Bio-logging science and new tools for marine bio-science

YASUHIKO NAITO
National Institute of Polar Research

ABSTRACT
Bio-logging science was started in 1965 in the study of diving physiology using mechanical diving recorder. Digital instruments replaced mechanical instruments in late 1980's and early 1990's. Accordingly advanced micro-electronic technology enabled an increase in both number of sensors and memory size of the digital instruments, animal borne bio-loggers, which allowed us to measure many variables in situ simultaneously with respect to behavior, physiology and environment of marine animals. The integrated information collected by bio-loggers has also allowed us to understand marine animals as part of complex marine system.

INTRODUCTION

Marine animals are always objectives of our intellectual interest and imagination, as their living features and their living environments, but rarely observed by us. Boundaries between land and ocean made marine animals objectives of our dream and intellectual search for their information. Even very basic information on how they move, how they forage, how they behave is very scarce so that systematic knowledge on their behavior, ecology and physiology from ocean fields were far beyond our needs for understanding. To fill these knowledge gaps, much effort has been made and many devices have been invented to explore the ocean. Among them most effective and successful developments to observe marine lives are SCUBA apparatus, ROV (Remote Operated Vehicle) and AUV (Autonomous Underwater Vehicle). Despite enormous effort on development of the tools, they were still inadequate to study living animals, because they move widely and some times quickly. How to follow their movements is a technological key subject in their behavior study. The first trial against the above key subject was made by a physiologist, who was eager to measure the voluntary dive limits of endothermic marine animals like as seals and diving birds. Kooyman (1965) first deployed TDR (Time Depth Recorder) on the back of Weddell seal (*Leptonychotes weddelli*) for measurement of diving behavior in Antarctica. Following Kooyman several attempts of development of instruments have been made (Gently and Kooyman 1986, Wilson and Brain 1984, Naito et al.1989). Although the mechanical animal-born instruments were highly advanced in those days, it was still inadequate to study animal behavior systematically in the ocean field, and development of digital recorders was strongly expected.

Once digital instruments had take over the mechanicals in 1990's, digital systems have completely changed measurement systems by the multi sensor system, which allowed us to measure many parameters of animal behavior, ecology and physiology simultaneously. Consequently dramatically increased data by digital systems made for a change in data analysis, and advanced computer system was induced for data analysis. Above drastic changes of the bio-logger systems brought us a new concept in the field biology so-called "Bio-logging Science". Here I introduce Bio-logging Science and I introduce a new camera logger recent developed as an example of bio-logging tools.

What is "Bio-logging Science"?

A word "Bio-logging Science" was first used in the theme of the symposium "International symposium on Bio-logging science", which was hold in March 2003 at the National Institute of Polar Research in Tokyo. Bio-logging science was well reviewed Boyd et al (2004) and details of the genesis and evolution of bio-logging were clearly documented by Kooyman (2004) and Naito (2004). According to Boyed et al. (2004), bio-logging has emerged as a tool in animal biology much as genomics has emerged as a tool in the study of cellular and organ function. Bio-logging is certain to increase in its importance and to influence the way we study events and processes that are beyond the usual boundaries of perception and that are remote from the observer. As mentioned above bio-logging science is a truly tool-based science as all modern sciences are. The difference from genomic science is that bio-logging is field science with the objective of understanding complex systems in the animal life and environments in the field. Being different from the experimental biology in the laboratory, it aims to understand the natural system of animal life under uncontrolled conditions. To the question how we can study such complexity in remote fields, the answer is “observation tools”. Technology on digital sensing and recording system is one of the important ways to solve the above question as it allows us to measure many temporal and spatial variables of events and processes simultaneously. The digital recording system is fully dependant on micro electronic technology. In this context we can say that bio-logging science is developing keeping a close relation to new advancing technology, which may amplify magnitude of data both in size and preciseness. This may give us new sights and perceptions in understanding the natural system of the ocean creatures. Thus we can say that the advanced technology plays a role of springboard in field bioscience just as modern genomic science have developed depending on the new tools. Science sometimes moves towards unexpected goals by getting new tools and new methodologies, which might be called a “technological effect”. This technological effect was not predictable in the very early days of bio-logging science. At the start of this science, as Kooyman (2004) describes, genesis of bio-logging has started from the capillary tube for maximum dive depth measurements (Sholander 1940) followed by the depth gauge driven by the kitchen timer (Kooyman 1965). Although these challenging tools were used for understanding physiological limits of the animals underwater, these were by no means challenges to understand complexity of the marine systems. However we now have challenges towards more comprehensive studies getting the technological or methodological effect such as paradigm shift that happed in the gnomic biology. This means, however, that fate of bio-logging is unpredictable by the same reason, because advance of technology is unpredictable. But it is clear at present that bio-logging is a new science to understand the animals and its environment under the unconstrained whole natural system. In this context we can say that bio-logging science is a system science in the field biology”

Visualization by camera loggers

Microprocessor controlled digital bio-loggers allow us to sample data on animal behavior by the depth, light level, conductivity, swim speed, acceleration and geomagnetic fields, heart rate, ECG, body temperature sensors (Fig.1). Not only behavior of the objected animals but also we are now able to monitor the physical environment of the animals by water depth, temperature, conductivity, light level. However, to understand interaction between animals and environment biological information such as prey distribution is the most important. Prey field survey is one previously difficult subject. Thus we have developed miniaturized digital still camera logger (DSL) for measuring the prey distribution by getting the “organisms-eye” views. By combining the camera logger and behavior data logger we can survey the prey distribution from the “Organisms-eye” view in relation to their dive paths (Davis et al 1999, Ponganis et al. 2000, Hooker et al. 3002, Watanabe et al, 2003, Mitani et al, 2004). Digital camera systems had also demonstrated the social events under water such as mother pup relationship in Weddel seals (Sato et al, 2003) and group diving behavior in Adelie penguins *Pygoscelis adeliae* (Takahashi et al. 2004). In developing DSL first effort was also paid on miniaturization and our recently developed DSL is 21mm in diameter, 138mm long, 73g in air with 1300 full color images in memory, which is equipped with pre-programmable command system in both intervals and depth. This DSL was so miniaturized that it was used for estimation of salmon habitat (Kudo et al, unpublished information). With regard to the image data logger there are two systems, video movie logger (VML) and DSL. Although working duration of VML is limited, it can take detail information about prey and predator motion precisely. On the other hand DSL can take information on prey distribution along the dive paths of the animals by randomly sampled image data. To increase the preciseness of information on the prey distribution it is required to increase sampling rate that is depending on memory size or data compression rate. We started to develop new powerful DSL by applying the JPEG equipped camera module with 1.3M pixel resolution, ten times more than our former DSL model. New models will be as same as former model in size and weight and 10 thousands images are expected. This high resolution and large memory camera can conduct the habitat monitoring by estimating the prey condition and other general environments such as predators, marine debris, artificial obstacles, fishing gears and so on.

Miniaturized digital bio-loggers are now powerful tools in animal studies. However the advanced bio-logger is no more than a tool for animal studies, because advanced technologies have made our perception on animal studies fully changed into system biology, which handle huge amount of integrated data on many variables in situ. We also need sophisticated computer system to analyze complexity of marine bio-system. Digital bio-logger tools have also allowed us to link many bio-logger data base by the digital net work systems.

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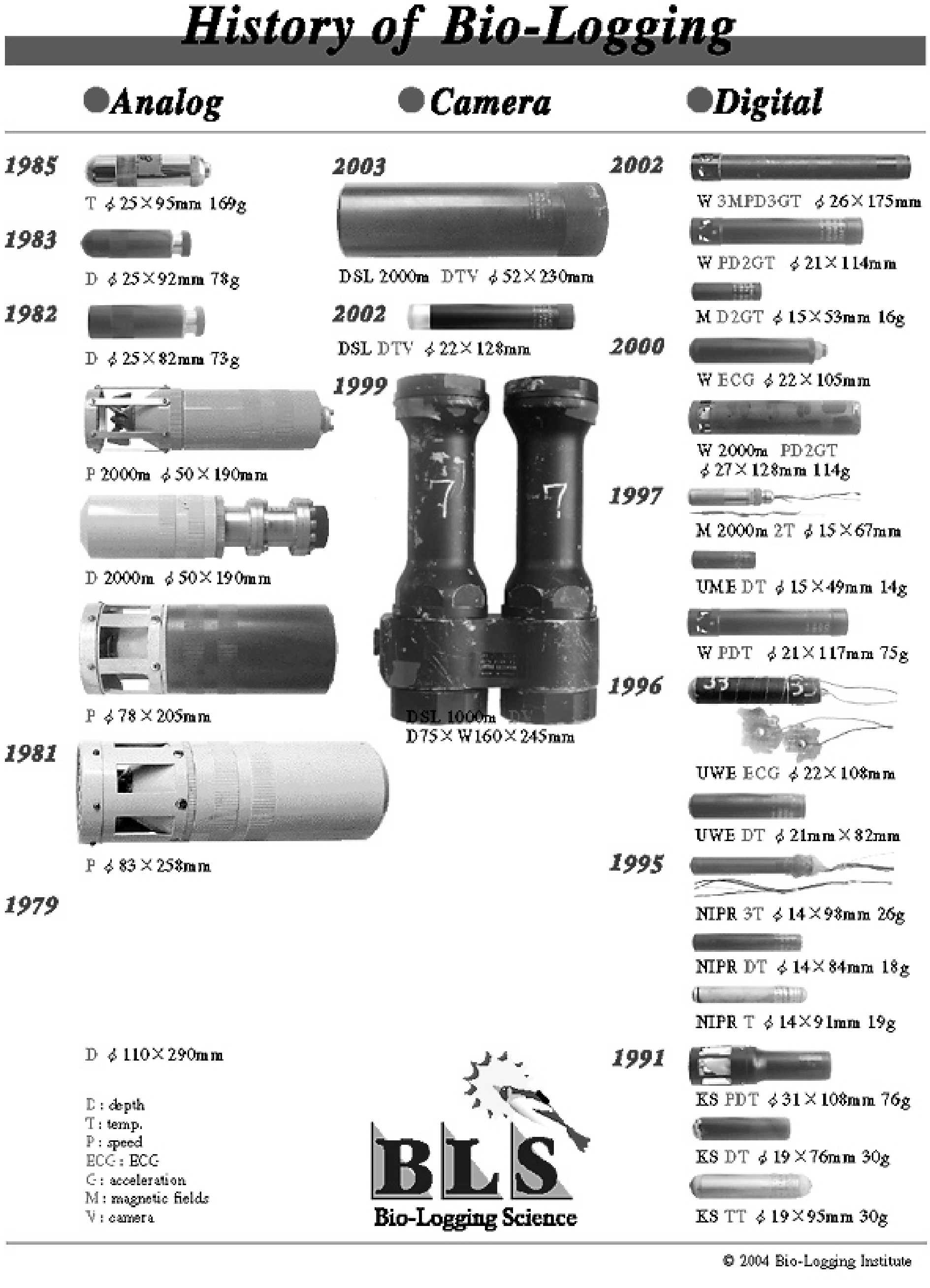
Figure caption

Figure 1

Variety of animal born data loggers has been developed since 1979 in Japan. Replacing the mechanical data loggers developed in 1980's, digital loggers increased memory size and sensors while sizes were decreased.


History of Bio-Logging
Analog
Camera
Digital
1985
T ϕ25×95mm 169g
1983
D ϕ25×92mm 78g
1982
D ϕ25×82mm 73g
P 2000m ϕ50×190mm
D 2000m ϕ50×190mm
P ϕ78×205mm
1981
P ϕ83×258mm
1979
D ϕ110×290mm
D : depth
T : temp.
P : speed
ECG : ECG
G : acceleration
M : magnetic fields
V : camera
2003
DSL 2000m DTV ϕ52×230mm
2002
DSL DTV ϕ22×128mm
1999
DSL 1000m
D75×W160×245mm
BLS
Bio-Logging Science
2002
W 3MPD3GT ϕ26×175mm
W PD2GT ϕ21×114mm
M D2GT ϕ15×53mm 16g
2000
W ECG ϕ22×105mm
W 2000m PD2GT
ϕ27×128mm 114g
1997
M 2000m 2T ϕ15×67mm
UME DT ϕ15×49mm 14g
W PDT ϕ21×117mm 75g
1996
UWE ECG ϕ22×108mm
UWE DT ϕ21mm×82mm
1995
NIPR 3T ϕ14×98mm 26g
NIPR DT ϕ14×84mm 18g
NIPR T ϕ14×91mm 19g
1991
KS PDT ϕ31×108mm 76g
KS DT ϕ19×76mm 30g
KS TT ϕ19×95mm 30g
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