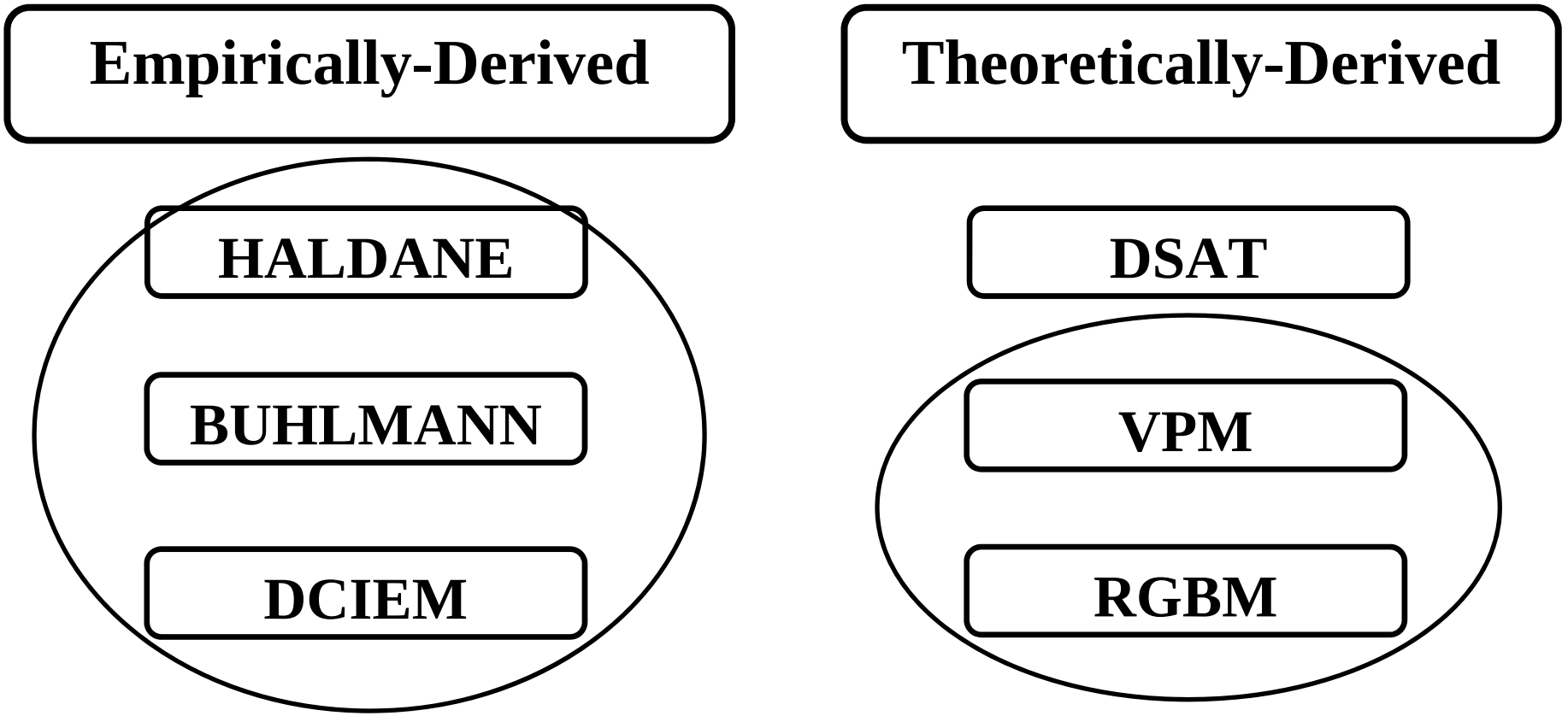
- We will discuss:
  - faith as a hazard in decompression
  - factors that can influence decompression safety
  - practical strategies to reduce decompression stress

DECOMPRESSION ALGORITHMS

- Many (mathematical models) now in use
  - substantial variability in both limits and human testing
- Provide only first order approximation of risk



POPULAR DECOMPRESSION ALGORITHMS



- Feature common to bubble models?
  - **None measure bubbles!**

DIVE COMPUTER ALGORITHMS

Buhlmann ZH-L16

- APD Vision Electronics
- Dive Rite NiTek Q Advance
- Heinruchs Weikamp OSTC 2/3
- Hollis DG02, DG03, TX1
- Liquivision Lynx / Xeo / Kaon
- Shearwater Petrel / Predator
- Tusa Element / Zen / Talis
- VR Tech. NHeO3 / VRX

Buhlmann ZH-L12

- Apeks Quantum / Quantum X

Buhlmann ZH-L8

- Scubapro/Uwatech Galileo

RGBM

- Atomic Cobalt 2
- Cressi Giotto / Leonardo / Newton
- HydroSpace HS Explorer Model M
- Mares Nemo / Puck / Matrix / Smart
- Suunto Cobra / Eon / Vyper / Zoop / etc.
- U/W Technology Center UDI

DSAT

- Aeris Atmos / Manta
- Genesis React Pro / Resource Pro
- Oceanic Datamask HUD
- Sherwood Amphos / Wisdom 3 / Vision

Dual/Hybrid

- several Oceanic; VR Technologies

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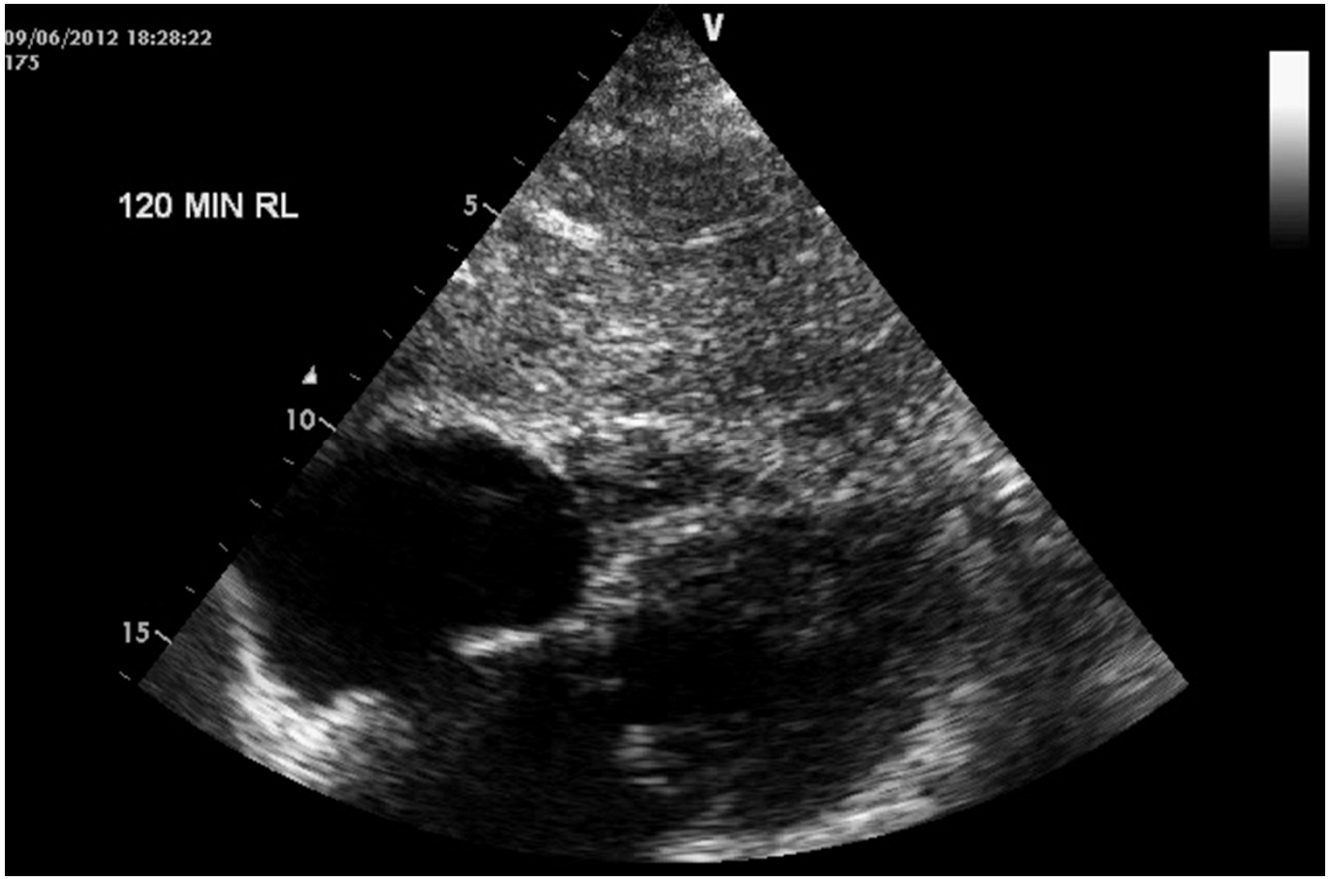
revised 06/15

POST-DIVE EXPOSURE



The bubble-free post-dive status most divers hope to have

POST-DIVE EXPOSURE

High bubble loads can develop after dives within algorithm limits

DECOMPRESSION REALITIES

- Physiology is more than math
  - Models ≠ Reality
    - rely on many assumptions and incomplete data
- Dive computers do not get DCS
- Divers do get DCS

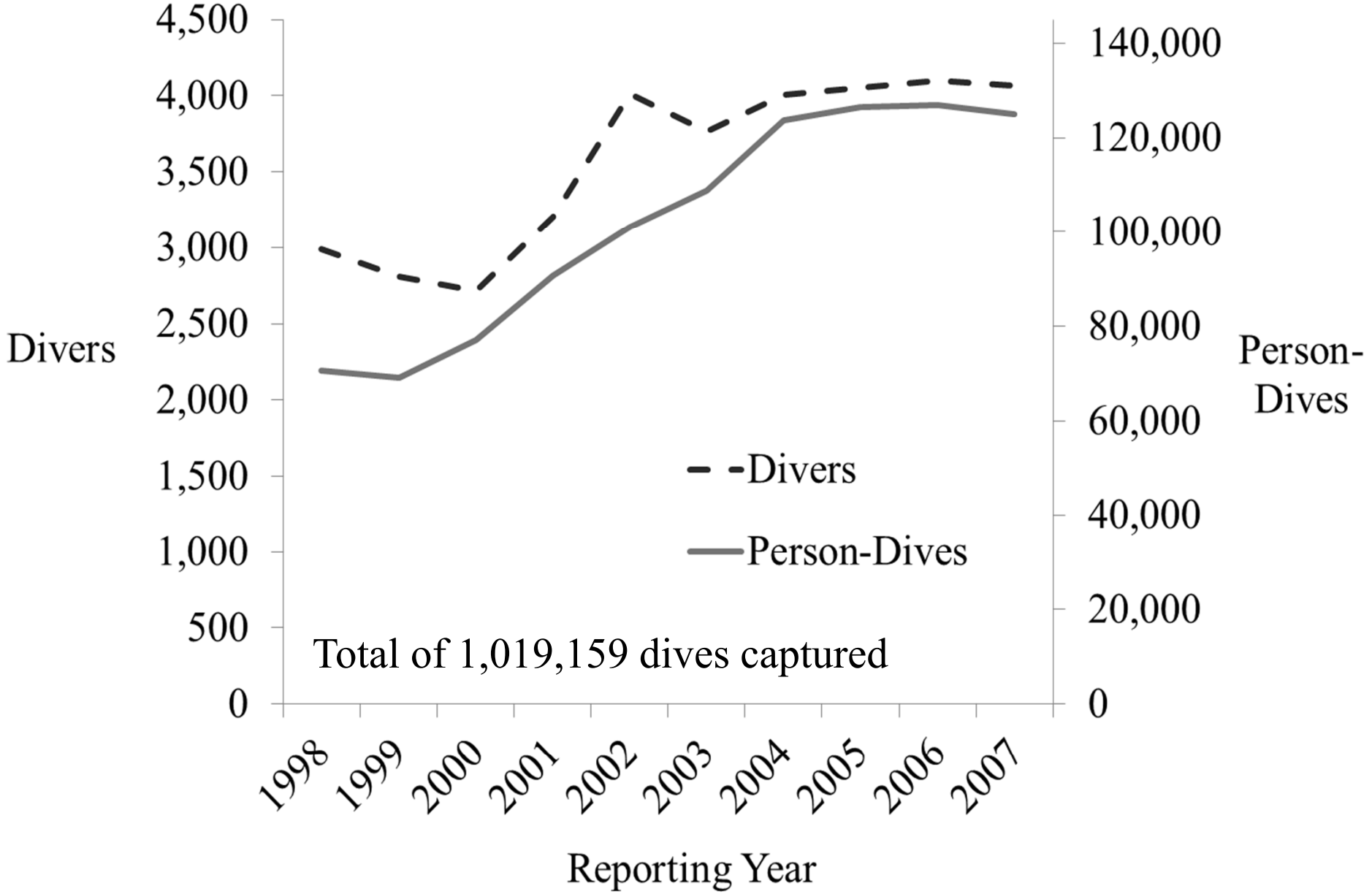


Figure 1. Number of divers and reported scientific dives by year (Dardeau et al., 2012).

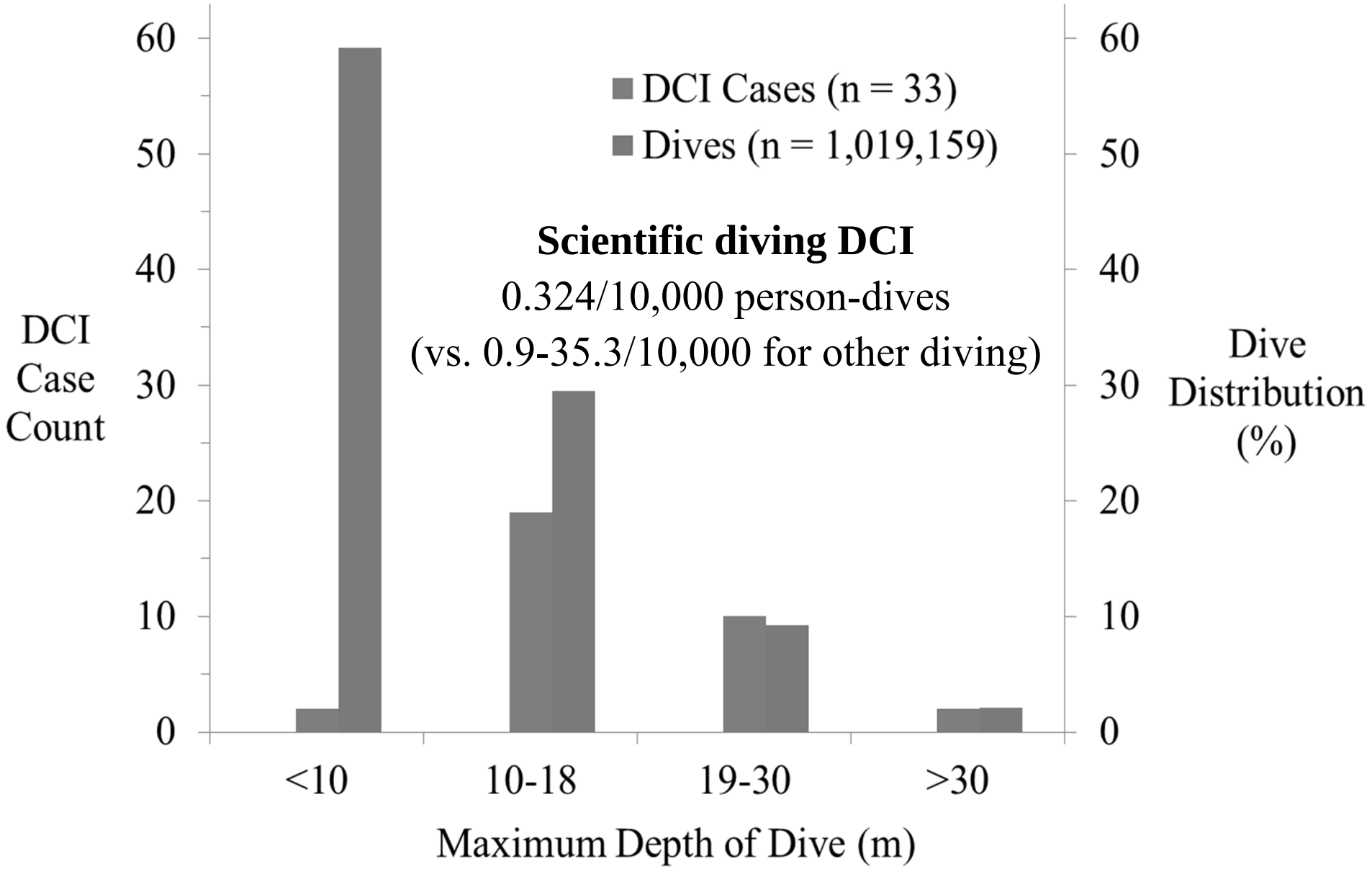
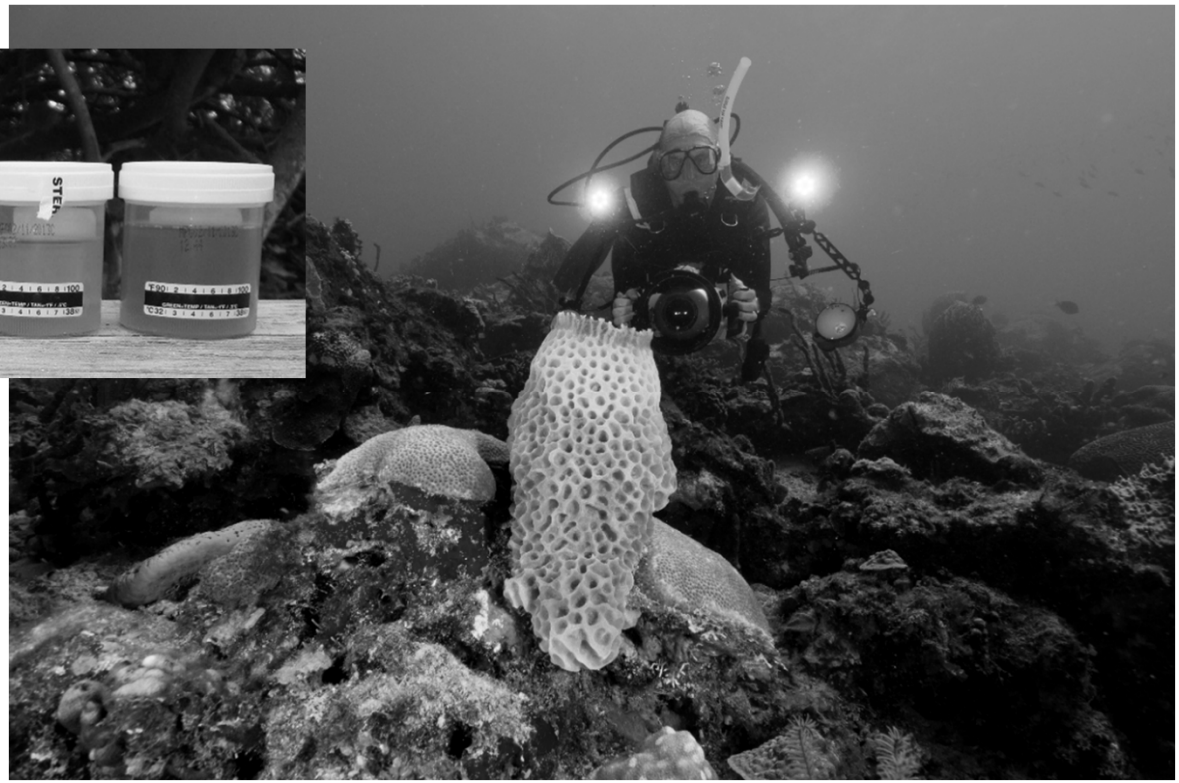
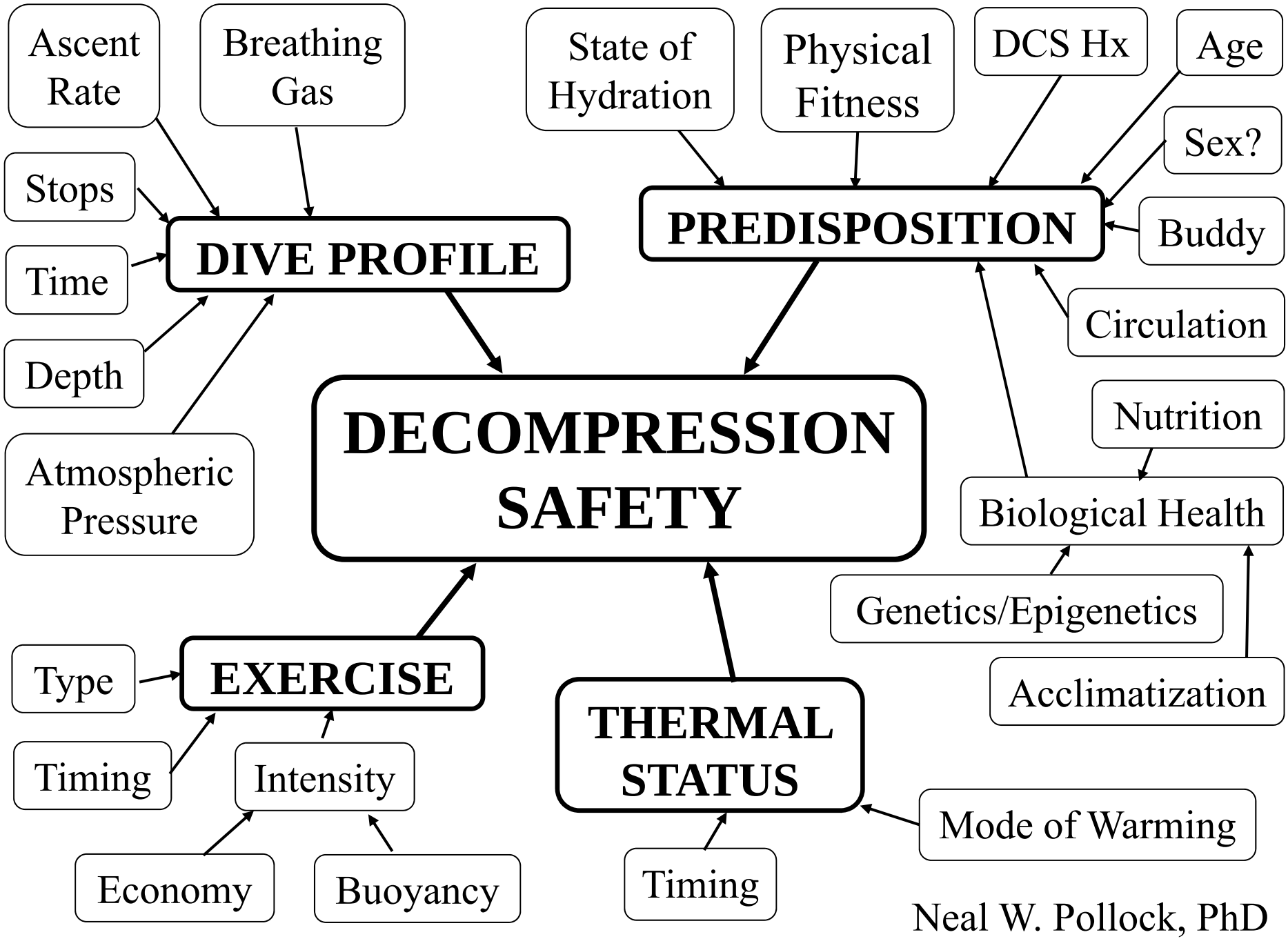


Figure 3. Depth distribution of DCI cases (count) and dive distribution (%) (Dardeau et al., 2012).

DCS - THE PERSONAL AFFRONT

- Divers typically look for something, anything to blame
  - other than themselves....
- Must appreciate
  - myriad influencing variables
  - probabilistic nature of the disease




Ascent Rate
Breathing Gas
State of Hydration
Physical Fitness
DCS Hx
Age
Sex?
Stops
Time
Depth
Atmospheric Pressure
DIVE PROFILE
PREDISPOSITION
Buddy
Circulation
Nutrition
DECOMPRESSION SAFETY
Biological Health
Genetics/Epigenetics
Acclimatization
Type
Timing
EXERCISE
Intensity
Economy
Buoyancy
THERMAL STATUS
Timing
Mode of Warming
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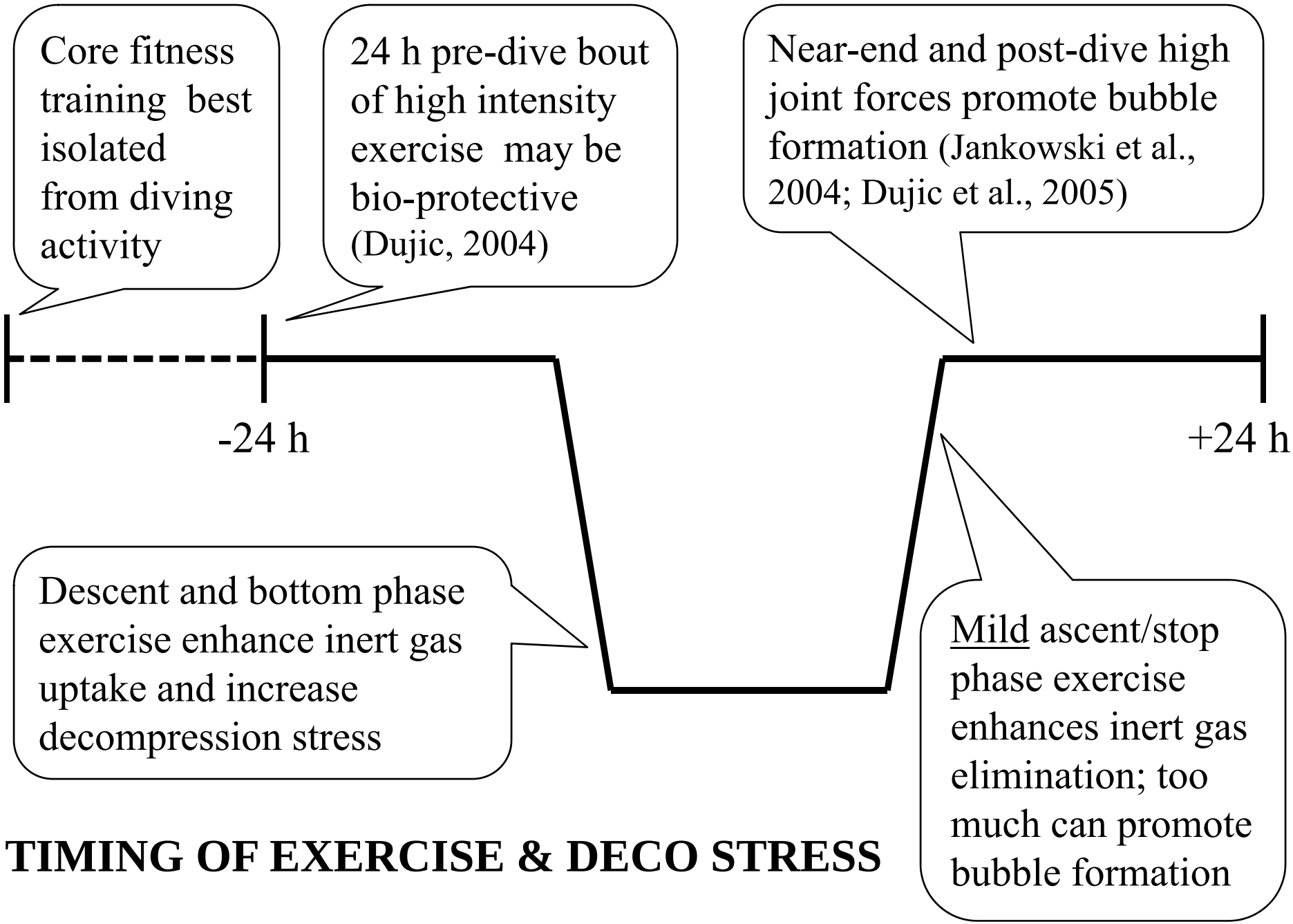
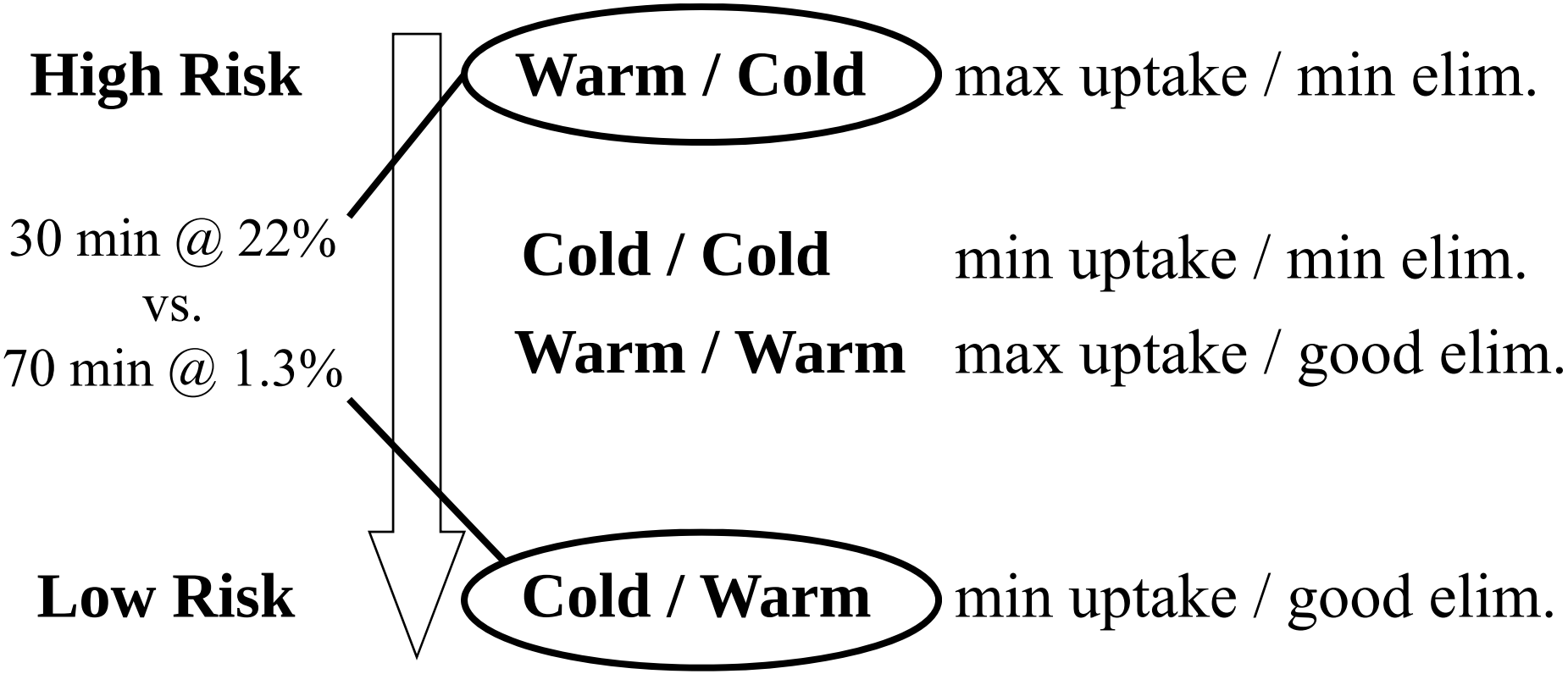


TIMING OF EXERCISE & DECO STRESS

THERMAL STATUS AND DECO STRESS

- NEDU immersion study (clamped water temperature)
  - two phases: descent/bottom and ascent/decompression
    - 37 m (120 fsw) for 30 min bottom / 87 min ascent
  - two temps: 'warm' = 36ºC (97ºF) and 'cold' = 27ºC (80ºF)
    - Gerth et al. (2007)



HOW TO INCORPORATE CONSERVATISM?

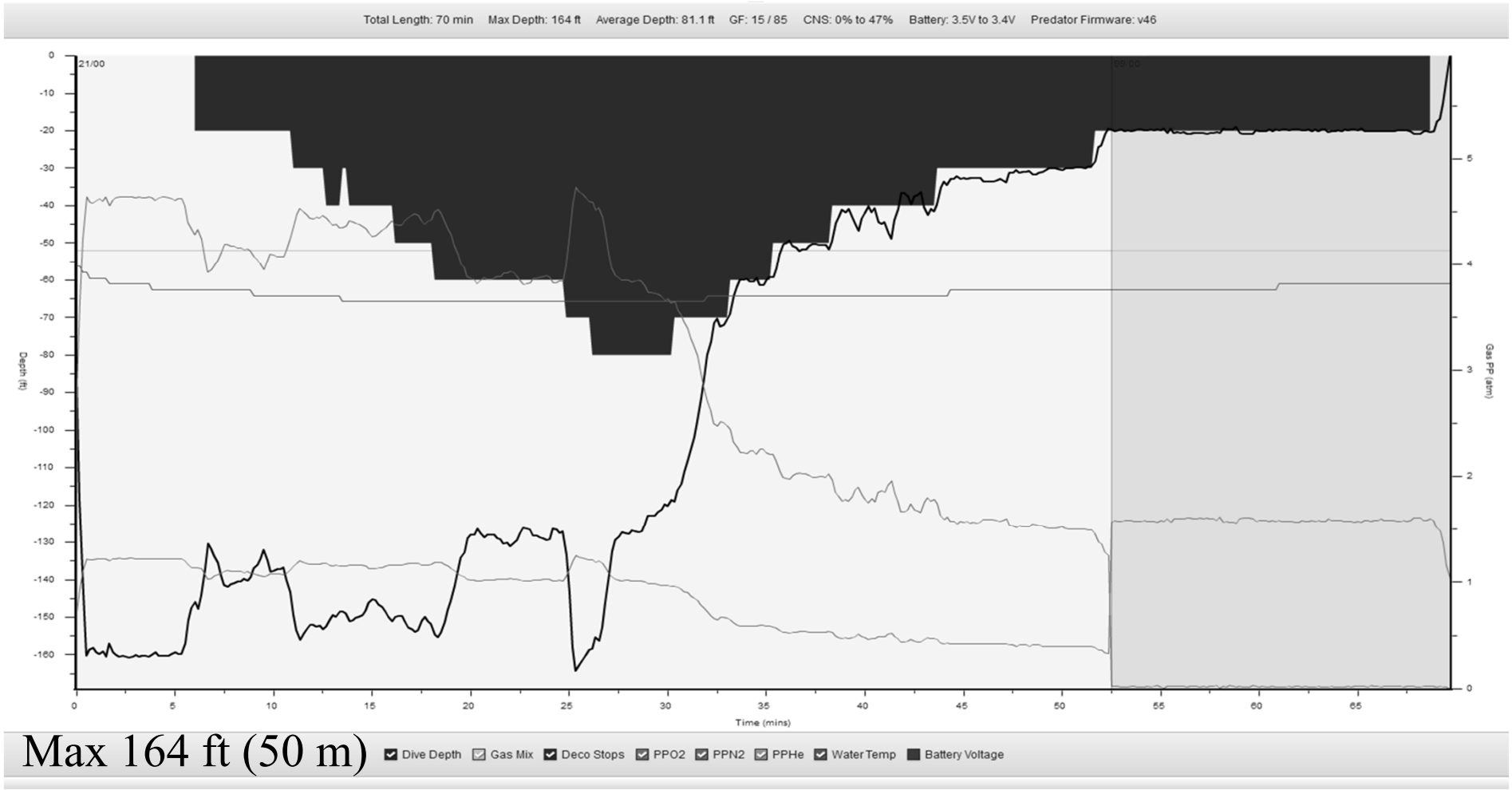
- Limit gas supply
- Actively stay away from limits

} Frequent conflict with human nature

- Nitrox on air tables
  - easy for OC divers
- Set dive computer on lower PO_2
  - easy for CCR divers

} Create incorrect computation of oxygen toxicity limits

- Gradient factors
  - flexible, intuitively clear



Max 164 ft (50 m)

- Decompression dive run close to limit with GF setting of 15/85
- Diver ended up with DCS symptoms after next dive

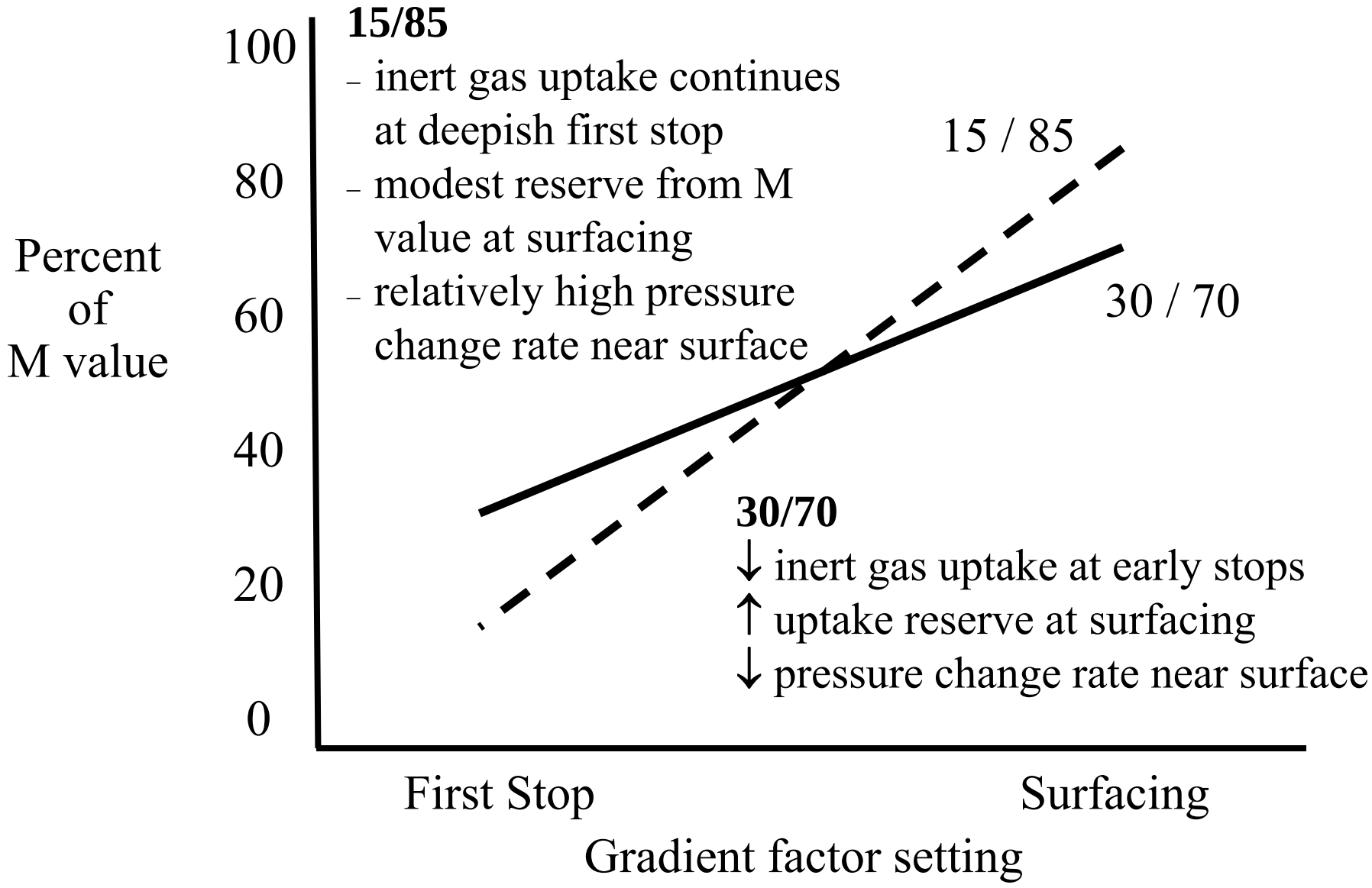
DECOMPRESSION: GRADIENT FACTORS

- M-values ('maximum allowable inert gas pressures') describe theoretical tissue limits for safe decompression
  - both bubbles and DCS can develop below M-value
- GF limit the fraction of M-value reached during ascent
  - often applied to Buhlmann algorithm
  - two-step - e.g., 30/70
    - first stop depth at 0.3 M-value
    - surface at 0.7 M-value

$$GF = \frac{\text{Tissue Compartment Pressure - Ambient Pressure}}{\text{M-value - Ambient Pressure}}$$

- Some computers with user-adjustable GF
  - APD Vision Trimix; Liquivision Xeo; Shearwater Petrel / Predator; VR Tech VRX / NHeO3

Images courtesy
Shearwater Research



Setting a wide range between the first stop and surfacing gradient factors increases the decompression slope at the critical shallowest end of the dive.

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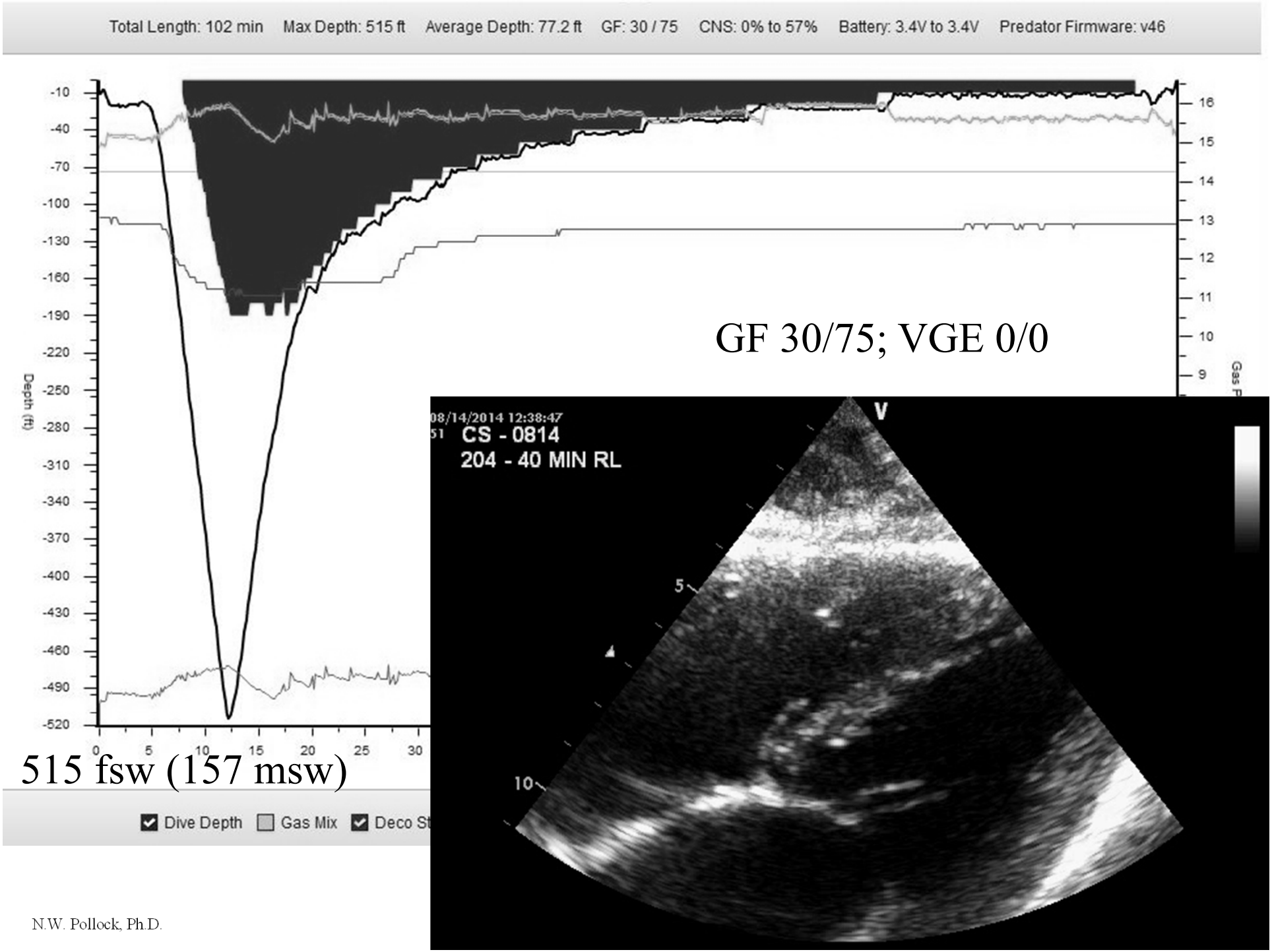


GF 30/75; VGE 0/0

515 fsw (157 msw)

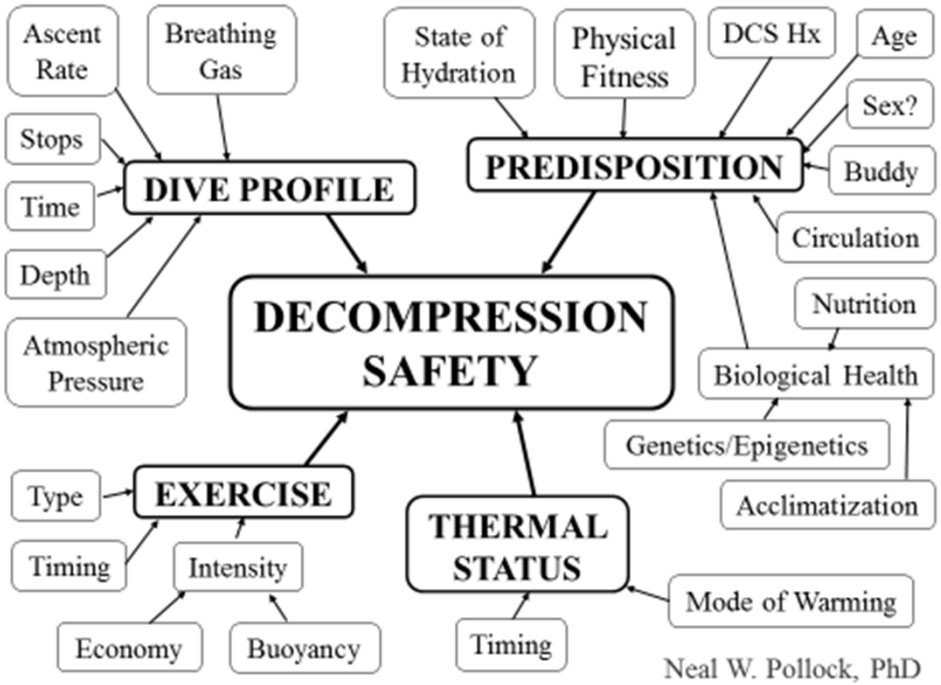
DAN ONLINE INCIDENT REPORTING

- New online system focuses on non-fatal events
  - facilitating collection of complete case data

http://DAN.org/IncidentReport

SUMMARY

- Deco stress represents a dynamic integration of factors
  - diver actions can dramatically alter level of risk
- DCS is not the only risk
  - awareness, documentation and sharing are critical



REFERENCES

- Dardeau MR, Pollock NW, McDonald CM, Lang MA. The incidence rate of decompression illness in 10 years of scientific diving. Diving Hyperb Med. 2012; 42(4): 195-200.
- Dujic Z, Duplancic D, Marinovic-Terzic I, Bakovic D, Ivancev V, Valic Z, Eterovic D, Petri NM, Wisloff U, Brubakk AO. Aerobic exercise before diving reduces venous gas bubble formation in humans. J Physiol. 2004; 555(3): 637-42.
- Dujic Z, Palada I, Obad A, Duplancic D, Bakovic D, Valic Z. Exercise during a 3-min decompression stop reduces postdive venous gas bubbles. Med Sci Sports Exerc. 2005; 37(8): 1319-23.
- Gerth WA, Ruterbusch VL, Long ET. The influence of thermal exposure on diver susceptibility to decompression sickness. NEDU Report TR 06-07. November, 2007; 70 pp.
- Jankowski LW, Tikuisis P, Nishi RY. Exercise effects during diving and decompression on post-dive venous gas emboli. Aviat Space Environ Med. 2004; 75(6): 489-95.