A inquiry into the ownership and use of dive computers

Drs. Johannes W.P. van Dam

In co-operation with
Dr. Nico A.M. Schellart

November 2010
Acknowledgments:

First of all I like to thank all those who participated in this inquiry and freely gave their time to complete the questionnaire, in particular the members of the Dutch Association for Diving medicine, NVD, and especially Drs. J.-J. Brandt Corstius and Drs. Pascale Kragt for the distribution and collection of the questionnaire forms. I would like to thank Dr. A.J. van der Kleij and Drs. E.A. van Riet Paap for their participation in the development of the setup, the questionnaire and their repeated proofreading of the concepts of this report. Furthermore I like to thank Ir. H.J. van Grol for his input, corrections, analyses and suggestions and for his unfailing support. A special word of thanks is owed to Dr. Nico A.M. Schellart who participated in all stages and who was material in the distribution of questionnaires, sometimes in exotic locations, their collection and scoring of a substantial part thereof. He also provided statistical analyses of the data, even during his stay in Australia.

I like to dedicate this report to my father Mr. A. van Dam, 1915 -2009.
Abstract
By means of a questionnaire, we attempt to gain insight in the ownership, use, safety and user satisfaction of dive computers (DC) by a group of Dutch sport divers.
On average, DC types that were developed more than 15 years ago are no longer used. A report of the SDR (1) shows that more recent DCs are at the least fairly reliable and the results of this inquiry show a high degree of confidence in the DC by their users. This proves to be justified, by us finding a high degree of reliability. However, about 1 in 6 of the divers in our survey fails in the safe use of the DC.

Introduction
Over a number of years, the Dutch Society for Diving Research, SDR (www.duikreserach.org), has spent a great deal of time and effort investigating the many aspects of dive computers, the principles of the algorithms they operate under (1, 2) and giving advice to the prevention of decompression sickness (3). Until now, primarily a functional approach was adopted e.g. testing DC’s to fixed diving profiles and collaborating in the screening of divers for bubble forming (4, 5). This enabled the SDR to issue recommendations for less-than-fit or aged divers for settings their DC.
In this inquiry the owner were asked how they use their dive computer (DC) and what functions and features they want in a DC. Also we look for insight in safe diving procedures and what problems were encountered and what reactions these invoked...
Many features of recent DCs promote safe diving and consequently hypotheses or expectances can be formulated about the use and about correlations between at the one hand characteristics of the users, such as age, sex and items about experience in diving, and at the other hand habits formed while diving with a DC and the relation with correct procedures and optimal use. In the Method section a number of obvious hypotheses will be addressed.

Methods:
For this investigation an inquiry form was drawn up with some 40 questions to gain insight in as many as possible relevant aspects of DC use and satisfaction. A small section of the Dutch diving community was asked to complete the form. The majority of the questionnaires were completed on the spot, supervised of one of our members. However the collection of all the data took place over the course of several months.
It was a pleasure that everyone asked freely gave his or her time to complete the forms. The members of the SDR would like to express their sincere gratitude to all the divers that participated!

Part 1 deals with the demographics, organisational affiliation, general diving experience and experience in the use of DC’s of the respondents, as well as brand and type DC owned at present and in the past.
Part 2 investigates the functions of their DC that the respondents actually use.
Part 3 evaluates the information displayed on the screen: is the right amount of data presented on the display in an adequate form and is it legible under all circumstances.
Part 5 asks for any anomalies and malfunctions users may have encountered.
Part 6 lists the best and least liked features of the users DC and provides the possibility to add comments.

From the occurrences of DCS (decompression sickness) as described in the literature, it is known that various types of dives carry an increased risk, such as decompression dives, repetitive dives, swift-current dives and dives in mountain lakes. The practice of making any of these 4 types of dives has been scored together. When all 4 are practiced the score is 4, so each type yields one point (R-score).

**Hypothesis 1.** We hypothesize that the R-score is correlated with experience as expressed in the next items: number of years of dive experience (Yexp), the number of dives/year (D/Y), the number of years of experience with a DC(Y-DCexp) and the number of dives made with this (or more) DCs (D-DC) (Part 2).

**Hypothesis 2.** It is generally adopted that females and older divers show more conservative behavior, in other words make less risk-dives. (Part 2).

**Hypothesis 3.** The more experience (as expressed in the four items mentioned above), the more the use of the DC is optimized. (Part 2)

**Hypothesis 4.** More experience is positively correlated with using the NDL. (no-decompression limit)

**Hypothesis 5.** The four items of experience are positively correlated with avoiding the NDL decrease to 0 minutes.

**Statistics**
Note that means, standard deviations, correlation coefficients (Pearson) and P-values were calculated, even when the distributions are somewhat deviating from normal or when the number of an ordinal variable is larger than 2. Variables with a distribution seriously deviating from normal are log-transformed (e.g. D-DC).
For dichotomous choices and a continuous variable the point biserial correlation coefficient was calculated.

**Results:**

This inquiry is divided into several parts:

**Part 1 Demographics, affiliation and brands of dive computers**
Questions 1 - 11
Up to date 104 respondents are included in this summary.
Not surprisingly, only 16 % of respondents is female.
The average age of 45 ± 9.6 (m±SD) years of our respondents is higher than expected. This is most likely due to the restriction of this survey to specific
groups. A full 70% are diving medical professionals within the Dutch Association of Diving medicine, NVD.

Most divers are certified by PADI and have an average certification level of Rescue Diver or the equivalent in other organisations, 26% were educated by the Dutch Sportdiving Association, NOB and their certification level was on average 2.5 star diver. The number of divers with IADS certification may be somewhat overestimated since all came from only one club visiting the decompression chamber.
The high certification level is reflected in the years of dive experience: $12 \pm 9.1$ on average.

Our respondents make an average number of $35 \pm 30$ dives yearly, however with a median of 25/year due to 11 divers who made more than 75 dives annually.
Ninety-eight times the brand of the DC was entered in the questionnaire and of these DCs 69 were made by SUUNTO (66%). The Cobra (old type), Gekko and Vyper (old type) models were most frequently mentioned. Of the other brands UWATEC is owned by 9% and Mares by 6% of the divers.

About 37% of our respondents previously owned at least one DC before their present one, also predominantly SUUNTO models.

![Figure 5: Types of Suunto and brands of other DC's](image)

![Figure 6: Years of experience with DC's](image)
Experience with DC’s is on average 6.1 ± 4.4 years and 79 (median, range 1-750) dives were made with the current DC

![Number of dives with DC's](Figure 7)

**Part 2 Functional application of DC’s**

**Questions 12 - 23**

Practically everyone (97%) uses his or her DC as a depth-gauge and bottom timer, not surprisingly because this is the very use it was conceived as. Only 82% use their DC for the display of NDL (no-deco limit). Why 18% does not use this information is enigmatic, since this information is key to safe diving. Use of NDL appears to be correlated with Dives/Year ($r = 0.2$, $p = 0.02$) and Dives-DC ($r = 0.34$, $P = 0.0002$; see Fig. 9), not with $Y_{exp}$ and $Y_{DCexp}$.

So, we must reject hypothesis 4.

Eighty-five percent of our participants use their DC to safeguard their ascent rate. A possible reason why not all use the ascent rate feature is that some DC models give a very weak audible warning or none at all. Although there is always a visual display of the ascent rate, its clarity leaves in many models much to be desired and it is often impractical having to watch ones DC during the entire ascent. Unexpectedly, only 61% use the NFT (no-fly time) indication on their DC. Although it is evident that a part of the non-users does not fly after diving, from personal observations it is known that many responders do fly after diving, even though the question-box was not checked.

Even more of a surprise is the claim that 44% use Nitrox occasionally as a breathing gas. This likely constitutes an overrepresentation due to the age and education level of our respondents. A majority (58%) indicate that they use their DC in logging their dives and 33% download dives for evaluation.

Repetitive diving is a very common practice (especially during diving holidays or weekend dive-trips), yet is known to severely increasing DCS risk.
Therefore, one would expect that a greater proportion than 84% would use their DC to monitor their saturation status.

Only 18% of the divers deliberately perform decompression dives with their DCs. Bearing in mind that PADI, as well as other diving associations, actively discourages all planned decompression dives, this low number does not come as a surprise. Indeed, there is a tendency that PADI divers make slightly less decompression dives (P=0.07).

Equally few divers dive under conditions of swift currents (20%). Not surprisingly, only 4 of the respondents claim to use their DCs for diving at altitude, in mountain lakes, since these circumstances are not present in Holland nor in most of the common holiday dive destinations.

We have concentrated all DC applications in one chart:

Hypothesis 1. By correlating the R-score it with years of experience, Yexp, Dives per year, D/Y; Years of experience with DCs, Y-DCexp; and the number of dives with a particular DC, D-DC; we found that only D/Y is well correlated (r=0.36, P=0.00008), Y-DC is only weakly correlated (0.19, P=0.026), whereas Yexp only shows a tendency (0.16, P=0.053). D-DC shows no correlation at all.

Hypothesis 2. Our results do no find that, in our test population, females and older divers make less high-risk dives. Thus we must reject this hypothesis.

Hypothesis 3. A higher number of Yexp, D/Y, Y-DCexp and D-DC is not related with the cumulative score of the 5 items of good practise (GP; question pp to qq); Therefore we must reject Hypothesis 3 as well.
Use of 1) NDL info (yes =1 and none=0) and 2) good practise score (0-5) versus the number of dives made with DC (D-DC). 1) Correct NDL increases with logD-DC ($r=0.34$, $P=0.0002$), but good practise (GP) are not related with logD-DC.
Part 3 Risk management by the users
In this section we ask for potentially risky behaviour in respect to the use of DCs. Desirable behaviour is scored with a 1, while undesirable scores 0, this score depending on factors that might differ e.g. age.
Of all divers 24% indicate in question 26 that they go to the limit as far as bottom-time is concerned: diving till NDL = 0 minute. This appears to be inversely related with the number of years of diving (Yexp, r=-0.32, P=0.0004) and of diving with a DC (Y-DCExp, r=-0.27, P=0.002) but not with numbers of dives. Some 40% allow some extra time, as asked in question 27; how they allow for this, question 28 gets too many mixed returns to give us a proper picture. Therefore Hypothesis 5 must be rejected.

Regarding question 29, about half (45%) will take adequate steps to avoid decompression sickness caused by a too rapid ascent. Of course this is in theory only and the desirable answer is obvious. Furthermore the respondents had ample time to reflect upon this question, a luxury not available in real life when the emergency is pressed upon the diver. One may fear that, when put to the test, still less of the respondents will know how to react appropriately.

For the item, question 30, of the personal or micro-bubble setting a diver of 39 years or under will be awarded an 1 for using the default (factory) settings, whereas a diver of 40 year or older will score a 0 using the same setting, since the underlying decompression model in the default setting cannot cope with ages >39 years and with divers in less-than-desirable physical shape (VO2 max <40 ml/kg.min,) and thus his behaviour is to be considered to increase risk. Only about 52% of the respondents use the default or factory setting correctly. Since the relatively low incidence of decompression sickness, safety margins must be in place elsewhere.
It is most likely due to the practice to avoid reducing the no-decompression limit to, or nearly to, 0 minutes. This has proved to be a very effective strategy. Nine divers put themselves at extra risk since they show the bad habit to dive to the limit (NDL=0) while simultaneously using an incorrect personal setting.

Fortunately, 80% score a 1 for their adequate reaction on total failure of their DC, as proposed in question 31. A matter that is not entirely unheard of, since 18 % report difficulties or malfunctions, included total failure, of their DC at some point in time.

Part 4 Data presentation and display clarity
Questions 24, 25 and 32 – 35.
This paragraph considers with the way the multitude of data is presented and the legibility of the LCD display. Since sensory overload is a significant factor in aviation safety we wonder whether this might be the same in diving. This seems not to be the case, since over 88% of the respondents find the amount and the presentation of the presented data satisfactory. Quite possibly because diving is in its very nature a more sedate endeavour than flying an aircraft. The only complaint that a significant minority (18%) has concerns about legibility in the dark; most of the complaints are with the lack of built-in lighting. In case of the breakage or loss of a diving torch, presenting difficulties in reading the display of
the DC at night, in deep water or in water with poor visibility, a common situation in our home waters! This, without doubt, will lead to an increase in workload, diver stress and the associated risk.

Part 5. Anomalies and malfunctions

Questions 38-41

We try to assess the reliability of de current DCs with four questions; about defects, problems, abnormalities and about any odd information. A failure rate of 12 %, as an average over the 4 items indicates that current DCs are very reliable indeed. Bear in mind that this is not a percentage per dive, but rather over the entire lifespan of the DC until the present. So a full 88% of DC users never encounter a single problem at all. Even than most problems occur when batteries die unexpectedly. This often happens rather sudden and it leaves divers looking for alternatives. Some manufacturers, such as UWATEC, implement a low battery detection system giving adequate backup time, a feature we fully endorse. Remarkably, not even once flooding was the cause of a malfunction, which tells a lot about water tightness.

Figure 11
Part 6 Best and worst properties
Questions 36, 37 and 38.
The owners report as the best properties of their DC’s predominantly: ease of use, clarity of the display and simplicity.
Complaints vary among the divers, but lack of lighting, small or hard-to-use buttons, too loud or too low audible alarms and cluttering of information on the display are most frequently mentioned.

Discussion
This enquiry is of a limited scope in different respects.
The results may be biased by the relatively low number and the non-random selection of the respondents. The majority of respondents are members of diving clubs we are associated with, divers visiting a decompression tank we help to operate and in particular members of the NVD attending courses in diving medicine.
Since questionnaires were distributed at a number of medical seminars and other ones were given out during introduction at the decompression facility this most likely means that respondents have a better-than-average education, insight in decompression sickness and diver safety and above average interest in these matters.
A concern is that the answers are not necessarily always given fairly and correctly. This is something we have noticed evaluating the forms filled out twice by the same diver with an interval of about one year. Another indication is that sometimes answers were given which seems to be less than completely truthful, since the investigators are familiar with specific behaviour of the diver concerned. Also it sometimes happens that answers are inconsistent. Diving to the NDL limit necessitates the use of the NDL-value in the display. It was found that in 18 of the 20 times that NDL info was said to be not used, respondents still reported making dives to the deco-limit, which seems to contradict this.
Nevertheless we feel that the results are of consequence for the general diving public and that the general conclusions will hold up even when a larger and more randomised group of participants were to be used.

Conclusion
We conclude that most divers are satisfied with the very decompression computer they own.
In general, the DC proves to be a dependable piece of equipment, generally giving years of reliable service. According to the users and corroborated by our own test results there are good and better DC’s, but certainly no bad or dangerous ones for sale at present.
This enquiry of 104 divers suggests that the way they use their DCs is adequate, but certainly not more than that. Our sample of divers has on average a high education and is very likely more experienced than the average DC user.
Despite this, about one in six divers does not use crucial information about no-decompression limits, ascent rate and no-flying time!
A serious concern is that the more experienced, the higher the participation in risk-dives and diving to the decompression limits is.
This suggests a certain cavalier attitude that comes with many dives that end well. It ignores the fact that more experience comes with age and with that, becoming more susceptible to decompression sickness.
We certainly cannot blame the manufacturers for this. Manuals clearly and abundantly explain how to use the DCs and how to optimize them for safe diving.
A possible solution for this problem might be to emphasize the proper setup and use of a DC during the theoretical training of novice divers and refresher courses for experienced divers; for the latter category, emphasis should be placed on the proper personal adjustment of the DC, reflecting their age and physical condition.
References:

1a. Dive computers, A comparative investigation of their performance and safety.


3. Een nieuwe methode om de nultijd bij te stellen op basis van leeftijd, aërobe conditie en diepte, Nico A.M. Schellart, 2006. 11 pg, in dutch. (www.duikresearch.org)

4. Bubble Formation After a 20-m Dive: Deep-Stop vs. Shallow-Stop Decompression Profiles, Schellart, Nico A.M.; Brandt Corstius, Jan-Jaap; Germonpré, Peter; Sterk, Wouter Aviation Space Environmental Medicine vol. 79,5 2008: pg. 488-494(7)
In samenwerking met de Scott Haldane Foundation

Enquête duikcomputers

Deze enquête is bedoeld voor alle duikers die regelmatig met de duikcomputer (DC) duiken. De uitkomsten dienen alleen om inzicht te krijgen in de manieren waarop de Nederlandse duiker de DC gebruikt en welke eigenschappen u belangrijk vindt. Alle gegevens worden in vertrouwen verwerkt en geen persoonlijke gegevens worden aan wie dan ook buiten de SDR ter beschikking gesteld. Alleen de samengevatte, bewerkte resultaten zullen op onze website en in onze publicaties openbaar gemaakt worden. (Op www.duikresearch.org, waar u ook veel andere artikelen op het gebied van duiken, decompressie en constructie vindt).

Omdat de antwoorden soms om nadere toelichting vragen, verzoeken wij u uw personalia in te vullen. Wij gaan zeer vertrouwelijk met al uw gegevens om.

Naam:……………………………………………………………………..1
Leeftijd: ……………jaar
Datum invullen:…………………………………………………………20.

E-mail Adres of tel. Nummer:………………………………………2
Geslacht: M / V

3 Brevet:………………………………………………………………………………..3

Organisatie:…………………………………………………………………………..4

5 Hoeveel jaar duikt u al?

6 Hoeveel duiken maakt u per jaar?

7 Hoeveel jaar ervaring heeft u met duiken met duikcomputers?

8 Hoeveel duiken heeft u gemaakt met de DC die u nu gebruikt?

9 Hoelang heeft u de DC die u nu gebruikt al ongeveer?

10 Hoeveel elektronische DC’s had U voor deze al: 0 1 2 3 4 5 meer dan 5?

11 Welk merk en type gebruikt U nu en welk merk en type bezat u hiervoor? (gebruik zonodig de achterkant)
Nu: ………………………merk ………………………………..type
Voorlaatste: …………………merk ………………………………..type

Waarvoor gebruikt u de duikcomputer?
Er zijn meerdere antwoorden mogelijk, graag rondje zwart maken:
12  0 Als dieptemeter + ‘bottom timer’
13  0 Als logboek
14  0 Om de juiste opstijgsnelheid aan te houden
15  0 Voor de 0 decotijden, om te voorkomen in het decompressiegebied te komen
16  0 Om de oppervlakte interval te bewaken
17  0 Om de niet-vliegtijd in de gaten te houden
18  0 Om decompressieduiken te maken
19  0 Voor stroomduiken
20  0 Voor herhalingsduiken
21  0 Om mengselduiken te maken? Zo ja, wat: 1 of meer Nitroxmengsels, of Trimix
22  0 Voor het duiken in bergmeren
23  0 Als………………………………………………………………………………

Hoe gebruikt u uw duikcomputer
24  Gebruikt u tijdens de duik alle info die op het scherm verschijnt?
……………………………………………………………………………………
25  Als u hierboven nee invulde, wat dan wel en wat niet?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
26  Duikt u door, als de omstandigheden dat toelaten, tot de 0 decotijd op nul staat?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
27  Houdt u met een decoduik precies de aangegeven tijden aan (of voegt u extra tijd toe)?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
28  Als u extra tijd toevoegt, hoe doet u dat dan precies?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
29  Wat doet u als u te snel opgestegen bent?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
30  Staat u DC in de fabriekstand of heeft u een persoonlijke stand ingesteld?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
31  Wat doet u of wat zou u doen als een DC onderwater uitvalt?
32  Download u ooit een duik op de computer?
……………………………………………………………………………………
……………………………………………………………………………………

Hoe vindt u van uw duikcomputer:
33  Is de indeling van het scherm overzichtelijk?
……………………………………………………………………………………
34  Geeft het scherm genoeg, teveel of te weinig informatie? ............................................
........................................................................................................................................

35  Is het scherm altijd goed afleesbaar? ...........................................................................
..

36  Wat is het beste punt van uw DC? ............................................................................... 

37  Wat vindt u het slechtste? ............................................................................................. 

38  Is het instrument ooit defect geraakt? ........................................................................ 

39  Heeft u tijdens een duik ooit moeilijkheden met uw DC gehad en zo ja, hoe zijn die opgelost? ..................................................................................................................................

40  Heeft u ooit rare dingen gemerkt zoals het toenemen van de nultijd op gelijke diepte?
..............................................................................................................................................

41  Bent u ooit afgeweken van wat de DC u vertelde omdat u de aanwijzingen vreemd of onlogisch vond? Zo ja, hoe? .................................................................................................................................. 

42  Heeft u verder nog op- of aanmerkingen of andere toevoegingen die ons inzicht in uw gebruik van en wensen voor duikcomputers kunnen geven?
.............................................................................................................................................. 

Hartelijk dank voor uw tijd en medewerking!
De Stichting Duik Research
Questionnaire about dive computers

This questionnaire is intended for all divers regularly using a dive computer, DC. The results will only be use to gather insight in the use of DC and the relevance of available features for all divers, but particularly the Dutch diver. All data are processed in full confidentiality and no personal information will be divulged in any shape or form outside SDR. Only condensed and anonymised results will be published in publications of the SDR and on our website (www.duikresearch.org). Here you may also find other interesting papers on diving, decompression (sickness) and submarine construction. Because some answers may warrant a further explanation we request you enter personal and contact data, which will be held in the strictest confidence.

Name: ........................................................................1 Age: ...........year

Date: ........................................................................20..

E-mail Address or Phone: ..............................................2 Gender: M / F

3 Diving Certification: .........................................................................................................................

4 Diving Association: ...........................................................................................................................

5 How many years do you dive? ...........................................................................................................years

6 How many dives do you make yearly? ...............................................................................................dives
7. How many years of experience do you have with dive computers? ........... years

8. How many dives did you make with the DC you presently own? .......... dives

9. For how many years do you own your present DC? .................... years

10. How many electronic DCs did you own before: 0 1 2 3 4 5 more than 5

11. What brand and what type of DC do you use now and what brand and type of DC(s) did you previously own? (Please use reverse if necessary)
   
   Now:
   Brand........................................ type..........................................
   Last before: Brand ................................ type...............................

   Which functions do you use?
   Most likely more answers apply, please cross all appropriate boxes

   12. 0 As a depth gauge + bottom timer
   13. 0 As a logbook
   14. 0 To maintain the proper ascent rate
   15. 0 To monitor the no decompression limits e.g. to avoid making decompression dives
   16. 0 To time your surface interval between repetitive dives
   17. 0 To guard your no-flying time after your last dive.
   18. 0 For making decompression dives
   19. 0 For diving in swift currents
   20. 0 For repetitive dives
   21. 0 To make mixed gas dives with? If so, what mix e.g. Nitrox; Trimix
   22. 0 For diving mountain lakes at altitude
   23. 0 For .............................................................

   Which features of your DC do you use?

   24. While diving do you use all info on screen?

   25. If not, what information do and what don’t you use?

   26. Conditions permitting, do you allow your no-decompression time on the display to reduce to zero?

   27. Do you surface after a deco dive right when the display tells you or do you add extra time?

   28. If you allowed extra time in Q.27, how do you go about this?

   29. What do you do in case of a too rapid ascent?
30 Is your DC in factory mode or did you make a personal setting to reflect your age, gender or physical fitness?

31 Which action do you undertake in case of total DC failure?

32 Do you ever download and / or analyse you dives on a PC?

How do you appreciate your dive computer?

33 Is the layout of the display clear?

34 Is the on-screen information good, too little or too much?

35 Is the display legible at all times?

36 What do you like best about your DC?

37 What property do you like least?

38 Did your DC ever show any defects at all, if so, what?

39 Did you ever experience difficulties with you DC while diving? If so, what were they and how did you react?

40 Did you ever experience anomalies like an increase in no deco time while staying at the same depth?

41 Did you ever ignore an indication on your DC because you thought it was in error? If so, what was it and how did you react?

42 Would you like to add anything else about the way you use your DC and / or your wishes for further developments?

We greatly appreciate your time and participation in filling out this questionnaire!

De Stichting Duik Research / Dutch Society for Diving Research