# Training and Education of Fisheries Civil Engineers through Case Studies Involving the Mechanized Fish “Mechanimal” and the “Productmeter” for Measuring Photosynthesis

# 魚類型機械生物「メカニマル」と光合成測定機器「プロダクトメーター」による事例研究を通した水産土木技術者のトレーニングと教育

Chika Suzuki [1*], Akira Kurashima [2], Yasutsugu Yokohama [3], Genjirou Nishi [4,5], Takeshi Sato [5], Sadao Tezuka [6], Takashige Sugimoto [7]
鈴木　千賀、倉島　彰、横浜　康継、西　源二郎
佐藤　猛、手塚　覚夫、杉本　隆成

Since the enactment of the Marine Fundamental Law, the importance of marine education has been strongly emphasized in school education, including mandatory education. The use of tools such as the “mechanimal” and “productmeter” is awaited for financial reasons based on their achievements in the training of fisheries civil engineers.

Key words: marine education, mechanized fish “mechanimal,” productmeter, fisheries civil engineers

水産土木とは、水産学と土木工学との融合からなる。海洋工学とは異なる、生物に重きを置いたその分野的特殊性から、大学における水産土木技術者の養成教育はこれまで十分におこなわれてきていなかった。東日本大震災、魚離れなど、水産国日本における解決すべき課題は累積している。水産基盤整備事業 ( 水産庁 ) の根幹をなす水産土木技術者の養成は、大学に限らず義務教育を含めた学校教育の時点から浸透させていくことが急務であろう。しかしながら、水産土木の根幹にあたる「海洋環境・生物環境を自然条件で比較しながら勉強する機会」は相変わらず学校教育では得にくい。教材となる関連機器が高額で操作が難しいという背景もある。世界的にも海の森 ( 藻場 ) を起点とする沿岸域の環境やその生物資源の利用に関して注目が集まっており、その重要性は増すばかりである。本研究では、機械生物メカニマルと光合成測定機器プロダクトメーターに焦点を当てて、水産土木技術者養成を念頭にその教材としての可能性について検証した。

キーワード：海洋教育、魚類型機械生物 ( メカニマル )、プロダクトメーター、水産土木技術者

1 Organization of Advanced Science and Technology, Kobe University, Kobe 658-8501, Japan／神戸大学自然科学系先端融合研究環
2 Graduate School of Bioresources, Mie University, Mie 514-8507, Japan／三重大学大学院生物資源学研究科
3 Association for Shore Environment Creation, Kanagawa 220-0023, Japan／海辺つくり研究会（元･筑波大学）
4 Tokyo Sea Life Park, Tokyo 134-8587, Japan／葛西 臨海水族園
5 Former affiliation: Marine Science Museum, Tokai University, Shizuoka 424-8620, Japan／元･東海大学海洋科学博物館
6 Social Education Center, Tokai University, Shizuoka 424-8620, Japan／東海大学社会教育センター
7 Atmosphere and Ocean Research Institute, Tokyo University, Chiba 277-8564, Japan／東京大学大気海洋研究所
*Corresponding author

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## 1. Introduction

The training of fisheries engineers is important in order to carry out the basic maintenance of fisheries and for compliance with the Marine Fundamental Law. However, according to research results, “currently, teaching materials for oceans are difficult to use at schools other than at some schools actually located by the oceans” (Sakai et al., 2005). A specific method for using teaching materials in fisheries civil engineering needs to be introduced in a form that can be applied at all school sites. Two examples of such materials are described below.

Mechanimal is a word created from mechanical and animal, meaning “creature made from a machine.” Mechanized fish broadly related to fisheries are collectively referred to as mechanimals in this study. A mechanimal replicates the movements of the fins of fish as its driving force. The development of mechanimals as a teaching material is receiving attention for the use of propellers that are environmentally low impact and are based on living organisms rather than mechanical screws (Suzuki, 2008). The commercially available Mechamo (Gakken Holdings Co., Ltd.), which is currently not in production, cost about 6,000 yen, whereas material costs for a simplified mechanimal (prototype model) are around several thousand yen each.

Another type of teaching material related to oceans is a productmeter (differential volumeter), a type of gas volumeter that measures changes in the cubic volume of gas while maintaining constant gas density in a container enclosing a sample. A reaction system is placed in the container to measure the photosynthesis and respiration rates of algae and small animals. It is simpler to operate, compared with Winkler's method or the oxygen electrode method, and is more intuitive to use, since the increase or decrease in oxygen can be measured directly. It is also useful for measuring photosynthesis because of its relatively moderate pricing (Kurashima et al., 2003). At present, some researchers (including Suzuki, Yokohama and Kurashima) are constructing their own productmeters.

Both types of teaching materials are considered a suitable “opportunity to study the ocean environment and biological environment through comparison under natural conditions.” In this study, we verify the methods for practicing such opportunities. Further, we throughly investigate the advantages of using mechanimals in marine education and demonstrate an example of photosynthesis measurement.

## 2. Overview of the mechanimal

The Marine Science Museum of Tokai University is famous for its collection of mechanimals. The Marine Science Museum consists of the aquarium, the science museum (Marine Science Hall), and the “mecha zone” in the aquarium (Mequarium), and its mechanimal is stored in the Mequarium. The mechanimal stored in the Mequarium (Photo 1) has been extensively improved for exhibition and is expensive; therefore, it is difficult to use it as a teaching material. However, it is realistically possible to use a simplified mechanimal (Photo 2) as a teaching material.

Case studies using the simplified mechanimal as a teaching material include the “education course under university-museum collaboration” conducted by us, as well as educational activities conducted under the Science Partnership Program (SPP) promoted by the Ministry of Education, Culture, Sports, Science, and Technology (FY2002-FY2005) and Japan Science and Technology Agency (FY2006-). The purpose of these case studies was to provide teachers with teaching materials.


Photo 1: Mechanimal


Photo 2: Simplified mechanimal

## 3. Practical use of the mechanimal

A case study involving the "education course under university-museum collaboration" is described here as an example of how mechanimals can be used. The "education course under university-museum collaboration" was conducted with 24 elementary and junior high school students. A textbook "Swimming of fish adapted to the aquatic environment-From observation to model processing" (Suzuki and Sugimoto, 2008) was prepared, followed by ecological observations (sketching), viewing an educational video, and exercises with a mechanimal following the textbook. The language used in the textbook was intended to be easy to understand and appropriate for elementary and junior high school students, while accurately and completely explaining the ecology of fish. The portion of the textbook entitled "Swimming of fish adapted to the aquatic environment-From observation to model processing (Suzuki and Sugimoto, 2008)" is indispensable for education using the mechanimal, and is reproduced as follows with additional explanation for the general public:

*【The shape of the body and caudal fin of the fish varies depending on the type, and eels and sharks swim by moving their bodies like a wave. Bonito and tuna swim by vibrating the caudal fins. Many fish have both properties. They are generally categorized into "eel-type," "semi-horse mackerel-type," "horse mackerel-type," "tuna-type," and "trunkfish-type" (Figure 1: adapted from Lindsey, 1978). Depending on the type, fish mainly use their caudal fins to acquire the driving force used for swimming. The swimming speed of the fish is often described with reference to the body size (body length: from the snout to the caudal fin), e.g., "x times body length per second." When fish grow to a certain size, the speed expressed in terms of body length slows because it is compared to the body length; many fish are believed to swim normally at a speed of two to four times the body length per second on average.*





*On the other hand, what about their speed when escaping from predators? The eel-type swims by relying on the wave motion of the body and similarly, the trunkfish-type cannot swim very fast because of the round shape of the caudal fin, while the semi-horse mackerel-type, mackerel-type, and tuna-type are able to move much faster than people.】*

The use of mechanimals (prototype model) as a teaching material to explain material in the text produces synergistic effects. Repeated experiments in underwater swimming by equipping caudal fins of different materials or power sources on the mechanimal helps teach the complexity of swimming in fish as living organisms as well as the characteristics that are unique to each species when adapting themselves to the environment.

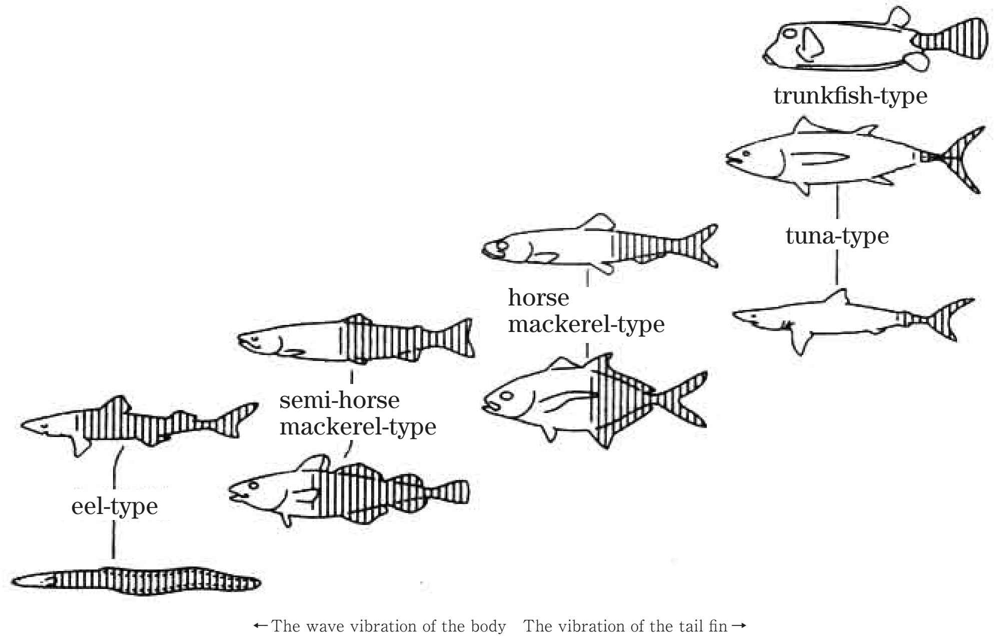


Figure 1: Swimming forms for the fish (partially quoting Lindsey, 1978);
The diagonal line is the part of movement for swimming.

## 4. Overview of the productmeter

The term productmeter covers a range of equipment including the simplest volumeter, a simple differential volumeter (Yokohama et al., 1996), a simple productmeter (Yokohama et al., 1996; Photo 3), and a more complex productmeter (Photo 4). We anticipate an increasing trend in the study of fuel production from algae both within and outside Japan, and have been describing related educational results and findings using productmeters at international conventions, including Algal Biofuels 2012 in San Diego, USA. Use of productmeters as attendant equipment for utilization of algal biomass is also an expected application of this educational equipment.

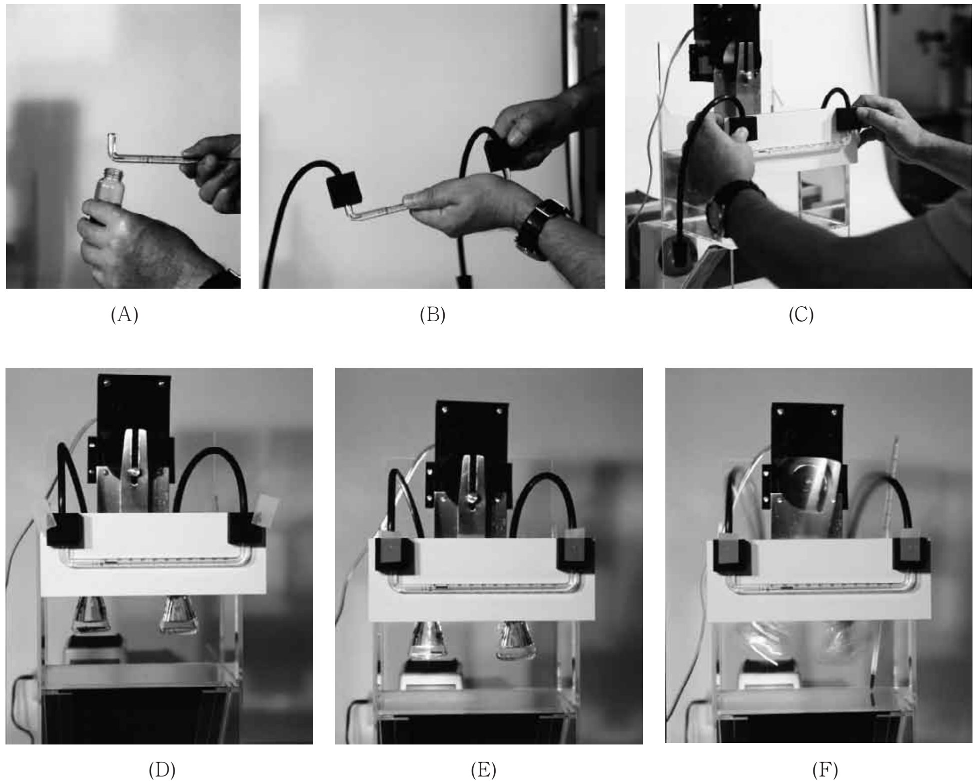


Photo 3: Measurement of photosynthetic oxygen production by a simple productmeter (provided by Sanseido). (A): Dripping a droplet. (B): Fitting the scale pipe. (C): Sticking the two-sided tape. (D)-(F): measurement. The photographs were provided by Sanseido, Co.Ltd..

Photo 4: Commonly known as 'product meter', the technical name of which is 'a more complex productmeter' (Chika Suzuki laboratory possession)





Meters measuring quantitative changes in gasses are generally categorized into 1) pressure meters that read pressure changes in gasses while maintaining constant volume and 2) volumeters that read volume changes in gasses while maintaining constant air pressure. Warburg's pressure meter (Nobel Prize in Physiology or Medicine; designed by O.H. Warburg) belongs to the former category and productmeters belong to the latter. Use of Warburg's pressure meter requires three years to master and there are many complicated operations when measuring with a dissolved oxygen meter to ensure a sealed condition and determine the volume of a container. Another widely used instrument is the dissolved oxygen meter, which is not suitable for educational uses due to its high cost, complexity in setting and handling, etc. Changes in $O_2$ are also not visible, unlike with productmeters, i.e., it functions as a black box. On the other hand, it has been found that even high school students are able to correctly measure changes in gasses using the traditional productmeter (differential volumeter) (Yokohama, 2008). In addition, a productmeter can be applied to larger-sized creatures by changing the size of the container, and is considered highly versatile equipment that can also measure respiration of terrestrial organisms.

## 5. Use of the productmeter

*Ulva pertusa* (Photo 5) was collected from Ise Bay to measure algae growth and photosynthesis, in addition to *Ulva meridionalis* (Photo 6), which had been used for verification in the past. For *U. meridionalis*, a strain that can be cultured in large quantities by spore clustering was used (provided by Kochi University).

*Ulva pertusa* is a species that can cause mass propagation (green tide), although not in all cases. *U. pertusa* can be sterile. Fertile *Ulva withers* if swarm spores or gametes are released, while sterile *Ulva* continues to grow without maturation. Its mass propagation (green tide) can increase to a size that can be identified with remote sensing, similar to red tide (Suzuki, 2009). For this study, *U. pertusa* was collected offshore of Toba in 2011, the strain was confirmed as sterile, and placed in Provasoli's enriched seawater medium.

Photo 5: *Ulva pertusa*

Photo 6: *Ulva meridionalis*

To measure the amount of photosynthesis using the productmeter, two replicates of 11.7 and 11.3 mg of *U. meridionalis* and two replicates of 3.2 and 6.7 mg of *U. pertusa* (dry weight) were used.

For *U. meridionalis*, the algal body was clipped with a cork borer. The considerable difference in weight between the *U. pertusa* replicates is due to differences in thickness between the tip of the algal body and the area near the appressorium. In the experiments, measured values of optical power and photosynthesis (per $cm^2$) for *U. meridionalis* and *U. pertusa* were used in a formula to approximate the photosynthesis–irradiance curve with a hyperbolic tangent (photosynthesis speed = Pmax * tanh(I/Ik) – R). Next, changes in optical power over a day were obtained from an approximate formula with a sine curve (optical power at time t = Imax * $(\sin(\pi * t/D)^{1.4})$ to determine the optical power at a certain water depth from early morning to midnight. Finally, changes in optical power over a day were substituted into the formula for the photosynthesis–irradiance curve to obtain changes in the $O_2$ (and $CO_2$) generation speed over a day. These calculations showed that *U. pertusa* had higher cumulative daily photosynthesis than *U. meridionalis* (Figures 2 and 3).

As explained above, Pmax is the maximum photosynthesis rate at saturation irradiances, I is the irradiance, Ik is the saturation irradiance, R is the respiration rate in darkness, Imax is the saturation irradiance, t is the elapsed time, and D is the sunshine duration.

More detailed experiments following the biorhythms of algae are required to obtain the photosynthesis and respiration rates of algae. However, measuring photosynthesis and respiration rates of algae in a simplified manner to experience the ecology of marine organisms fosters training of fisheries civil engineers who may play a role in preservation of the ocean environment.

## 6. Conclusion

In summary, implementation of tools such as the mechanimal and productmeter is awaited from a financial viewpoint based on their achievements in the training of fisheries civil engineers.
Mechanimal: A comparison of rubber with plastic reveals a general difference in flexibility. Since tails and fins of the mechanimal bend less with plastic, the force of the motor is used more efficiently and the mechanimal goes faster. The tail and fins are shaped according to the resistance of the water. The analysis of the data of the mechanimal gives us the opportunity to consider environmental adaptation. For fisheries engineers, this can provide further knowledge of the environment and the adaptation of creatures.
Productmeter: This device was used to measure the absorption of oxygen by breathing. If we use it to measure the release of oxygen, using lamina punched from algae, we can easily measure the photosynthetic rate. This is not done by observing flight recorder-like numerical data. Instead, the first-hand experience of watching the release of oxygen from algae helps inculcate a respect for plants and the environment. This is a start for the protection of the marine environment by focusing on the growth of algae, which is a point of paramount importance for fisheries engineering.

For the public, FIDEC (Fisheries Infrastructure Development Center http://www.fidec.or.jp/other/post-1.html) receives support from the Fisheries Agency, and holds a fisheries engineer training class spanning over 5 days. In this training, students learn about aspects such as the physiology and habits of marine life, the environment of the seaweed bed, the tide land, and shallow sea. One of the authors, Suzuki, personally received a qualification after completing this course and examination. The introduction of this class to the public will be effective in the future. We think that that the implementation of these points in the education system would improve fisheries engineering education.

For advantages of marine education using mechanimals, we consider this activity to be important in terms of developing a new method for studying the habits of submarine life using mechanized fish prepared by teachers as teaching materials. In a questionnaire distributed after a lecture with the participation of 24 children, the evaluation of supplemental teaching materials (ecological observation, video broadcasts of teaching materials, and textbooks describing the procedures) was good in an all fields, and we received positive evaluations such as comments stating that the lecture and practice were easy to understand. At the same time, we also received many comments that the students gained a deeper understanding of the Marine Fundamental Law and of the marine field.

The course welcomed observation by accompanying teachers and educators, not only the participating children (24 people), and seems to have been useful for both educators and participants. For educators and children, this is considered an introduction to an applied case study for incorporating "marine education using the mechanized fish" to school sites. The above aspects are important advantages.

Raising children and educators' consciousness contributes to the development of marine education in the future and is very important. In the example of the quantity of photosynthesis measurement, the use of productmeter in the field of education could provide the opportunity to have firsthand knowledge of the difference in photosynthesis amount through the biological phenomenon of photosynthesis. By the action that assumed such an experience an opportunity, we are very pleased to have been able to provide children with a greater understanding of the Marine Fundamental Law and who hope to become "marine (fishery) scientists or engineers" as possible career options in the future. We expect that the incorporation of these teaching materials will lead to the development of the marine policy.

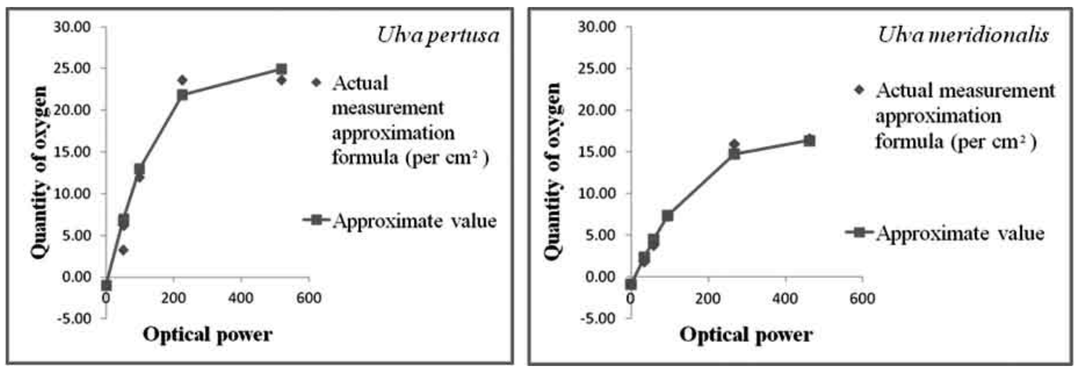


Figure 2: Photosynthesis and irradiation curve in *Ulva pertusa* and *Ulva meridionalis*. Quantity of oxygen (μℓ/$cm^2$).

Time (hour)

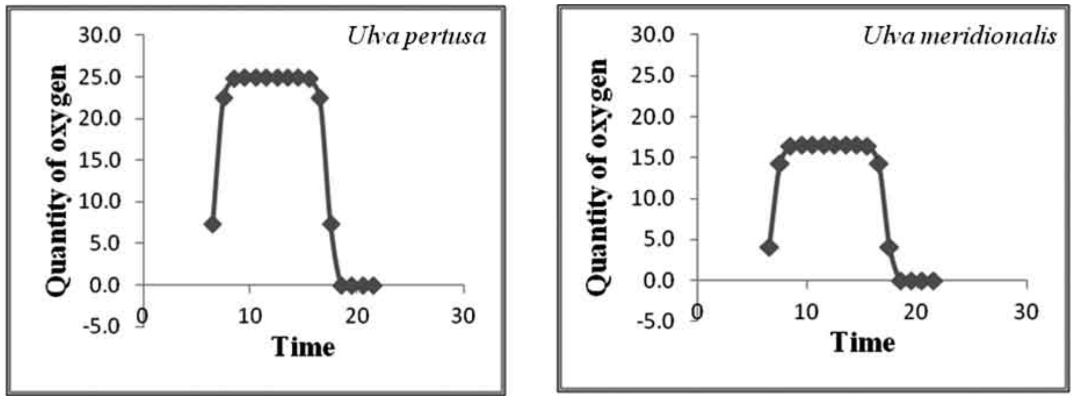


Figure 3: Daily photosynthesis amount in *Ulva pertusa* and *Ulva meridionalis*.
Quantity of oxygen ($\mu\ell/cm^2$), Time (hour)

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# 第4回年次大会の概要

日本海洋政策学会の第 4 回年次大会が、「新たな海洋秩序・政策構築への日本のイニシアティブ」というテーマのもと、2012 年 12 月 1 日（土）に明治大学（和泉キャンパス）第 1 校舎 002 教室において開催された。合計約 120 名以上が参加し、基調講演、応募論文発表、ポスターセッション、パネル・ディスカッション及び年次総会がいずれも盛会のうちに実施された。

まず、小宮山宏会長の開会の挨拶から始まり、寺島紘士事務局長が海洋基本法戦略研究会代表世話人髙木義明前衆議院議員（「総力をあげて海洋政策の前進を」）に代わって基調講演を行ない、続いて東京大学理学系研究科地球惑星科学専攻浦辺徹郎教授（「海底鉱物資源開発の現状と政策課題 - 資源開発 10 カ年計画とリスクの軽減」）による基調講演が行われた。

続いて次の 10 点の応募論文の発表が行われた。（敬称略）

1. 「海賊対処のための民間警備要員（PCASP）の乗船に関する諸外国の対応について」（長谷部正道）
2. 「通過通航制度と沿岸国の法令制定権」（石井由梨佳）
3. 「国連海洋法条約に立脚した東アジア海域の海洋権益を巡る国家間対立の考察 - 対立のエスカレート要因と抑制要因の分析 -」（原田有）
4. 「コンテナ船 MSC Flaminia 号事故について」（山地哲也）
5. 「南極海の資源・環境管理における国際制度間の調整」（大久保彩子）
6. 「海洋政策を支える国際医療貢献・病院船団構想の実現を急ごう」（浅野茂隆）
7. 「日本の海洋を総合的に観測するシステムの提案」（赤井秀樹）
8. 「親水水路におけるプレジャーボートの航行と条例による規制 - A 市の事例について」（藤本昌志）
9. 「大津波に対する沿岸域防災システムの現状と今後の視点」（岸田弘之）
10. 「日本の海洋産業におけるサブシープロダクション関連技術の方向性」（渡邉啓介）

更に、ポスターセッション「NOWPAP Medium-term Strategy (MTS) 2012-2017」（大山真且）とパネル・ディスカッション「国際コミュニティの中で海洋基本計画の実現方策を考える」が行われた（パネル・ディスカッションの概要は次に紹介する）。

最後に小宮山宏会長が挨拶を行い、年次大会は閉会となった