

DECOMPRESSION STRESS - BEYOND THE ALGORITHM



Neal W. Pollock, Ph.D.



Divers Alert Network and
Center for Hyperbaric Medicine and Environmental Physiology
Duke University Medical Center
Durham, NC

Undersea and Hyperbaric Medical Society
Montreal, Quebec – June 2015

neal.pollock@duke.edu

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

[illegible]

POPULAR DECOMPRESSION ALGORITHMS

Empirically-Derived

HALDANE

BUHLMANN

DCIEM

"Gas content models"

Theoretically-Derived

DSAT

VPM

RGBM

"Bubble models"

- ◆ 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

POST-DIVE EXPOSURE



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

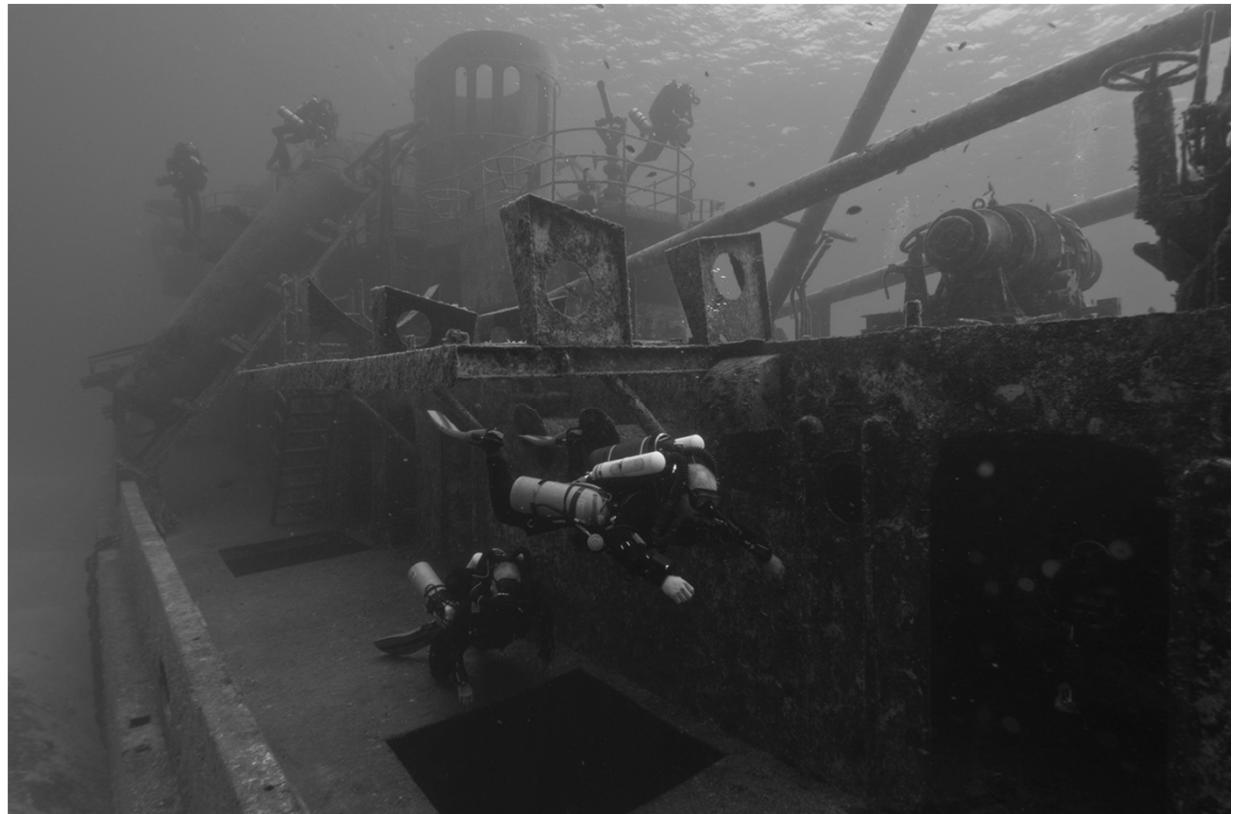
POST-DIVE EXPOSURE



High bubble loads can develop after dives within algorithm limits

DECOMPRESSION REALITIES

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



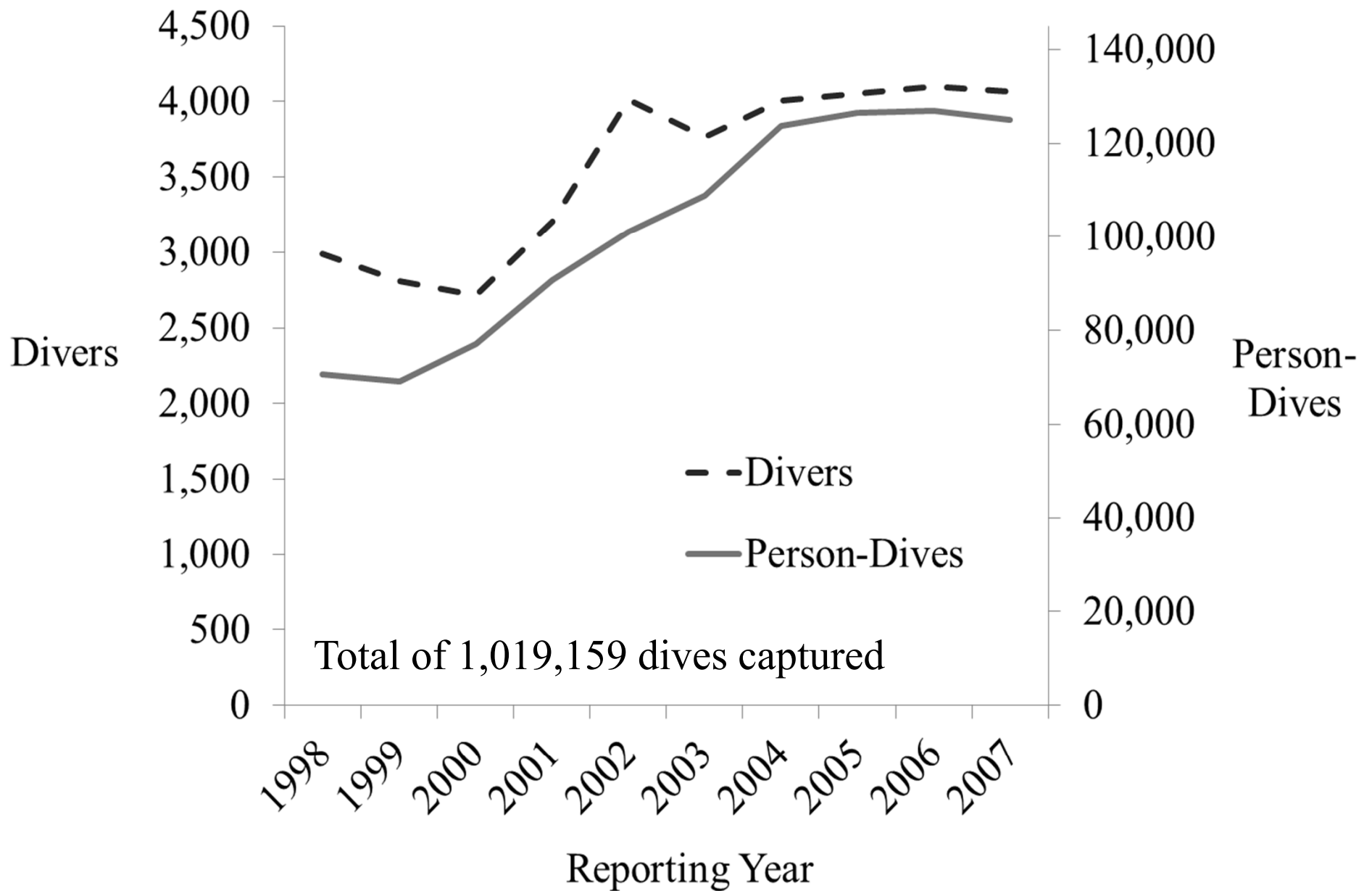


Figure 1. Number of divers and reported scientific dives by year (Dardeau et al., 2012).

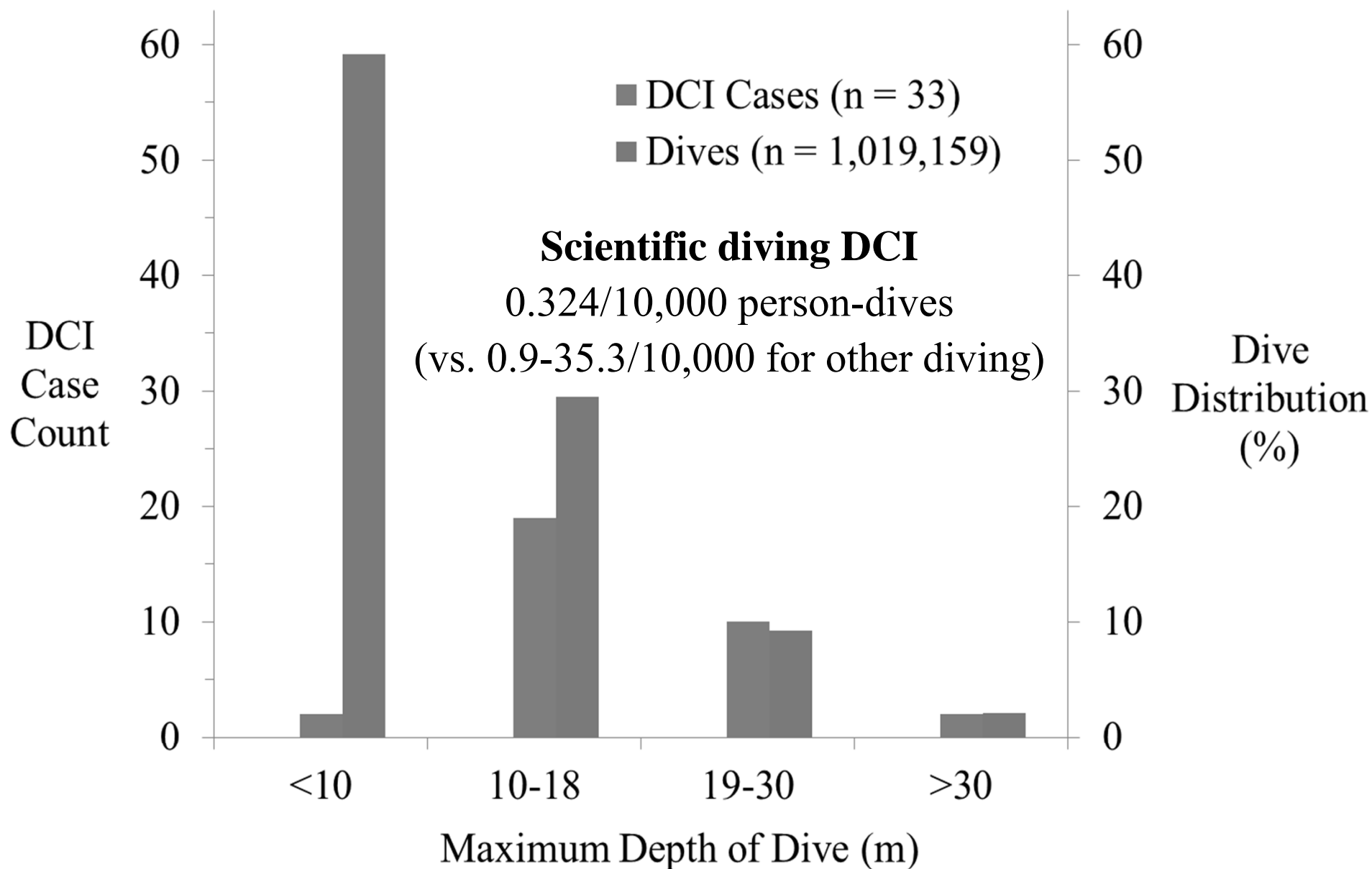
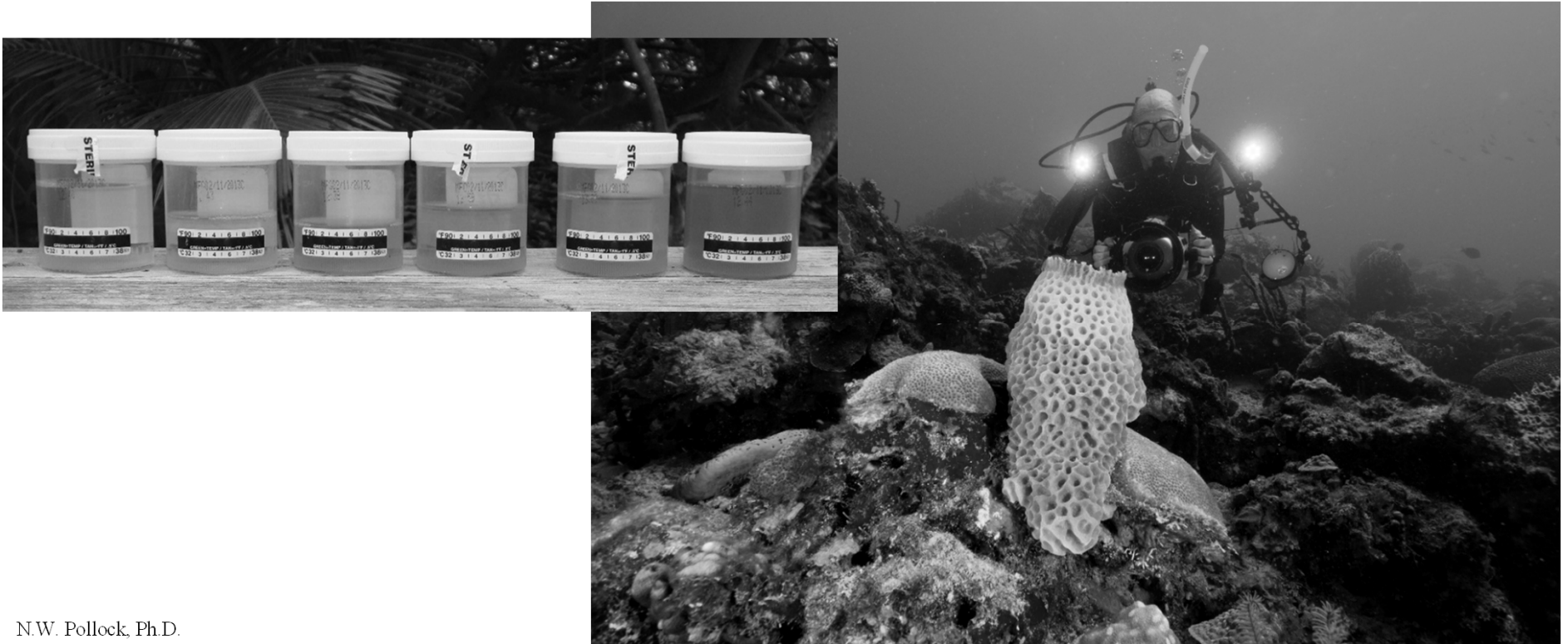
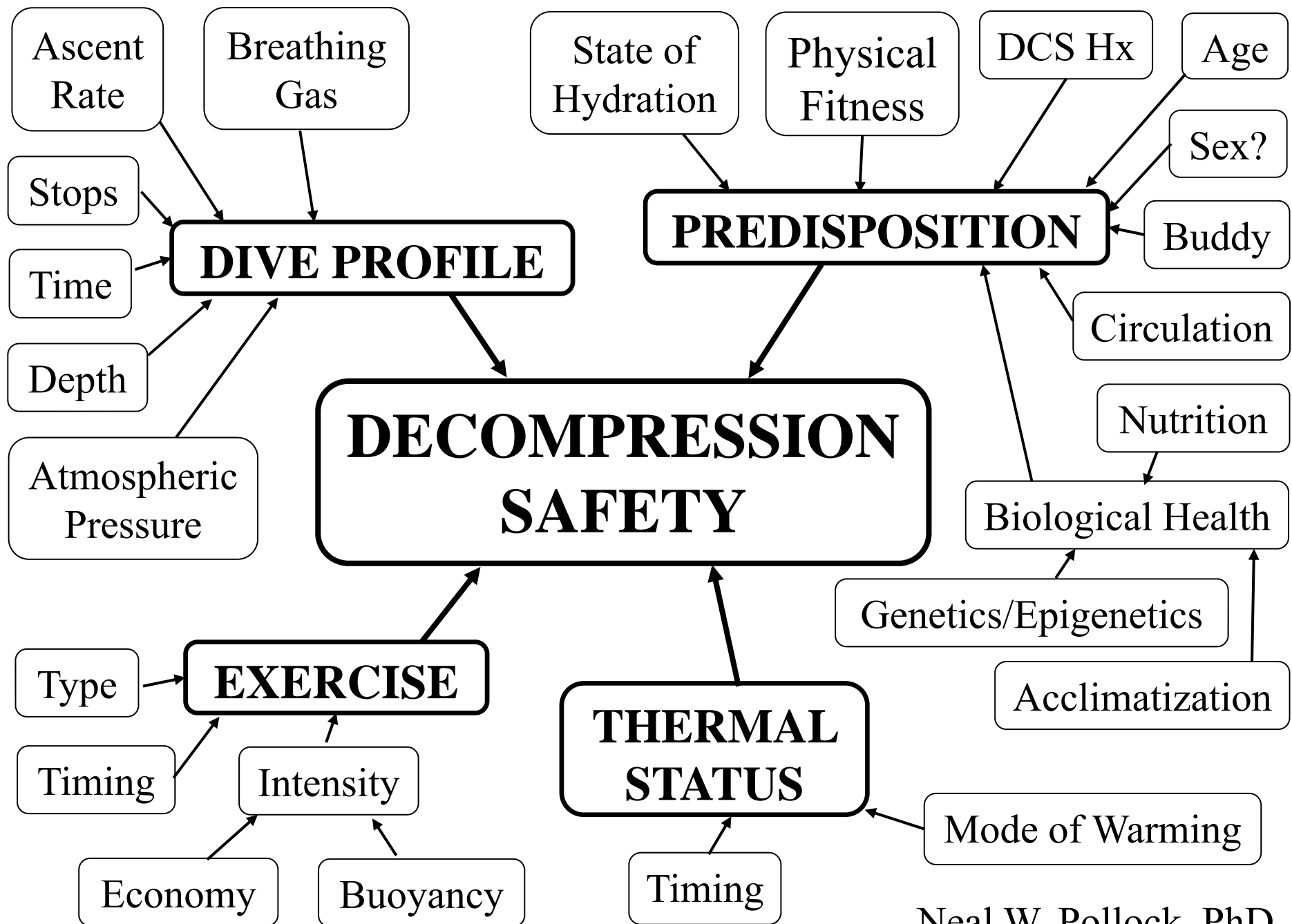


Figure 3. Depth distribution of DCI cases (count) and dive distribution (%) (Dardeau et al., 2012).

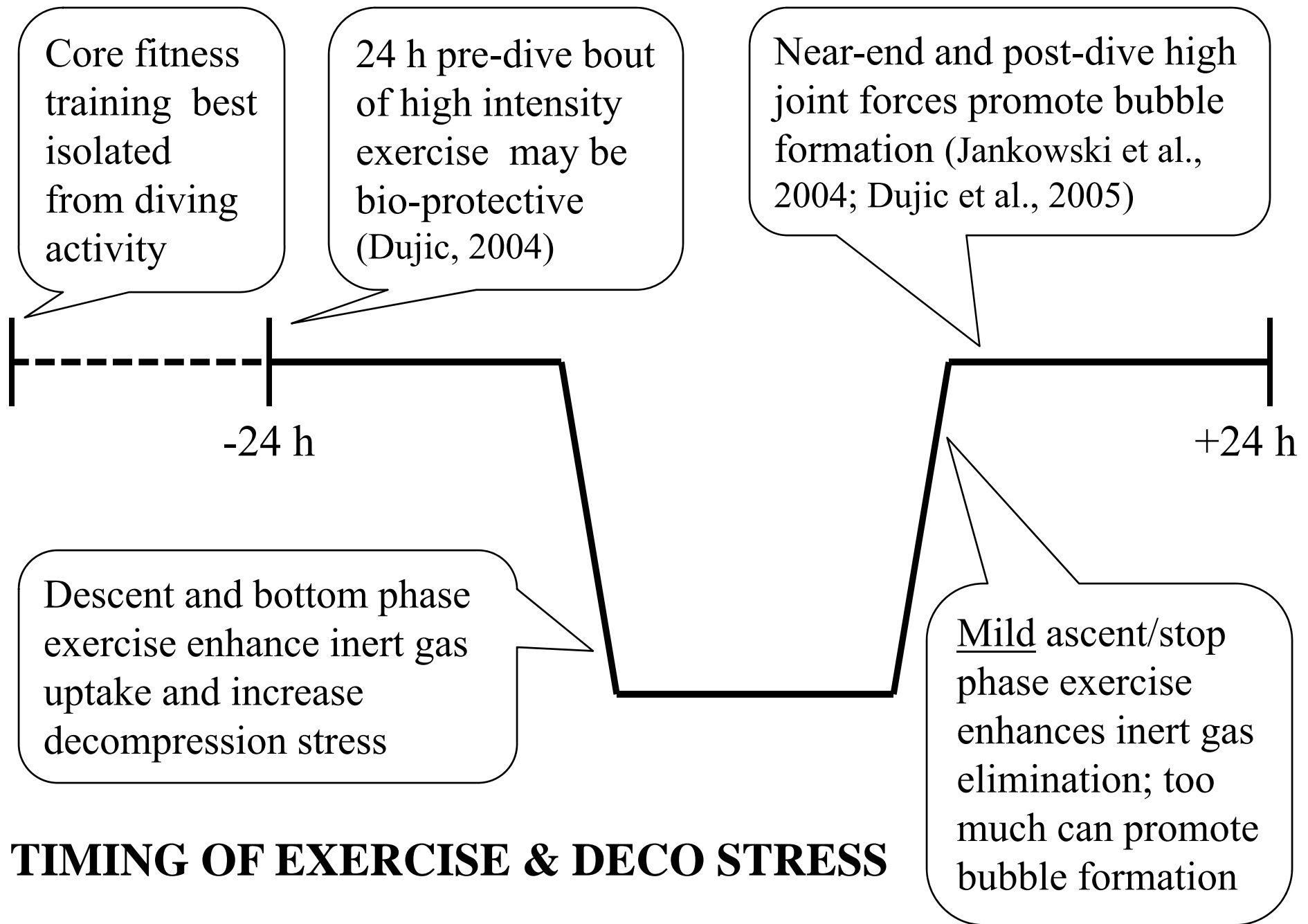
DCS - THE PERSONAL AFFRONT

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



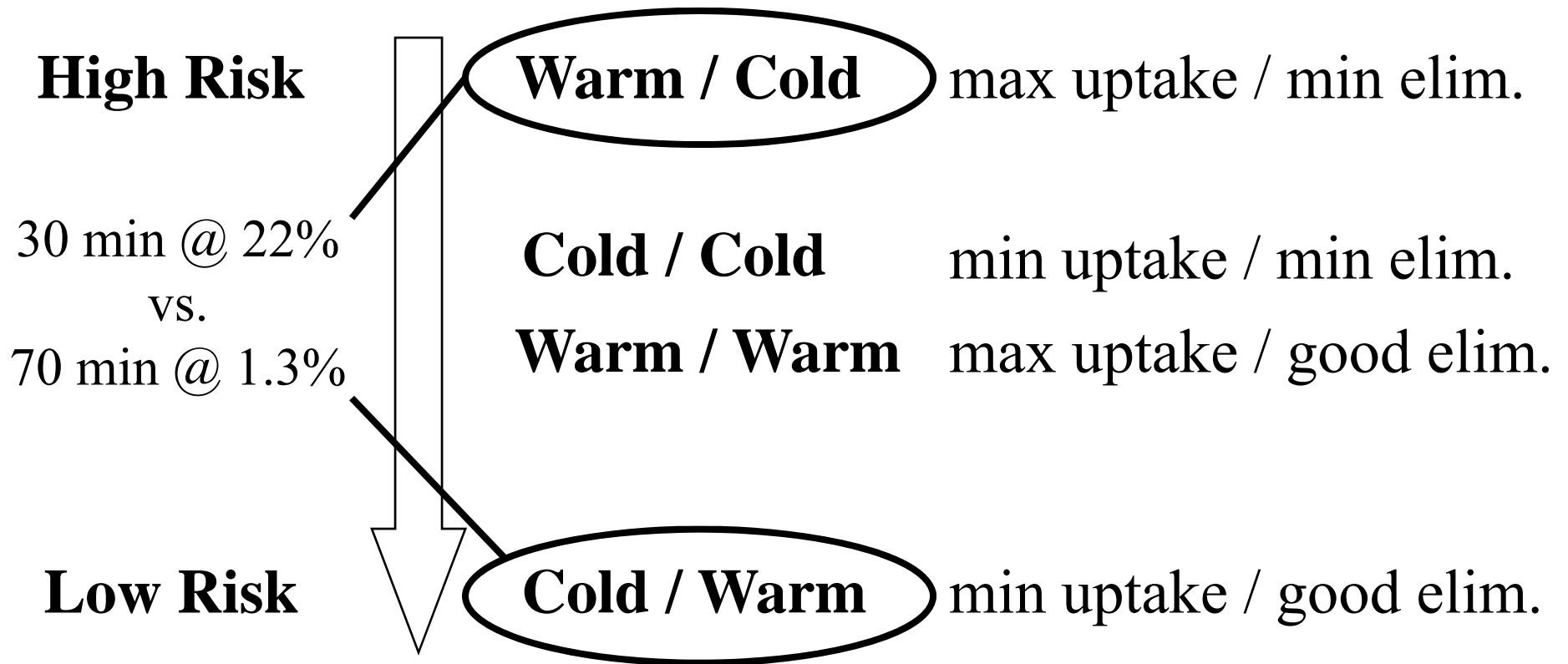


Neal W. Pollock, PhD



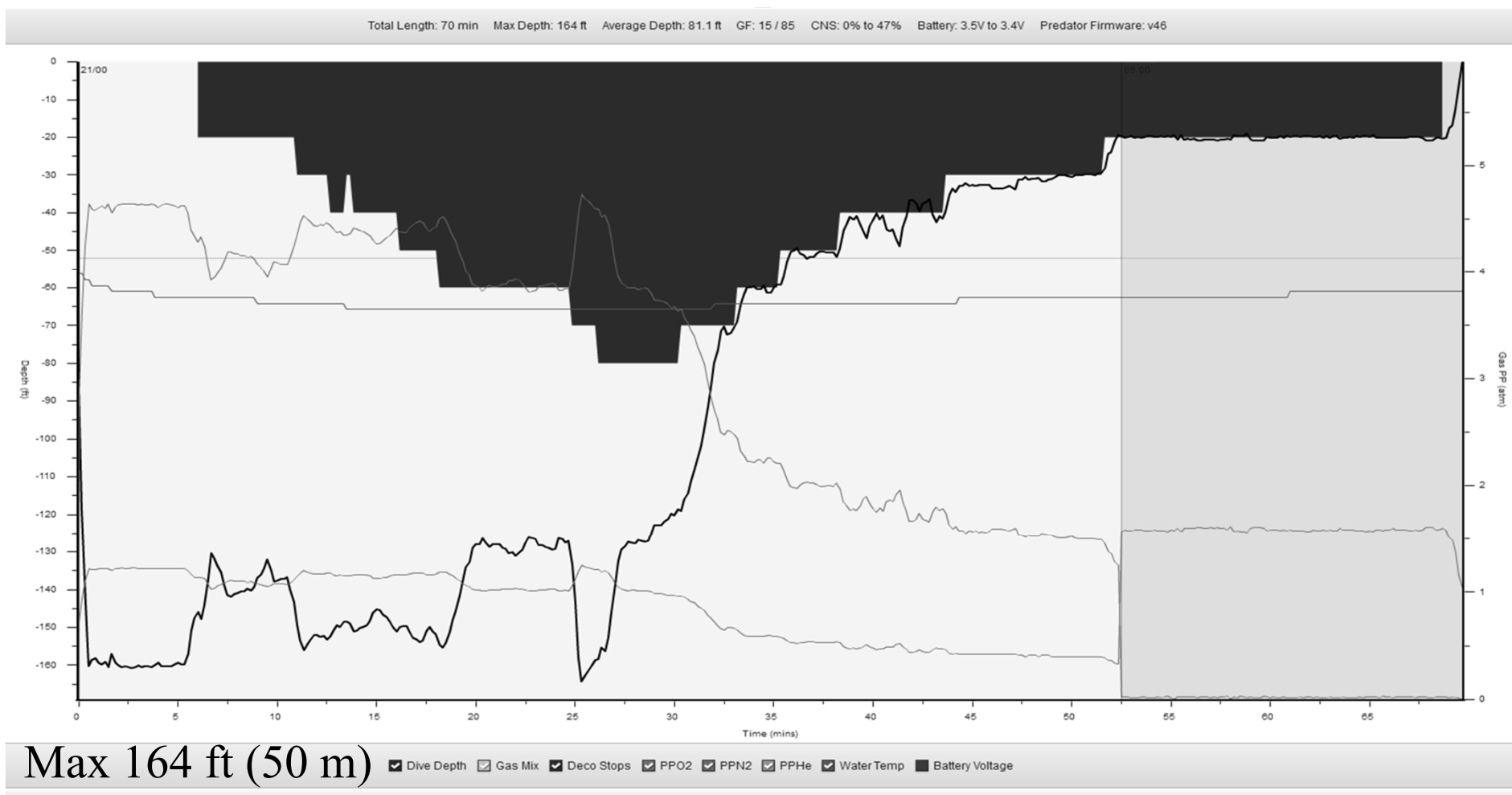
THERMAL STATUS AND DECO STRESS

- ◆ 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' = 36°C (97°F) and 'cold' = 27°C (80°F)
 - Gerth et al. (2007)



HOW TO INCORPORATE CONSERVATISM?

- ◆ Limit gas supply
 - ◆ Actively stay away from limits
 - ◆ Nitrox on air tables
 - easy for OC divers
 - ◆ Set dive computer on lower PO_2
 - easy for CCR divers
 - ◆ Gradient factors
 - flexible, intuitively clear
- Frequent conflict with human nature
- Create incorrect computation of oxygen toxicity limits



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

DECOMPRESSION: GRADIENT FACTORS

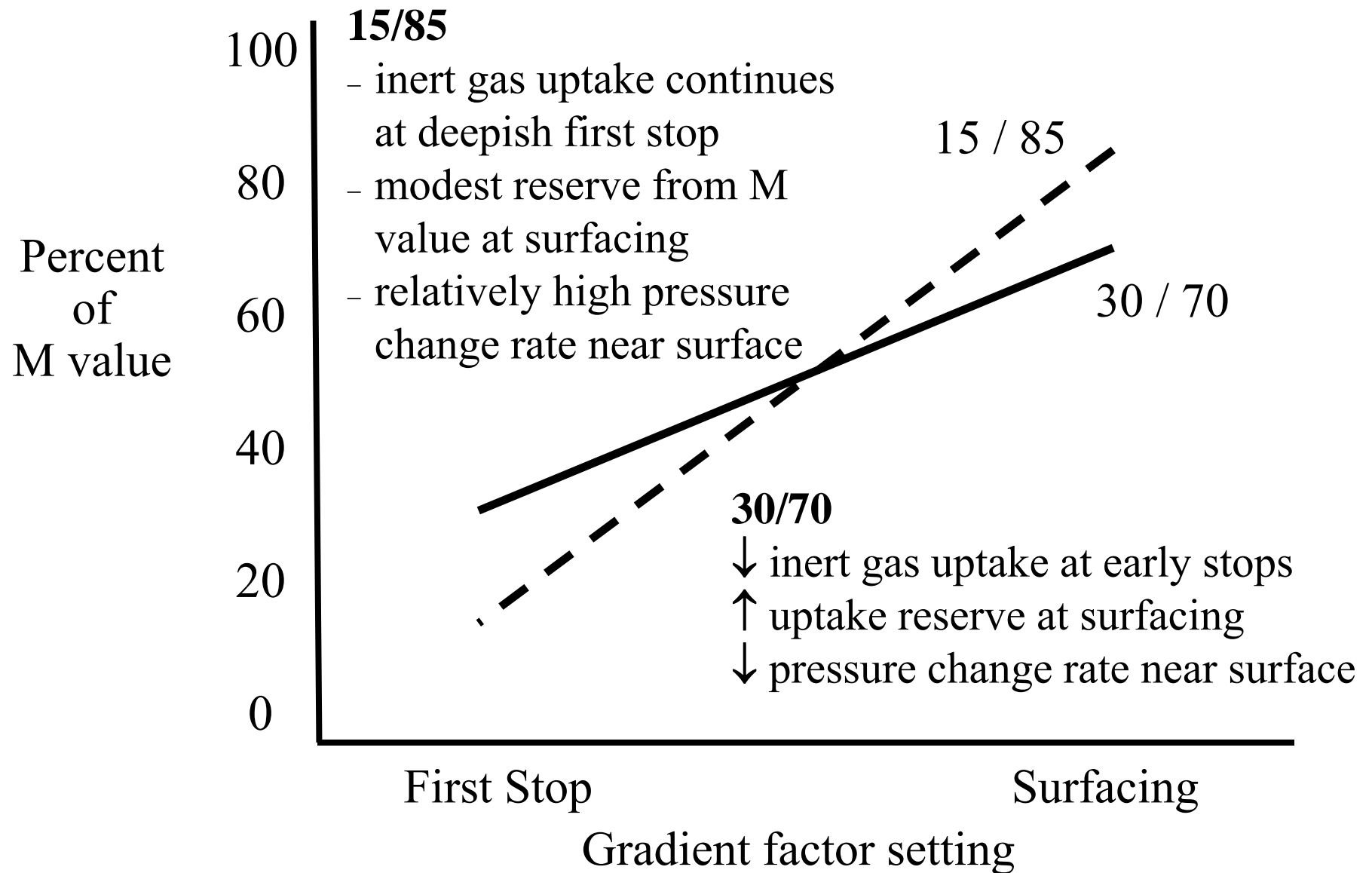
- ◆ M-values ('maximum allowable inert gas pressures') describe theoretical tissue limits for safe decompression
 - both bubbles and DCS can develop below M-value
- ◆ GF limit the fraction of M-value reached during ascent
 - often applied to Buhlmann algorithm
 - two-step - e.g., 30/70
 - ❖ first stop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

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

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

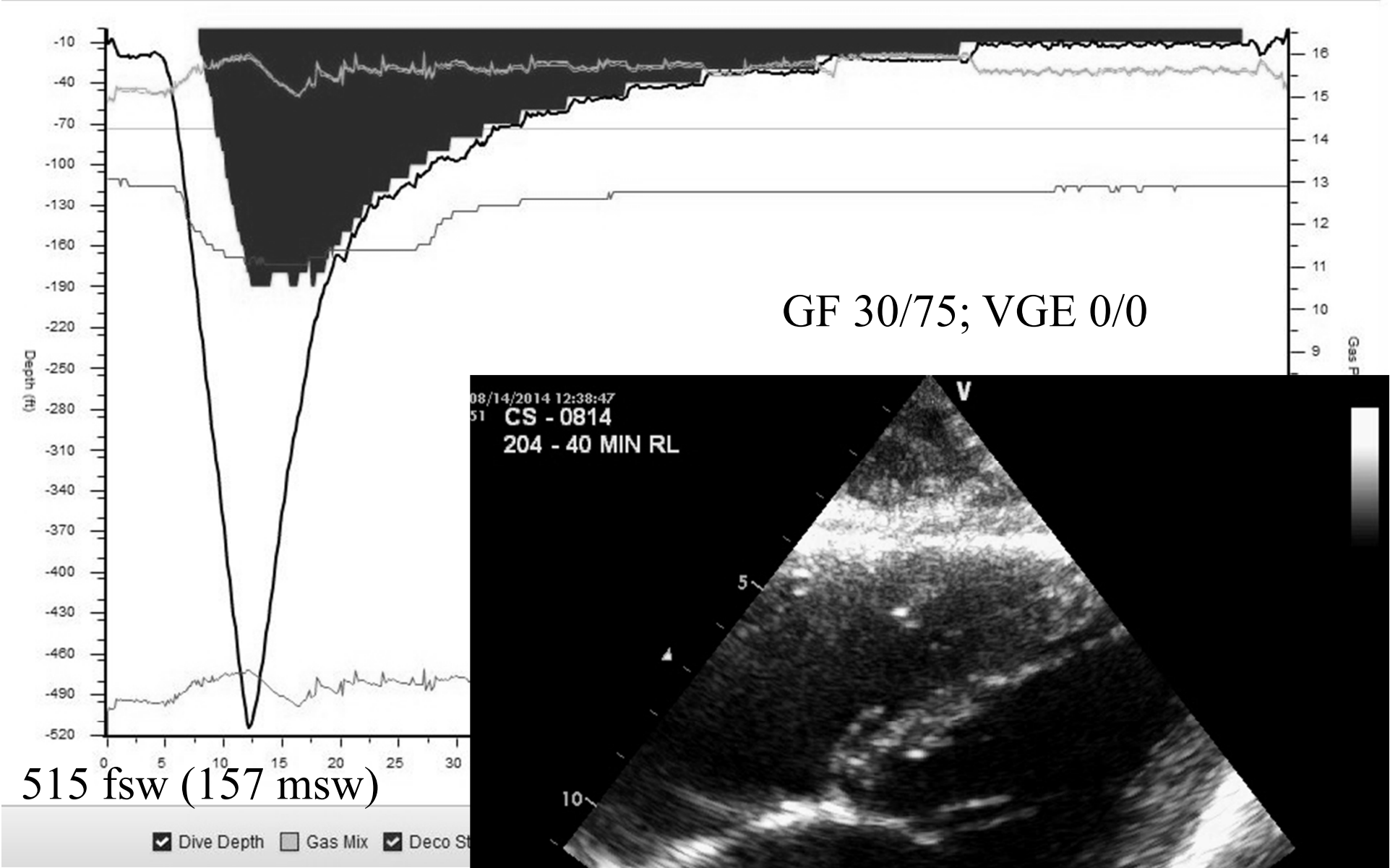
Images courtesy
Shearwater Research





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

Total Length: 102 min Max Depth: 515 ft Average Depth: 77.2 ft GF: 30 / 75 CNS: 0% to 57% Battery: 3.4V to 3.4V Predator Firmware: v46



DAN ONLINE INCIDENT REPORTING

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

<http://DAN.org/IncidentReport>

The screenshot shows the DAN Online Incident Reporting form, specifically the 'Step 1: Incident' tab. The form is titled 'INCIDENT REPORT (BREATH HOLD)' and includes a navigation bar with tabs for 'Intro', 'Step 1: Incident', 'Step 2: Victim', 'Step 3: Lifestyle', 'Step 4: Experience', 'Step 5: Trip', 'Step 6: Details', and 'Step 7: Additional Info'. The 'Intro' tab is currently selected.

ABOUT
Divers Alert Network (DAN) has maintained a diving incident database since 1989. Originally it was limited to scuba diving incidents. This on-line reporting system is designed to include breath-hold diving incidents. In addition, rebreather incidents will now be reported separately from scuba incidents.

INSTRUCTIONS
Persons reporting cases are not required to provide their name and contact information. The information is requested to facilitate follow up if warranted (and if the person grants permission for contact to be made - asked as one of the final questions). The results of our data collection and analyses are made public for the benefit of the community. Data are released only in anonymous form. No individual shall be identified in the reviews of cases presented verbally or published.

We appreciate your time and effort in providing this information. The incident collection instrument is divided into eight steps/tabs each with a series of questions. The time required to complete the forms will vary with the amount of detail available and the complexity of the case. Hidden fields will appear if responses prompt the need. Each tab will be saved automatically when you select "Submit and Continue." After saving a tab, you will automatically be moved to the next one. You will be able to move forward and backward through saved tabs to make any necessary changes until you select "Done - Submit Incident Report" on the final tab. At that time, you will no longer be able to return to the case.

All information obtained during the study, including the respondent's identity, will be kept confidential to the full extent allowed by law.

Please let us know if you have questions or problems concerning this process.

GETTING STARTED

FIRST NAME:

LAST NAME:

EMAIL:

PHONE:

INCIDENT: ☒ Incident happened to me ☐ Incident happened to someone else

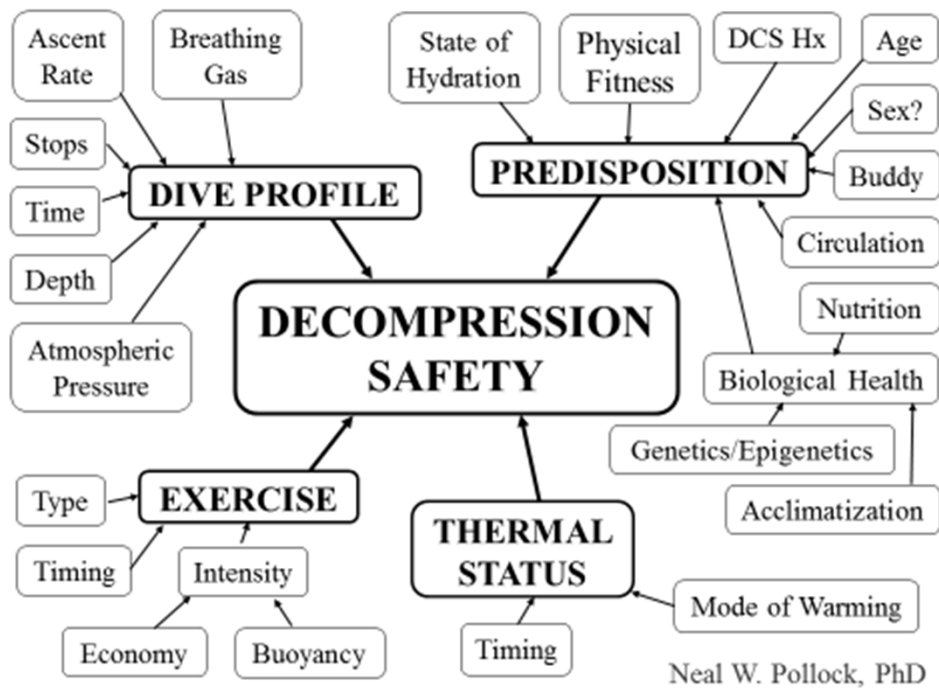
MEASUREMENTS: ☐ Imperial ☐ Metric

DIVE MODE: ☐ Breath Hold ☐ Rebreather ☐ Scuba Open Circuit

©2015 Divers Alert Network

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.