日本財団助成事業
The Nippon Foundation

ISSN 1880-0017

海 洋 政 策 研 究

第5号　2007年

海洋政策研究財団

各研究は、競艇交付金による日本財団の助成金を受けて実施したものである。ここに関係各位に対し深謝申し上げる。

These projects were carried out under the patronage of The Nippon Foundation from the proceeds of motorboat racing. We would like to thank all those who made this possible.

Ocean Policy Studies

No.5 (December 2007)

Ocean Policy Research Foundation
Kaiyo Senpaku Bldg.,
1-15-16 Toranomon, Minato-ku, Tokyo 105-0001 Japan
Phone: +81-3-3502-1828
Facsimile: +81-3-3502-2033
E-mail: info@sof.or.jp
URL: http://www.sof.or.jp

ISSN 1880-0017

Contents

Articles

Use of Seas and Management of Ocean Space: Analysis of the Policy Making Process for Creating the Basic Ocean Law

Masahiro Akiyama*

ABSTRACT

The Basic Ocean Law was enacted for the first time in Japan in April of this year (in 2007). It was initiated by lawmakers of not only the ruling parties but also the largest opposition party. The Nippon Foundation and Ocean Policy Research Foundation, NGOs in the private sectors long involved in maritime affairs, contributed significantly to creating the basic law.

This policy making process differed from the normal process in which the government takes large initiatives. It reflects the fact that more than 8 ministries and agencies are involved in and responsible for maritime affairs, so the government could not initiate such a basic law which would cover all aspects of maritime affairs.

This paper traces the policy making process for creating the Basic Ocean Law, with the aim of analyzing and thinking through a new theory of the policy making process in Japan. This process is neither the reasonable actor model in decision-making process theory nor the bureaucratic governance model of Graham Alison. This report could trigger the emergence of a new theory through further discussion and studies.

At the same time this report refers to the background elements that affected law makers as well as the Japanese public who have had their attentions increasingly drawn to maritime issues. These elements include Sino-Japan disputes over the development of oil and gas in the East China Sea, a number of state activities by China in the Japanese EEZ, environmental preservation and safety & security on the ocean, securing sea lines of communications, and marine fisheries.

The United Nations Convention on the Law of the Seas(UNCLOS) was adopted in 1982 and took effect in 1994. Japan ratified it in 1996. Even after the ratification, however, Japan did not actively address ocean related issues, nor sufficiently introduce appropriate domestic laws.

Introduction of the Basic Ocean Law reflects the concept of UNCLOS. It says that maritime issues must be addressed in a comprehensive manner, based on the principle of sustainable development, with international cooperation. Japan should now move toward becoming a new "ocean state" and actively and internationally address ocean problems.

Key words: Basic Ocean Law, UNCLOS, policy making process, comprehensive ocean policy, sustainable development, ocean management, lawmaker-initiated legislation, East China Sea

* Ocean Policy Research Foundation/Rikkyo University

Introduction

1. The Enactment of the Basic Ocean Law

On April 20, 2007, the House of Councilors voted for the Basic Ocean Law.[1] It went through the Land and Transportation Committee the previous day and was approved in the plenary session by an overwhelming margin.[2] The House of Representatives had adopted it on April 3. The Liberal Democratic Party (LDP), New Komeito Party (NKP), Democratic Party of Japan (DPJ), the Japanese Communist Party (JCP), and the People's New Party (PNP) supported the bill, while the Social Democratic Party (SDP) voted against it.

The Basic Ocean Law was initiated by lawmakers. It was supported by the largest opposition party, the DPJ, as well as the ruling coalition of the LDP and the NKP. In the House of Representatives, the chairperson of the Land and Transportation Committee introduced the bill to the Diet. It was deliberated on and adopted on the day of submission. In the House of Councilors, it was discussed as a House of Representatives-member-initiated bill and co-sponsor members of the House of Representatives from each party explained the bill.

In Japan, lawmaker-initiated legislation was not formerly a common practice but has recently become so. As for basic laws, while the long-established basic laws on education and agriculture are well-known, basic laws lately tend to be introduced as guiding laws bridging the Constitution and laws to be established and are said to be suitable for lawmaker-initiated legislation. However, it can be said that the Basic Ocean Law[3] was the first full-fledged and comprehensive basic law to regulate the policies and administrations of more than eight ministries and agencies. Most basic laws,[4] such as the basic laws on fisheries and the environment, cover only one ministry or agency.

This paper is not intended to give a full interpretation of the Basic Ocean Law, but rather a brief summary and outline of its purpose.

Article 1 (Purpose) advocates the following: the ocean is essential in sustaining human life; it is important for Japan, being surrounded by the ocean, to become an ocean state, harmonizing peaceful and active use of the sea with conservation of the marine environment, under the spirit of international cooperation, in accordance with the principles enunciated in international agreements such as UNCLOS or international initiatives (such as the Rio Earth Summit Agenda 21)[5] to realize sustainable development and use of the oceans; policies concerning the oceans should be developed comprehensively and systematically by specifying the responsibilities of the national government, local authorities, business owners, and the people, by formulating a Basic Plan for the Ocean and other policy measures concerning the ocean, and by creating a Headquarters for Comprehensive Ocean Policy within the Cabinet.[6]

---

[1] The Basic Ocean Law (2007 Act No.33)
[2] Total vote: 184. Yeas 180; Nays 4.
[3] The Basic Ocean Law consists of four chapters (I: General Rule, II: Ocean Basic Plan, III: Basic Policy, IV: A Headquarters for Comprehensive Ocean Policy and Supplementary Provisions) and 38 Articles.
[4] There are basic laws on: Fisheries, Environment, Nuclear Policy, Education, Land, Gender-Equal Society, Science and Technology. The last two were initiated by lawmakers.
[5] The Action Plan adopted at the United Nations Convention on environment and development held in Rio de Janeiro, Brazil in 1992.
[6] Article 29 of the Basic Ocean Law.

The Article then reads that the purpose of the Law is to improve the healthy development of economic society and the quality of life of people in Japan as well as to contribute to the coexistence of the ocean and mankind.

The Basic Ocean Law is to be enforced within three months after proclamation. The Law was proclaimed in April, so it is to enter into force in July.

2. Research Question

The Basic Ocean Law is just one example of lawmaker-initiated legislation. However, the lawmaking process as analyzed and explained below, was unusual in its being made into law, in a very short period, without any revision in the Diet, as the activities of politicians, government, non-governmental organizations, individuals, and the media fortuitously converged. By reconstructing this process as a case study, it is expected to contribute to understanding the new policy making process in Japan and to trace Japan's activities regarding ocean issues, which might help us better understand global trends in the use of the seas and the management of ocean space.

The lawmaking process for the Basic Ocean Law will be examined, first of all, by looking at the most recent year, then by looking back several years for the background of the movement, and finally by looking at the overall process from a long-term viewpoint. By doing so, this paper is expected to reveal Japan's sluggish (nonexistent) ocean policy of clinging to freedom of navigation and the free use of the oceans, in other words, the "vast high seas and narrow territorial seas" concept (especially for fisheries), and the reality that the only ocean issue Japan gave importance to were the strained relations with China in the East China Sea, and how Japan came finally to realize the importance of ocean use and the management of ocean space.

As a private organization, the Ocean Policy Research Foundation (OPRF), to which the author belongs, and, as an individual, the author himself, were deeply involved in the lawmaking process of the Basic Ocean Law. Therefore, while subjective viewpoints and analyses cannot be avoided entirely, the author has tried to maintain as much objectivity as possible, by conducting interviews, for example, and has analyzed the process advantageously by making the best use of detailed facts not easily available to non-participants. This process was unique in that a private organization was involved in lawmaking, so it might also be considered an important contribution to record the details of such involvement.

I. Movement Directly Related to the Enactment of the Basic Ocean Law: From the Establishment of the Basic Ocean Law Study Group to Legislation Initiated by Lawmakers

In April 2006, the Basic Ocean Law Study Group, comprised of bipartisan members of the Diet and academic and industry experts, was established. This group, after nine months of deliberations, announced the Guideline for Ocean Policy and the Outline of Basic Ocean Law in December. Following this, the legislative body (members of the Diet and the House of Representative Legislation Bureau) played a central role in setting the stage for lawmaking and submission to the 166th Diet session (regular). In April 2007, the bill was passed in the House of Councilors and enacted. This policy making process was, while the lawmaking itself was initiated by lawmakers, unprecedented and epoch-making in Japan in that a non-governmental organization played an important role.

1. Formulating the Basic Ocean Law Study Group

The Study Group was not established immediately but only after a preliminary period.

(1) A Proposal from a Non-Governmental Organization and Approach to Political Leaders

In November 2005, the Nippon Foundation (Chairman: Yohei Sasakawa)[7] and OPRF (Chairman: Masahiro Akiyama)[8] announced "The Oceans and Japan: Proposal for a 21st-Century Ocean Policy."[9] The proposal was prepared by OPRF's Study Committee on Ocean and Coastal Zone Management (Chairman: Tadao Kuribayashi, Professor Emeritus, Keio University). The proposal called for the management of "territory" now extending to the seas and international coordination as well as the establishment of a Guideline for Ocean Policy and a Basic Ocean Law.[10]

Chairman Sasakawa of the Nippon Foundation immediately presented this proposal to then Chief Cabinet Secretary Shinzo Abe and, in February 2006, gave an account of it to Hidenao Nakagawa, then Chairman of the LDP Policy Research Council. OPRF Chairman Akiyama and Executive Director Hiroshi Terashima accompanied Sasakawa. Nakagawa immediately showed his interest in the proposal and promised to consider it within the LDP. Nakagawa then left this issue with Keizo Takemi (LDP member of the House of Councilors), Chairman, Special Committee on Maritime Interests. Takemi, intending to provide a place for discussion within his party, formulated a bipartisan study group to which he invited academic specialists from various ocean fields.

Takemi, the Nippon Foundation, and OPRF held preparatory talks and the study group was set up in April. At first, the group was named the Ocean Problems Study Group, but, reflecting Sasakawa's strong interest in a Basic Ocean Law, it became the "Basic Ocean Law Study Group."

(2) Members of the Study Group and Secretariat

Takemi formulated the study group consisting of bipartisan members of the Diet and academic and industry experts from various ocean fields. As explained later, Takemi, based on his own experience, acknowledged that it was impossible to establish a Basic Ocean Law without educating members of the Diet on ocean issues to enable them to share knowledge and viewpoints concerning the oceans. Takemi also thought it important to coordinate with the largest opposition, the DPJ, as well as the coalition partner, the NKP. Takemi therefore brought his personal friend, Akihisa Nagashima, into the group.[11] As for academic experts, OPRF's Terashima selected the members in contact with the people concerned and Takemi endorsed the selection.

Director-generals of relevant governmental

---

[7] http://www.nippon-foundation.or.jp/
[8] http://www.sof.or.jp/
[9] http://www.sof.or.jp/topics/2005/051120_01.html Accessed March 30, 2007. Committee members list is also available.
[10] The proposal also calls for the establishment of a Basic Plan and a ministerial council and the appointment of a minister for ocean policy.
[11] Nagashima participated from the second meeting in May.

ministries and agencies were brought in as observers at the request of Takemi's office. Ten people from nine ministries and agencies participated. The study group became relatively large, consisting of about 30 people, including the Secretary-General.

Takemi became the representative facilitator of the study group and Hiroshi Takano, an NKP House of Councilors member, Professor Emeritus Tadao Kuribayashi of Keio University, and OPRF Chairman Akiyama became its facilitators. The Study Group was chaired by Shigeru Ishiba, an LDP House of Representatives member, and co-chaired by Kuribayashi. The DPJ was then contesting the LDP in local elections and so could not formally participate in the policy-making process with the ruling parties. Therefore, Nagashima and others participated as individuals.

Due to its role in reaching out to political leaders, OPRF became the Secretariat of the Study Group and Terashima became Secretary-General. Takemi's office (within the House of Councilors Members' Building) played the role of coordinator among political circles. OPRF took responsibility for planning, management, logistics, and funding for the Basic Ocean Law Study Group, while providing agenda, selection, and arrangement of presenters and materials for each meeting. Before every meeting, OPRF coordinated with Takemi's office as well as Ishiba and Takano in advance. Separately, OPRF continued the above-mentioned Study Committee on Ocean and Coastal Zone Management and considered a prototype Guideline for Ocean Policy and a draft Basic Ocean Law.

The LDP's actions in March and April were interesting. In response to this process of setting up the Basic Ocean Law Study Group outside the party, the LDP decided to discuss a Basic Ocean Law in its Special Committee on Maritime Interests on March 17 and restructured the system by changing the name of the committee to the Special Committee on Ocean Policy. The media responded to this move as well.[12]

The NKP changed its stance and showed its support for submission of a Bill on a 500-Meter Safe Water Zone,[13] on condition that a Basic Ocean Law be introduced. The Safe Water Zone Bill had been proposed by the LDP in 2005 in relation to resource development in the East China Sea but met with opposition from the NKP as being a provocation to China. The NKP welcomed the introduction of a Basic Ocean Law and actively supported the establishment of the Study Group from the beginning.

Chairman Nakagawa of the LDP Policy Research Council and Chairman Sasakawa of the Nippon Foundation delivered strong messages calling for the introduction of a Basic Ocean Law at the first meeting of the Study Group.

(3) Deliberation in the Basic Ocean Law Study Group

The Study Group had their meetings on a monthly basis and 10 meetings were held from April to December 2006. As with other LDP policy divisions and committees, the meetings began at 8:00 a.m., making it possible for many parliamentarians and experts with busy schedules to attend.

Until October, the Study Group discussed a range of ocean issues, although at that time only

[12] The Mainichi Shimbun, March 18, 2006; the Yomiuri Shimbun, March 18, 2006; and the NHK News, March 17, 2006.
[13] The Bill on the Establishment of a Safety Zone with regard to Maritime Platforms

the problem of oil and gas exploitation by China in the East China Sea continental shelf attracted everyone's attention. Deliberations covered the need for a positive response toward UNCLOS, ocean security in general, marine environmental problems, the importance of marine science, integrated management of the ocean and coastal zones, marine resources, marine transportation, ocean education, ocean states theory, etc. Members of the Study Group, as experts in different disciplines, explained the current situation and offered their opinions. Next, problems in current national initiatives and necessary policies were discussed. As early as July, hearings with 8 relevant ministries and agencies were conducted regarding their efforts on ocean policy issues. In October, hearings with industrial stakeholders were conducted regarding marine transportation, fisheries and aquaculture, petroleum mining, civil engineering and construction. In November, the draft of a Guideline for Ocean Policy prepared by OPRF was discussed. Deliberation on the draft of a Basic Ocean Law followed. Based on the above, the Guideline for Ocean Policy and the general outline of the draft for a Basic Ocean Law were formulated in December.

Prior to these deliberations, the Study Committee on Ocean and Coastal Zone Management established by OPRF had a series of debates. Regarding a Basic Ocean Law, a draft proposal was formulated under the leadership of Committee member Professor Shin Kisugi. Based on the proposal, the Committee elaborated the draft of the law. On the other hand, within the Basic Ocean Law Study Group, a core-group consisting of Takemi, Ishiba, Takano, Kuribayashi, Akiyama, and Terashima,[14] had in-depth discussions. The fact that the ocean involves a broad range of issues was gradually understood throughout the discussion at the Study Group, whereas the LDP's focus was consistently on the East China Sea issue. Takemi, among others, had a strong interest in ocean science (incl. Sea-Grant) and emphasized the international character of ocean issues and a global perspective. Ishiba, on the other hand, had an interest in security issues relating to the ocean as well as how provisions of a Basic Ocean Law are set down from the beginning. This reflected the fact that Ishiba was knowledgeable and experienced in the drafting of laws, having actually participated in drafting the Basic Space Law. As for the draft of a Basic Ocean Law, he recognized structural and institutional arrangements within the Cabinet to be a major agenda. Takano served as a counter-weight to the LDP, emphasizing environmental issues and balance in ocean policy as a whole, as well as mitigating conflict with China and avoiding excessive emphasis on security issues.

(4) Final Agreement at the Study Group and Media Coverage

On December 7th, the Guideline for Ocean Policy and the Outline for a Basic Ocean Law were adopted at the 10th meeting of the Basic Ocean Law Study Group. Details of this are explained below. Shoichi Nakagawa, Chairman of the LDP Policy Research Council (the successor of Hidenao Nakagawa), Tetsuo Saito, Chairman of the NKP Policy Research Council, and Yohei Sasakawa, Chairman of the Nippon Foundation attended and delivered short addresses as honored

[14] From late November, Yasutoshi Nishimura, LDP Member of the House of Representatives (Director of LDP's Special Committee on Ocean Policy), took part in the last two meetings of the Study Group as well as the core group.

guests at the meeting in support of the establishment of a Basic Ocean Law. This last meeting was a rather large one, with 3 honored guests, 10 parliamentarians, 10 academic and industry experts, 10 observers from related ministries and agencies, and 41 other persons.

To involve Chairman Nakagawa in the meeting was extremely difficult, due to a procedural mistake. However, persistent negotiations by Takaharu Makino, secretary in charge of ocean affairs in the office of Takemi, and Terashima from OPRF, made it possible. Although we can only speculate, it is thought that Nakagawa's participation at this stage was critical in deciding how the LDP should commit to draft a Basic Ocean Law as lawmaker-initiated legislation.

Sasakawa, on the other hand, emphasized the need for a conceptual shift, from "a Japan protected by the ocean" to "a Japan that protects the ocean". It was agreed that this should serve as a core concept for future ocean initiatives.

The mass media were also an important factor. Just before this last meeting of the Study Group, the Yomiuri Shimbun newspaper carried a large article[15] introducing the Basic Ocean Law on the first 1st and 2nd pages of its morning edition of December 6th. This coverage, coinciding with the meeting of the LDP's Special Committee on Ocean Policy on the same day, was very influential, as noted below. With this, not only the persons in charge of the Study Group, but members of the party, related ministries and agencies, related organizations, and academic and industry experts understood that the Basic Ocean Law was now proceeding from a discussion into a realization stage. Following this, the Sankei Shimbun newspaper[16] described the enactment of a Basic Ocean Law as a foregone conclusion. Together with some later reports by the Yomiuri Shimbun,[17] this kind of media coverage paved the way for enacting the Basic Ocean Law.

2. Adoption of the Guideline for Ocean Policy and the General Outline of the Draft of the Basic Ocean Law

This section roughly explains Guideline for Ocean Policy and general outline of the draft of the Basic Ocean Law formulated by Basic Ocean Law Study Group.[18] Although the deliberation period lasted only 10 months, these documents were elaborated by parliamentarians, academic and industry experts in ocean related disciplines, and representatives from related ministries and agencies, through surveys, discussions and hearings with related organizations. Fundamental elements of current national efforts on ocean issues are therefore reflected in these two documents.

(1) Guideline for Ocean Policy

First, as international conflicts arise over enclosure of ocean areas and the problems of overexploitation of marine resources and the environment have became more and more serious, the ocean is called on to play a large role in securing water, food and other resources necessitated by the increasing world population. It was against this background that UNCLOS was

[15] Yomiuri Shimbun, December 6, 2006.
[16] Sankei Shimbun, December 8, 2006 and January 7, 2007.
[17] Yomiuri Shimbun, December 16, 2006, December 31, 2006, March 8, 2007, March 10, 2007, and March 28, 2007.
[18] www.sof.or.jp/topics/2007/070105.html. Accessed March 30, 2007. OPRF, "Kaiyou Hakusho(White Paper on the Ocean) 2007", pp.134-140.

signed. UNCLOS maintains freedom of navigation, while granting sovereign rights and jurisdiction to coastal states, as well as imposing obligations on them to conserve the environment.

The Earth Summit in Rio de Janeiro adopted an action plan, Agenda 21, for sustainable development. It requires coastal states to implement comprehensive management of the ocean, an integrated policy, and decision-making procedures. We are now in an era when ocean issues are to be addressed by countries in a cooperative manner for the common interest of mankind, based on the management of their respective coastal ocean zones.

Japan has achieved its development by enjoying various benefits from the ocean, including its protection.[19] The exclusive economic zone (hereinafter noted as "EEZ") of Japan has the 6th largest area in the world. Moreover, scientific knowledge on the ocean is increasing. However, there has been a serious delay in addressing the above issues and in policy making and institutional arrangements for a comprehensive ocean management. Progress has also been delayed in addressing ocean related issues because of the old-fashioned compartmentalized public administration system. Due to this, delimitation of ocean areas between neighboring states has lagged behind, as have the development, exploitation, management and conservation of marine resources. Problems such as environmental issues, oil and gas exploitation, ocean research, the intrusion of spy ships, and security issues involving the sea lanes have also not been addressed.

To address these situations, Japan needs to establish a new institutional arrangement for ocean issues as soon as possible. It is necessary for the establishment of an ocean policy befitting an ocean state to make ocean policy a major national agenda, as well as to make efforts towards integrated ocean management and international cooperation. For this, a Basic Ocean Law should be enacted immediately.

The Guideline describes the above concept as "the line that should be taken by Japan regarding ocean issues", and then calls for "an enactment of a Basic Ocean Law".

(2) General Outline of the Draft of a Basic Ocean Law

As for the enactment of a Basic Ocean Law, the draft specifies the general principles of an ocean policy. It sets "Co-existence of the Ocean and Mankind" as its basic philosophy, based on the following seven principles: conservation of the marine environment; ensuring the use and safety of the ocean; sustainable development and use; enrichment of scientific knowledge; comprehensive management of the ocean; international cooperation. The provisions of the current Basic Ocean Law generally follow this structure and content.

The draft states that the following provisions should be included in a Basic Ocean Law: obligations of the national government, local municipalities, businesses and citizens; a clear statement on basic measures regarding comprehensive management of the ocean, e.g. a Basic Ocean Plan; institutional arrangements to promote ocean related administration comprehensively. Further, the proper administrative structure is identified as an indispensable element, especially the estab-

[19] Ryouhei Murata," Kaiyou o Meguru Sekai to Nihon(The World, Japan, and the Ocean)", Tokyo Seizando Shoten, 2001, p.16, p.18.; Masahiro Akiyama, "Kaiyou Mondai no Honshitsu to Konnichi-teki Kadai(Ocean Problems and Current Issues)", Yomiuri Research Institute, Choken Quarterly, 2003 Summer, No.8.

lishment of a comprehensive ocean policy council in the Cabinet and a Minister designated to oversee the range of ocean related measures.

12 items are identified as major ocean related measures. These are included in the current Basic Ocean Law with a slight change in their treatment. These 12 measures are as follows: ensuring management of the national ocean area; development, utilization and management of the exclusive economic zones and continental shelf; promotion of the protection, conservation and recovery of the marine environment; facilitation of sustainable development and utilization of marine resources; ensuring the marine transportation that supports Japanese economic activities and daily life; ensuring security of the national ocean area and safety at sea; facilitation of the conservation of the national territory and promotion of disaster prevention measures; better utilization and management of coastal areas, nurturing and advancing marine industries; promotion of research and development of science and technology related to the ocean, increasing public awareness of the ocean as well as extension of ocean education and research activities; taking a leadership role to ensure order on the ocean and promotion of international cooperation. The Guideline for Ocean Policy concludes with a statement emphasizing the need to shift from being an island state to an ocean state.

3. Process toward Lawmaker-initiated Legislation

To formulate the Basic Ocean Law, the method of lawmaker-initiated legislation was adopted because the Law would involve many ministries and agencies, though there were no ministries or agencies that positively promoted the agenda, including those concerning diplomacy and security issues. However, this methodology was not consistently adopted from the beginning. Even in lawmaker-initiated legislation, it is difficult to formulate the draft of a law without any support from the government. In the drafting process, expert knowledge regarding ocean issues is required for lawmakers.

(1) Decision to Take Lawmaker-initiated Legislation Process

In November, a draft proposal for a Basic Ocean Law prepared by OPRF was tabled for the discussion of the core group. The proposal was also distributed as an information document at the Study Group. As for this proposal, hearings with related ministries were conducted and various opinions were submitted. Regarding ocean science and ocean security issues, opinions were also submitted from members of the Study Group.

Takemi, head facilitator of the Study Group, and Ishiba, Chairman of the Study Group, considered a Cabinet law[20] formulation as a more promising option for adoption, based on coordination with the government under the basic recognition that major challenges existed in institutional arrangements for addressing ocean issues within the Cabinet. Chairman Ishida especially, as an individual parliamentarian, felt it a heavy burden to have two pending lawmaker-initiated bills, as he was also a facilitator in legislation for a Basic Space Law. However, in the last stage of the deliberation at the Study Group, he preferred the course of law-

[20] This is a bill put forward by the government after being agreed upon within the Cabinet. Usually, there is a prior consensus between the government and the majority party on the contents of the bill.

maker-initiated legislation. This was because the Basic Ocean Law would have a cross-cutting character over many ministries and agencies, as well as comprehensive and integrated contents. He also took into consideration the situation at that time, as coordination with the government was becoming difficult, especially regarding institutional arrangements. On the other hand, Sasakawa consistently insisted on the course of lawmaker-initiated legislation. It was his opinion that the compartmentalized ministries and agencies could not formulate a good law, due to the comprehensive and integrated character of ocean issues. He considered this rather as a political matter.

(2) Actions by Ishiba and Nishimura and Response by the Legislative Bureau House of Representatives

With the prospect in mind of introducing a Basic Ocean Law as lawmaker-initiated legislation, Ishiba and Yasutoshi Nishimura acted quickly. Nishimura is a House of Representatives member and the Director of the LDP Special Board on Ocean Policy and Ishiba requested him to join the Basic Ocean Law Study Group. On December 6, a day before the proposal of the Study Group, the LDP Special Board on Ocean Policy was held, where the basic framework of a Basic Ocean Law by the Study Group was approved. In the Board meeting, it was also explained that the Law would be introduced to the Diet as lawmaker-initiated legislation. Based on this movement, the Yomiuri Shimbun reported on the enactment of a Basic Ocean Law in the morning paper of December 7 (See above). Immediately after the Basic Ocean Law Study Group agreed on the contents of the Law, Ishiba and Nishimura requested the Legislative Bureau House of Representatives to work on a Basic Ocean Law. At the same time, Ishiba added that it would be a big problem to establish a council of Ministers on ocean affairs in the Cabinet Office as agreed and announced in the Study Group. Based on his additional remark, the Cabinet Office urged ocean related Ministries to coordinate differences of opinions on the Law. On the other hand, simultaneously, a Working Team on a Basic Ocean Law was established in the LDP. Itsunori Onodera, a House of Representatives member, became Chairman of the team.

Meanwhile, the Ocean Policy Research Foundation, as secretariat of the Study Group, revised the draft proposal of a Basic Ocean Law, which was discussed in the Study Group in November, and submitted it as an Ishiba proposal. Therefore, the Basic Ocean Law reflects the Outline of Ocean Policy the Study Group agreed upon and the discussions that took place there.

Takemi and Ishiba met Prime Minister Shinzo Abe to explain the importance of enacting a Basic Ocean Law and Prime Minister Abe expressed his understanding of its significance. Nishimura, by virtue of his close political association, often met with Chief Cabinet Secretary Yasuhisa Shiozaki to explain the importance of a Basic Ocean Law and to ask Shiozaki's cooperation in passing the law through a lawmaker-initiated legislation process. He also agreed to the law.

When a law is drafted in a legislative body, legislative bureaus in both the House of Representatives and House of Councilors work on a draft. In this case, the Legislative Bureau of the House of Representatives addressed the issue because Ishiba and Nishimura were its members. With the permission of Ishiba, Akiyama and Terashima of OPRF explained in detail a preliminary draft of a Basic Ocean Law initiated by the foundation to Chieko Kayano, Manager of the Fourth Division, and to others in charge of the draft in the Legislative Bureau. In addition, they explained UNCLOS and Agenda 21, which have become the basis for integrated ocean policy, and presented the deliberations and all materials to the Study Group. Kayano was receptive to the somewhat unorthodox lawmaker-initiated legislation process. In addition, Deputy Manager Hiroaki Kamitsuma responded effectively on the issue of legal structures.

The Legislative Bureau immediately exchanged views on a draft Ocean Basic Law with government, i.e., ocean related ministries and the Cabinet Secretariat. The preliminary draft by OPRF was circulated as an Ishiba Proposal to the Ministries for comments by January 15th. With this, the process of establishing of a Basic Ocean Law rapidly took on a definite form.

The Ministry of Land, Infrastructure, and Transport(MLIT)'s behind-the-scenes work contributed to the Ishiba and Nishimura-driven decision-making in the LDP, i.e., decision-making to introduce a Basic Ocean Law through a lawmaker-initiated legislation process. As described below, MLIT acted like a governing agency for the Basic Ocean Law and lobbied hard towards the LDP, influential politicians, government, and the Diet, on the initiative of Masafumi Shukuri, Director of the Policy Bureau. It is rare that a ministry lobbies for passage of a law that is lawmaker-initiated.

(3) Cabinet Secretariat or Cabinet Office?

It became a political problem how to build a framework in the Cabinet, i.e., whether a comprehensive ocean policy council should be established in the Cabinet Secretariat or the Cabinet Office. The Cabinet Secretariat insisted that the council should be established in the Cabinet Office, because there have been so many councils in the Cabinet Secretariat and ocean policy should be addressed by the administration continuously, not in a sporadic manner. On the other hand, the members of the Diet thought that the Cabinet Secretariat was the most suitable organ within which to establish the council on the view that a power base is needed to move forward strategies, policies, and administration on ocean issues. MLIT, which would lead ocean policy, and OPRF had the same opinions[21] as the politicians. In addition, Sasagawa and Takemi were firmly of the same opinion on this issue.

While Takemi insisted strongly on establishing the council in the Cabinet Secretariat, he refused the proposal by the Cabinet Secretariat to establish a task force in the Cabinet as part of a package that would also deal with space issues. Ishiba also questioned establishing it in the Cabinet Office and thought it appropriate to establish it in the Cabinet Secretariat.

Both the LDP Working Team and government discussed this issue from mid-January to early February but couldn't reach a conclusion. In February, the Cabinet Secretariat submitted a compromise proposal that both the Cabinet Secretariat and Cabinet Office would look after the council. However, it was concluded to establish the council in the Cabinet Secretariat through discussion in meetings of senior policymakers from the ruling parties, a more politically oriented

[21] The draft of a Basic Ocean Law was prepared by OPRF and approved in the Study Group in December 2006. In the draft, it was bore in mind that a council of integrated ocean policy should be established in the Cabinet Office, but based on the Ishiba's proposal, it was revised.

group.[22] During this period, Takemi, Ishiba, Nishimura, and Onodera met with Prime Minister Abe and Chief Cabinet Secretary Shiozaki. In addition, views of the chairman of the LDP Policy Research Council, Shouichi Nakagawa, influenced the conclusion. Nakagawa thought that the Cabinet Secretariat should take care of the council because ocean issues were vitally important, and so made a request to Prime Minister Abe.

At the stage of imminent passing of the bill, the Committee on Land, Infrastructure and Transport held careful discussions on its relation to other bills introduced by the Cabinet. Finally, the Committee agreed to a draft Ocean Basic Law upon the request by Shiozaki. It was also a factor in facilitating the passage that Toshihiro Nikai, chairman of the LDP Diet Affairs Committee and former Minister of Transport, understood the issue, which was in essence a MLIT matter.

An important point in establishing the headquarters for integrated ocean policy in the Cabinet Secretariat is that the Prime Minister becomes the chief of the council and controls ocean issues. In addition, it is important that the Cabinet Secretary and the Minister of Oceans take office as deputy chiefs. This means that a system will be established to develop integrated ocean policy by the Minister of Oceans in cooperation with the Prime Minister. If the council were established in the Cabinet Office, with its lesser capacity for coordination, ocean policy would likely become a patchwork of policies put forth by the various ministries and agencies.

Although the headquarters for integrated ocean policy is to be established in the Cabinet Secretariat, which can use its coordinating capabilities to effectively implement projects on the oceans, this system is not a permanent one and will be reviewed every 5 years according to the law.[23]

Here, the author would like to add a few things that became problems during the legislative process of the Basic Ocean Law.

There was the opinion that the word "management" should not be used in the law because management in Japanese has the negative connotations of control and supervision. However, internationally, the term ocean governance/management is generally used. In this respect, although Article 1 and 16 of the Basic Ocean Law provide "to promote ocean related policy in integrated and systematic manners," Article 6 has the title "Integrated Ocean Management."

In addition, there was the opinion that the focus should be limited to the general principles of the Law and expressed in the most concise form. But based on discussion in the Study Group, it was finally agreed to leave in 6 principles that were deemed important in various fields.[24]

The provision on a basic plan for the oceans is written in simple terms following the style of other basic laws. However, the provision stipulates 12 topics as specific issues on ocean policy.[25] This reflects the Guideline for Ocean Policy (see above) adopted by the Study Group. It

[22] It is said that the final decision was made in the three parties meeting of the LDP, the NKP, and the DPJ on February 21. However, the meeting was a closed one. During this period, the DPJ couldn't announce officially that a Basic Ocean Law would be proposed in the Diet as a three parties' joint introduction.
[23] Article 2 of the Basic Ocean Law Supplementary Provisions provides that the headquarters office on the integrated ocean policy shall be examined.
[24] Basic Ocean Law, Art. 2-7.
[25] Ibid. Art. 17-28.

is especially important that Article 27 stipulates that Japan should play a crucial role in international society on ocean related issues.

(4) Consensus Building of the Three Parties

The NKP also acted promptly to introduce a Basic Ocean Law in the Diet. In tandem with the deliberations of the Study Group, the NKP established a project team on a Basic Ocean Law (Chairman Hiroshi Takano and Director Yoshinori Oguchi) in June 2006. Directors and Chairmen of 8 relevant committees participated in this team. Chairman Saito of Policy Research Council attended the last meeting of the Study Group and expressed his intention to introduce a Basic Ocean Law to the Diet. In January 2007, the NKP began to examine the OPRF proposal for a Basic Ocean Law with the initiatives of Takano and Oguchi. While exchanging views with the government, the NKP, as part of the ruling coalition, participated in the legislative process led by the LDP.[26] Secretary General Kazuo Kitagawa of the NKP, former Minister of Land, Infrastructure and Transportation, also coordinated the issue, having addressed integrated ocean issues in the past.

From the DPJ, Nagashima, Kazuya Shimba (the House of Councilors), and Goushi Hosono (the House of Representatives) participated in the Study Group in a private capacity. With the adoption of the Guideline for Ocean Policy and the general outline of the draft of the Basic Ocean Law and with the movements of the LDP and the NKP, the DPJ also participated in the process to pass a Basic Ocean Law. After the turn of the year, the DPJ established a project team on the Basic Ocean Law and Chair Yoshiaki Takagi (elected from Nagasaki Prefecture) of the Diet Affairs Committee was appointed as leader. The Party also launched the federation of diet members on “Ocean State Japan” and appointed its front bench MD Takeo Nishioka (the House of Councilors) as Chairman. As deputy chairman, former president of the Party Seiji Maehara was appointed. Nagashima took initiatives on the establishment of the project team and the federation in cooperation with Maehara. This lineup became an important factor in building consensus on the law in the Party. A call from the LDP Policy Research Council Chairman Shoichi Nakagawa to Policy Research Committee Chair Takeaki Matsumoto of the DPJ to ask for his cooperation also facilitated these movements.[27]

On March 9, the LDP held a joint committee meeting on ocean related issues and approved the contents and introduction of a draft Basic Ocean Law. At the same time, it became clear that the draft would be introduced as lawmaker-initiated legislation under agreements of the three parties.

The LDP built consensus with the NKP in the early stages and the NKP’s opinions were introduced in the draft. For example, based on the opinion of the Seashore Environmental Protection Project Team established in January in the NKP, Article 25 (2) was added to the draft. Article 25 (2) provides to protect the seashore, improve the seashore environment, and ensure appropriate use of the seashore. In the NKP, there is a group that recognizes the importance of hub ports and maritime transportation, and Article 20 (Ensuring of Maritime Transportation) and Article 24 (Promo-

[26] Interview with Hiroshi Takano, member of the House of Councilors (the NKP), by the author (in Tokyo, April 12, 2007).
[27] Interview with Akihisa Nagashima, member of the House of Representatives (the DPJ), by the author (in Tokyo, April 11, 2007). The record of the activities of the DPJ included here is based on this interview.

tion of Marine Industry and Strengthening of International Competitive Power) were confirmed. The NKP confirmed that the law didn't target ocean related disputes with China and accepted Article 1(Purpose).[28]

The LDP also faced some difficulty in coordination with the DPJ. While the DPJ supported a Basic Ocean Law, it insisted on matching the LDP-introduced 500 meter Ocean Safety Zone Act together with at least one of two pieces of legislation[29] introduced by the DPJ. It also insisted that the Coast Guard should operate more aggressively under the supervision of the cross-sectoral Cabinet Office rather than under the limited framework of MLIT. In the end, the compromise was struck by integrating opinions of the DPJ into a Basic Ocean Law and by presenting the above opinions of the party in the resolution that would be passed previous to the deliberation in the Diet. In this sense, the resolution[30] adopted on April 3 in the House of Representative Committee on Land, Infrastructure, and Transport is significant and interesting.

As comment on this resolution, it should be noted that including the establishment of an advisory panel of eminent persons and protection of the marine environment in the resolution,[31] all parties were generally satisfied with the Basic Ocean Law and there was little opposition.

At the end of March, the three Parties agreed to the joint introduction of a Basic Ocean Law through the meeting of diet policy committee chairmen of the LDP and the DPJ and it is generally understood that the law will be passed in this ordinary diet session.[32] A draft Basic Ocean Law was introduced by Chairman Ryu Shionoya of House of Representatives Committee on Land, Infrastructure and Transport and it was passed after a half-day's deliberation in the committee. On the same day, the draft was urgently submitted and passed at the plenary session. At this time, Chinese Prime Minister Wen Jiabao visited Japan. The passage process of the draft was interesting politically, in that the draft was passed before his arrival in the House of Representatives and introduced to the House of Councilors after his departure.

II. Maritime Interests, the Environment, and Initial Steps toward Integrated Ocean Management

Thus far, the author has explored and analyzed the process of policy making which took place mostly in the past year. The background of the process also requires analysis, however. An important part of this background is the incident that occurred in March 2004, when Chinese activists landed on the Senkaku Islands. Also, the following may be considered as background

---

[28] Interview with Takano, see note 26.

[29] The Bill on Promotion of Development of Seabed Resources and the Bill on Survey of Natural Resources in the Exclusive Economic Zone and the Sovereign Right to Scientific Research and its Use.

[30] On April 3, the House of Representative Committee on Land and Infrastructure, and Transport adopted a resolution whose section 3 calls for immediate enactment of domestic laws. Section 4 calls for comprehensive consideration and enrichment of the Coast Guard and section 5 calls for the conservation of territory. It is understood that there reflected the DPJ's opinions.

[31] The first section of the Resolution calls for the establishment of a system for intensive and comprehensive promotion of ocean policy and the second section calls for the establishment of a council consisting of experts within the Headquarters for Comprehensive Ocean Policy to be established in the Cabinet. The last part of the third section calls for the conservation of marine environment, including the establishment of marine protective zone.

[32] Yomiuri Shimbun, March 28, 2007.

factors: Chinese movement toward the development of oil and gas fields near the Japan-China continental shelf; Chinese denial of Okinotori Island as an "island", thus denying the basis to Japan's claim to the EEZ; China conducting a wide range of marine surveys in the western Pacific without prior notice; the Japan-Korea dispute regarding seabed surveys in the vicinity of Take Island(Takeshima). All of these have been considered as important ocean problems and most have relevance to the new ocean order expressed in UNCLOS.

1. Maritime Interest Issues in the East China Sea and Reactions of Political Parties

(1) LDP

Taking account of the incident in March 2003, when Chinese activists landed on Senkaku Island, Takemi organized a project team for ocean interests within the party to consider responses. By June, he organized a set of recommendations and emphasized the need for a ministerial council for ocean interests. Responding to such movements, in February, 2004, the government received and later nationalized the unauthorized lighthouse set up on the Senkaku Islands by a civilian political group. As a result, this strengthened management over the Senkaku Islands by the state. This was a significant process and displayed Japan's ability to take actions toward integrated management of the Senkaku Islands.

On the other hand, regarding the project team led by Takemi, the pre-existing Special Committee on Oceans was renamed the Special Committee on Ocean Interests, with Takemi as the chair, thus making the issue one for the LDP as a whole.

Furthermore, it was also seen as a serious political problem that China was developing oil and gas fields in the vicinity of the Japan-China equidistance line on the continental shelf. While those like Keizo Takemi in the LDP (emphasizing national interest and rights) criticized China harshly, Shoichi Nakagawa (then Minister of Economy, Trade and Industry) decided to take a hard-line stance from the perspective of preserving interests over resources of the continental shelf. He set out a policy in which Japan should also conduct surveys for development if China continued its present course. This policy became the trigger for the submission of the Draft Safety Zone Act.

On February 2006, when Yohei Sasagawa (Chairman, the Nippon Foundation) brought the issue of a Basic Ocean Law to Hidenao Nakagawa (then Policy Research Council chairman, LDP), Nakagawa did not hesitate to entrust the matter to Takemi (Chairman of the Special Committee on Ocean Interests). Also, Nakagawa decided to rename this committee the Special Committee on Ocean Policy, and make the Basic Ocean Law the primary theme for discussion. This reflected the LDP's intention to introduce the Basic Ocean Law. The years of working with ocean issues by the Special Committee on Ocean Interests under Takemi became the basis for Hidenao Nakagawa's own efforts towards a Basic Ocean Law.[33]

[33] Interview with Takemi Keizo, Vice Minister for Health, Labor and Welfare (former Chairman, LDP's Special Committee on Ocean Policy) in Tokyo, April 4, 2007; Kai Masaaki, Environment and Ocean Division, Comprehensive Policy Bureau, Ministry of Land, Infrastructure and Transport, Tokyo, April 16, 2007.

(2) DPJ

Responding to the oil and gas development on the continental shelf by China in the East China Sea and Chinese ocean surveys in the western Pacific since around 2004, the DPJ also began discussing ocean security. Though foreign minister Kono exchanged verbal notes between China and introduced the prior notice system, China ignored these and continued with its activities. UNCLOS had taken effect in international society, and Japan had ratified it in 1996. However, Japan was slow to adjust its domestic laws into conformity with UNCLOS. Thus, with Nagashima and Hosono as core members, the DPJ prepared bills to deal with the following three issues: the facilitation of seabed resource development, the enhancement of resource and scientific research within the EEZ, and regulation of passage in territorial waters which cannot be considered "innocent." However, the last piece of legislation did not gain a consensus within the party due to concern that it might create tensions with neighboring states. The first and second bills were set to be submitted as MD sponsored legislation. These are the two ocean-related bills mentioned above that were submitted to the legislature during three sessions from October 2005.

Under such circumstances, Nagashima, Shinba and Hosono were asked to join the Basic Ocean Law Study Group. They participated in their personal capacities, while Nagashima reported regularly to party leader Ichiro Ozawa, former party leader Maehara, and to Policy Research Council Chairman Matsumoto.

It should be noted that though the DPJ was first motivated by the Japan-China issues over the East China Sea and western Pacific, it faced squarely the issue of UNCLOS and related domestic legislation. This point is clearly reflected in Hosono's statement in the House of Councilors, Committee on Land, Infrastructure and Transport on April 19.[34]

(3) NKP

Relations with China in the East China Sea were also the catalyst for the NKP becoming interested in ocean issues. However, the NKP took a rather different approach compared to that of the LDP and the DPJ. At the end of 2005, the East China Sea issue was discussed at the LDP Special Committee on Ocean Interests, and a request for cooperation regarding the legislation of the Safety Zone Act was made to the NKP. Takano, receiving the request from Takemi, assembled the relevant officers and discussed the issue, where the following views were expressed. Could this not be seen as deliberately targeting China? Has Japan not been lax in enacting the necessary domestic laws in conformity with UNCLOS? Are we not lacking systems with which to take comprehensive views on the subject? Should we not first have a Basic Ocean Law in place? (expressed by then Policy Research Council Chairman Yoshihisa Inoue). Thus, on the whole, they expressed reluctance towards the Safety Zone Act. Land, Infrastructure, and Transportation Minister Kitagawa also had an incentive not to provoke China. However, regardless of these reservations, it was decided that the party would not be opposed to submitting the Safety Zone Act to the Diet. Thus, for the NKP,

[34] See Record of Committee on Land, Infrastructure, and Transport, House of Councilors, April 19, 2007. Member of the Diet(MD) Goushi Hosono's response to MD Shinpei Matsushita's question.

the subsequent move towards the Basic Ocean Law was warmly welcomed and the establishment of the Basic Ocean Law Study Group was highly regarded.[35]

What was significant about the NKP's movement was that it realized that (in the context of the East China Sea issue) Japan's domestic law was not in sufficient conformity with UNCLOS and also that Japan still lacked a comprehensive, integrated ocean policy. Inevitably, this led to the establishment of the Basic Ocean Law.

2. The Function of the Media

In the process of establishing the Basic Ocean Law, the mass media was a significant factor. As mentioned earlier, the Yomiuri Shimbun was actively engaged, but there is a need to examine the background.

As can be seen from the series of seminars held jointly with The Japan Forum on International Relations (JFIR) from 1998 to 2001 regarding Japan as an "ocean state", the Yomiuri Shimbun had long taken an interest in ocean issues.[36] However, it can be said that the reason the Yomiuri took such a positive stance towards the Basic Ocean Law can be traced back to a fundamental change several years prior in how they would investigate and report on ocean issues.[37] Like other newspapers, the Yomiuri experienced a certain amount of confusion on which division within the newspaper should be in charge of reporting the Chinese oil and gas development in the East China Sea. If it was an issue of resources, the economic division should take the lead. Likewise, if it were a diplomatic issue it would go to the political division, an ocean investigation would go to the scientific division, and a maritime security issue would go to the social division (Japan Coast Guard relations). The divisions were organized in a compartmentalized manner that made effective communication difficult. In this regard, the social division of the Tokyo Shimbun handled the issue of the Chinese oil and gas development in the best manner.

The Yomiuri Shimbun placed the political division in charge of this case on the rationale that the issue was part of a cross-cutting state policy. Thus, the Yomiuri organized a state strategy project team under the political division. From 2005, the Yomiuri launched a series of articles entitled "Thinking about State Strategy," and maritime issues were taken up in 2006 as a part of this series.[38] Through these articles, the public became widely interested in issues such as the limits of the continental shelf, issues relating to Okinotori Island, and maritime security issues. Literacy regarding maritime issues increased and news sources and information were made easily accessible. Also, discussion within Yomiuri was stimulated to the point that it even made the front page of the December 6th, 2006 edition. This indicates that ocean literacy among the editors had increased as well.

What should be noted here is that the media could not sufficiently grasp ocean issues (which include science, technology, natural resources, security and environmental issues) using the existing, compartmentalized methodology. The

35 Interview with Takano, see note 26.
36 Kenichi Ito ed., "Kaiyo Kokka Nihon no Koso (A Concept of Japan as a Maritime State)", Tokyo, Forest Shuppan, 2001,pp.4-9.
37 Interview with Shin Nagahara, member of the editorial board, Yomiuri Shimbun, Tokyo, April 10, 2007.
38 Yomiuri Shinbun, Political Division, "Kensho Kokka Senryakunaki Nihon (Investigation: Japan without a National Strategy)", Tokyo, Shinchosha, 2006.

Yomiuri Shimbun established a special project team to deal with this situation. It can thus be said that the media adapted to the need to understand ocean issues through a comprehensive, integrated approach.

3. Activities of the Nippon Foundation and Ocean Policy Research Foundation

Why did the Nippon Foundation and the Ocean Policy Research Foundation commit themselves to these ocean issues? Leaving aside the fact that the Nippon Foundation group had long been committed to this area, several other factors behind this may be observed, as follows: President Sasagawa's foresight in the late 1990s to have the Ship and Ocean Foundation play the role of an ocean think tank and then Nippon Foundation Executive Director Terashima's initiatives and activities. Terashima believed that Japan was lagging far behind (or completely lacking) in policy compared to other UNCLOS and Rio Summit participant states. He was determined to rectify this situation and promote research and activities in this area.

(1) Japan and the Ocean- Two Proposals

The Nippon Foundation, with Terashima's leadership, organized in 2000 a study group on ocean management and explored what might constitute the ideal ocean policy that Japan (a member of UNCLOS and the Rio Summit) could pursue. After conducting interviews with intellectuals and other researchers, it published "Oceans and Japan: A Proposal on the Ocean Policy of Japan for the 21st Century" in May 2002. The following six points were expressed in this proposal: establishment of comprehensive ocean policy, establishment of administrative bodies, setting the legal foundation for integrated coastal zone management, rational management of fish stocks, building a framework for management of the EEZ and continental shelf, promotion of research and education.[39]

Following this proposal paper, Terashima continued with a more specific proposal by establishing the Study Committee on Ocean and Coastal Zone Management, with Kuribayashi, Kisugi and Hiroyuki Nakahara (Executive Director, Research Institute for Ocean Economics) as core members. This committee released a proposal entitled "Proposal for a 21st Century Ocean Policy" on November 2005.[40] In this proposal, concrete proposals were made concerning establishment of Ocean Policy Objectives, establishment of a framework to facilitate the enactment of a Basic Ocean Law and management of the nation's expanded ocean territory and international coordination. It is not too much to state that this proposal provided the base for the Basic Ocean Law.

In the introduction of this proposal can be found a summary, entitled "On becoming a true ocean state", as below:

"The Oceans cover 70% of the earth's surface and are of a continuum both physically and ecologically; they are also difficult to demarcate by borders and thus international by nature. In the late 20th century, coastal countries began to expand their jurisdictional claims to ocean areas and a trend to 'enclosure of oceans' gained momentum. At the same time, global environmental

[39] http://nippon.zaidan.info/seikabutsu/2001/00888/ Accessed April 15, 2007.
[40] See note 9.

issues surfaced and many countries began to give priority to the protection and preservation of the ocean environment. Against these backgrounds, the United Nations Convention on the Law of the Sea was adopted, and the action plan for sustainable development 'Agenda 21' that was adopted at the Rio Earth Summit attached great importance to oceans and coastal regions. The sustainable development of oceans to enable future generations to enjoy their benefits is one of the most important tasks of the international community.

In recent years, we have experienced abnormal weather conditions accompanied by rises in sea levels due to global warming, natural disasters such as tsunamis and high tides, and human menaces such as terror at sea, piracy, and the issue of spy ships. It is therefore an urgent necessity for our country to take countermeasures against these various ocean-related threats. Also, calls are mounting for an integrated approach that would address the environment, natural resources, and other issues from the perspectives of a comprehensive security policy.

Based on the new ocean regime, it is more important than ever for our country to tackle these ocean issues in an integrated manner. However, planned and integrated approaches to resolve these problems and to exercise our country's ocean-related rights and obligations have not yet been fully developed.

Since oceans are international by nature, our country as an ocean state should demonstrate leadership and accelerate its approaches to these various problems in collaboration with the international community."

In this proposal, keywords such as UNCLOS, Agenda 21, sustainable development, maritime security, and international cooperation are explained in a systematic manner. To a state that lags far behind, this proposal provided the very basic principles.

What is interesting about this proposal is the fact that under the topic headings of management of expanded ocean "territory" and international cooperation, it first explains the framework of the EEZ and continental shelf management and then the establishment of maritime security. In the Study Committee on Ocean and Coastal Zone Management, the issues raised included the ocean environment, ecosystems, integrated coastal management, maritime information, and maritime research and education. However, given the current political context, especially concerning maritime security issues such as in the East China Sea, the two topics mentioned above generated most interest.

In deliberations within the Nippon Foundation, there was little mention of security issues. However, in this committee several specialists on national security and defense participated, which led to the recognition that assertions regarding security issues should be made as well. The author, at this point, was convinced that it was realistic to use the East China Sea issue (now a major public concern) as a trigger to introduce the Basic Ocean Law.

(2) Okinotori Island Issue

Recently, the Okinotori Island (Okinotorishima) issue has attracted public attention. This largely resulted from the Nippon Foundation's efforts from 2004 to 2005 to take the initiative in chartering ships and sending non-governmental missions consisting of journalists, oceanographers, and maritime law scholars and other academics to the island. Okinotori Island received substantial newspaper and magazine coverage, and the mass media presented the views of academics. Following this media coverage, Shintaro Ishihara, Governor of Tokyo, visited the island. These efforts and media coverage effectively made people and politicians, as well as the government, more aware of ocean issues.[41]

(3) Ocean Security

Since Akiyama joined the Ocean Policy Research Foundation (OPRF), ocean security has been particularly emphasized, in addition to ocean safety. In this field, OPRF recently conducted the following research activities, which are closely connected to the concept of the Basic Ocean Law.

Firstly, OPRF held three international conferences, adopting and announcing the Tokyo Declaration on Securing the Oceans in December 2004.[42] The Tokyo Declaration begins as follows: "The concept of Securing the Oceans, which we advocate, regards the implementation of ocean governance as an integral part of comprehensive security. It requires that all aspects of ocean management, including military activities, the peaceful use of the oceans, resource extraction, environmental management, and scientific research should be addressed in an integrated manner." The declaration proposes a new concept of ocean security including environmental and resource security, extending from the conventional concept of security.

OPRF held four international conferences from 2003 to 2005, studying the coordination between activities in a country's Exclusive Economic Zone (EEZ) conducted by other countries, particularly military activities, and the jurisdiction of the littoral country. The conferences finally adopted and announced the Guidelines for Navigation and Overflight in the Exclusive Economic Zone. Concerning such activities, the U.N. Convention on the Law of the Sea (UNCLOS) does not provide clear guidelines, and many serious disputes occur around the world. In response, OPRF attempted to establish tentative guidelines as an institution from a non-governmental sector.

OPRF has also organized several track-two ocean security dialogues. With these efforts, OPRF was among the first to indicate the importance of ocean security in discussing the Basic Ocean Law.

3. MLIT's Efforts to Address Ocean Issues

The Japanese Ministry of Land, Infrastructure, and Transport (MLIT) is a giant government agency, merged in 2001 from the former Ministry of Construction, Ministry of Transport, National Land Agency, and Hokkaido Development Agency. MLIT addresses broad ocean issues including seacoasts, rivers, water resources, ports and harbors, maritime affairs and safety, weather, and environment, as well as the EEZ and continental shelf as Japanese land.

In this Ministry, that oversees national land and transport in an integrated manner, a Policy Bureau was established. The Policy Bureau's tasks include establishing integrated efforts for ocean policies. In September 2004, a study group was formed under the Director-General of the Policy Bureau. Finally in June 2006, the Policy Outline for Ocean and Coastal Areas was adopted,

[41] Okinotori Island – The report of the first non-governmental inspection visit to the island, Nippon Foundation.
http://www.nippon-foundation.or.jp/ships/topics_dtl/2004783/20047831.html Accessed on May 6, 2007.
[42] Adopting the Tokyo Declaration on Securing the Oceans.
http://www.sof.or.jp/topics/2004/pdf/041220_1.pdf Accessed on May 6, 2007.

indicating eight fundamental policies, as well as establishing the Head Office for the Ocean and Coastal Area Policies in MLIT. MLIT, responsible for almost all ocean issues, was clearly determined to develop integrated policies addressing the several ocean issues that MLIT is responsible for, considering that such issues are ocean and coastal area issues.[43]

The Japan Coast Guard is a subordinate organization to MLIT and was closely involved in the efforts concerning the Senkaku Islands and ocean survey issues, as well as the continental shelf extension. At those times, MLIT was carefully responding to the ocean issues in the East China Sea and West Pacific Ocean. In December 2002, the Office for the Continental Shelf Surveys was established in the Cabinet Secretariat. MLIT, taking up this issue from the Nippon Foundation's "Oceans and Japan: A Proposal on the Ocean Policy of Japan for the 21st Century" (May 2002), encouraged the Cabinet Secretariat to establish this office. The special office was established in the Cabinet Secretariat because these issues require the attention of the entire Cabinet; however, the office was run mainly by former MLIT officials.

Masaaki Kai, currently the Director of the Environment and Ocean Division, Policy Bureau, MLIT, was transferred to the Cabinet Secretariat in 2004, where he addressed the issues concerning the Senkaku Islands, development of oil and gas fields in the East China Sea, Okinotori Island, and seafloor surveys of the sea areas surrounding Take Island (Takeshima). He returned to MLIT in July 2006 and worked to establish the Basic Ocean Law. He is very knowledgeable about the background of these matters, as well as aware of the necessity of addressing ocean issues in an integrated manner and the importance of the Cabinet Secretariat's integrated coordination function.[44]

Concerning human factors, Vice-Minister Yasutomi of Land, Infrastructure, and Transport, formerly the Director-General of the Maritime Bureau, MLIT, is very knowledgeable about maritime and ocean issues. In recent years, former Director-Generals of the Maritime Bureau have rarely become the Vice-Minister. Director-General Shukuri of the Policy Bureau was formerly the Director of the General Affairs Division, Maritime Technology and Safety Bureau, and has been deeply involved with the Nippon Foundation and ocean issues.

After the Basic Ocean Law Study Group was formed in April 2006, Vice-Minister Yasutomi directed the related division to work with OPRF in drafting the Basic Ocean Law. A law drafting experts was sent to OPRF from MLIT. OPRF and MLIT collaborated in the Basic Ocean Law Study Group. In the last meeting of the Study Group, when they discussed whether there should be a Minister in charge of ocean policies or not, Director-General Shukuri was at the meeting where he made the comment, "I devote much of myself to these issues. If there is going to be a Minister in charge of ocean policies, I am prepared to assume the post."

[43] About the Policy Outline for Ocean and Coastal Areas, MLIT.
http://www.mlit.go.jp/kisha/kisha06/01/010621_2_html　Accessed on May 6, 2007.
[44] Interview with Masaaki Kai. See note 33.

III. From Freedom of the Seas to Ocean Management

The above analyzes and describes the adoption process and background of the Basic Ocean Law, which was promulgated and came into force in April, this year. The analysis and description make it clear that the dispute between China and Japan over the development of oil and gas fields on the continental shelf in the East China Sea and other ocean issues triggered Japanese public concern over ocean issues. If this was the case, why did their concern lead to the political decision of building a major framework, i.e., the adoption of the Basic Ocean Law, rather than addressing each issue individually? Why did it lead to such an unusual process with a non-governmental organization playing an important role and the Diet members, instead of the government, presenting the bill to the Diet after all three major parties agreed on the bill?

In order to understand why, we need to discuss the relationship between ocean issues and UNCLOS that is behind these ocean issues, past Japanese government attitudes towards UNCLOS, and insufficient recognition of the major shift in the ocean paradigm.

1. Ocean Issues and the U.N. Convention on the Law of the Sea[45]

In 2004, Chinese demonstrators tried to land on the Senkaku Islands, claiming sovereignty, and the Japan Coast Guard tried to stop them. This incident had a significant impact on Japanese public opinion. This incident resulted from national interests over oil and gas fields on the continental shelf, and China unilaterally moved forward in developing the fields and producing oil and gas on the continental shelf in the East China Sea, where demarcation was not fixed between China and Japan. Japanese citizen concern awakened over ocean interests, which were little discussed in Japan before the incident. This is one reason why the special committee set up in the LDP was named the Ocean Interests Special Committee. The DPJ also prepared maritime related bills for lawmaker-initiated legislation, one of which was named the Bill for the Development of Offshore Resources.

At that time, China's ocean surveys and military training and surveys in Japan's surrounding sea areas and the vast West Pacific areas were too frequent and too prominent to ignore.[46] Most of these areas are within the Japanese EEZ, and China consistently violated the Mutual Prior-Notification Framework for Ocean Surveys that was concluded between the two countries in 2001. China also claimed that Okinotori Island is not an island providing a basis for the Japanese EEZ, claiming Okinotori Island was only rocks according to the UNCLOS definition. In 2006, a dispute between South Korea and Japan came to light over a seafloor survey of the sea area surrounding Take Island(Takeshima). Again, in this dispute, the territorial issue over the island itself relates to the issue concerning ocean surveys in the EEZ. The same is true with the Northern Territory issue, a dispute between Russia and Japan over the Northern Territory. Whether the territory belongs to Russia or Japan decisively

[45] Officially called "United Nations Convention on the Law of the Sea," consisting of 320 articles and 9 annexes.
[46] Defense Agency of Japan, “White Paper on Defense 2004”, National Printing Bureau, July 6, 2004, pp.58 and 59. After 2004, similar statements are included in the White Paper every year, in Military Situation 3 – China, Chapter 1.

influences the EEZ and continental shelf issues.

The above-mentioned issues are closely related to the area management system, newly established based on UNCLOS. EEZ is a new sea area management issue that was brought in by UNCLOS. Also, continental shelves should not be considered as conventional continental shelves, but as a new concept of continental shelves based on UNCLOS. Continental shelves, if littoral states submit appropriate data, can be extended from the usual 200 sea miles to 350 sea miles. This extension is based on UNCLOS, which was adopted at the third U.N. Conference on the Law of the Sea in 1982 and took effect in 1994. The dispute over whether Okinotori Island is an island or rocks occurred due to UNCLOS, and this dispute is over a definition based on UNCLOS. If Okinotori Island is not an island providing a basis for the EEZ, then Japan will lose 10 percent of the area that it now considers as its EEZ.

Furthermore, there are many controversies over ocean surveys carried out by one country in another country's EEZ. If a survey has purely scientific purposes, the littoral country should permit the survey. If it is an ocean resource survey, however, the littoral country can refuse it at its own discretion.[47] This is because the littoral country has sovereign rights over resources in its EEZ. UNCLOS, however, does not clearly regulate ocean surveys for military purposes. UNCLOS was discussed and adopted during the Cold War, and the United States and the Soviet Union strongly opposed establishing any restrictions on military activities conducted in EEZs outside territorial waters, which used to be open waters. Therefore, UNCLOS could not provide any concrete rules concerning this matter. Moreover, we cannot tell from the outside what kind of ocean surveys Chinese ships are conducting in the Japanese EEZ in the West Pacific Ocean.

Concerning ocean security, a Chinese navy submarine intruded into Japanese territorial waters in 2004. This intrusion was obviously part of military activities that China conducts in the West Pacific Ocean, more specifically, on the line connecting the Chinese mainland, Taiwan, Guam, and Hawaii. In addition to these incidents that resulted from the relationship between the U.S. and China, or the relationship between China and the U.S.-Japan alliance, North Korean spy boats intruded into Japanese territorial waters several times. In 2001, one such spy boat intruded into Japanese territorial waters, and, while running away, blew up their boat and sank. The case became very complicated because the destruction and sinking occurred in the Chinese EEZ. Chinese navy ships and Chinese government owned ships are also observed sailing and engaging in activities with unknown purposes in the surrounding and territorial waters of Japan. Whether the navigation and activities of such ships require notification and approval or not is related to UNCLOS. The issue also relates to the unsatisfactory Japanese domestic law that fails to define which navigation is harmless and which is not.

Other safety issues are pirates in the Malacca Straits and the maritime terrorism that is expected to occur. These issues jeopardize stable maritime traffic, which is essential for the Japanese economy. Securing the safety of the sea lanes is more important than ever. Although military activities and exercises are permitted in the open sea, a littoral country cannot simply ignore them if they are conducted in its EEZ. These issues are also

[47] "Oceans Act Textbook", Yushindo, 2005, pp. 160-168, edited by Moritaka Hayashi and Yukio Shimada.

related to UNCLOS in a broad sense and should be within the scope of international systems that are under the umbrella of UNCLOS. Recently, most of such systems have been established as International Maritime Organization (IMO) conventions.

People are becoming more aware of the ocean environment too. There are a myriad of ocean environmental issues including coral bleaching, rising sea-level caused by global warming, and global warming becoming more serious due to ocean environmental changes. More immediate problems include oil pollution of the sea, waste washed ashore, explosive increase of "Echizen jellyfish", and disruption of the ocean ecology. In international society, several conventions for preserving the ocean environment have been adopted. These topics are now covered by the mass media more often, and people are more aware of ocean environmental issues. The Japanese government, however, has no minister in charge of ocean issues, and government efforts are often too late and too sectionalized due to their vertically divided administrative functions. More comprehensive and strategic ocean policies are needed.

The above-mentioned ocean issues all relate to each other. The preamble of UNCLOS states that they have to be solved in a comprehensive and integrated manner.[48] The Earth Summit held in Rio de Janeiro in 1992 adopted Agenda 21, confirming the necessity of sustainable development and comprehensive management of the oceans (Chapter 17).[49]

2. UNCLOS and Japan's Response

How has Japan responded to the United Nations convention on the Law of the Sea (UNCLOS)?[50] The 3rd United Nations Conference on the Law of the Sea adopted a consensus and package-deal formula[51] for its proceedings. UNCLOS, as a result, was enacted in 1982 after 10 years deliberation, with little opposition. Japan strongly asserted freedom of navigation and use of the seas, as in the prewar period, throughout the first half of the Conference. It supported wide high seas and narrow territorial seas and objected to expansion of territorial seas. While the United States asserted freedom of navigation, including on the high seas, primarily for military reasons, Japan aimed at protecting its fishery profits and freedom for maritime traffic. It was for this reason that the Japanese government always sent representatives from the Fisheries Agency along with Foreign Ministry representatives to take part in the Conference. Although a number of states, including the United States, sent their naval officers to the Conference, Japan did not.

In 1960, a proposal to extend territorial seas to 6nm and establish 6nm exclusive fishery zones outside territorial waters was set to be approved and go to a division at the 2nd United Nations Conference for the Law of the Sea. Japan, however, abstained from voting because of its adher-

[48] The UNCLOS preamble states, "Conscious that the problems of ocean space are closely interrelated and need to be considered as a whole….."

[49] Soji Yamamoto, "Kaiyou Hou(Ocean Act)", Tokyo, Sanseido, 1992 and Tadao Kuribayashi, "Gendai Kokusai Hou(Modern International Law)", Tokyo, Keio University Press, 1999. These two books were generally used for reference when describing UNCLOS.

[50] Tadao Kuribayashi, "Kokusai Kaiyou Chitsujo to Nihon no Houteki Taio(International Ocean Order and Japan's Legal Resonse)" in Tadao Kuribayashi and Masahiro Akiyama, ed.,"Umino Kokusai Chitsujo to Kaiyou Seisaku(International Order at Sea and Ocean Policy)", Tokyo, Toshindo, 2006, pp.4-6.

[51] A Consensus formula requires agreement by all parties. A package-deal formula calls for a vote on the proposal as a whole, not allowing reservations on particular articles.

ence to wide high seas and narrow territorial seas. This proposal, in consequence, obtaining just one vote less than the required two-thirds number of votes, was defeated. If Japan had been more in step with the times regarding ocean management and approved the proposal, an ocean regime of 6nm territorial seas coupled with an additional 6nm exclusively fishery zone might have been established. Afterwards, the United States and Soviet Union arbitrarily established exclusive fishery zones over 200nm in 1976. Japan reluctantly approved the zones to protect its domestic fisheries. Although Japan had opposed the establishment of the zone out of concern for its negative impacts on its fishing industry, it was compelled to accept the zone in 1977. Consequently, this zone was introduced into the 3rd United Nations Conference for the Law of the Sea as the exclusive economic zone, giving coastal states sovereign rights over marine resources in the zone.

UNCLOS was established in 1982 and took effect in 1994 after ratification by sixty States. Japan ratified UNCLOS in 1996. Although the need to adjust domestic law to UNCLOS requires time, active efforts to ratify UNCLOS were lacking in Japan for over a decade.

To make matters worse, domestic laws that were enacted to adapt to UNCLOS were improper. The Law on the Territorial Seas and the Contiguous Zone and the Law for the Exclusive Economic Zone and Continental Shelf[52] were almost verbatim that of UNCLOS. Those laws merely stipulated that existing domestic laws should be applied to difficulties within the domestic legal order; therefore, the Law for Mines should be applied to the exploitation on the continental shelves. In addition, since domestic law had no provisions regarding non-innocent passage in the territorial seas, enforcement under domestic law was impossible. Although the Law on Enforcement of Sovereign Rights on Fishing in the Exclusive Economic Zone[53] seemed to correspond to UNCLOS in terms of protection of fishing, it has problems concerning enforcement due to the existing Coast Guard Law.

After UNCLOS was adopted, the Ministry of Foreign Affairs gradually reduced its organization and manpower for UNCLOS. The Ocean Development Council that was a consultative body to the Prime Minister was demoted to the Ocean Development Committee, a part of the Scientific Technology and Academic Council established under the Minster for Education, Culture, Sports, Science and Technology. In the private sector, the International Ocean Institute also scaled back its activities.

In such circumstances, the People’s Republic of China began to exploit the gas fields on the continental shelf in the East China Sea. Though exploration and exploitation by China in the East China Sea began in the 1990’s, Japan did not register a strong protest. Such lack of response by Japan, in consequence, gave China the mistaken impression that Japan would not assert any rights in the sea area on the China side of the Japan-China intermediate line in the South China Sea. In addition, the intermediate line, which was established by the Law for the Exclusive Economic Zone and Continental Shelf, as men-

[52] The Law on the Territorial Sea and the Contiguous Zone(Law No.30 of 1977, as amended by Law No.73 of 1996). The Law on the Exclusive Economic Zone and the Continental Shelf(Law No.74 of 1996).
[53] Law on Enforcement of Sovereign Rights on Fishing in the Exclusive Economic Zone (Law No.76 of 1996).

tioned above, should be considered a diplomatic failure. Although the law posits as a condition the recognition by the other state involved, it did not necessarily have political significance.

As for Japan's position on straits used for international navigation (international straits), in 1977 when it enacted the Law for territorial sea which extended its territorial sea from 3nm to 12nm, it retained the 3nm limit in specific international straits such as the Tsugaru and the Tsushima, leaving them as high seas. Such measures on international straits were taken to avoid unnecessary conflict caused by passage of U.S. and Soviet submarines. In the present, however, those measures have created the unwanted scenario in which Chinese military vessels pass freely through and carry out activities in those straits. Since Indonesia, Malaysia and Singapore established 12nm territorial seas in the Malacca strait, few areas remain that are considered the high sea. It is thus the Coastal States' understanding that Ocean States are only allowed the innocent passage that is recognized in territorial waters. Ocean States such as the United States and Soviet Union complained about the measure, resulting in the right of transit passage, which can be not regulated as long as it is continuous and expeditious, being introduced into UNCLOS.

3. Change of Ocean Paradigm

What is clear is that Japan's policy decisions repeatedly lagged behind the world's paradigm shift regarding the ocean. This paradigm shifted from freedom of seas to management of the seas. Japan, however, couldn't adapt to this change; instead, throughout the post-war period, it adhered to the broad high seas and narrow territorial seas paradigm and concentrated on securing its fishing rights.

It was the United States, who had most strongly asserted freedom of navigation and use of the seas, that triggered expansion of coastal management by coastal states when it issued the Truman declaration for continental shelves and conservation zones in 1945 and unilaterally established 200nm exclusive fishery zones in 1976.

Looking at the relation between states and the ocean from a political science perspective, the United States, backed by the sea power theory of Alfred Mahan, used its naval power, marine industries, and economy to surpass Great Britain and became the leading naval power of the 20th century. Although Japan since the Meiji restoration had aimed at being a sea power second only to the United States, that aim was defeated by its defeat in WWⅡ. After the war, Prime Minister Shigeru Yoshida advocated Japan becoming a different kind of ocean state.[54] It was his position that Japan should promote its recovery by allying itself to the United States and the United Kingdom, the world's leading sea powers, based on freedom of trade and democracy. In his 1960's work Ideas for an Ocean State, Masaaki Kousaka received much attention for his attempt to define Japan's role in Asia in terms of its position towards China. More recently, a Western Pacific Ocean Union was advanced by Heita Kawakatsu as an aspect of maritime cultural history. Nevertheless, it is noteworthy that Kousaka, at that point in time, foresaw the principle of freedom of the seas becoming an inadequate one, a prediction that shocked the international marine order. Starting from these premises, he asserted that the ocean should be considered by how it affects the

[54] Shigeru Yoshida, "Kaiso Junen (Reflection: Ten Years)", Tokyo, Chukoshinsho, 1998, p.34.

nation and he urged its development.[55]

Japan, in any case, didn't consider the ocean in strategic terms throughout the process of enacting of UNCLOS nor after its coming into effect. Other leading countries, however, such as the United States, Australia, China, Korea, and the European States, formulated comprehensive marine policies and enacted the necessary domestic legislation in this period and consolidated government systems to promote integrated ocean policy.[56] Japanese activity on ocean policy lagged far behind and lacked an ocean management perspective.[57]

It was in those circumstances that a variety of ocean problems began to emerge that did not fit the previous conceptions and could not be resolved by traditional methods. Japan, consequently, recognized that those difficulties should be treated comprehensively and that enactment of a Basic Ocean Law as a framework for integrated ocean policy was necessary.

Conclusion

It was only one year from the time concrete actions began that the Basic Ocean Law was enacted. By the above analysis of that process of enactment of the law, the following was learned.

While it is true that public awareness of ocean problems in general had been on the rise, the most direct impetus for the Basic Ocean Law came from NGOs and individuals from the private sector. As for the concrete steps in getting the bill passed, the Diet members-initiated legislation was the method chosen, with the bill sponsored by members of the Diet from the ruling Liberal Democratic Party and the New Komeito Party, as well as the largest opposition party, the Democratic Party of Japan.

Along with responses by members of the Diet, the casting of oceans issues as a matter for national strategy by some of the mass media was also an important factor What prompted them to do so were increased interest by the public, especially as tensions grew between Japan and her neighbors from 2004 over marine interests in the East China Sea and the Western Pacific

One reason why a policy issue as important as a Basic Ocean Law was not developed through the usual decision-making processes of the ruling Liberal Democratic Party was that ocean problems demand comprehensive and integrated responses and the government could not make them due to sectoralism among the various ministries and agencies. Another reason was that Japan could not break away from its rigid adherence to the freedom of the seas approach it had asserted during the UNCLOS negotiations and so lacked the flexibility to find solutions to current problems.

It should also be pointed out that the government underestimated the importance of UNCLOS, could not understand the paradigm shift from freedom of the seas to ocean governance, or, if it did, took no significant action in response. What this analysis has provided is a surer understanding of world trends regarding ocean use and management of ocean space.

This process is neither the reasonable actor model in decision-making process theory, nor the

[55] Masataka Kosaka, "Kaiyo Kokka Nihon no Koso," in "Kosaka Masataka Chosakushu", Vol. 1, Tokyo, Toshi Shuppan, 1998.
[56] Ocean Policy Research Foundation, "Kaiyou Hakusho(Ocean White Paper) 2007", pp.11-12 and 14-21.
[57] Hiroshi Terashima, "Nijuisseiki no Kaiyo Seisaku(Ocean Policy in the 21st Century)", in "Kaiji Koutsu Kenkyu", No.55, 2006, pp.19-23.

bureaucratic governance model of Graham Alison. Neither does it fit the decision-making model by case-study method concerning the decision-making process of a central bureaucracy. Comprehensive decision-making on the Basic Ocean Law at this time was done not by traditional actors such as the Liberal Democratic Party, bureaucrats, big business interests, the cabinet secretary, and mass media, but by NGOs, individual diet members, certain private citizens, one newspaper, and the support of one ministry. This phenomenon may provide a base for the formulation of a new decision-making model. However, this model should be concerned with policy-making decisions on issues that share the same factors as those ocean problems demanding comprehensive responses, which Japan did not sufficiently provide and which have been the object of this analysis. Specifically, the anther refers to those ocean problems that have for a background the paradigm shift involving UNCLOS and sustainable development.

海の利用と海洋空間の管理：海洋基本法立法政策決定過程の分析

秋　山　昌　廣*

要　旨

日本としては初めての海洋基本法が、2007 年 4 月に参議院で成立し、7 月に施行された。海洋基本法は議員立法という形で導入されたが、その過程で、日本財団や海洋政策研究財団といった民間の組織が導入のイニシャチブを取り、重要な役割を果たした。

日本における立法政策決定プロセスは、多くの場合、政府が企画立案し、閣議決定を経て国会に提出されるのであるが、今回、海洋基本法といった重要な法律が議員立法という手法で導入された理由は、海洋問題を管轄する省庁が 8 つに及び、どの省庁も、総合的管理を必要とする海洋問題のリード官庁になれなかったことである。

本レポートは、この海洋基本法導入プロセスを、ケーススタディーの分析手法によりトレースし、そこに新しい政策決定過程論ないしモデルの研究にきっかけを与えようとするものである。今回の政策決定プロセスは、いわゆる合理的行為者モデルでも、グリアム・アリソンの説く官僚政治モデルでもないことが明らかとなる。

同時にこのレポートは、海洋基本法導入の背景として、日本国民の海洋問題への関心の高まりとそのきっかけ、原因などを説明する。2004 年頃より顕在化した、東シナ海における尖閣諸島領有権問題、日中間の大陸棚における石油ガス開発問題、日本の排他的経済水域における中国船舶による海洋調査問題、その他シーレーンにおける海賊・海上テロ問題、さらには海洋環境問題などが、日本国内世論に大きな影響を与え、日本が海洋権益に対して強い関心を持つようになったと言えよう。

国連海洋法条約は 1982 年に採択され、1994 年に発効された。日本はしかし、1996 年の条約批准後においてさえ、総合的かつ統合的に管理されなければならない海洋問題を積極的取り上げることはしてこなかった。このため、海洋資源開発、海洋環境保護、近隣国との境界画定などにおいての対応が、不十分かつ後れを取る結果となってしまった。

今回海洋基本法を導入することにより、島国日本から新しい海洋立国日本へと変容することが期待される。

キーワード：海洋基本法、国連海洋法条約、議員立法、政策決定過程、海洋空間、持続可能な開発、東シナ海

* 海洋政策研究財団／立教大学

Metabiology of Decapods: Construction of axiomatic system of the Autopoiesis Theory

Hajime Watabe*

ABSTRACT

The large and the serious problems concerning biology and bio-industry using marine animals, especially, deep-sea organisms, that are difficult to access due to their inhabiting in deep-sea environment, can be summarized as following two lines. At first, due to the difficulty on observing directly in deep-sea environment, planning management is very difficult, that penetrates the entire body of the planning and carrying out of research program, successive establishment of marine bio-industry, and simultaneous resource and environment conservation. Second, fundamental basis, that is established by good theoretical background, should be prepared from the research program itself and successive bio-industry. In this study, I adopted the Autopoiesis Theory on managing the research program, and then, theory and practice of animal taxonomy, that is the most fundamental basis of marine biology. The Autopoiesi Theory clearly defines the “living organisms”or “living state,” and was derived from the cognitive neuroscience. This study is the first application case of this theory to animal taxonomy. For the example, microtaxonomy (taxonomy at species taxon level) of deep-sea nephropid and lithodid decapods, macrotaxonomy (taxonomy at the taxa higher than species level) of crab-shaped decapods, distributional analyses of saprophagous decapods in the bathyal zone of the Tokyo Submarine Canyon, ecological analyses of lithodid decapods using deep-sea manned submersible, abnormal ecology of deep-sea lithodid decapods in the Tokyo Submarine Canyon after the sever fishing impact, construction of taxonomic basis on the interrelationship between decapods and their symbionts, and finally, establishment of axiomatic system of the Autopoiesis Theory, were analyzed and studied.

Key words: deep-sea decapods, management of research planning, animal taxonomy, the Autopoiesis Theory, axiomatic system

* Ocean Policy Research Foundation

I. GENERAL INTRODUCTION

I-1. SCIENTIFIC BACKGROUND

The interaction and interrelationship have been considered as one of the central subject in the biological investigation. The related discussion can be constructed for any biological hierarchy, and quite wide varieties can be also provided according to the interest of us biologist. For example, the interrelationship between individual and species are completely formalized by the concept, "biological species," proposed in Mayr and Ashlock (1991). On turning our eyes to the microscopic level, the intracellular symbiosis, namely, the specific interrelationship between bacterial symbionts and host eukaryotic cell can be easily found (Ishikawa, 1994; Margulis and Sagan, 1995). Moreover, these interrelationships are characterized by the corresponding interaction.

Especially in the ecological survey concerning the deep-sea organisms, faunal zonation is placed as the major object to be investigated. The traditional approach to it had been restricted to precise description through multivariate analysis, but trials to identify or elucidate the biological cause on the maintenance of the structure are reported after 1980's (Haedrich *et al*., 1980). However, due to large difficulties to carry out deep-sea investigation, both field experiments on zonation structure and laboratory analysis concerning physiological and ecological characteristics of relevant individuals had been left on unripe stage compared with the case of intertidal or shallower zone (Jensen and Armstrong, 1991). Among the biological factors to construct faunal zonation of bathyal decapods, unusually narrow physiological characteristics had been pointed out from field surveys based on statistic methodology (for example, Abelló *et al*., 1988, Macpherson, 1991, and Cartes and Sardà, 1993). However, corresponding results concerning bathyal decapods in physiological interests can be scarcely found compared with the case in fishes (Henry *et al*., 1990; Vetter *et al*., 1994). Additionally, (1) large difficulties concerning taxonomic inference (*sensu* Mayr and Ashlock, 1991) and our understanding of its conceptual difference from mere categorization, and (2) the conceptual contamination of statistic and biological semantics may give a negative influence on it. At least, besides the elaborate planning and enforcement of intensive field survey on board, conceptual reconstruction concerning the maintaining mechanism of faunal zonation should be carried out according to the original intention like Haedrich *et al*. (1980) or Ohta (1983).

As for the special interrelationship, namely, symbiosis, recognized on individual order, the infection of kentrogonid barnacles on decapods had constantly attracted many biologists. However, the rigorous understanding of it can not help being retreated in the quite immature stage in spite of many results and reviews (for the latest review, see Høeg, 1995). The reason is roughly summarized as follows: (1) The sampling difficulty in the field due to the scarceness of infected decapods; (2) difficulty in proper selection to represent relevant interrelationship. Similarly in the case of faunal zonation, the sampling and conceptual maintenance should be established at the same time, naturally based on the rich material set. Moreover, the elementary experiment should be appreciated for the ease of understanding relevant interrelationship, and the gaining rigorous basis answering for a wider expansion in future stage.

For the complete solution to both of above mentioned requirements, the unique taxon, namely, the family Lithodidae (Anomura: Decapoda), can be undoubtedly appreciated as a concrete material, from the aspect of (1) ecological characteristics of referred individuals in the deep-sea environment, namely, saprophagous and migratory natures, and the deviation from food-web assured by large body and hard armature on adult stage, and (2) existence of huge kentrogonid symbionts exclusively infecting them. If adequate sampling of them and the conceptual maintenance on both the sampling procedure and the related terms could be completely satisfied, above mentioned demands could be actually solved.

Moreover, foundation of biology is the most important problem in modern biology. Mayr and Ashlock (1991) repeatedly suggested this matter, but they could not propose the concrete strategy to construct rigid foundation by taxonomy like in the case of mathematics by set theory. In present study, I would like to construct the basic foundation like in the case of mathematics by “formalized taxonomy” by way of the unique theory, “Autopoiesis Theory” (Maturana and Varela, 1980). The term, “metabiology,” this is the analogue of “meta-mathematics,” or “foundation of mathematics,” and I would like to express the development of axiomatic view point in biology.

At the end of this Introduction, the need for environmental protection should be proposed concerning study areas, especially the Tokyo Submarine Canyon, central Japan, due to the heavy ship traffic there.

I-2. OBJECTIVES OF PRESENT STUDY

Present study consists of twelve main chapters (Chapters I to XI). After description of study areas, and sampling programs and results (Chapter II), I will discuss particular issues concerning the requirements proposed in I-1.

(1) taxonomic inference on the genus *Nephropsis* chiefly collected in Japanese waters, based on traditional microtaxonomy using morphological characteristics (Chapter III)

(2) macrotaxonomic system of crab shaped decapods (Chapter IV)

(3) description of interspecific zonation in the genus *Paralomis* in the bathyal zone of the Tokyo Submarine Canyon, and their taxonomic inference at species taxon level (shallower than 400 m) (Chapter V)

(4) description of faunal zonation in the guild (*sensu* Kobayashi, 1995) of the bathyal zone in the Tokyo Submarine Canyon (shallower than 400 m) (Chapter VI)

(5) strong interspecific segregation in the genus *Paralomis* around active hydrothermal vents on the Minami Ensei Knoll through *in situ* observation (Chapter VII)

(6) extra-high prevalence concerning *Briarosaccus callosus* on migrating population referred to *Paralomis multispina* into the Tokyo Submarine Canyon (Chapter VIII)

(7) proposal of the term, “kentrogonid maternalization,” for the interrelationship recognized in the case, kentrogonids / corresponding decapod hosts (Chapter IX)

(8) construction of axiomatic system of the Autopoiesis Theory, *CGAT* (Chapter X)

As for the objectives categorized into “ordinary biology,” they can be roughly divided into following three components according to the requirements proposed in I-1, namely, (I) the over view on taxonomic inference on various level of animal hierarchy (1-2), (II) the investigation of maintenance mode of faunal zonation, and the development of planning on field experiments (3 - 6), and (III) the elucidation of interrelationship between kentrogonids and corresponding host decapods, with reconfirmation of related terms (7). For general discussion, (1) combining from (I) to (III), (2) the implication of axiomatic system construction of the Autopoiesis Theory, and (3) presentation of environment protection and future perspective on crustacean biology and animal taxonomy general, Chapter XI will be established.

I-3. BIOLOGY OF BATHYAL LITHODIDS OF *PARALOMIS* INCLUDING THEIR SYMBIONTS

To demonstrate concrete discussion, general knowledge concerning relevant organisms should be available. Due to scarceness concerning gained biological results, the genus *Nephropsis* was excluded here (see also Chapter III).

1. Genus *Paralomis* White, 1856

The genus *Paralomis* White, 1856 (feminine gender) is characterized by the lithodid individuals that commonly possess following morphological characteristics. Moreover, these characteristics clearly discriminate other ones referred to the other lithodid genera, in spite of long taxonomic confusion after the original settlement by A. White (Sakai, 1971, 1976; Macpherson, 1988c). Slight modifications to eliminate *Paralomis odawarai* (Sakai, 1980) from the genus were added (see also Chapter IV).

(1) second abdominal plate entire and completely united with lateral and marginal plates, without linea nor membranous interspace
(2) third to fifth abdominal segments distinct, and median and lateral plates of each segment connected with extremely narrow membranous connection
(3) main gastric spine usually consisting of acute or blunt spine, and sometimes tubercle cluster, but never forming bifid one
(4) rostrum formed by a basal spine and at least one pair of dorsal spines
(5) total length of third ambulatory leg always subequal to or apparently longer than carapace width
(6) spinulation of total body varying from acute spine to tubercle cluster, but never forming feather-like ones

However, some suggestions by Macpherson (1988c) and another taxonomic problem have been still remaining, and the present generic character set should be used with caution, and further modification should be added in future stage (Macpherson, personal communication; Watabe, unpublished data).

Nearly 50 morphological phena satisfying above mentioned character set had been described (Macpherson, 1988a-c, 1994; Watabe, 1995; Macpherson, personal communication), and the bathymetric occurrence of referred individuals revealed to be restricted to cold, or bathyal to abyssal zone through recent large-scaled operation of deep-sea fishing and scientific investigation. Moreover, their occurrence has been recognized not only on the continental slopes or at the top of seamounts but also around the cold seeps or hydrothermally active regions (Macpherson, 1988a-c, 1994; Kimura *et al*., 1989; Kim and Ohta, 1991; Hashimoto *et al*., 1990; Ohta, 1990; Takeda and Hashimoto, 1990; Desbruyères *et al*., 1994; Hashimoto *et al*., 1995). However, ecological characteristics of them had been poorly known (Watabe, 1995), and biogeography of the genus has been scarcely discussed due to the limitation of the results from scattered study areas.

For the main materials, the lithodid species, *Paralomis multispina* (Benedict, 1894), is selected to deal with the planning presented in previous I-2. The species had been so far known from off San Diego to the Kii Channel, between 550 and 1603 m deep, and represented by the relatively larger individuals in the genus (Sakai, 1971, 1976; Ohta, 1983; Sakai, K., 1987). Moreover, the occurrence of referred individual had been frequently recognized in the cold seep area off Hatsushima around 1000 m deep, western part of Sagami Nada, central Japan (Ohta, 1990). These characteristics can represent the relevant species as the best representative among 10 Japanese species in the genus.

2. *Briarosaccus callosus* Boschma, 1930 and suborder Kentrogonida Delage, 1884

As for the symbiotic interrelationship around the genus *Paralomis*, *Briarosaccus callosus* Boschma, 1930 (Peltogastridae: Kentrogonida: Rhizocephala) should be closely introduced, with special reference to its taxonomic status in the suborder Kentrogonida Delage, 1884 (Rhizocephala: Cirripedia). The suborder name had been known as the name categorizing the unusual cirriped individual that possesses (a) interna, amorphous cluster of cells in the body of host decapod individual, and (b) externa, that can be usually recognized in the position where the host embryos usually occupy. It can be further subdivided into three closely related families, namely, Sacculinidae Lilljeborg, 1860, Peltogastridae Lilljeborg, 1860, and Lernaeodiscidae Boschma, 1928 (Høeg and Rybakov, 1992). The kentrogonid individuals referred to *B. callosus* are considered as a typical form in the diverse Kentrogonida, and had been (1) known to select diverse lithodid individuals as exclusive host (Watabe, 1995), and (2) expected to construct unitary externa from a female individual quite apart from other congeners in Peltogastridae, that had been highly expected to carry multiple budding of externa from single female individual (Lützen, personal communication). The suborder had been also known as the notorious set of “parasitic” individuals on diverse decapods. However, many misleading interpretations seem to be widely distributed in biology, even in the taxonomy and ecological survey of the relevant suborder (for examples, see Dawkins, 1994 and Høeg, 1995).

Especially, the “evolutionary elucidation” concerning the focused suborder had been intensively discussed and reviewed by Høeg (1992), (1995), and Høeg and Lützen (1995). However, in the present study, all the evolutionary discussion will be excluded based on the conceptual division provided by Mayr and Ashlock (1991).

The characteristics common to all the species referred to Kentrogonida can be summarized as follows (Høeg and Rybakov, 1992), with special respect to the life cycle (the diagrammatic representation of it was shown in Fig. I-1).

(1) female kentrogon and male trichogon instars present during ontogeny
(2) male individuals introduced into female individuals later forming complete externa on host individuals through mantle aperture developing early in ontogeny
(3) externa with paired and cuticle-lined, male receptacles, and mesenteric canal always absent

Actually, taxonomic system of remaining

rhizocephalans, that categorizes them into the other suborder Akentrogonida Häfele, 1911, had intensively been described and studied (Høeg and Rybakov, 1992). However, its conclusion seems to consist of a provisional set under the name of Akentrogonida. The heterogeneity in Akentrogonida needs further study to construct robust taxonomic system, compared with higher homogeneity in Kentrogonida.

In close relation to their unusual life cycle, the interrelationship and interaction (see also Chapter IX) between kentrogonids and decapod hosts exhibit interesting implication for various divisions in biology (Rasmussen, 1959; Phillips and Cannon, 1978; Bishop and Cannon, 1979; Charniaux-Cotton and Payen, 1985). The kentrogonid individuals referred to *B. callosus* had been known as the largest in diverse rhizocephalan barnacles. Moreover, several ecological characteristics, namely, diverse host selection and unique interaction with host individuals were reported and discussed (Watabe, 1995). However, fundamental observations concerning their biological characteristics like prevalence on host individuals, host modification and immunological response, and morphological characteristics of adults and larvae, have been investigated but not in detail (Boschma, 1930, 1962; McMullen & Yoshihara, 1970; Sloan, 1984, 1985; Lützen, 1985; Hawkes *et al*., 1986; Shirley *et al*., 1986; Sparks and Morado, 1986). In any way, further investigation in field, and experiment and analysis in laboratory are highly expected.

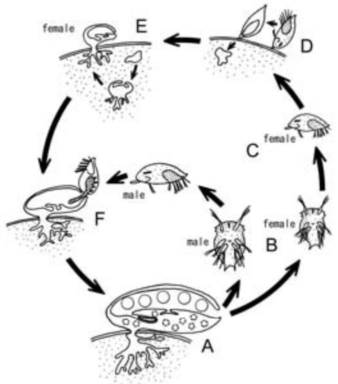

Fig. I-1. Schematic diagram of life cycle of kentrogonids. A. Externa attached to the surface of host abdomen. B. Nauplii larvae, different size in each sexual individual. C. Metamorphosis to cyprid larvae. D. Attachment to host and metamorphosis to kentrogon of female larvae, and successive invasion to host individuals. E. Eruption of virgin externa, usually at the surface of host abdomen. F. Attachment to virgin externa, metamorphosis to trichogon, and mating with male cyprid larvae (after Høeg , 1995).

II. STUDY AREA AND SAMPLING

II-1. STUDY AREA

For the initial access to the animal taxonomy and ecological investigation, the actual catch of relevant individuals must be prepared. Main survey was concentrated to the Tokyo Submarine Canyon, central Japan (see also Chapter I), but additional sampling in other regions was necessary for present study (see also Chapters V and VI).

The study area is roughly divided into following three parts, namely, (a) scientific cruise of R/V *Tansei Maru*, JAMSTEC/ORI (Suruga Bay, Enshu Nada, central Japan, and near Amami-Ohshima Island, southwestern Japan, chiefly concerning Chapter III), (b) the daily catch of commercial pot fishing in the Tokyo Submarine Canyon and neighboring Sagami

Nada, central Japan (concerning Chapters V, VI, VIII, and IX), and (c) intensive diving of the DSRV *Shinkai 2000*, JAMSTEC, on the Minami-Ensei Knoll, southwestern Japan (concerning Chapter VII).

The following abbreviations are herein introduced: JAMSTEC; Japan Agency for Marine-Earth Science and Technology, Japan: ORI; the Ocean Research Institute, University of Tokyo.

1. Research cruises of R/V *Tansei Maru*, JAMSTEC/ORI

The samplings were scattered to central to southern Japan, and thus, close description of them can be concluded to possess less importance. Here show briefly the sampling station again, namely, the bathyal zone in Suruga Bay and Enshu Nada, and near Amami-Ohshima Island.

2. Tokyo Submarine Canyon

The decapod fauna recognized in the Tokyo Submarine Canyon and the neighboring Sagami Nada had been incessantly studied from the end of 19th century, from the initial access by the German carcinologists like H. Balss, F. Doflein, and A. Ortmann. However, in spite of the faunal check lists like Sakai (1965) and Ikeda (1981, 1991, and 1998), systematic sampling in rigorous study program had not been carried out so far. Thus, present study is the largest and well-programmed one, and is the first application of them.

The submarine topography of the Tokyo Submarine Canyon was shown in Fig. II-1. The Tokyo Submarine Canyon is located in the southeastern coast of Honshu, the Japanese main island. It is enclosed by two peninsulas, namely, Miura Peninsula on the western side and Boso Peninsula on the eastern side, and connected with eastern border of Sagami Nada. It cuts deeply into the shelf, and starts from the eastern rim of the trough floor of Sagami Nada south off Miura Peninsula (approximately 1000 m deep). It goes around the southeastern tip of the peninsula, then comes into the strait between Miura and Boso Peninsulas. Detailed topographic description had been provided elsewhere (for example, Horikoshi, 1962).

For the introduction of particular analyses in Chapters V and VI, topographic characteristics of each subarea established there are introduced (Fig. II-2). In the northern part, namely, the subarea KN, muddy bottom is frequently observed, and topographic pattern exhibits rather moderate one. However, the middle to the southern part, the subarea MZ, constantly represents complicated topographic features with 4 main spurs and hard substratum with frequent occurrence of rocky bottom with corals. Strong bottom current there could be inferred from frequent entangling and torn-off of pot or pot system itself. The southwestern part, the subarea NY, rather sandy bottom with dead shells for the bathyal environment can be constantly observed.

For closer description of topographic characteristics of the study area in Chapter VIII, the submarine topography at the southeast off Tsurugi Zaki (530 - 740 m deep), just the turning point of the Tokyo Submarine Canyon where it cuts into the strait northward, is shown in Fig. II-3. Its submarine topography is very rugged, and is clearly divided into two parts, namely, spur (shallower than ca. 700 m) and trough floor (deeper than ca. 700 m). On the spur, the inclination between the depths between 530 and 600 m is relatively moderate (80/1000 on average), and very steep below 620 m (400/1000 - 700/1000).

The trough floor can be monitored as fairly flat. The bottom feature on the shallower spur is mostly bare rock with scarce silty sediment, whereas mud and silt is blanketed with the deeper trough floor. Moreover, both the bottom and surface current there were so strong between June and October that pot operation itself could not be carried out. Besides the rugged topography there, busy ship traffic makes sampling to be almost impossible there.

Hydrographic characteristics of the study area are represented by the CTD observations during the research cruise of the R/V *Tansei Maru*, (KT-94-07, St. wt-05 (35º 01.77' N, 139º 39.39' E, bottom depth was 1000 m, 20 May, 1994) (Fig. II-4). All the parameters seem to be gradual with increase of depth, but salinity could be almost constant.

3. Minami-Ensei Knoll

For the Minami-Ensei Knoll, I can indicate the apparent difference from the Tokyo Submarine Canyon. Active hydrothermalism was found and intensively surveyed by the manned-submersible (Hashimoto *et al*., 1995). Unfortunately, additional survey turned out to be almost impossible due to large amount of surrendered fishing net (Hashimoto, personal communication).

In the present study, the lithodid fauna in the C-depression of the Minami-Ensei Knoll was analyzed and discussed due to the absence and scarceness of lithodid individuals in other depressions like A (inactive phase) and B (with less activity indicated by small assemblages of vestimentiferan pogonophores with some decapods) (Ohta and Kim, 1992; Hashimoto *et al*., 1995).

As the most active hydrothermalism was found in the southeastern half of the C-depression, topographic description was restricted there (Fig. III-5). The study area is almost oval in outline, 500 × 300 m in diameter, and surrounded by a steep escarpment approximately 100 m high with talus. The floor is approximately 690 - 720 m and rather flat, but interrupted by (1) a small spur at the western flank, where many chimneys with high activity gushing out superheated waters, and (2) a row of large chimneys longitudinally cutting the central floor. Near the active chimneys, the substratum is consistently rocky, but coarse sandy bottom dominates far from them. High abundance of mytilid mussels could be found in the former, whereas it was substituted by medium-sized sponges and anemones in the latter. The direct effect of hydrothermalism could be easily inferred by the topographic situation of chimney and the confirmation of CO_2 bubbling region (Fig. II-5).

Unusual but vent-specific characteristics of seawater could be observed in temperature anomaly, high concentration of metals and CO_2 (often recognized as gas hydrate), low pH (< pH 5) (Chiba *et al*., 1992; Nedachi *et al*., 1992; Hashimoto *et al*., 1995), and high concentration of H_2S. Bottom current could be considered to be rather strong from the observation of sediment type (Hashimoto & Ohta, personal communication).

II-2. SAMPLING

1. Research cruises of R/V *Tansei Maru*, JAMSTEC/ORI

During three research cruises KT-93-09 (near Amami-Ohshima Island, southwestern Japan), KT-94-07 (off Daio Saki, central Japan), and KT-95-17 (Enshu Nada, central Japan), of R/V *Tansei Maru*, ORI, several nephropids and lithodids referred to the genus *Nephropsis* Wood-Mason, 1873 and *Paralomis* White, 1856, respectively, could be collected. The sampling results and gears are summarized as follows.

i. KT-93-09

St. AM-01, 28º 33.84' N, 129º 08.34' E - 28º 32.87' N, 129º 07.26' E, 946 - 957 m deep, fine sand and mud, with pumice, 3 m ORE Beam Trawl, 20 Jun. 1993.

ii. KT-94-07

St. KN-25, 34º 05.12' N, 136º 51.24' E - 34º 05.05' N, 136º 50.50' E, 475 - 494 m deep, rock, 3 m ORE beam Trawl, 25 May, 1994.

iii. KT-95-17

St. EN-01(3), 34º 22.87' N, 138º 00.01' E - 34º 24.01' N, 138º 00.01' E, 457 - 489 m deep, fine sand and mud, 3 m ORE Beam Trawl, 10 Dec. 1995.

The sampling information concerning ORI collection should be provided concerning Chapter IV. The materials, collected during the following research cruises in Suruga Bay, will be used in Chapter IV.

iv. Cruises in Suruga Bay, central Japan

iv-1. KT-78-18

St. OT-10, 34º 53.9' N, 138º 43.1' E - 34º 55.6' N, 138º 43.6' E, 382 - 425 m deep, fine sand and mud, 15-foot Otter Trawl, 20 Nov. 1978.

St. OT-11, 34º 54.3' N, 138º 42.8' E - 34º 54.8' N, 138º 42.9' E, 520 - 545 m deep, fine sand and mud, 15-foot Otter Trawl, 23 Nov. 1978.

St. OT-12, 34º 55.0' N, 138º 42.7' E - 34º 53.2' N, 138º 42.6' E, 516 - 630 m deep, fine sand and mud, 15-foot Otter Trawl, 23 Nov. 1978.

iv-2. KT-89-06

St. SB27, 34º 41.23' N, 138º 22.14' E - 34º 41.86' N, 138º 21.76' E, 444 - 468 m deep, fine sand and mud, 2 m S. -A. Beam Trawl, 18 May 1989.

2. Commercial pot fishing in the Tokyo Submarine Canyon and neighboring Sagami Nada

For the sampling gear, (1) adequate choice and (2) sufficient amount of catch should be assured. For the case of the Tokyo Submarine Canyon and neighboring Sagami Nada, both requirements was fulfilled by intensive activity of commercial pot fishing boats throughout the year. On sampling saprophagous decapods there, 4 fishing boats afforded all of the samples joining myself to their ordinary fishing operation. Main sampling period in the Tokyo Submarine Canyon was from February 1992 to May 1997 throughout the year. Five additional results on the eastern slopes (1985-86) carried out before the period were included in the sampling results of Chapter V.

Total 832 stations of sampling by pot systems were carried out during above mentioned sampling period, in the depth zone between 140 and 740 m (Fig. III-6). Sometimes and somewhere, sampling was rather difficult due to the heavy ship traffic, and strong surface and bottom currents were suggested. The essential characteristics of used gear are introduced below.

Through the daily fishing activity aiming at nephropid species, *Metanephrops japonica* (Tapparone-Canefri, 1873) and *M. sagamiensis* (Parisi, 1917) (Nephropidae: Caridea), famous brachyuran species, *Macrocheira kaempferi* (Temminck, 1836), and several lithodid species, mainly *Lithodes aequispina* Benedict, 1894 and *Paralomis multispina* (Benedict, 1894) (Lithodidae: Anomura), of commercial pot fishing boat belonging to Nagai and Odawara ports, Kanagawa Prefecture, central Japan, the intensive survey there can be easily carried out.

For the fishing of nephropid lobsters, the fishermen exclusively use lobster pot. It is a truncated cone-shaped pot, equipped with an entry of 15 cm diameter on the top, 0.7 m top diameter × 1.0 m base diameter measuring 30 cm high, netted with 1 cm synthetic webbing. As for the other large-sized crabs, they used exclusively another type, a crab pot. It is also a truncated cone-shaped pot, equipped with an entry of 50 cm diameter on the top, 0.8 m top diameter × 1.6 m base diameter, measuring 0.8 m high, covered with 7.5 cm knotted webbing. For both of them, low-priced fish, generally frozen sardine or head of large fish, is usually adopted as attracting bait. In the case of the former, a set of 110 - 150 lobster pots at 10 - 12 m intervals on a groundline is defined as a unit of lobster pot system, and 9 - 52 crab pots at 20 - 50 m intervals on a groundline was also defined as a unit of crab pot system. Detailed description concerning the latter had been reported in Tanino and Kato (1971).

The position of each fishing station was fixed by the aid of three Loran C receivers (LC-300, Furuno, Japan, and two equivalents) and two GPS navigators (Koden, Japan), and represented by that of the first pot. The depth of each station was represented by the mean depth of used pot system, and determined on the monitors of echo sounders (Furuno, and three equivalents provided by other companies). When the depth difference between the shallowest and deepest record exceeded 100 m, I excluded the sampling results from the data set. The depth of pot system was monitored at both deployment and hauling, the mean depth was calculated on the monitor at hauling. The soak time of pot system was basically fixed as 7 days, but sufficient catch could be recognized within 3 days. Thus, here determined the valid catch of saprophagous decapod individuals could be gained by 3-day soak time.

Total 382 of samplings in the upper bathyal zone (150 - 750 m deep) of Sagami Nada were carried out in the same sampling period. Among them, only the sampling results concerning *P. multispina* were adopted in the present study (Chapter VIII).

3. Dives of DSRV *Shinkai 2000* on the Minami-Ensei Knoll

As for the Minami-Ensei Knoll, the video records and several collected specimens of the total 15 dives of a manned-submersible, the DSRV *Shinkai 2000* (#428, 538, 542, 547, 548, 549, 575, 610, 611, 612, 615, 616, 617, 618, and 622) are examined. Close description is provided as follows. All the dives of the DSRV *Shinkai 2000* were intermittently (mainly summer and autumn) carried out from August 1988 to October 1992.

Due to the use of submersible equipped only with a manipulator, actual catch of lithodids with high mobility was difficult, and I relied mainly on the video record of each dive in the present study. However, the use of simple baited trap and pot (Hashimoto & Ohta, personal communication), and a slurp gun system (Hashimoto *et al*., 1992), should be noted. By the aid of them, direct comparison with other specimens of lithodid individual could be realized (Chapter VII). The track charts of dives were compiled in Fig. II-7.

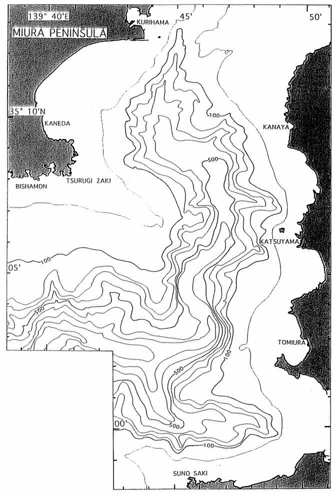

Fig. II-1. Submarine topography of the Tokyo Submarine Canyon. Modified from Japan Maritime Safety Agency (1973).

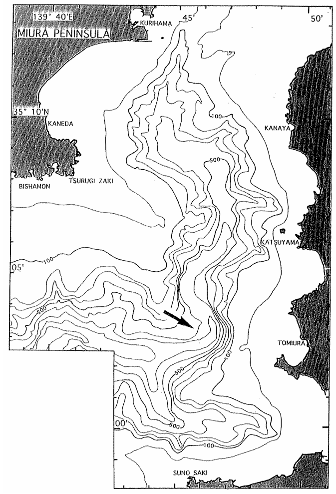

Fig. II-3. Submarine topography of the Tokyo Submarine Canyon. Arrow indicates the study area in Chapter VII concerning the selective elimination was carried out.

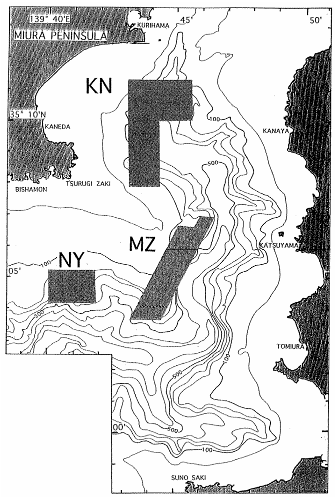

Fig. II-2. Submarine topography of the Tokyo Submarine Canyon. Each subarea, KN, MZ, and NY, was shown by the shaded region.

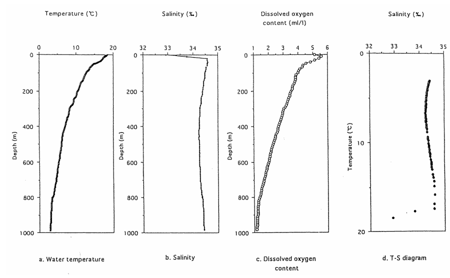

Fig. II-4. Vertical profiles of hydrographic observations, T-S diagram in the Tokyo Submarine Canyon. A. Water temperature. B. Salinity. C. Dissolved oxygen content. D. T-S diagram. The profiles are based on the CTD observation south off Tsurugi Zaki on May 20, 1994 (KT-94-07, St. wt-05 (35º 01.77’N, 139º 39.39’E, 1000 m deep)).

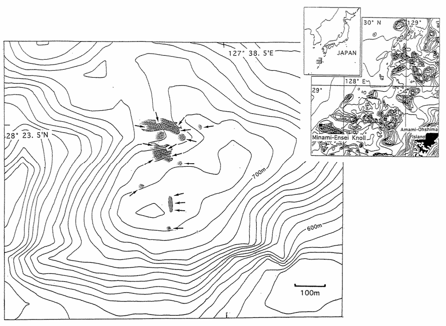

Fig. II-5. Submarine topography of the C-depression on the Minami-Ensei Knoll. Topographic map obtained by SeaBeam was shown. The hydrothermally active region was expressed by CO_2 bubbling (shaded) and the position of major chimneys (indicated by arrows).

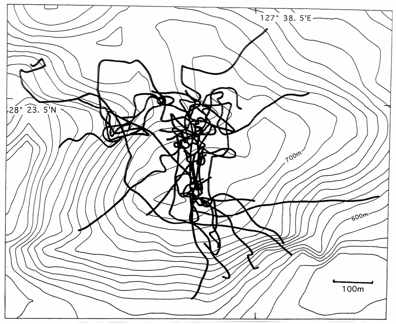

Fig. II-7. Track chart of the DSRV *Shinkai 2000* in the C-depression on the Minami-Ensei Knoll. Total 15 dive tracks were indicated by the thick lines on the topographic map.

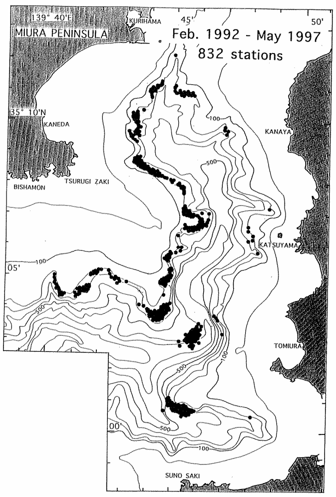

Fig. II-6. Sampling results in the bathyal zone of the Tokyo Submarine Canyon. Solid circle indicates one sampling result by crab- or lobster- pot system.

III. *NEPHROPSIS* WOOD-MASON, 1873 (NEPHROPIDAE: DECAPODA) CHIEFLY AROUND JAPAN

III-1. ABSTRACT

Taxonomic revision concerning the genus *Nephropsis* Wood-Mason, 1873 (Nephropidae: Decapoda), based on the materials chiefly from the bathyal zone in Japanese waters, was provided. Main conclusions were summarized as follows: (1) Total species referred to the genus around Japan were inferred as following 5 spp., namely, *N. acanthura* Macpherson, 1990, *N. hamadai* Watabe and Ikeda, 1994, *N. holthuisi* Macpherson, 1993, *N. stewarti* Wood-Mason, 1873, and *N. sulcata* Macpherson, 1990. The technical problems concerning traditional microtaxonomy are summarized as follows: (1) Objective division of specimen set with one ruled standard; (2) precise understanding of macrotaxonomic interrelationship among species in one genus; (3) understanding of the difference between animal taxonomy and set theory, which is the most fundamental basis of mathematics.

III-2. INTRODUCTION

For the recent few decades, the genus *Nephropsis* Wood-Mason, 1873 (Nephropidae: Decapoda) had been intensively studied by several taxonomists (Holthuis, 1974, 1991, 1995; Macpherson, 1990b, 1993; Watabe and Ikeda, 1994; Griffin and Stoddart, 1995; Chan, 1997). In spite of complete taxonomic definition on generic order provided by Holthuis (1974) and intensive elections of new species and taxonomic revision on species order (Macpherson, 1990b, 1993), several taxonomic problems on species order are still recognized (Chan, 1997; Chan, personal communication). Especially on the species recorded from Japanese waters, only the provisional work in Watabe and Ikeda (1994) and Watabe and Iizuka (1999) can be recognized so far.

Here summarize the major points of so far unfixed problems as follows.

(1) re-confirmation of taxonomic status of *N. hamadai* Watabe and Ikeda, 1994 (Chan, 1997), and *N. sulcata* Macpherson, 1993

(2) whole species check list of Japanese *Nephropsis* species

As for the taxonomic inference of dioecious individuals like the nephropid lobster, Mayr and Ashlock (1991) provides the complete version of methodological and conceptual framework, that is apparently characterized by the concept, "biological species." Thus, our concrete effort is theoretically concentrated to the proper selection of taxonomic signifier (*sensu* Mayr and Ashlock, 1991) designated in the concrete taxonomic papers, and the confirmation of logical validity and the strength of taxonomic inference. On considering the most basic and fundamental status in the ecological survey of the methodology in taxonomic inference, valid utilization and understanding of it must be provided according to the original suggestion by Mayr himself.

In this Chapter, I would like to deal with both of issues above mentioned, namely, concrete labors in taxonomic inference, and the confirmation of methodological importance of taxonomic inference itself.

III-3. MATERIALS & METHODS

Examined individuals were basically collected by the author or partially provided from following institutions and sources. Close sampling information had been already provided in Chapter II partially (Amami Basin AB; KT-93-09 Cruise of R/V *Tansei Maru*, JAMSTEC/ORI: Tosa Bay TB; National Research Institute of Fisheries Science, Fisheries Research Agency NRIFS collection through the courtesy of H. Sakaji, by R/V *Kotaka Maru*: Enshu Nada EN; KT-95-17 Cruise of R/V *Tansei Maru*: Suruga Bay SB; Iizuka collection based on the catch of commercial trawlers around Numazu, and the several specimens belonging to ORI collection: Sagami Nada SN; comparative sampling of present study, and Ikeda collection. Moreover, both the types of *Nephropsis holthuisi* in the Northern Territory Museum NTM, Australia, and the specimen referred to the species in Griffin and Stoddart (1995) in the Australian Museum AM were also examined. Comparative materials in the collection of the Muséum National d'Histoire Naturelle, Paris MNHN, France, and the National Taiwan Ocean University NTOU, Republic of China, were available through the courtesy of T. -Y. Chan.

Used terminology and the selection of signifier (*sensu* Mayr and Ashlock, 1991) followed Holthuis (1991) in this chapter, and minor modifications were properly added. The strategy and conceptual background of taxonomic inference exclusively followed Mayr and Ashlock (1991) to exclude the conceptual confusion around the terms, "species taxon" and "species category." The measurements refer to carapace length excluding rostral one CL.

III-4. TAXONOMY

Nephropsis Wood-Mason, 1873

Nephropsis Wood-Mason, 1873: 60. -Holthuis, 1974: 772. Macpherson, 1990b: 301. -Chan and Yu, 1993: 64. Type species by monotypy: *Nephropsis stewarti* Wood-Mason, 1873: 60. Gender: feminine.

Nephropsis acanthura Macpherson, 1990

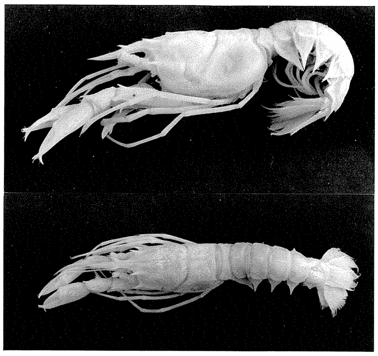

Fig. III-1

Nephropsis acanthura Macpherson, 1990b: 302 (key), 311, figs. 5d, 9d-f, 11a, b, 16d. -Holthuis, 1991: 32 (key), 35, fig. 61. -Macpherson, 1993: 55, 64 (key). -Griffin and Stoddart, 1995: 234. -Chan, 1997: 413.

Nephropsis sp. -Toriyama, Horikawa, and Kishida, 1990: 20, Plate 5b.

Materials examined. -TB: 1 ♂ (16.6 mm) 1 non-ovig. ♀ (18.8 mm).

AB: 1 ♂ (11.8 mm) 4 non-ovig. ♀ (7.9 - 16.0 mm), KT-93-09, St. AM-01.

Distribution. Previously known from Indo-West Pacific widely, Madagascar, Philippines, Indonesia, southern Japan, northwestern and eastern Australia, Tasman Sea, Coral Sea, Chesterfield Islands, and New Caledonia, 720 - 1305 m deep. Present taxonomic results provide confirmation of the northern extremity of this species to southern Japan.

Nephropsis hamadai Watabe and Ikeda, 1994

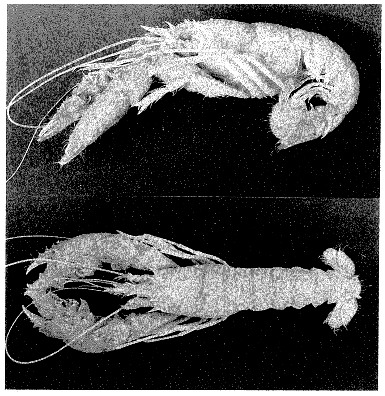

Fig. III-2

Nephropsis hamadai Watabe and Ikeda, 1994: 102, figs. 1a-b, 2a-e.

Materials examined. -SN: Holotype, 1 ♂ (50.1 mm), NSMT-Cr 11216, paratype 1 non-ovig. ♀ (44.9 mm), NSMT-Cr 11217, the top of Misaki Knoll, eastern part of Sagami Nada, 35° 03' N, 139° 29' E, 420 - 500 m, muddy fine sand, lobster pot, 28 May 1992, coll. by the author.

EN: 1 non-ovig. ♀ (24.2 mm), KT-95-17, St. EN-01(3).

TB: 5 ♂♂ (14.8 - 23.8 mm) 2 non-ovig. ♀♀ (21.3 - 23.8 mm) 1 ovig. ♀ (25.3 mm), south off Kouchi, 650 m deep, 2 Sept. 1987, trawl; 1 ♂ (21.8mm), same locality and collector, 600 m deep, 24 Mar. 1989.

Remarks. The individuals referred to *Nephropsis hamadai* are morphologically close to those referred to *N. serrata* Macpherson, 1990 from the Australian water. Actually, (1) the invalidity of the originally constructed character set of the former on discriminating from the latter, especially the shape of coxa of third pereopod, and (2) the successive suggestion to synonymize the former into the latter had been proposed (Chan, 1997; Chan, personal communication). However, following differences between their character sets, extracted through the direct comparison of those referred to the latter (3 ♂♂ (44.1 - 47.2 mm) 5 non-ovig. ♀♀ (43.3 - 51.7 mm) in the NTOU collection), may discriminate clearly the former from the latter: (1) Larger and more robust first pereopod in *N. hamadai* than in the latter: (2) Morphological difference concerning the palm of first pereopod; strongly compressed dorsoventrally, especially in male individual, and only armed with several tufts of setae in *N. hamadai*, whereas subcylindrical in both sexual ones and tomentous with long soft setae through entire length in *N. serrata*: (3) More setose dorsal rostral carina by smaller spines in *N. hamadai* than in *N. serrata*, namely, 1 - 6 (usually 3) pairs in the former, whereas 1 - 3 (usually 2) in *N. serrata*: (4) Spinulation of subdorsal carina, never possessing the spines in *N. hamadai* but sometimes bearing large spines in *N. serrata*.

Distribution. Known only from central to southern Japan, from Sagami Nada to Tosa Bay, 400 - 650 m deep.

Nephropsis holthuisi **Macpherson, 1993**

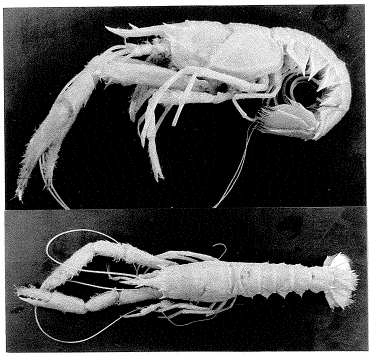

Fig. III-3

Nephropsis holthuisi Macpherson, 1993: 55, figs. 1-3 (but not fig 3B), 6B (erroneously as *N. serrata* Macpherson 1990). -Chan, 1997: 414.

not *Nephropsis holthuisi*: Griffin and Stoddart, 1995: 234.

Materials examined. -Northeastern Australia: Holotype, 1 ♂ (47.3 mm), NTM Cr007044, Indian Ocean, west off Ashmore Reef, St. S9, 13° 06' S, 122° 18' E, 900 - 1000 m deep, coll. by B. Wallner, 25 Jan. 1988.

SB: Iizuka Collection; 1 ♂ (50.4 mm) 1 non-ovig. ♀ (50.6 mm), NSMT-Cr 12181, off Heda, 350 m deep, muddy sand with broken shell, commercial trawl, 25 Feb. 1993: ORI collection; 1 ♂ (34.1 mm) 1 non-ovig. ♀ (49.3 mm), KT-78-18, St. OT-10; 1 ♂ (44.8 mm), KT-78-18, St. OT-11; 1 non-ovig. ♀ (53.0 mm), KT-78-18, St. OT-12; 1 ♂ (48.7 mm), KT-89-06, St. SB27.

Kai Islands, Indonesia: 1 ♂ (22.2 mm), MNHN, KARUBAR, St. CP-38, 07° 40' S, 132° 27' E, 620 - 666 m deep, 28 Oct. 1991.

Remarks. *Nephropsis holthuisi* had been originally described based on a pair of specimens from the bathyal zone in Australian waters, and has so far also known from off Indonesia (Macpherson, 1993; Griffin and Stoddart, 1995;

Chan, 1997). For its taxonomic status in the genus, Chan (1997) strongly pointed out several requirements, especially concerning (1) the acquisition of the firmer discriminating characteristics from the Atlantic nearest, *N. rosea* Bate, 1888, and (2) the enrichment of the examined materials from the other regions. Moreover, some morphological differences among the Australian materials, even in the type materials, were recognized (Griffin and Stoddart, 1995; Stoddart, personal communication). Thus, taxonomic re-examination concerning the relevant species taxon based on another material set should be strongly carried out, including the firm definition of the valid types.

N. holthuisi can be categorized into the taxonomic group in the genus, which is characterized by the combination of (1) a pair of lateral spines on the rostrum, (2) absence of spines on the anterior borders of the abdominal pleurae, (3) presence of diaeresis on the uropodal exopod, and (4) presence of the median carina on the abdomen (Macpherson, 1990b). The group also contains *N. rosea*, and another Australian species, *N. macphersoni*, successively described as new species in this chapter. Here present only the discriminating characteristics of the former from the latter.

Besides the discriminating characteristics provided by the original description and Chan (1997), following new characteristics can be recognized through the direct comparison between above mentioned material and the specimens referable to *N. rosea* (5 ♂♂ 5 non-ovig. ♀♀ 1 ovig. ♀, NSMT-Cr 8876, off Surinam). They can be also confirmed commonly in the comparison with the other lots of materials from central Japan (1 ♂ from Sagami Bay, neighboring to Suruga Bay, in Ikeda collection, and 28 ♂♂ 14 non-ovig. ♀♀ from Suruga Bay, in Iizuka collection): (1) Palm of first pereopod slightly compressed dorsoventrally in *N. rosea* (2.94 - 3.31 and 3.07 - 3.36 as long as high in male individuals and female ones, respectively), whereas slender and subcylindrical in *N. holthuisi* (more than 3.4 times in both sexual ones); (2) a large spine on mesial margin of carpus of first pereopod often accompanied by 1 - 3 accessory spines in *N. rosea*, but bearing no spine and granule in *N. holthuisi*; (3) in male individuals, broad plate on coxa of third pereopod usually ending in 3 spines in *N. rosea*, whereas ending in 3 - 5, most frequently 4, spines in *N. holthuisi*.

Balss (1914) reported the single nephropid specimen from Yodomi, the fishing ground situated at the eastern part of Sagami Bay (Balss, 1924), in the collection of Tokyo Museum (the predecessor of NSMT), under the name of *N. carpenteri* Wood-Mason, 1885. However, his identification can be never confirmed due to the loss of relevant specimen (Takeda, personal communication). On carefully considering the geographic range of *N. holthuisi*, it seems to be safe to conclude that the specimen examined by Balss (1914) might be also referable to the relevant species.

Distribution. Known from off northeastern Australia (off Ashmore Reef; type locality), off Indonesia, and central Japan, 350 - 1000 m deep. Off Heda, the bathymetric range of the species seems to be concentrated to the deeper zone (350 - 500 m deep) compared with the case of *N. stewarti* (200 - 400 m deep) (Iizuka, personal communication). Present taxonomic result provides the further knowledge concerning the biogeographic range of this species northward to central Japan for the first time.

Nephropsis macphersoni **Watabe and Iizuka, 1999**

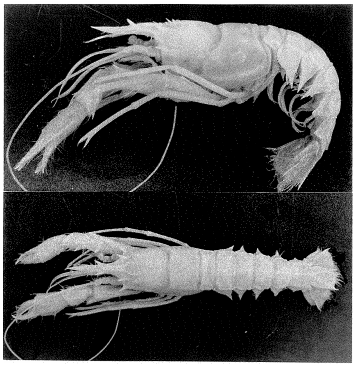

Fig. III-4

Nephropsis macphersoni Watabe and Iizuka, 1999: 376, figs. 3-4.

not *Nephropsis holthuisi*. -Macpherson, 1993: 55 figs. 1-3, 6B (concerning paratype). Griffin and Stoddart, 1995: 234 (=*N. macphersoni*).

Materials examined. Holotype, 1 ♂ (32.6 mm), AM P44029, east of Terrigal, 33° 33' S, 152° 10' E, 1080 - 1135 m deep, trawl, 31 August 1988, FV Kapala, St. K88-17-04. Paratype, 1 ovig. ♀ (40.4 mm), NTM Cr007043, west of Ashmore Reef, WA, 13° 06' S, 122° 18' E, 900 - 1000 m deep, coll. by B. Wallner, 25 Jan. 1988.

Remarks. *Nephropsis macphersoni* can be characterized by belonging to the taxonomic group containing the nearest, *N. holthuisi*. However, following morphological characteristics may clearly differentiate the former from the latter: (1) Subdorsal carina spinose and well developed in *N. macphersoni*, whereas simply granulose and faint in *N. holthuisi*; (2) merus and carpus of second pereopod less pubescent in *N. macphersoni* than in *N. holthuisi*; (3) armature on the anterior margin of second tergite with stronger granulation in *N. macphersoni* than in *N. holthuisi*; (4) first pereopod more robust in *N. macphersoni* than in *N. holthuisi*.

Etymology. The species name is dedicated to E. Macpherson, who established the latest taxonomic system concerning the genus from its initial foundation by L. B. Holthuis.

Distribution. Known only from northern Australian water, 900 - 1135 m deep.

Nephropsis stewarti **Wood-Mason, 1873**

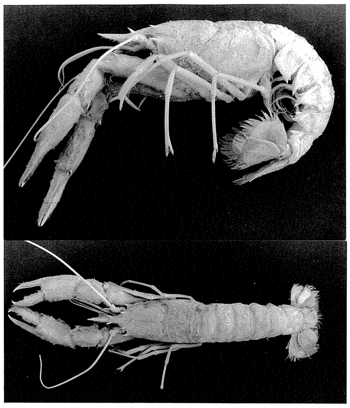

Fig. III-5

Nephropsis Stewarti Wood-Mason, 1873: 60. -Alcock, 1901: 158 (key), 159. - Alcock and Anderson, 1896: pl. 27, fig. 1a; 1899: 286. Anderson, 1896: 96. -Balss, 1925: 208.

Nephropsis stewarti. Alcock, 1902: 148 (not seen). -Miyake, 1982: 77, pl. 26, fig. 1. -Baba, *in* Baba, Hayashi, & Toriyama, 1986: 153, 281, fig. 103. -Macpherson, 1990b: 312, figs. 5e, 10, 11 c-d, and 164; 1993: 63, 65 (key), figs. 7 - 8. -Chan, 1997: 415.

Materials examined. SB: Iizuka collection; 48 ♂♂ (45.9 - 77.5 mm) 26 non-ovig. ♀♀ (47.1 - 71.7 mm), off Heda, 350 - 400 m deep, sandy mud, commercial trawl, between Sept. 1996 to May 1997.

Remarks. Recently, Macpherson (1993) and Chan (1997) had suggested the further division of individual set previously referred to *Nephropsis stewarti*, and the possibility of the election of another species. In fact, specimens from the Philippines seem to represent a different species (Watabe, unpublished data). However, here provisionally use the taxonomic definition of relevant morphological phenon constructed before them due to the scarceness of comparative materials.

Distribution. According to Macpherson (1990b) and additional record by his successive paper in 1993, known from Madagascar, Natal, Mozambique, Kenya, the Gulf of Aden, Andaman Sea, Bengal Bay, Indonesia, western Australia, the Philippines, and Japan, 170 - 1060 m deep. As summarized above, this might become narrower according to the successive taxonomic division (see also Chan, 1997).

***Nephropsis sulcata* Macpherson, 1990**

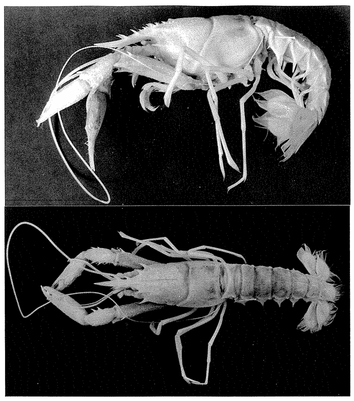

Fig. III-6

Nephropsis sulcata Macpherson, 1990b: 302 (key), 311, figs. 5d, 9d-f, 11a, b, 16d. -Holthuis, 1991: 32 (key), 35, fig. 61. -Macpherson, 1993: 55, 64 (key). -Griffin and Stoddart, 1995: 234. -Chan, 1997: 415.

not *Nephropsis atlantica*. -Wood-Mason and Alcock, 1891: 197, fig. 4. -Alcock, 1894a: 230. -Alcock and Anderson, 1894: 162. -Anderson, 1896: 96. -Alcock, 1901: 158 (key), 161. -Kensley, 1981: 29.

Materials examined. AB: 2 ♂♂ (16.4 - 18.8 mm) 1 non-ovig. ♀ (18.5 mm), KT-93-09, St. AM-01.

Remarks. Chan (1997) suggested some uncertainties of original description concerning *Nephropsis sulcata* in Macpherson (1990b), and provided new discriminating character set concerning referred individual from Atlantic species, *N. atlantica* Norman, 1882; (1) the relative length of carpus against palm concerning second pereopod (slightly shorter in *N. sulcata*), (2) size of sexually matured individuals (considerably smaller in *N. sulcata*), and (3) the presence of terminal spine on the posterior extremity of fifth somite mesially in *N. sulcata*. These characteristics can be also recognized in all the specimens presently examined. Moreover, lucid discrimination of individuals respectively referred to *N. sulcata* and *N. atlantica* may be readily provided to the original description additionally.

Distribution. Previously known from southern Africa (off Natal), southwestern Indian Ocean (off Madagascar), Indonesia, Laccadive Sea, South China Sea, off Chesterfield Islands, and off New Caledonia, 200 - 1115 m deep. Present taxonomic result expands our knowledge concerning the northern extremity of this species northward to the Amami Basin, southwestern Japan, for the first time.

III-5. DISCUSSION

In this Chapter, I constructed and demonstrated the latest taxonomic system concerning the genus *Nephropsis* chiefly based on the materials collected from the Japanese waters. After the presentation of its conclusive remarks, I would like to point out and confirm some technical characteristics of taxonomic inference originally founded in Mayr and Ashlock (1991).

For the concrete results of taxonomic inference in this chapter, several taxonomic problems concerning the genus suggested in previous papers had been almost solved. Main issues of it can be summarized as follows: (1) Election of distinct species, *N. macphersoni*, through fixing of taxonomic problem around *N. holthuisi*; (2) redescription and the exclusion of paratype from type series concerning *N. holthuisi* (Watabe and Iizuka, 1999); (3) high referable probability to *N. holthuisi* concerning the nephropid specimen in Balss (1914), where it was referred to *N. carpenteri* (see also Watabe and Ikeda, 1994 and Watabe and Iizuka, 1999; Holthuis, personal communication); (4) new records to the Japanese waters concerning the species, *N. sulcata*; (5) re-confirmation and some verifications on the taxonomic description concerning following three species, *N. acanthura*, *N. hamadai*, and *N. sulcata*.

All the taxonomic efforts herein provided are naturally considered to possess the orientation to gain the robust results concerning "species taxon," and must be treated as the consequence from weak taxonomic inference supported by the "biological species concept" (Mayr and Ashlock, 1991). Moreover, present taxonomic stage demonstrated concerning the pertinent genus is almost identical to the definition of robust morphological phenon. Apparently, it is concluded as the presentation of the candidates to be successively converted to the distinct species taxon, using the ecological signifiers. Due to the scarceness of the samples available to us and the problems relating to allopatry, further taxonomic inference may be difficult to be carried out concerning the pertinent genus like in the case of *Rimicaris* species complex (Watabe and Hashimoto, 2002). Thus, generic definition of *Nephropsis* itself is the strong key to identify and recognize species taxon based on such less number of specimens, and ecological and biogeographical information. In other words, meta-rule governing the specimen categorization by taxonomists should be prepared besides the usual "concrete morphological description" of species or genus.

On considering the inferring sequence of each nephropid species demonstrated in this chapter, conceptual differentiation of individual, species taxon, and species category, namely, a certain set of individual defined under the biological species concept, must be remembered. Following aspects must be commonly confirmed, and they will be indispensable cue to investigate the biological factor to maintain the population structure and interspecific interaction recognized among the relevant species taxa.

(1) The defined species category univalently represents a certain species taxon.

(2) The term, species taxon, never indicates a certain set of individuals. On the case of dioecious organisms like the nephropids and lithodids, it indicates the entire body of inter-individual interaction absolutely closed by the reproductive interaction (see also Mayr, 1994, and Mayr and Ashlock, 1991).

(3) The scientific name is univalently and finally given to a certain species taxon taxonomically on the strictest implication, never to a certain individual or idealized one. Provisional providing of it to morphological phenon may be permitted according to the gained materials and accompanying information.

(4) Taxonomic inference must be constantly provided to every examined material set, and absolutely constructive results can be always given to us taxonomically.

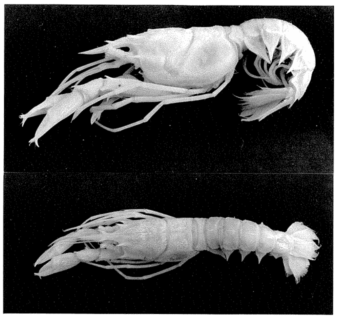

Fig. III-7. *Nephropsis acanthura* Macpherson, 1990, non-ovig. female (CL 16.0 mm) from KT-93-09, St. AM-01. Lateral and dorsal views of entire animal.

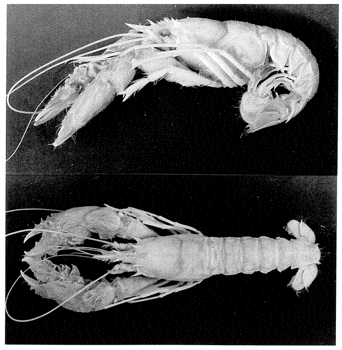

Fig. III-8. *Nephropsis hamadai* Watabe and Ikeda, 1994, male (CL 32.4 mm) from the type locality. Lateral and dorsal view of entire animal.

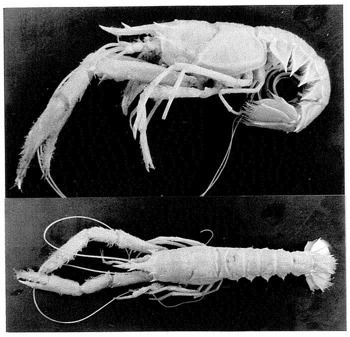

Fig. III-9. *Nephropsis holthuisi* Macpherson, 1993, male (CL 50.4 mm) from Suruga Bay, NSMT-Cr 12181, lateral and dorsal view.

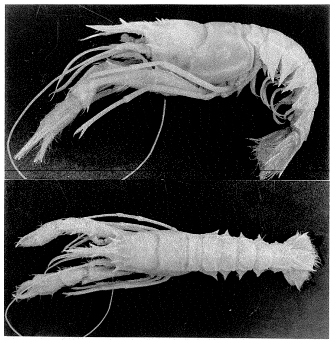

Fig. III-10. *Nephropsis macphersoni* Watabe and Iizuka, 1999, holotype (CL 32.6 mm) from east of Terrigal, AM P44209, lateral and dorsal view.

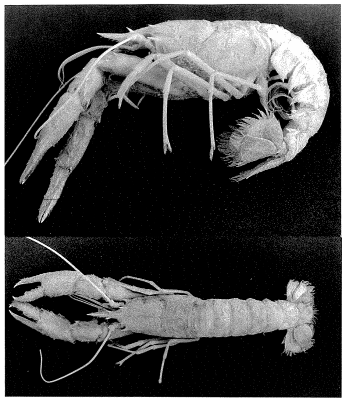

Fig. III-11. *Nephropsis stewarti* Wood-Mason, 1873, male (CL 45.3 mm) from Suruga Bay in the Iizuka collection, lateral and dorsal view.

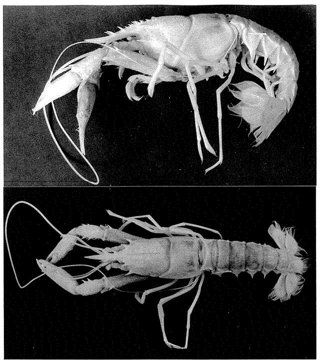

Fig. III-12. *Nephropsis sulcata* Macpherson, 1990, male (CL 18.8 mm) from KT-93-09, St. AB-01, lateral and dorsal view.

IV. MACROTAXONOMIC SYSTEM OF CRAB-SHAPED DECAPODS ON EARTH

IV-1. ABSTRACT

The macrotaxonomic system of Brachyuran crabs is presented. It consists of 15 Superfamilies together with another Suborder, Gymnopleura, that is now excluded from Brachyura. The Superfamilies are: Potamoidea (new proposal of referable lower taxa), Fossil Superfamily (tentative establishment accumulating the Families such as Prosoponidae or Dakoticancridae), Dromioidea, Archaeobrachyura, Oxystomata, Oxyrhyncha, Cancroidea, Xanthoidea (new proposal of referable lower taxa), Ucoidea (new establishment), Sakainoidea (new establishment), Pinnotheroidea (new establishment), Hapalocarcinoidea, Calvactaeoidea (new establishment), Bellioidea (elevation of taxonomic rank), and Acmaeopleuroidea (new establishment). In present taxonomic system, 15 × 15 square system is developed to accommodate whole the Brachyuran crab taxa. The taxonomic system is represented by several taxonomic categories (usually three categories of simple (primitive)-complex (advanced)-atrophied taxa), started from Σ, and then, simple (Α, 1, 2, 3), complex (4, 5, 6, Ω), atrophied ((Ε, Ο'), Ρ', 無', ＝'), and ended in ◎ (placed prior to Σ in the taxonomic dendrogram, that is showing the taxonomic similarity from Σ to ◎-taxa). Additionally, the macrotaxonomic position of the Order Decapoda and the Family Hominidae, and enigmatic taxon, "*Xenoturbella*," are also presented, to demonstrate the validity of present taxonomic strategy.

IV-2. INTRODUCTION

The macrotaxonomic system of Brachyuran crabs had been developed from the starting point of decapod taxonomy (Sakai, 1976; Chen and Sun, 2002; McLaughlin *et al*., 2007). In the earlier literature of Sakai (1976), that is constructed from the naïve morphological taxonomy and ecology, the Section Brachyura is subdivided into seven Subsections, namely, Dromiacea, Gymnopleura, Oxystomata, Oxyrhyncha, Corystidea, Brachyrhyncha, and Hapalocaricinidea. Bowman and Abele (1982) raised the Section Brachyura into the level of Infraorder, and constructed six Sections, namely, Dromiacea, Archaeobrahyura, Oxystomata, Oxyrhyncha, Cancridea, and Brachyrhyncha. These two macrotaxonomic systems seem to put strong value on morphology general of crab individual and their ecology from the "inclusive" view point. On the other hand, Guinot (1977) is quite different system, that is strictly based on the structure of genital system in Brachyuran crabs, such as the opening position of gonopore and pleopod morphology. The system strongly reflects the evolution of the relevant animals chiefly based on the Cladistics. It consists of three Sections, namely, Podotremata, Heterotremata, and Thoracotremata. Chen and Sun (2002) only pointed out these two trends on macrotaxomic system of Brachyuran crabs, and did not discussed which system is superior on discussing "crab taxonomy" on higher level than Family. However, they adopted the system of Bowman and Abele (1982). Later, Miyake (1982 and 1983) presented the higher macrotaxonomic position of Brachyura and the other crab-shaped decapods general. However, these seem scale-expansion into Decapoda general from the results of Sakai (1976) and Bowman and Abele

(1982).

The macrotaxonomic systems of Sakai (1976), and Bowman and Abele (1982), share the basic concept concerning categorizing of various crabs chiefly based on the morphology general, and well reflect the “concept of crabs and naïve intuition about them” created by observing human being. From the aspect of cognitive physiology aiming at recognition of objects by living organisms, macrotaxonomic system of particular animal must reflect the “concept of relevant taxon” and “both the scientific and vernacular names of pertinent taxon” (Maturana and Varela, 1980; Mayr and Ashlock, 1991). These demands mean the dual view points of each taxonomist to work on the analysis of taxonomic system and rule of taxonomy from the “second order observation” as well as simple taxonomy of relevant animals. Thus, the construction of macrotaxonomic system of Brachyuran crabs should be based on simple taxonomy (never starting from the Cladistics that strongly reflects the evolutionary aspect, but using any signifier extractable from individual and species taxon), and at once, close examination of taxonomic system and taxonomy itself.

On considering the system structure of both Sakai (1976) and Bowman and Abele (1982), unresolved problems can be roughly pointed out as follows: (1) Further division of Brachyrhyncha; (2) validity of inclusion of Gymnopleura into Brachyura; (3) settlement of taxonomic rank and number of lower taxa in any taxon, especially Family level, commonly usable in whole the taxonomic region in Brachyura; (4) settlement of taxonomic position of some taxonomically problematic taxa like Zalasiinae or *Actaeomorpha*; (5) settlement of number of lower taxa in each taxon which can be established by the taxonomic system itself; (6) extraction cue of meta-description from each description of various taxa, that governs the taxonomic rule on the pertinent taxon; (7) corresponding of meta-description and ordinary taxonomic description, and the settlement of hierarchical interrelationship between any taxon and its higher taxa.

Here, I would like to present new macrotaxonomic system of Brachyuran crabs general, and the settlement of the Suborder Gymnopleura out of the Suborder Brachyura. It also suggests further division of “Subsection Brachyrhyncha” in Sakai (1976) into several parts in the macrotaxonomic system structure. Moreover, macrotaxomic position of Order Decapoda is also provided, together with the taxonomic position of Hominidae (Theria: Mammalia) representing the “human being” and an enigmatic taxon, “*Xenoturbella*.” The determination of the taxonomic position of the Family Hominidae and “*Xenoturbella*” will be useful as the comparative examples, to demonstrate the validity and efficiency of the taxonomic strategy proposed in this Chapter.

IV-3. MATERIALS & METHODS

Whole the scientific names and morphological description, and diagnoses of various level of taxa, and representative taxonomic system of Brachyuran crabs such as check list in Sakai (1976) or Miyake (1982 and 1983) can be examined with the summary presented in Dai (1999), Chen and Sun (2002), and elsewhere. As for the higher macrotaxomic position of Section Brachyura in Decapoda, Miyake (1982 and 1983) and McLaughlin *et al*. (2007) can be used. Here relies chiefly on the system of Sakai (1976) and over-laid taxonomic philosophy there, and Mayr and Ashlock (1991).

As for the concrete construction of macrotaxonomic system, Subsection Oxyrhyncha in Sakai (1976) is quite good example. In Sakai (1976), this Subsection is subdivided into three Families, namely, Hymenosomatidae, Majidae, and Parthenopidae. The Family Majidae is further subdivided into following 7 Subfamilies; Inachinae, Oregoninae, Ophthalmiinae, Acanthonychinae, Pisinae, Majinae, and Mithrachinae. The Family Parthenopidae is also subdivided into three Subfamilies; Parthenopinae, Aethrinae, and Eumedoninae. Here, I would like to raise the taxonomic rank of all the Subfamilies into Family level. Moreover, two more Families, Actaeomorphiidae and Dairoidae, respectively represented only by the genera *Actaeomorpha* and *Dairoides* are established (Family diagnosis followed generic diagnosis in Sakai (1976)). In Chen and Sun (2002), Family Mimilambridae is present, and here uses this Family name designating the genera, *Sakaila* and *Osachila*. In Sakai (1976), Subfamily Zalasiinae is treated as "Incerta Sedis," which is characterized by the following four genera, namely, *Zalasius, Banareia, Calvactaea,* and *Daira*. For the taxon that can be referable to the Subsection, here created new Family, Zalasiidae, which consists of typical *Zalasius* species taxa, namely, *Z. dromiaephormis*, *Z. imajimai*, *Z. australis*, and *Z. sakaii*, in narrower taxonomic implication of the genus *Zalasius* in Sakai (1976). Only this Family is referred to the Subsection Oxyrhyncha. The remaining *Zalasius* species taxon, namely, *Z. horiii*, is referred to the other genus *Miyakezalasius* (new establishment: generic diagnosis followed the species description in Sakai (1976) and Miyake (1983)), which is referred to the Family Miyakezalasiidae (new establishment: Family diagnosis followed species diagnosis). Moreover, remaining three genera are raised into Family level, namely, Banareidae, Calvactaeidae, and Dairidae (all three are new establishment: Family diagnosis followed each generic diagnosis in Sakai (1976)). Thus, this Subsection can be subdivided into 15 Families, and characterized by three major "taxonomic categories."

For the standardization of Family level in whole the system of Brachyuran macrotaxonomic system, here chooses the Subsections "potamids" and Dromiacea. As for "potamids," Dai (1999) shows three Superfamilies, namely, Pseudothelphusoidea (Trichodactylidae and Pseudothelphusidae), Parathelphusoidea (Gecarcinucoidae, Parathelphusidae, and Sundathelphusidae), and Potamoidea (Potamidae, Sinopotamidae, Isolapotamidae, and Potamonautidae), as well as the Family Deckenidae. Thus, major three "taxonomic categories" with identical taxonomic characteristics can be also recognized in "potamids." Turning eyes to the Subsection Dromiacea, similar "taxonomic categories" can be also observed in Sakai (1976): Homolodromiidae, Dromiidae, Dynomenidae, and twin genera in the Family Dromiidae, namely, *Dromidia* and *Lasiodromia*, like in the case of the Superfamily Pseudothelphusoidea *sensu* Dai (1999).

As was shown in the case of Subsection Oxyrhyncha (*sensu* Sakai, 1976), maximally 15 Families can be placed in one Subsection, and can be recognized several taxonomic categories (usually three major categories) in one Subsection. Moreover, on considering the morphology and ecology of examined crabs, certain taxonomic trend in each Subsection can be also recognized, namely, morphologically simple (primitive) to complex (advanced), and then, atrophied. Here, 15 × 15 taxonomic square (Superfamily versus Family) can be proposed, and taxonomic trend can be also recognized quite easily. This taxonomic square is also usable to the interrelationships like species taxon versus genus, genus versus Family, and any other taxonomic hierarchy irrespective of taxonomic field concerning the living organisms.

Here, I would like to construct macrotaxonomic system modified from Sakai (1976) by the modern taxonomic trend. In this system, the taxonomic rank of "Subsection" in Sakai (1976) is respectively changed into "Superfamily."

IV-4. TAXONOMY

The result concerning Brachyuran mactrotaxomic system is shown in Table IV-1, by the creation of "15 taxonomic slots" from Σ to ◎-taxa. The higher macrotaxonomic position of Brachyura is also shown in Table IV-2, together with the other decapod taxa. The 2D arrangement by the dendrogram is shown in Fig. IV-1, that shows (1) the taxonomic similarity from Σ to ◎-taxa, and (2) the evolutionary closeness among them (phylogram). For the comparison with Brachyura, several macrotaxonomic results in previously called, "Anomura," are shown in Table IV-2 from the level of intragenus (the genus *Paralomis*) to inter-Superfamily (the Suborders Brachyura, Anomura, Galatheidea, Caridea, Thalassinidea, Glypheidea, and Hippidea: All are new designation in this Chapter). As for the results concerning the Superfamily Lithodidoidea in Table IV-2, genus name, "*Sakaia*," is given to the unusual lithodid species taxon, *"Paralomis" odawarai* (new establishment: Generic diagnosis followed Sakai (1980): See also Chapters I and V). The genus *Sakaia* is taxonomically close to the genus *Lopholithodes* (Table IV-2), but clearly differentiated by the shape of *Paralomis*-like abdominal structure and unusually developed (bifid) gastric spine.

Finally, the macrotaxonomic position of the Family Hominidae and "*Xenoturbella*," an enigmatic taxon whose taxonomic status have been unclear, are also presented in Table IV-3, (1) to explain the special status of human being on earth, and (2) to demonstrate the validity of the present taxonomic manner of "15 × 15 taxonomic square strategy."

Following taxonomic rankings are showing the "depth of taxonomic rank" both in the cases of Brachyuran crab and human being.

1. *Dicranodromia doederleini* (Brachyuran crab species taxon)

Phylum: Pogonophora-Brachiopoda
 Subphylum: Arthropoda
  Class: Crustacea
   Subclass: Eumalacostraca
    Order: Decapoda
     Suborder: Brachyura
      Superfamily: Dromioidea
       Family: Homolodromiidae
        Genus: *Dicranodromia*
         Species: *Dicranodromia doederleini*

2. *Homo sapiens* (species taxon of human being)

Phylum: Chordata
 Class: Mammalia
  Subclass: Theria
   Order: Primates
    Family: Hominidae
     Genus: *Homo*
      Species: *Homo sapiens*

I. Suborder Gymnopleura (proposal of new taxonomic position)

From the morphological characteristics of referred individuals and the abnormal position in the decapod macrotaxonomic system (usually in the Superfamily Archaeobrachyura), I excluded Gymnopleura from the Suborder Brachyura. From the morphological structure chiefly around rostrum and eye-stalk, three taxonomic categories, namely, Raninoidea (new establishment, represented only by the genus *Ranina*), Cosmonotoidea (new establishment, represented by the genus *Cosmonotus*)-Notopoidea (new establishment, represented by the genus *Notopus*)-Ranilioidea (new establishment, represented by the genus *Ranilia*)-Notopoidoidea (new establishment, represented by the genus *Notopoides*), and Raninoidoidea (new establishment, represented by the genus *Raninoides*)-Lyreidoidea (new establishment, including *Lyreidus* and *Lysirude*)-Cyrtorhinoidea (new establishment, represented only by the genus *Cyrtorhina*)-Symethoidea (new establishment, represented only by the genus *Symethis*), can be established. The taxonomic status of fossil taxon, the Subfamily Palaeocorystinae, can not be settled in this study.

II. Suborder Brachyura

1. Superfamily Potamoidea (new proposal of referable lower taxa)

This Superfamily is derived from Brachyrhyncha, and placed at the first position of the Suborder Brachyura by its representative nature in Brachyura. The Family Epigrapsidae (new establishment, diagnosis followed Sakai (1976)), represented only by the genus *Epigrapsus,* is placed as the morphologically simplest (primitive) potamid taxon. As for the Family name, “Insulapotamidae,” it is tentatively given inclusively to the unknown species taxon recognized from the mountain stream in Haha-jima, Ogasawara Group, southern Japan (Habu, personal communication). Moreover, two more tentative Family names are used, namely, “Geothelphusidae-1” and “Geothelphusidae-2” (both are represented only by the genus *Geothelphusa*, and suggesting the division of the genus), and they are denoting the biogeographic junction between the Family Sinopotamidae and two American Families, namely, Pseudothelphusidae and Trichodactylidae, via tentative Family, “Insulapotamidae.” The ◎-Family can not be established in this study, but further examination of the Family Deckenidae may be useful. Totally, 14 Families can be established in this Superfamily.

2. Fossil Superfamily (no name, and thus, tentative treatment)

This Superfamily is placed chiefly to accumulate the fossil taxa that had been emerged earlier on earth, such as the Families Prosoponidae and Dakoticancridae. Tentatively, here established 15 maximal slots of fossil Families. As for recent taxon, an unusual prosoponid-like species taxon, characterized by the extremely long and slender walking legs of the crab specimen, is recognized based on the material from the abyssal zone of the Sulu Sea, the Philippines (Ohta, personal communication: Watabe, unpublished data). The taxonomic position of the Family Homolodromiidae seems to be rather unstable, it might be transferred to this Superfamily. So far, I would like to put this Family in the next Superfamily Dromioidea, as the “most primitive” taxon there (◎-Family).

3. Superfamily Dromioidea

The Superfamily Dromioidea has three major taxonomic categories, namely, Acanthodromiidae (new establishment, represented only by the genus *Acanthodromia*)-Paradynomenidae (new establishment, represented only by the genus *Paradynomene*)-Dynomenidae (new establishment, represented only by the genus *Dynomene*)-Hirstodynomenidae (new establishment, represented only by the genus *Hirstodynomene*), Cryptodromiidae (new establishment, family diagnosis followed the generic diagnosis of the genus *Cryptodromia* in Sakai (1976))-Petalomeridae (new establishment, family diagnosis followed the generic diagnosis of the genus *Petalomera* in Sakai (1976))-Dromiidae (new establishment, represented only by the genus *Dromia*)-Lauridromiidae (new establishment, family diagnosis followed the generic diagnosis of the genus "*Dromia*" in Sakai (1976)), and Dromidiidae (new establishment, represented by the genus *Dromidia*)-Lasiodromiidae (new establishment, represented only by the genus *Lasiodromia*)-Sphaerodromiidae (new establishment, represented by the genus *Sphaerodromia*)-Choncoecetidae (new establishment, represented by the genus *Choncoecete*)-Genkaiidae (new establishment, represented only by the genus *Genkaia*). The uppermost Σ- and lowermost ◎-Families in the taxonomic matrix are designated as Metadynomenidae (new establishment, represented only by the genus *Metadynomene*) and Homolodromiidae (see also Guinot (1995)), respectively. Totally, 15 Families are recognized in this Superfamily.

4. Superfamily Archaeobrachyura (new proposal of referable lower taxa)

In this Superfamily, formally called, the Family Dorippidae, is divided into four Families, namely, Dorippidae (represented only by the genus *Dorippe*), Heikeidae (represented by the recent genera *Heikea*, *Medorippe*, *Neodorippe*, and *Nobilum*), Paradorippidae (represented only by the genus *Paradorippe*), and Philippidorippidae (represented only by the genus *Philippidorippe*) (see also Holthuis and Manning (1990)). Like in the case of the Superfamily Dromioidea, three major taxonomic categories can be placed: Xeinostomiidae (new establishment, represented by the genera *Xeinostoma* and *Ketamia*)-Cymonomidae-Cyclodorippidae (excluding the genus *Phylodorippe*)-Phylodorippidae (new establishment, represented only by the genus *Phylodorippe*), Poupinidae-Homolidae-Latreillidae-Homologenidae (new establishment, represented only by the genus *Homologenus*) (as for these four Families, see also Guinot and Richer de Forges (1995)), Ethusinidae (new establishment, represented only by the genus *Ethusina*)-Ethusidae (new establishment, represented only by the genus *Ethusa*)-Heikeidae-Paradorippidae-Philippidorippidae. Moreover, the Family Homolomanniidae (new establishment, represented only by the genus *Homolomannia*) is placed as the Σ-Family. Totally, 15 Families can be recognized in this Superfamily.

5. Superfamily Oxystomata

This Superfamily has three major taxonomic categories (Ebaliidae-Phyliridae-Leucosiidae-Cryptocnemidae, Hepatidae-Calappidae-Paracycloesidae-Acanthocarpidae, and Mursiidae-Cycloesidae-Matutidae-Izanamidae-Orithiidae). The Family Calappidae is represented by the recent genera *Calappa* and *Calappoides*. The Families Paracycloesidae and Acanthocarpidae (new establishment) are represented by the genera *Paracycloes* (only by this genus), and *Acanthocarpus* and related genera characterized by the unusually developed spines on carapace and chelae, respectively. The Families Mursiidae and Cycloesidae (new establishment) are represented by the genera *Mursia* and *Cycloes*, respectively. The Family Izanamidae is newly established, and represented only by the genus *Izanami*. The family Matutidae is represented by the remaining *Matuta*-related genera. The taxonomic status of the newly established Family Acanthocarpidae seems to be rather unstable, due to the closeness to the fossil Family Necrocancridae. Thus, further examination is needed. I would like to leave this taxonomic problem unresolved so far. The Families Iphiculidae and Drachiellidae are also newly established, and represented only by the genera *Iphiculus* and *Drachiella*, respectively. Totally, 15 Families are recognized in this Superfamily.

6. Superfamily Oxyrhyncha

As was shown in Matherials & Methods in this Chapter, this Superfamily is key stone of present macrotaxonomic system. It is started from the Family Dairoidae and ended in the Family Zalasiidae. Totally, 15 Families and three major taxonomic categories can be established. As for the Family Aethridae, it is represented only by the genus *Aethra*. The genera, *Cryptopodia* and *Heterocrypta*, both were formerly referred to Aethridae, are now transferred to the Family Parthenopidae.

7. Superfamily Cancroidea

This Superfamily is rather difficult to recognize the taxonomic categories, and also, hard to establish appropriate division and extremity of each Family. It is started from the Family Miyakezalasiidae and ended in the Family Erimacridae (new establishment, represented only by the genera *Erimacrus* and *Thelmessus*). The Family Jonasidae (new establishment) is represented only by the genera *Jonas* and *Gomeza*. The Family Corystidae is represented by the genera *Corystes* and *Podocatactes*. As for formerly called, "the Family Cancridae," it is subdivided into the following five Families (with Japanese representative species taxa): Cancridae (*Platepistoma anaglyptum*, and major part of Atlantic cancrid species taxa referred to the genus *Cancer*)-Paracancridae (new establishment, represented only by the species taxon, *Cancer magister*)-Yamatocancridae (new establishment, represented only by the species taxon, *Cancer japonicus*), Asiacancridae (new establishment, represented only by the species taxa, *Cancer nadaensis* and *C. gibbosulus*), and Pacificancridae (new establishment, represented only by the species taxon, *Cancer amphioetus*). As for the Family Chimeracancridae (tentative establishment), it will be established based on the materials from Tosa Bay, southern Japan (Fig. IV-2). Similar division is also carried out on the Family Thiidae, divided into the following two Families, Thiidae (*sensu stricto*) (characterized by spineless species taxa and genera, such as *Kraussia integra* and *K. truncatifrons,* and *Thia*) and Parathiidae (characterized by the other species taxa and genera such as "*Kraussia*" *nitida* and "*K.*" *rugulosa* in Sakai (1976)). Moreover, Trichopeltarionidae (new establishment, represented only by the genus *Trichopeltarion*) is also placed in this Superfamily. Totally, 15 Families are established in this Superfamily.

8. Superfamily Xanthoidea (new proposal of referable lower taxa)

Formerly, the Subsection Brachyrhyncha is the largest taxon in the macrotaxonomic system of Brachyura provided in Sakai (1976). In present taxonomic system, this "Subsection" is divided into 8 Superfamilies: Potamoidea, Xanthoidea (new proposal of referrable lower taxa), Ucoidea (new establishment), Sakainoidea (new establishment), Pinnotheroidea (new establishment), Calvactaeoidea (new establishment), Bellioidea, and Acmaeopleuroidea (new establishment) (diagnoses of these Superfamilies (excluding that of the Superfamily Bellioidea) followed the generic diagnoses provided in Sakai (1976)). The

Superfamily Xanthoidea is started from the Family Dairidae like in the case of the Superfamily Oxyrhyncha (in this Superfamily, the Family Dairoidae), and ended in the Family Banareidae. The Family Liagoridae is newly established (diagnosis followed generic diagnosis in Sakai (1976)), and total 15 Families are established in this Superfamily.

9. Superfamily Ucoidea (new establishment)

This Superfamily is represented by many Brachyuran taxa, which are well characterized by their striking reproductive ecology like in the case of the genus *Uca*. It is started from the Family Cyclograpsidae (new establishment, represented only by the genus *Cyclograpsus*) and ended in the Family Eryocheiridae (new establishment, represented by the genera *Eriocheir* and *Neoeriocheir*), and is totally represented by 15 Families. The diagnoses of the newly established families, namely, Ucidae, Ocypodidae (represented only by the genus *Ocypode*), Scopimeridae, Macrophthalmidae, Camptandriidae, and Pragusiidae, can be extracted from the diagnoses of the following genera and other level of taxa in Sakai (1976) and Miyake (1983), namely, *Uca*, *Ocypode*, Scopimerinae, Macrophthalminae, Camptandriinae, and Pragusiinae.

10. Superfamily Sakainoidea (new establishment)

This Superfamily includes 8 families, from the Families Sakainidae to Daidynamiidae. The Family Daidynamiidae is newly established to the "swimming" species taxon, *Tritodynamia horvathi*. Each diagnosis of the Family can be established from the relevant genus diagnosis in Sakai (1976).

11. Superfamily Pinnotheroidea (new establishment)

This Superfamily is just the twin Superfamily of Sakainoidea, and consists of 8 Families. It is started from the Family Archaeotheridae (new establishment, represented by the species taxon, which is formerly called, *Pinnotheres laquei*) and ending in the Family Chentheridae (new establishment, represented by the "fresh water" species taxon like formerly called, *Pinnotheres corbiculae*). Each diagnosis of the Family can be established from the relevant genus diagnosis in Sakai (1976).

12. Superfamily Hapalocarcinoidea

This Superfamily is characterized by 11 Families elevated from the genus level. It is resulted from the standardization with the Superfamily Potamoidea.

13. Superfamily Calvactaeoidea (new establishment)

This Superfamily is also represented only by the genus *Calvactaea*.

14. Superfamily Bellioidea

This Superfamily is also represented only by the Family Belliidae.

15. Superfamily Acmaeopleuroidea (new establishment)

This Superfamily is also represented only by the genus *Acmaeopleura*.

III. Taxonomic status of the other decapods and arthropods

1. Suborder Anomura (new proposal of referable lower taxa)

The Suborder Anomura is well characterized by "hermit crab" and "king crab." It is started from the Superfamily Coenobitoidea (new establishment, and represented only by the genus *Coenobita*) and ended in the Superfamily Birgusoidea (new establishment, represented only by the genus *Birgus*). The diagnoses of following Superfamilies can be extracted from Miyake (1982) and elsewhere, and here expresses the corresponding of the Superfamily and genus: Cheiroplateoidea-*Cheiroplatea*; Pomatocheloidea-*Pomatocheles*; Pylocheloidea-*Pylocheles*; Cancellocheloidea-*Cancellocheles*. The Superfamily Paguristoidea (new establishment) is characterized by the hermit crab individual with equal-sized chelae of the genera such as *Aniculus*, *Trizopagurus*, *Cancellus*, *Paguropsis*, and *Paguristes* (*sensu* Miyake, 1982). The diagnosis of the Superfamily can be constructed from the diagnoses of above mentioned genera. The Superfamily Diogenidae is now characterized by the left-handed hermit crab individual of the genera such as *Diogenes*, *Calcinus*, *Dardanus*, and *Clibanarius* (*sensu* Miyake, 1982). The Superfamily Paguroidea is characterized only by the Family Paguridae (*sensu* Miyake, 1982). The Superfamily Parapaguroidea is also characterized only by the Family Parapaguridae (*sensu* Miyake (1982), but excluding the genera *Tylaspis* and *Probeebei*). The Superfamilies Tylaspoidea and Probeebeoidea are newly established, and characterized only by the genera *Tylaspis* and *Probeebei*, respectively. The Superfamily Lithodidoidea is represented only by the Family Lithodidae, and here, lower taxonomic structure is shown (inter-genera in the Family Lithodidae, and intra-genus of the genus *Paralomis*). The Superfamilies Lomisoidea and Albuneoidea are represented by the Families Lomisidae and Albuneidae, respectively.

2. Suborder Galatheidea (new proposal of taxonomic position)

The Suborder Galatheidea is newly established from the Suborder Anomura (*sensu* Miyake, 1982), and coincides with the Superfamily Galatheoidea *sensu* Miyake (1982). The diagnosis of each Superfamily can be chiefly established from the generic diagnoses provided in Baba (1988). It is started from the Superfamily Chilostyloidea (represented only by the genus *Chilostylus*) and ended in the Superfamily Porcellanoidea (new establishment, represented only by the Family Porcellanidae). The inner structure is as follows: Gastroptychoidea (new establishment, represented only by the genus *Gastroptychus*)-Uroptychoidea (new establishment, represented only by the genus *Uroptychus sensu* Baba (1988))-Eumunidoidea (new establishment, represented by the genera *Eumunida* and *Pseudomunida*)-Kiwoidea (new establishment, represented only by the genus *Kiwa*); Galatheoidea (new establishment, represented by the genera *Galathea*, *Liogalathea, Allogalathea*, *Phylladiorhynchus*, *Sadayoshia*, and *Lauriea* (*sensu* Miyake, 1982)-Munidoidea (new establishment, represented by the genera *Cervimunida*, and *Munida* and recently established allied genera)-Paramunidoidea (new establishment, represented only by the genus *Paramunida*)-Bathymunidoidea (new establishment, represented only by the genus *Bathymunida*); Superfamily 1-Superfamily 2 (both are intermediates of Bathymunidoidea and Munidopsoidea, the corresponding species taxa will be extracted from the genus *Munidopsis sensu* Baba (1988))-Munidopsoidea (new establishment, represented only by the genus *Munidopsis sensu* Baba (1988))-Shinkaioidea (new establishment, represented only by the genus *Shinkaia*)-Aegloidea (new establishment, represented only by the genus *Aegla*, well known as “fresh-water squat lobster”). As is shown by the unoccupied taxonomic slots denoted by Superfamily 1 and 2, the interrelationship between “Munidoidea” and “Munidopsoidea” taxonomic groups is the last frontier of decapod taxonomy.

3. Suborder Caridea

Present decapod taxonomic system is constructed to reflect naïve human intuition on decapods. As was well shown by the taxonomic name "Dendrobranchiata" and "Pleocyemata," and the successive works by Guinot (1977) on "Infraorder Brachyura," the morphological structure of decapod reproductive system had been treated as the most important taxonomic characteristics. However, it does not reflect the taxonomic structure and trend in the Subphylum Arthropoda (Table V-2), and the interrelationship among taxonomic hierarchy there such as species taxon versus genus, genus versus family, and so on. Thus, here provides new taxonomic system concerning "Caridea." The check list of Caridea had been provided in Miyake (1982) at the Superfamily level, and here uses it. It is started from the Superfamily Phycetocaridoidea, and ended in the Superfamily Eryonoidea-Palinuloidea (new establishment, replaced name should be provided in future). The inner structure is as follows: Stenopodoidea-Penaeoidea-Sergestoidea-Oplophoroidea; Pasiphaeoidea-Alpheoidea-Bresilioidea-Palaemonoidea; Stylodactyloidea-Psalidopodoidea-"Astacoidea-Nephropoidea" (new establishment, replaced name should be provided in future)-Pandaloidea-Crangonoidea.

4. Suborder Thalassinidea (new establishment)

The Suborder Thalassinidea is small Suborder. It is started from the Superfamily Thalassinoidea (represented only by the genus *Thalassina*), and ended in the Superfamily Tuerkayogebioidea (represented only by the genus *Tuerkayogebia*). The inner structure is as follows: Laomedioidea (represented only by the genus *Laomedia*)-Axioidea-Callianassoidea (represented only by the genus *Callianassa*)-Callianideoidea (represented by the Subfamily Callianideinae *sensu* Miyake (1982)); Acutigebioidea (represented by the subgenera *Acutigebia* and *Neogebicula sensu* Sakai (1982))-Upoegbioidea (represented by the subgenus *Upogebia*)-Wolffogebioidea (represented only by the genus *Wolffogebia*)-Tuerkayogebioidea (see also Sakai (1982), and Sakai and Sawada (2006)).

5. Suborder Glypheidea (new establishment)

The Suborder Glypheidea is characterized only by the Family Glypheidae, and well known by the recent genus *Neoglyphaea*.

6. Suborder Hippidea (new establishment)

The Suborder Hippidea is characterized only by the Family Hippidae.

7. Taxonomic position of the higher taxa in the Subphylum Arthropoda

In Table IV-2, the taxonomic trend in the Subphylum Arthropoda is shown. It proposes the subdivision of the Class Aracnida, namely, Acarida (formerly, Acari), Opilionida (formerly, Opiliones), and Aracnida (*sensu stricto*, represented by the following nine recent lower taxa, namely, the Orders Pseudoscorpiones, Scorpionida, Thelyphonida, Palpigradi, Shizomida, Ricinulei, Amblypygi, and Solifugae (characterized by the spider-shaped arthropods)).

IV. Taxonomic position of the Family Hominidae and "*Xenoturbella*"

The taxonomic position of the Family Hominidae can be shown by the same manner in the case of the Subphylum Arthropoda (see Table IV-3). The taxonomic system of the Phylum Chordata seems to be rather incomplete, further taxonomic study to recognize lower taxa should be provided. The taxonomic position of the Family Hominidae can be settled as the ◎-Family in the Order Primates.

As for the taxonomic position of "*Xenoturbella*," it can be settled as the ＝'–position in the Phylum Ctenophora-Cnidaria.

IV-5. DISCUSSION

Present results concerning crab-shaped decapods are one of the typical cases of "taxonomic analysis" on particular taxon. The major aiming is rather, not to the construction of taxonomic system itself, but the extraction of meta-description beyond the each taxon in the taxonomic system, such as taxonomic trend and taxonomic rule over-laid on the International Code of Zoological Nomenclature (ICZN) or present results on crab-shaped decapods.

As a whole, each Superfamily of Brachyuran crab taxa is arranged in one manner. At first, ideal Family of the relevant Superfamily is determined (Σ-Family), and then, 4 successive Families are placed as "simple (primitive) group" (Α, 1, 2, and 3 -Family). Successively, another 4 Families are placed in one category as "complex (advanced) group" (4, 5, 6, and Ω-Family), and then followed "twin Family group" (Ε and Ο' –Family). The three of remaining four Families (Ρ', 無', and ＝' –Family) have weak taxonomic similarity one another, but middle of them (無'-Family) is closely related to third family of "advanced group" (6-Family). Totally, Ε and Ο', Ρ', 無', and ＝' –Families constructs the "atrophied group." The last Family (◎-Family), it represents whole the Superfamily like Homolodromiidae, Zalasiidae, and Banareidae. Conversely, the arrangement of each Superfamily is also regulated by the same manner. Then, totally, 15 × 15 square macrotaxonomic system can be constructed in one ruled "dendrogram" manner (Fig. IV-1). This ruled manner can be also applicable to any other interrelationship, such as those between species taxon and genus, and genus and family, as the regulating rule of macrotaxonomy (see also Tables IV-2 and 3). As for the influence to microtaxonomy (taxonomy at the species taxon level), it can be also applicable to the reflection of macrotaxonomic results into microtaxonomy, when available specimens or taxonomic information such as literatures are quite few in number. This solution is positive one proposed in the previous Chapter about traditional microtaxonomy aiming at the morphological characteristics on the genus *Nephropsis* (see also Chapter IV). Moreover, the implication of macrotaxonomy proposed in Mayr and Ashlock (1991) is (1) the recognition of the "taxonomic chain" from Σ to ◎-taxa by the aid of the careful observation of concrete specimens and animal ecology, and (2) the construction of hierarchical taxonomic system concerning the "taxonomic chain." This is the most striking difference from the microtaxonomy proposed in Mayr and Ashlock (1991), that is exclusively aiming at the recognition and distinction of each species taxon (see also Chapters III and V).

For the next subject after the construction of macrotaxonomic system of Brachyuran crabs, "meta-description" of each Family or Superfamily and higher taxa should be prepared. The meta-description is defining the absolute position of each taxon. Moreover, it is existing at the higher taxonomic position than ordinary taxonomic descriptions. These ordinary descriptions are usually represented by the species diagnosis or description, that shows the relative differences (recognized by skilled taxonomists and sharable among human being) among various taxa chiefly based on morphological characteristics of animal individuals. Thus, the exclusive demands for these ordinary descriptions do not have basis to designate the "absolute taxonomic position" in all cases. They should be rather treated as the trends in traditional taxonomy, or merely, they imply one of the methods to recognize and designate various kind of taxa. Actually, they can be substituted by the designation demonstrated in this Chapter, namely, characterization by (1) the designation of referable lower taxa and (2) the construction of taxonomic trend from Σ to ◎-taxa. Moreover, the above mentioned "15 × 15 taxonomic square manner" must be prepared like in the manner of "set theory" in meta-mathematics, or foundation of mathematics (see also Chapters I and XI; Watabe, 1999a and b). As the foundation of biology, it is completely different from the foundation based on "numerical science" like mathematics, namely, "taxon-based science."

Fig. IV-1. Taxonomic dendrogram which governs macrotaxonomy and the guide to microtaxonomy with few taxonomic informations and specimens.

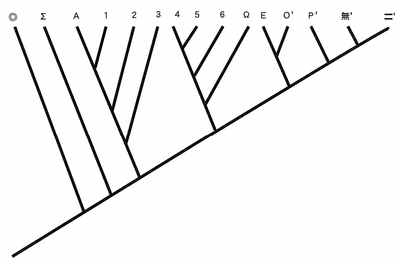

Fig. IV-2. An example of the Family "Chimeracancridae." A female specimen from Tosa Bay, southern Japan.

Table IV-1. Macrotaxonomic system of Brachyuran crabs on earth. The square system (15 × 15), which fully covers the Brachyuran crabs on earth, is presented.

	Symbol	1	2	3	4	5	6	7
Symbol		∑	A	1	2	3	4	5
Superfamily /suborder		**Potamoidea**	**Homolodromioidea**	**Dromioidea**	**Archaeobrachyura**	**Oxystomata**	**Oxyrhyncha**	**Cancroidea**
1	∑	Deckenidae	Fossile family 1	Metadynomenidae	Dorippidae	Actaeomorphiidae	Dairoidae	Miyakezalasiidae
2		Epigrapsidae	Fossile family 2	Acanthodromiidae	Xeinostomiidae	Ebaliidae	Hymenosomatidae	Jonasidae
3	1	Gecarcinucoidae	Fossile family 3	Paradynomenidae	Cymonomidae	Phyliridae	Inachidae	Corystidae
4A		Parathelphusidae	Fossile family 4	Dynomenidae	Cyclodorippidae	Leucosiidae	Oregoniidae	Atelechyclidae
5		Sundathelphusidae	Fossile family 5	Hirstodynomenidae	Phylodorippidae	Cryptocnemidae	Acanthonychidae	Trichopeltarionidae
62		Potamonautidae	Fossile family 6	Cryptodromiidae	Homologenidae	Hepatidae	Pisidae	Chimeracancridae
73	5	Potamidae	Fossile family 7	Petalomidae	Homolidae	Calappidae	Majidae	Cancridae
84		Isolapotamidae	Fossile family 8	Lauridromiidae	Poupinidae	Matutidae	Mithracidae	Eurocancridae
9		Sinopotamidae	Fossile family 9	Sphaerodromiidae	Latreillidae	Orithiidae	Ophthalmiidae	Yamatocancridae
106		Trichodactylidae	Fossile family 10	Dromidiidae	Ethusidae	none	Parthenopidae	Thiidae
11Ω	O'	Pseudothelphusidae	Fossile family 11	Lasiodromiidae	Heikeidae	none	Aethridae	Parathiidae
12E	P'	Insulapotamidae	Fossile family 12	Choncoecetidae	none	none	Eumedonidae	Pirimeridae
13	無'	none	Fossile family 13	Dromiidae	none	none	Zewidae	Asiacancridae
14	='	none	Fossile family 14	Genkaiidae	none	none	Zalasiidae	Erimacuridae
15	◎	none	Homolodromiidae	none	none	none	Mimilambridae	none

	Symbol	8	9	10	11	12	13	14	#
Symbol		6	Ω	E	O'	P'	無'	='	
Superfamily /suborder		**Xanthoidea**	**Scopimeroidea**	**Sakainoidea**	**Pinnotheroidea**	**Bellioidea**	**Carvactaeoidea**	**Hapalocarcinoidea**	**Gymnopleura**
1	∑	Dairidae	Myctryridae	Sakainidae	Archaeotheridae	Belliidae	Carvactaeidae	Pseudocryptochiridae	Raninoidea
2		Liagoridae	Grapsidae	Xenophthalmidae	Pinnaxodidae	none	none	Fizeserenidae	Cosmonotoidea
3	1	Portunidae	Varunidae	Pinnixidae	Orthotheridae	none	none	Cryptochiridae	Notopoidea
4A		Geryonidae	Gecarcinidae	Tetriidae	Durkheimiidae	none	none	Fungicolidae	Ranilioidea
5		Bythograeidae	Sesarmidae	Pseudopinnixidae	Xanthasiidae	none	none	Utinomiidae	Notopoidoidea
62		Goneplacidae	Ocypodidae	Asthenognathidae	Ostracotheridae	none	none	Favicolidae	Raninoidoidea
73	5	Xanthidae	Scopimeridae	Tritodynamiidae	Pinnotheridae	none	none	Hapalocarcinidae	Lyreidoidea
84		Menippidae	Macrophthalmidae	Daidynamiidae	Chentheridae	none	none	Hiroidae	Symethoidea
9		Pilmunidae	Uciidae	none	none	none	none	Pseudohapalocarcinidae	none
106		Lybidae	Palicidae	none	none	none	none	Troglocarcinidae	none
11Ω	O'	Polydectidae	Retroplumidae	none	none	none	none	Neotroglocarcinidae	none
12E	P'	Trapeziidae	Pragusiidae	none	none	none	none	none	none
13	無'	Platyxanthidae	Camptandriidae	none	none	none	none	none	none
14	='	Hexapodidae	none	none	none	none	none	none	none
15	◎	Banareiidae	none	none	none	none	none	none	none

Table IV-2. Macrotaxonomic system of the Subphylum Arthropoda, especially concerning crab-shaped decapods. The macrotaxonomic position of Suborder Brachyura in diverse Decapoda, the macrotaxonomic system of both “hermit crabs” (Suborder Anomura: From Coenobitoidea to Birgusoidea) and “squat lobsters” (Suborder Galatheidea: From Chylostiloidea to Porcellanoidea), and the example of macrotaxonomy in one genus (the genus *Paralomis*, with the presentation of typical species taxon), are presented. The taxonomic arrangement of lithodid genera in the Superfamily Lithodidoidea is also given. Other Suborders, namely, Caridea, Thalassinidea, Glypheidea, and Hippidea, are also shown. Closer issues should be consulted to the text.

	Symbol	Arthropoda	Crustacea	Eumalacostraca	Decapoda	Gymnopleura	Brachyura
1	∑	Xiphosura	Remipedia	Anaspidacea	Gymnopleura	Raninoidea	Potamoidea
2	A	Fossile group	Cephalocarida	Waterstonellidea	Potamoidea	Cosmonotoidea	Homolodromioidea
3	1	Trilobita	Sarsostraca	Mysida	Homolodromioidea-Oxystomata	Notopoidea	Dromioidea
4		Fossile group	Diprostraca	Lophogastrida	Oxyrhyncha-Scopimeroidea	Ranilioidea	Archaeobrachyura
5_2		Eurypterida	Notostraca	Thermosbaenacea	Sakainoidea-Hapalocaricinoidea	Notopoidoidea	Oxystomata
6_3		Symphyla	Mystacocarida	Cumacea	Hippoidea	Raninoidoidea	Oxyrhyncha
7_4	5	Insecta	Copepoda	Tanaidacea	Lomisoidea	Lyreidoidea	Cancroidea
8		Diplopoda	Thecostraca	Mictacea	Cheiroplateoidea-Cancellocheloidea	Symethoidea	Xanthoidea
9_6		Pauropoda	Tantulocarida	Speleogriphacea	Paguristoidea-Albuneoidea	none	Scopimeroidea
10_{Ω}		Acarida	Phyllocarida	Isopoda	Porcellanoidea	none	Sakainoidea
11_E	O'	Aracnida	Hoplocarida	Amphipoda	Chylostyloidea-Aegloidea	none	Pinnotheroidea
12	P'	Crustacea	Eumalacostraca	Decapoda	Caridea	none	Bellioidea
13	無'	Chilopoda	Ostracoda	Euphausiacea	Thalassinidea	none	Carvactaeoidea
14	='	Opilionida	Brachiura	Amphionidacea	Glypheidea	none	Hapalocarcinoidea
15	◎	Pycnogonida	none	Bathynellacea	none	none	none

	Symbol	Anomura	Lithodidoidea	*Paralomis*	Galatheidea
1	∑	Lomisoidea	*Sakaia*	*P. spectabilis*	Chylostyloidea
2		Cheiroplateoidea	*Neolithodes*	*P. kyushupalauensis*	Gastroptychoidea
3 A	1	Pomatocheloidea	*Lithodes*	*P. hystrix*	Uroptychoidea
4	2	Pylocheloidea	*Paralithodes*	*P. hystrixoides*	Eumunidoidea
5		Cancellocheloidea	*Sculptolithodes*	*P. multispina*	Kiwoidea
6 3	4	Paguristoidea	*Rhinolithodes*	*P. investigatoris*	Galatheoidea
7	5	Diogenoidea	*Paralomis*	*P. verrilli*	Munidoidea
8	6	Paguroidea	*Phylolithodes*	*P. pectinata*	Paramunidoidea
9		Parapaguroidea	*Glyptolithodes*	*P. cristata*	Bathymunidoidea
10 Ω		Tylaspoidea	*Dermaturus*	*P. dofleini*	Munidopsoidea
11 E	O'	Probeebeoidea	*Oedignathus*	*P. ochthodes*	Shinkaioidea
12	P'	Coenobitoidea	*Hapalogaster*	*P. japonica*	Aegloidea
13	無'	Lithodidoidea	*Lopholithodes*	*P. jamsteci*	none
14	='	Albuneoidea	*Cryptolithodes*	*P. truncatispinosa*	none
15	◎	Hippoidea	*Placetron*	*P. hirsuta*	Porcellanoidea

Table IV-3. Macrotaxonomic position of the Family Hominidae and the Subphylum Arthropoda, and “*Xenoturbella*.” Close issue should be consulted to the text.

	Symbol	"Living organisms"	Chordata	Theria	Primates	Cnidaria-Ctenophora	Pogonophora-Brachiopoda
1	∑	Chordata	Agnatha	Primates	Indridae	Cnidaria	Pogonophora
2		Archaea	Placodermi	Xenarthra	Daubentoniidae	Placozoa	Nematomorpha
3 A	1	Bacteria	Chondrichthyes	Insectivora	Cheirogaleidae	Platyhelminthes	Nematoda
4		Fungi	Acanthodii	Scandenetia-Plesiadapiformes	Lepilemuridae	Nemertina	Ectoprocta
5 2		Protista	Osteichthyes	Chiroptera	Lemuridae	Gnathostomulida	Phoronida
6 3		"chlorophytes"	Amphibia	Carnivora	Tarsiidae	Gastrorinchia	Annelida
7 4	5	"vascular plants"	Reptilia	Rodentia	Atelidae	Rotifera	Arthropoda
8		Bryophyta	Mammalia	Perissodactyla-Artiodactyla	Cebidae	Kinorhyncha	Onychophora
9 6		Charales	Aves	Proboscidea-Sirenia-Hyracoidea	Pongidae	Loricifera	Pentastoma
10 Ω		Cnidaria-Ctenophora	Cephalochordata	Lagomorpha	Loridae	Rhombozoa	Sipunculoida
11 E	O'	Pogonophora-Brachiopoda	Urochordata	Macroscelidea	Galagonidae	Orthonectida	Echiuroida
12	P'	Echinodermata	Hemichordata	Tubulidentata	Cercopithecidae	Entoprocta	Mollusca
13	無'	Porifera	none	Cetacea	Hylobatidae	Acanthocephala	Tardigrada
14	='	Chaetognatha	none	Pholidota	Cynocephalidae	Ctenophora	Priapulida
15	◎	Virus	none	Marsupialia	Hominidae	none	Brachiopoda

V. *PARALOMIS* WHITE, 1856 (LITHODIDAE: DECAPODA) IN THE TOKYO SUBMARINE CANYON, WITH SPECIAL REFERENCE TO NARROW INTERSPECIFIC ZONATION

V-1. ABSTRACT

Complete interspecific zonation concerning the genus *Paralomis* White, 1856 (Lithodidae: Anomura) was detected in the bathyal zone of the Tokyo Submarine Canyon, central Japan, using commercial pot fishing. Three species, namely, *P. dofleini* Balss, 1911, *P. hystrix* (Dana, 1844), and *P. japonica* Balss, 1911, could be identified through the methodological strategy in taxonomic inference proposed by Mayr and Ashlock (1991). For the horizontal distribution pattern, they commonly occupied a particular habitat on coarse sediment to rocky bottom environments where strong bottom water movements were predicted with slight species-specific differences. Extremely narrow interspecific zonation was inferred for *P. hystrix* between 200 and 280 m, for *P. japonica* between 280 and 320 m and for *P. dofleini* between 320 and probably down to 450 m on the continental slope. Also, the genus-specific reproductive structure (bathymetrically wider occurrence of male individuals) could be inferred commonly among them. Several eco-taxonomic characteristics commonly recognized in the genus were discussed. The indication of biological components to maintain the present interspecific zonation, and future perspective to specify their respective attributions to it were also suggested.

VI-2. INTRODUCTION

The biological knowledge concerning the genus *Paralomis* White, 1856 (Lithodidae: Anomura) has surprisingly increased according to the fishing development of bathyal organisms (Macpherson, 1988a-c). Its unusual characteristics in the system of biology have been becoming to be well known (see also Chapter I). Moreover, abundant lithodids referred to this genus in the hydrothermal vent fields has been also known (Takeda and Hashimoto, 1990; see also Chapter VII), thus, our understanding concerning the genus is now in progress into quite different one.

The series of taxonomic works to define the morphological phena by E. Macpherson, T. Sakai, and M. Takeda from the 1970's had been maintaining the philological basis around the genus. For the Japanese species, fairly complete taxonomic definition of morphological phena had been established, and successive results in field sampling had so far answered for it robustness. However, the direct contribution to convert them into valid "species taxon" has not been recognized for any morphological phenon (Macpherson, 1988a-c; Macpherson, personal communication). Not only the importance as the mere completion of the generic taxonomic system or enrichment of our biological knowledge, above mentioned effort is also welcomed as basic knowledge of fishing resource, "king crabs," in fishery science and commercial fishing.

For the concrete materials to study faunal zonation of bathyal megabenthos at species order, the pertinent genus afford us the following strong advantages, that are recognized irrespective of species taxa: (1) Larger body size without specific predators at their full-grown stage; (2) specific feeding characteristics, saprophagous (probably also carnivorous) nature; (3) high mobility expressed by the adult individuals and relatively high potential at larval stage to emigrate from the maternal abdomen to another bottom environment by larval dispersal, in spite of highly abbreviated development of larvae (Campodonico and Guzman, 1981; Hayashi and Yanagisawa, 1985; Maihara and Konishi, personal communication); (4) promiscuity and dioecious characteristics on reproductive structure of particular species and referable individuals, respectively. On considering the poverty of the pertinent ecological results concerning the bathyal and large-sized saprophagous decapods like lithodids (Jensen and Armstrong, 1991), we must start from the description of distribution pattern among several species taxa. Moreover, it is also required to consider the physical dimension of lithodid individual, namely, the absolute requirement for intensive sampling in fields. Conceptually, we should be quite aware of the interdependence of the above mentioned subject with valid taxonomic inference guided by “biological species” concept, especially from the aspect of reproductive interaction among relevant lithodid individuals (see also Mayr and Ashlock, 1991).

In this chapter, I describe the unusually narrow interspecific zonation in the genus *Paralomis* in the bathyal zone of the Tokyo Submarine Canyon, through daily activity of commercial pot fishing. From the results, the biological factor to maintain the relevant interspecific zonation will be also pointed out, with special attention to the reproductive structure on respective species taxon.

V-3. MATERIALS & METHODS

Based on following practical and technical efficiencies, survey area and sampling gear were selected as the bathyal zone of the Tokyo Submarine Canyon and commercial pot fishing, respectively: (1) Sampling possibility all the year round; (2) highly efficient catch of lithodid individuals in short sampling period using relevant pot fishing; (3) taxonomic implication concerning the geographic situation of the Tokyo Submarine Canyon itself, namely, type locality or neighboring to it of relevant species (avoidance of the taxonomic problem connecting to allopatry).

On describing the particular structure of each species taxon, horizontal distribution pattern was at first examined from the sampling results, and inferred and plotted on topographic map. Successively, bathymetric abundance of referable individuals and sex ratio concerning each species were expressed on the 2D plane constructed by the axes (mean depth, abundance (Catch Per Unit Effort CPUE / 100 lobster and crab pots or sex ratio (%)) in the inferred niche. Pot operation and device was described in Chapter I. From the observation on board, I provisionally define (1) the catch efficiency of lithodid individuals from bottom environments is constant irrespective of the type of pot, and (2) simply random sampling is carried out, when more than 100 pots are used to describe single mean depth column.

Concrete taxonomic inference is carried out referring to respective morphological phenon, after the definition provided in Sakai (1976). However, additional references to original description or other ones are properly carried out. Then, conversion of gained taxonomic result into the inference of the pertinent species taxon is carried out from the confirmation of reproductively isolated population. Conceptual and technical definitions exclusively followed Mayr and Ashlock (1991) and Watabe (1999a and b).

V-4. RESULTS

Collected lithodid individuals were easily referred to following three morphological phena respectively, namely, *Paralomis dofleini* Balss, 1911 PD, *P. hystrix* (Dana, 1844) PH, and *P. japonica* Balss, 1911 PJ. Another morphological phenon, *P. odawarai* (Sakai, 1980) was also recognized, but its taxonomic status in the genus was problematic (Watabe, unpublished data; Macpherson, personal communication; see also Chapters I and IV), so that its elimination from the data set was carried out. Sampling results were shown in Table VI-1, and sex reversal in lithodid individuals could not be supported from obtained results at the certain period in their life cycle.

Horizontal distribution pattern of respective morphological phenon was plotted on Fig. V-1. Commonly, they occupied exclusively coarse sediment floor to rocky bottom environments, and where strong bottom water movements were predicted. The pertinent individuals were highly expected to form small but high-density patches on bottom environments. It was inferred from the observations on board that the good catch was always obtained in only 2 to 3 successive pots, even in the case when the gained number of lithodids exceeded 10.

The trajectory of the abundance of individual concerning each morphological phenon into 2D plane 〈mean depth, abundance〉 apparently showed habitat segregation among the pertinent morphological phena (Fig. V-2, upper). However, the CPUE of each morphological phenon was recognized as fairly low, constantly below 2.5 individuals / 100 pots. Each bathymetric range (peak depth) was inferred as follows: PH; 181 - 320 m (221 - 280 m): PJ; 241 - 340 m (281 - 300 m): PD; 241 - 360 m (321 - 340 m). The lower limit of bathymetric abundance of PD could not be confirmed due to the lack of sampling effort, but was expected down to 450 m deep (Watabe, unpublished data).

Moreover, the trajectory of the structure of each morphological phenon into 2D plane 〈mean depth, sex ratio〉 clearly showed commonly a certain reproductive structure in spite of no significant deviation of sex ratio from 1:1 (Fig. V-2, lower). In spite of no support from statistics probably due to the smaller size of data set, it suggests that male individuals occur in wider bathymetric range than in female ones.

On considering the summation process of raw data obtained by pot system, the results shown in Fig. V-2 might be underestimation. Scrutiny of pot hauling suggested more acute and least overlapped bathymetric abundance among them, and species change around 200, 280, and 320 m deep among them could be highly expected on the bottom environments. Thus, I concluded that each morphological phenon herein inferred represents the univalent species taxon, respectively.

The infection of kentrogonid individuals on the focused individuals turned out to be rare in the case of present study (<5 % of total individuals), only two cases were recognized (Table V-1). One of them was the case of PH with *Briarosaccus* sp., whereas the other was the case of PJ with *B. callosus* Boschma, 1930.

V-5. DISCUSSION

Present results demonstrated for the first time that the complete interspecific zonation among bathyal lithodid species taxa. Especially for the eco-taxonomic discussion concerning the genus *Paralomis*, it bears special status on following particulars: (1) Intentional usage of taxonomic inference proposed by Mayr and Ashlock (1991) and Watabe (1999a and b); (2) appropriate selection of (a) the pot fishing as sampling gear, and (b) the area to avoid several taxonomic problems, especially associated with allopatry and sampling in rugged bottom environment, where the pertinent lithodid individuals exclusively occur.

1. Ecological characteristics recognized in the genus *Paralomis*

Before proposal to investigate biological factors to maintain the interspecific zonation among the present lithodid species, the specific characteristics of the taxon, the genus *Paralomis*, in the family Lithodidae, should be discussed.

First of all, present result represents commonly the narrow occupation of bathymetric range of *Paralomis* spp. on continental slope in the pertinent genus. This should not be considered as the genus or locality specific characteristics, but resulted from the sampling difficulty in rugged environment from the more general viewpoint.

The inferred reproductive structure of each species of *Paralomis* is quite different from other lithodid species, even in the bathyal species like *Lithodes ferox* (Filhol, 1855) off Namibia, that is highly expected to maintain its reproductive structure by the seasonal migration of referred individuals (Abelló and Macpherson, 1991; Stone *et al*., 1992). To investigate the reproductive seasonality in each *Paralomis* sp., (1) the detection of size of reproductively effective size of interindividual interaction on the bottom environment, and (2) positive support for the promiscuity in the inferred species taxon in any part of its reproductive structure, are indispensable. Due to smaller data size and inability to carry out adequate seasonal sampling in the Tokyo Submarine Canyon, present results neither represent positive conclusion nor provides two requirements above mentioned. However, following tendency may be proposed for the relevant three *Paralomis* spp. from the present results and additional field observations (Watabe, unpublished data): (1) Aseasonal reproduction; aseasonal occurrence of ovigerous female individual without apparent inclination to eyed embryos in specific season: (2) aseasonal migratory maintenance of reproductive structure by referable adult individuals of both sexes. When the more sufficient and the more well-programmed sampling result of the genus *Paralomis* were gained, these genus-specific characteristics might become important taxonomic characteristics to discriminate the component species from the species referred to another genus.

Moreover, clear discrimination, between simple description of correlating structure through multivariate analysis (for example, Abelló and Macpherson, 1989, 1990) and the investigation of the contribution of respective biological factors to maintain the species structure, had better be provided to prevent the contamination in them from spreading.

2. Indication of biological factors to maintain interspecific zonation

Through the field observations and appropriate treatment of multivariate analysis, interspecific zonation among taxonomically close species taxon can be easily detected especially in decapod crustaceans (Jensen and Armstrong, 1991). Moreover, it is also observed irrespective of feeding habit expressed by referred individuals, varying from filter feeding to saprophagous.

In the present case of the genus *Paralomis*, interspecific zonation can be simply described on the 2D plane constructed by the axes ⟨mean depth, abundance of referred individual or sex ratio⟩. Thus, further correspondence by multivariate analysis to characterize the unusual interspecific interaction detected here, interspecific zonation, had better be considered to the secondary issue. Rather, appropriate but simple indication of the biological factors to maintain the interspecific zonation will be appreciated for the present purpose. Additionally, (1) the extending discussion and planning to generalize the conclusion in the genus *Paralomis* to diverse bathyal saprophagous decapods, and (2) the interpreting frame and field experiment or equivalent phenomena to decide the quantitative attribution from each factor concerning the relevant interspecific zonation should be also provided.

On carefully examining the definition of biological species and additional discussion in Mayr and Ashlock (1991), the maintenance of species structure is easily concluded to be realized by following interlinked three components: (1) Physiological and ecological characteristics expressed by the individuals; (2) interaction recognized among the individuals referred to the same species; (3) interaction recognized among the ones referred to the different species respectively.

From above mentioned indication of three factors to maintain interspecific zonation, the extending discussion aiming at wider discussing domain, namely, faunal zonation, should be equipped with the careful consideration. For example, (1) the extending generalization of interspecific zonation recognized among *Paralomis* spp. into diverse saprophagous decapods, (2) the confirmation of concordant faunal break irrespective of the kind of species in the data set by the selection of appropriate explanatory variables (see Chapter VI). Planning should be considered as the mere generalization of interspecific zonation into faunal one. Thus, the biological discussion to explain the maintaining force must be investigated through the special treatment in the field as below.

To investigate the biological factors maintaining the interspecific zonation, only the field experiment and fishery impacts serve the concluding results. To reflect both the physiological and ecological characteristics expressed by the pertinent individuals and inter-individual interaction on the relevant experimental planning, (a) selective elimination of a species, and (b) special transplant experiment, namely, to transplant considerably large number of individuals into an open niche established in the niche of another species, should be proposed (for close discussion, see also Chapter VIII).

For the conceptual summary of this chapter, I emphasize following two lines again.

(1) Interdependence between (a) taxonomic inference concerning the pertinent species taxa and (b) the ecological investigation concerning the biological factors to maintain its structure in the physical environment.

(2) Independence of (a) characterization of species structure through the treatment in multivariate analysis and (b) investigation of the biological factors to maintain the species structure or interspecific interaction.

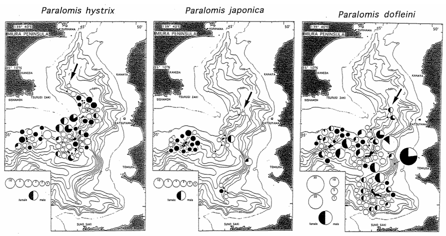

Fig. V-1. Three species referred to the genus *Paralomis* recognized from the bathyal zone in the Tokyo Submarine Canyon. Their trajectories on the topographic map of the Tokyo Submarine Canyon were shown respectively with sex ratio and relative abundance of individuals. Arrow indicate the northern extremity of geographic range of each species.

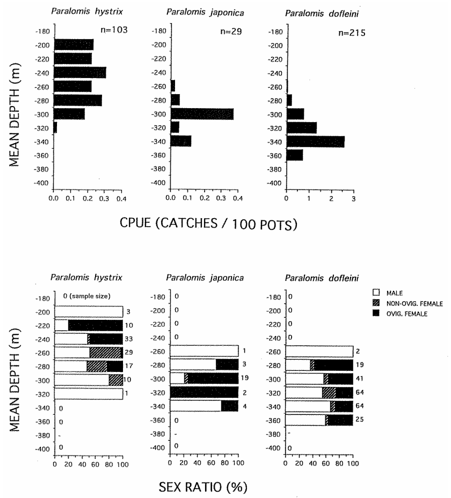

Fig. V-2. Three species referred to the genus *Paralomis* recognized from the bathyal zone in the Tokyo Submarine Canyon. Their trajectories on the 2D plane constructed by the axes of mean depth of each quadrat, and abundance of individuals or sex ratio, were shown. Upper: Abundance expressed by CPUE (catches/100 pots), Lower: Sex ratio, without statistically significant deviation from 1:1 in any column (p>0.05).

Table V-1. Three species referred to the genus *Paralomis* recognized from the bathyal zone in the Tokyo Submarine Canyon. The taxonomic result concerning examined lithodid individuals was shown. # and * denote the occurrence of an individual with the infection of kentrogonid individuals referred to *Briarosaccus* sp. And *B. callosus*, respectively. Significant deviation of sex ratio from 1:1 was not recognized in any case (p>0.05).

Paralomis spp.	male (ratio(%))	non-ovig. female (ratio (%))	ovig. female (ratio (%))	total (ratio (%))
P. hystrix (Dana, 1844)	53# (51.5)	44 (42.7)	6 (5.8)	103 (100.0)
P. japonica Balss, 1911	10# (34.5)	1 (3.4)	18 (62.1)	29 (100.0)
P. dofleini Balss, 1911	125 (58.2)	22 (10.2)	68 (31.6)	215 (100.0)

VI. FAUNAL ZONATION AMONG BATHYAL SAPROPHAGOUS DECAPODS IN THE TOKYO SUBARMINE CANYON

VI-1. ABSTRACT

Through elaborate cluster analyses and stronger taxonomic inference, and intensive pot sampling, unusually narrow faunal zonation of saprophagous decapods in the bathyal zone of the Tokyo Submarine Canyon, central Japan, was investigated. Main results were as follows: (1) The major faunal breaks were situated around 190, 260 - 280, and 310 - 320 m deep, irrespective of submarine topography and sediment type, and consisting species taxa; (2) the bathymetric oc-

currence and interspecific zonation among *Paralomis* spp. (Lithodidae: Decapoda) coincided well with present faunal zonation, in spite of their low scores in the data set; (3) nevertheless, the eurybathic species taxa were recognized in the data set (12 spp. out of total 66 spp.). These results provided simple cues to investigate the maintaining mechanism of decapod faunal zonation as follows; (1) to represent relevant faunal zonation by specific interspecific zonation among *P.* spp.; (2) less competitive interaction among decapods respectively referred to different species taxon. Several suggestions to further field experiments were also provided.

VI-2. INTRODUCTION

Faunal zonation is defined as the changing trends of species composition in the relevant fauna along the gradient of physical variables, and can be rigorously described by the aid of multivariate analysis (Akamine, 1982; Kobayashi, 1995). In the case of bathyal decapods, few results had been reported due to difficulties associated with field sampling, but the selection of depth as the primary explanatory variable has been so far supported as in the case of the other taxa (Abelló *et al.*, 1988; Macpherson, 1991; Cartes and Sardà, 1993). To study faunal zonation in bathyal decapods, several problems can be proposed concerning (1) taxonomic inference (*sensu* Mayr and Ashlock, 1991), (2) appropriate methodological selection of multivariate analysis, and finally, (3) the simplifying strategy to elucidate the maintaining mechanism of relevant faunal zonation.

For (1), two taxonomic components, namely, the taxonomic distinction among relevant materials and philological naming for inferred species taxa must be discussed. For the former, the stronger taxonomic inference based on the "biological species concept" can be easily provided in bathyal decapods, from their ecological characteristics of promiscuity and high mobility (Mayr and Ashlock, 1991; Mayr, 1994; Wada *et al.*, 1997; Asakura, 1998). Thus, the taxonomic inference of species taxon from corresponding morphological phenon can be generally permitted, when the apparent difference in distribution pattern among examined morphological phena were recognized. For the latter, the taxonomic problems associated with allopatry can be proposed. However, these problems are excluded through appropriate selection of sampling area, especially in the case, type locality of examined decapod species taxon. For the enforcement of both of them, intensive sampling demonstrating the reproductive isolation directly or indirectly should be carried out.

For (2), the original concept of multivariate analysis, namely, the rigorous description of relevant object in the multivariate hypervolume should be remembered (Kobayashi, 1995). Especially in it, cluster analysis is superior to the others from the aspect of (1) syntax, or simple logical structure to demonstrate the correlating structure of relevant faunal zonation on 2D plane, and (2) semantics, namely, theoretical completion from mathematical and geometric implication. Thus, only the cares concerning (a) methodological combination between similarity index and aggregating strategy, (b) explanatory variables representing physical environments, and (c) the construction of OTU (Operational Taxonomic Unit), are needed.

As for the case of (3), the finding of representative interspecific zonation in the relevant faunal zonation is the primary subject (see also

Chapter V). As the results from cluster analysis describe only the correlating structure concerning the relevant faunal zonation, the maintaining mechanism of it can not be directly elucidated. Moreover, the complicated interaction among numerous species taxa herein examined causes the interpreting difficulties in its interpretation. Thus, if the representative interspecific zonation were found, the problems could be solved clearly. Moreover, to examine the contribution of competitive interaction within decapods respectively referred to different species taxon, the structural difference of interspecific zonation should be provided.

In this chapter, I will demonstrate the faunal zonation among bathyal saprophagous decapods in the Tokyo Submarine Canyon, central Japan. The study area had been frequently defined as the type locality of examined decapod species taxa, and the faunal composition of relevant decapods can be easily inferred from the results in neighboring Sagami Nada (see also Chapter I). Moreover, daily commercial pot fishing there enables the intensive sampling of the relevant taxa. As for the representative interspecific zonation, that among *Paralomis* spp. (Lithodidae: Decapoda) is selected based on the ecological characteristics expressed by the referable lithodids.

VI-3. MATERIALS & METHODS

1. Sampling and taxonomic inference

Field sampling was exclusively carried out through lobster pot system, close explanation of its equipment and operation were provided in Chapter II. The abundance of decapods is represented by CPUE (Catch Per Unit Effort / 100 lobster pots). Moreover, the lobster pots are herein defined as the simple random sampler of saprophagous decapods when more than 100 pots / quadrat are used, based on the observation on board.

Conceptual frame and the use of terms of taxonomic inference exclusively followed Mayr and Ashlock (1991) and Watabe (1999a and b), and concrete definitions of each morphological phenon were primarily provided in Sakai (1976), and Miyake (1982, 1983). Additional reference to other literature was properly added. On inferring species taxon from corresponding morphological phenon, only the candidates with higher CPUE (>0.5) were introduced into the data set. Conversely, the lower scores indicating CPUE <0.5 of inferred species taxa were also excluded.

To standardize the life style with *Paralomis* spp. among examined decapods, the species taxa represented by shelter constructor like nephropids, or filter feeding chilostylids associated with echinoids and corals, were excluded from the data set.

2. Basic concept of cluster analysis

Prior to the explanation of respective analysis, abstract of cluster analysis had better be provided.

Let us consider the trajectory of a set of species taxa $\{SPa\}$ (a=1, 2, 3, , N) collected from the study area A (further divided into M quadrats $\{Qi\}$ (i=1, 2, 3, , M)) into the multivariate hypervolume H that is constructed by M or N axes. The dimension of H is determined by the selection of species or quadrat as its axis. We can conclude the dim H as N in the former, and M in the latter, respectively. H satisfies the axioms required for the construction of metric distance space ($x, y, z \in \{X\}$, (1) $d(x, y) \geq 0$, $d(x, y)=0 \Leftrightarrow x=y$, (2) $d(x, y)=d(y, x)$, (3) $d(x, y)+d(y, z) \geq d(x, \mathrm{z})$, where *d*, $X=(X, d)$, $d(x, y)$ denote the distance on *X*, distance space, and distance between *x* and *y*, respectively).

The basic concept of cluster analysis is simple "clustering" by certain kind of rigorous methodology in *H*, and the combination of metric index / UPGMA is easily founded by geometric understanding (Kobayashi, 1995). This combination possesses following advantages; (1) independence of dimensional degeneration of *H*; (2) once established the distance matrix among the elements of *H*, we need no more establish it like in non-metric index / weighted pair group method using arithmetic average (Kobayashi, 1995).

As for the similarity index, I would like to select standardized geodesic metric ($(2/\pi)\cdot G$) for the ease on geometric understanding of its implication (Kobayashi, 1995). This index does not satisfy all the axioms required for the constructing the distance space, but it is cleared by following frame of interpretation: Geodesic metric is defined as the angle measuring on the surface of $N(M)$-dimensional unit sphere in *H*.

Prior to each cluster analysis, the log $(X+1)$ transformation of raw data is carried out to reduce the influence from the non-linear correlating characteristics on the relevant data set. As UPGMA is programmed only to use the arithmetic average on clustering OTUs or generated clusters, so that appropriate description of non-linear correlation can be seldom obtained.

3. Gradient analysis and cluster analysis of species

At first, study area *A* and $\{Qi\}$ should be defined. The study area *A*, here Tokyo Submarine Canyon, is divided into three subareas according to (a) types of sediment and submarine topography and (b) abundance concerning *P.* spp., to confirm the concordance in faunal breaks of each subarea (Fig. VI-1; see also Chapters II and V): KN (no catch of lithodids referred to the genus); MZ (less catches of those referred to *P. japonica* Balss, 1911 PJ); NY (sufficient catches of those referred to all *P*. spp., namely, *P. dofleini* Balss, 1911 PD, *P. hystrix* (Dana, 1844) PH, and PJ). Each subarea is further divided into the quadrat at 10 m depth intervals, and total quadrats are settled as (KN, MZ, NY)=(13, 16, 10). The final data sets are then provided as data matrix whose dimension is $M\times N$.

For the gradient analysis, all the scores of *P*. spp. are excluded from the data matrix, and thus data matrix* of each subarea is given (*M* of each data matrix* is KN=13, MZ=16, and NY=10, and *N* is determined totally 66 including 3 *P*. spp.), to demonstrate the concordant faunal break with excluded ones. For the cluster analysis of species, species data matrix KN+MZ+NY, whose dimension is $N=66\times M=39$, is prepared and used for the analysis. Data transformation with the formula, log $(X+1)$, is carried out in both analyses. Each cluster is defined at the appropriate value of similarity index in both analyses.

For the statistic evaluation of remoteness from randomness concerning described correlating structure, bootstrap is often recommended (Manly, 1997). In present study, however, primary interest is situated at the mere description of relevant zonation structure. Naturally, the evaluation never supports the random sampling of saprophagous decapods by the pot system, so that its enforcement was treated as secondary issue.

VI-4. RESULTS

1. Taxonomic results

Total 125 morphological phena were identified, and 66 of them could be inferred as valid species taxa based on their CPUE (Table VI-1; see also Fig. VI-3). The inferred species taxa accounted for over 94 % of total number of individuals in any subarea. The contribution to data sets of excluded morphological phena was quite small. Species composition among subareas was clearly different, only 16 spp. were commonly recognized (Table VI-2). Subarea-specific species taxa were often recognized, especially in MZ up to 22 spp.

2. Gradient analysis

Irrespective of subareas, concordant faunal breaks among them were recognized (Fig. VI-2). Total three faunal breaks, namely, 190 m, 260-280 m, and 310-320 m, were recognized from each result. Moreover, they were also semi-univalently concordant to the patterns of bathymetric abundance of PD, PH, and PJ, in spite of the lack of their scores in each data matrix*. From the comparison between the result in MZ and that in NY, the absence of PJ in MZ turned out to represent the faunal zonation there. The catch of PD in quadrat MZ 280 (indicated by solid circle in Fig. VI-2) was considered as the result of mechanical summation of raw data, rather than the indication of niche shift concerning PD.

3. Cluster analysis of species

The result of cluster analysis of species was almost concordant with those of previous gradient analysis, and roughly divided into three large clusters, namely, KN, MZ, NY >200, KN, MZ <210, and NY 230 (Fig. IV-3). Total 12 clusters, that represent the trajectories of examined species into *H* with least overlapping, were recognized. The correspondence with gradient analysis was as follows: <190 m; {KN 170-190}, {MZ 180-190}: 190 - 210 m; {MZ 190-200}, {MZ 200}, {MZ 200-210}: 230 - 280 m; {NY 230}, {NY 240-280}: 270 - 310 m: {MZ, NY 270-280}, {MZ, NY 270-310}, {NY 270-290}: 300 - 330 m: {MZ, NY 300-330}. However, 12 spp. out of the present 66 spp. were clustered as the set of eurybathic species taxon, {KN, MZ, NY 210-330}.

Each trajectory into *H* of *P*. spp. was clustered independently, with those of different decapod species taxa: PH in {NY 240-280}, with *Cervimunida princeps* Benedict, 1902 and *Pandalus nipponensis* Yokoya, 1933; PJ in {NY 270-290}, with *Munidopsis granulata* Miyake & Baba, 1967; PD in {MZ, NY 300-330}, with *Munidopsis trifida* Henderson, 1885, *Heterocarpus sibogae* De Man, 1917, *H.* sp., and *Plesionika* sp.

VI-5. DISCUSSION

Present results provide quite successful answers for the proposals suggested in Chapter V and the section VI-2. Especially concerning the taxonomic inference, the reliance on Mayr and Ashlock (1991) and Watabe (1999a and b) should be pointed out. The particular discussion will be provided as follows. Compared with the previous works introduced in the section VI-2 from the viewpoint of (1) sampling efforts and (2) accuracy of sampling, present results are also concluded to possess special status among them.

1. Taxonomic results

Present result is the first description of faunal zonation of bathyal saprophagous decapods in the Tokyo Submarine Canyon, with intensive sampling by commercial pot. Moreover, the results are also appreciated from following aspects for the further studies based on the gained materials; (1) mitigation of the taxonomic problems associated with allopatry; (2) taxonomic guide for the future definition of undescribed morphological phena. Especially for the latter, nearly 30 morphological phena may be elected, in spite of the intensive taxonomic studies in neighboring Sagami Nada (see also Chapters I and II).

The species composition is quite variable according to subarea, but its representative species taxa are eurybathic species like *Munidopsis camerus* (Ortmann, 1892), *Goniopugettia sagamiensis* (Gordon, 1931), and *Paguristes* sp. (data not shown; see also Fig. VI-3 and Tables VI-1, 2). On considering the definition of biological species concept in Mayr and Ashlock (1991), it simply represents the diversity of niche-occupying strategy of each species taxon on bottom in the higher ecological category, saprophagous decapods. Further taxonomic inference aiming at stronger results should use efficiently this signifier (*sensu* Mayr and Ashlock, 1991), in addition to the traditional morphological categorization.

2. Faunal and interspecific zonation

For the construction of initial stage to investigate the maintaining mechanism of faunal zonation, (1) rigorous description of relevant faunal zonation, and (2) finding of representative interspecific zonation in it, were proposed in the section VI-2 (see also Chapter V). Several cautions concerning them can be provided as follows.

For (1), division of subarea according to the distribution pattern in *Paralomis* spp. and the selection of depth as the primary explanatory variable in the whole analyses should be discussed. To get the representative interspecific zonation in the relevant faunal zonation, passive confirmation of the validity to select the genus *Paralomis* on the data set of faunal list must be carried out, besides the demonstration of the unique ecological characteristics recognized among saprophagous decapods also in the genus. In present case, (a) the correspondence, namely, horizontal distribution pattern in the genus versus the types of sediment and submarine topography (the definition of subareas, KN, MZ, and NY), and (b) the selection of depth, shows appropriately the faunal zonation among saprophagous decapods. Thus, the initial requirements for the description of relevant faunal zonation in ordinary continental slope can be easily gained through traditional strategy also in the present case.

For (2), present results also provide the positive answer to get the appropriate interspecific zonation representing the relevant faunal zonation. On considering the conceptual definition of the latter, it is defined as the entire body of complicated interspecific interaction among the relevant decapod species taxa (see also Chapter I). Thus, for the most convenient strategy for the present purpose, the selection of representative interspecific zonation at both the orders of species and individual, possesses special status in the study program and field sampling.

3. Small contribution of competitive interaction to faunal zonation

From present results, (1) the representative status of the genus *Paralomis*, and (2) concordant faunal breaks in all subareas, are easily observed. Especially from the comparison with faunal zonation pattern in MZ and that in NY, and corresponding interspecific zonation pattern in the genus *Paralomis*, following suggestion may possess strong probability to maintain their structures respectively.

These results provisionally drive the competitive interaction among the saprophagous decapods respectively referred to different species away from the primary factor to maintain the relevant faunal zonation. However, this suggestion does not indicate the positive conclusion to exclude the competitive interaction, and should be considered as the establishment of second step, accompanied by the first step, description of faunal zonation itself. Only the third step, namely, the special field experiments based on the both steps, can provide the positive conclusion to the present purpose (Jensen and Armstrong, 1991).

For the summary of this chapter, the successful results concerning (1) precise description of faunal zonation among saprophagous decapods in the bathyal zone of the Tokyo Submarine Canyon, based on the rigorous foundation concerning cluster analysis, (2) confirmation of representative status of the genus *Paralomis*, from the viewpoints of (a) ecological characteristics expressed by referred lithodids and (b) construction of desirable interspecific zonation, should be pointed out. Further taxonomic works and the investigation on faunal zonation will be born from them.

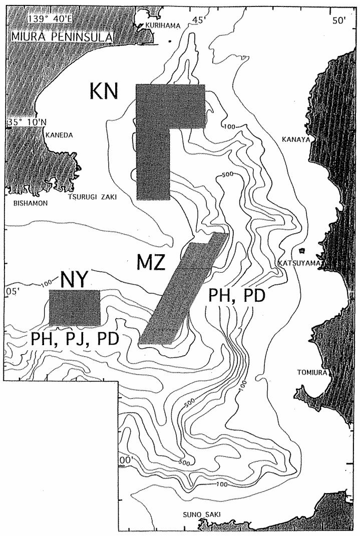

Fig. VI-1. Submarine topography of the Tokyo Submarine Canyon. Each subarea was shown. KN: No lithodid individual captured, MZ: Lithodids referred to *Paralomis japonica* Balss, 1911 rarely captured but the others abundant, NY: Lithodids referred to all *P.* spp. sufficiently captured. PH (*P. hystrix* (Dana, 1844)), PJ (*P. japonica*), and PD (*P. dofleini* Balss, 1911) indicate the positive catch of corresponding lithodids, respectively.

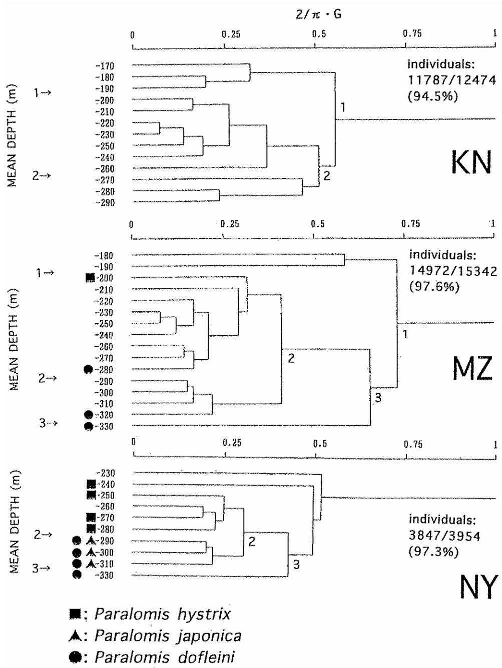

Fig. VI-2. Dendrograms concerning each subarea obtained from gradient analysis. Major faunal breaks, and the number and ratio of used individuals for them were also shown. Corresponding positive catches of *Paralomis* spp. were also indicated.

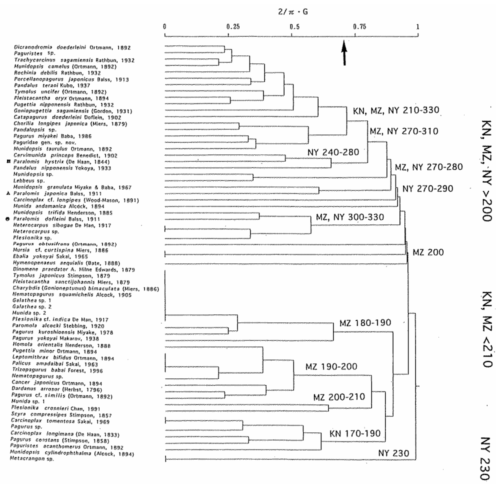

Fig. VI-3. Dendrogram concerning focused species obtained from cluster analysis of species. Arrow indicates the index value to define each cluster.

Table VI-1. Captured saprophagous decapod individuals from the bathyal zone in the Tokyo Submarine Canyon. The number and used ratio of both species taxon ST from total morphological phena MP, and individuals IL from total catch TC, were shown, respectively.

Subarea	ST (MP) (%)	IL (TC) (%)
KN	26 (68) (38.2)	11787 (12474) (94.5)
MZ	52 (90) (57.8)	14972 (15342) (97.6)
NY	33 (53) (62.3)	3847 (3954) (97.3)
Total	66 (125) (52.8)	30606 (31770) (96.3)

Table VI-2. Captured saprophagous decapod individuals from the bathyal one in the Tokyo Submarine Canyon. Species composition herein inferred of each subarea was shown. Numbers in parentheses indicates the total number of species taxa including *Paralomis* spp.

Subarea & category	Number of inferred species taxa
KN	26 (26)
MZ	50 (52)
NY	30 (33)
KN ∩ MZ	21 (21)
MZ ∩ NY	23 (25)
NY ∩ KN	16 (16)
KN ∩ MZ ∩ NY	16 (16)
Total	63 (66)

VII. *PARALOMIS* WHITE, 1856 (LITHODIDAE: ANOMURA) ON THE MINAMI-ENSEI KNOLL, WITH SPECIAL REFERENCE TO DISTRIBUTION PATTERN ASSOCIATED WITH HYDROTHERMALISM

VII-1. ABSTRACT

The faunal composition and interspecific strong segregation concerning the genus *Paralomis* White, 1856 associating with active hydrothermalism in the C-depression of the Minami-Ensei Knoll, southwestern Japan, was investigated and described for the first time by the manned-submersible, DSRV *Shinkai 2000*. Two species taxa, namely, *P. dofleini* Balss, 1911 and *P. jamsteci* Takeda and Hashimoto, 1990, and a morphological phenon highly referable to *P. verrilli* (Benedict, 1894), could be inferred from the video records. Direct comparison of gained lithodid specimens with the others from central

Japan, New Caledonia, and Samoa Island, *P. haigae* Eldredge, 1976, previously known from southern part of the West Pacific, revealed that it should be synonymized to *P. dofleini*, with first record from hydrothermal fields. The horizontal range of *P. jamsteci* and *P. dofleini* was quite different each other, and could be inferred as follows; (1) on the mussel beds closely associated with active hydrothermalism in the case of former, but (2) on the coarse sandy bottom apparently away from there in the case of the latter. Several ecological discussion and suggestion were also provided.

VII-2. INTRODUCTION

The abundant occurrence of lithodid individuals referred to the genus *Paralomis* (Lithodidae: Anomura) in the hydrothermal fields had widely been known to us by the aid of submersibles, ROVs, and TV systems (Kimura *et al*., 1989; Hashimoto *et al*., 1990; Takeda and Hashimoto, 1990; Hashimoto *et al*., 1995). Moreover, their occurrence had been reported around the Nansei Group, southwestern Japan, North Fiji Basin, and where the biological knowledge concerning the genus had never been discussed apart from few limited sampling results and description of new species taxon (Takeda and Miyake, 1980; Takeda, 1985; Saint Laurent and Macpherson, 1997). In the former area, lithodids can be referred to several different species taxa respectively, but only the single species taxon, *P. jamsteci* Takeda and Hashimoto, 1990, had been described as new species taxon, and *P. verrilli* (Benedict, 1894) and an unknown species had also been reported from the other hydrothermal vent site there (Yamamoto *et al*., 2000; Watabe and Miyake, 2000). To get the most basic knowledge for the future biological activity on the relevant genus, the rigorous taxonomic work based on the materials with precise sampling information should be carried out.

As for the ecological survey concerning interspecific zonation or strong segregation among the pertinent species taxa, hydrothermally active spot with considerably small scale is considered as the best study site from the following basis: (1) The formation of steep physicochemical gradient (water temperature, dissolved H_2S concentration, and others) from chimneys to encompassing floor; (2) the highest potential to realize (a) the initial observation of distribution pattern, and (b) successive enforcement of proper field experiment (see also Chapters V and VIII). When (a) several species referable to the relevant genus could be inferred from the gained materials and (b) the apparent zonation or segregation among them could be also recognized successively, both the purposes (1) the investigation of *Paralomis* faunule in hydrothermally active region, and (2) the initial step to carry out the *in situ* experiment concerning the elucidation of maintaining mechanism of relevant zonation or segregation, can be realized.

In this chapter, I would like to demonstrate the taxonomic result obtained from the hydrothermal fields around the Nansei Group, using the manned submersible. For the study area, not referring to the other study sites there, namely, the Iheya Ridge, Izena Caldron, and Hatoma Knoll (Kim and Ohta, 1991; Kimura *et al*., 1989; Watabe and Miyake, 2000), the C-depression on the Minami-Ensei Knoll, situated 140 km westward to Amami-Ohshima Island, was selected simply by following reasons; (1) the achievement of sufficient sampling; (2) the dimension of study area (approximately 500 m × 300 m dimension of southeastern part in the C- depression, and its topographic characteristics as "hydrothermal island" sufficiently isolated from the other active sites by non-vent environment); (3) the highest number of recognized lithodid species there.

The methodological and conceptual framework of taxonomic inference followed Mayr and Ashlock (1991) and Watabe (1999a and b), and concrete taxonomic definition will be properly indicated in the course of discussion. Following abbreviations were also used: JAMSTEC; Japan Agency for Marine-Earth Science and Technology, Japan: MNHN; Muséum National d'Histoire Naturelle, Paris: ORI; the Ocean Research Institute, University of Tokyo.

VII-3. MATERIALS & METHODS

The video records of 15 dives (#428 - #622) of the DSRV *Shinkai 2000*, JAMSTEC, at the study site, the C-depression (July 1989 - June 1992), were analyzed and summed up under following procedure. Recognized lithodid individuals were recorded in each inspected video record and identified by the definition provided in Balss (1911 and 1913), Eldredge (1976), Macpherson (1990a), Sakai (1976) and Takeda and Hashimoto (1990).

The lithodid individuals were captured by a slurp gun and baited traps (for the slurp gun, see Hashimoto, *et al*., 1992). For the determination of taxonomic status of captured individuals, that were provisionally referred to *Paralomis dofleini* Balss, 1911, their direct comparison with other specimens also referred to the species taxon from the other localities was carried out.

Examined material. -The C-depression (all specimens now deposited in JAMSTEC collection): 1 ♂ (carapace length excluding rostral length CL 44.4 mm), #547, unregistered and dried; 3 ♂♂ (33.2 - 47.3 mm) and 1 non-ovig. ♀ (31.5 mm), #548, unregistered and dried; 1 ♂ (24.2 mm) and 4 non-ovig. ♀♀ (21.5 - 30.0 mm), #549, Ano-0002-0006-91, preserved in 70 % ethanol; 1♂ (23.7 mm), 1 non-ovig. ♀ (30.5 mm), and 2 ovig. ♀♀ (37.6 - 39.3 mm), #611, unregistered and preserved in 10% formalin).

Enshu-Nada (ORI collection): 1 ovig. ♀, KT-94-07, St. KN-25.

Kii-Channel (Matsuzawa collection): 1 ♂ (65.1 mm), 18 miles off Muroto, Kochi Prefecture, southern Japan, 300 m deep, longline fishing, collected by K. Matsuzawa, 7 Jan., 1997.

New Caledonia and Samoa Island (MNHN collection): 1 ♂ (74 mm), New Caledonia, outside of the reef, MP Pg 4276; 1 ovig. ♀ (48 mm), off Samoa Island, Alepata Point, 550 m deep, trap, 19 November, 1977 MP Pg 4274. The latter two had been referred to *P. haigae* Eldredge, 1976 in Macpherson (1990a).

General description, mineralogical and topographic characteristics of the study site, and the dive records had been already published and discussed elsewhere (Hashimoto *et al*., 1990; Chiba *et al*., 1992; Nedachi *et al*., 1992; Hashimoto *et al*., 1995; see also Chapter II). In this chapter, only the CO_2 bubbling region was shown as the indicator of hydrothermal activity (see Chapter II).

VII-4. RESULTS

All the taxonomic results on the video records were summarized in Table VII-1. Total two species taxa, namely, *P. dofleini* and *P. jamsteci*, could be inferred from the video record (as for the case of the former, close taxonomic discussion will be provided in Discussion). However, as for the case of a morphological phenon provisionally referred to *P. verrilli* (Benedict, 1894), the sufficiently strong inference turned out to be in vain (Table VII-1). Thus, the successive description of distribution pattern was restricted to the case of the former two species taxa.

From the observations of video records, no positive effect induced by the operation or photo-flashes of submersible was recognized. The lithodid individuals seemed to be usually indifferent to the submersible, but active escape and movement were recognized only when (1) manipulator or slurp gun was used near them or touched them, and (2) baited traps were set near them, respectively. Especially for (2), individuals near trap within 2 - 3 m diameter approached without fail irrespective of species taxon, sex, or size.

The lithodid individuals referred to *P. jamsteci* were the most abundant, but the remaining individuals were relatively few in number (Fig. VII-1). The interspecific segregation was clearly recognized in *P. dofleini* and *P. jamsteci*. The trajectory of species niche on the bottom surface was usually recognized on the mussel beds closely associated with the hydrothermalism around the chimneys in the case of the former, whereas on the coarse sand bottom with sponges and anemones in the case of the latter.

VII-5. DISCUSSION

First of all, (1) successful description of non-overlapping, and strong segregation among the *Paralomis* spp. associating with the active hydrothermalism, and (2) first descriptive record of several *Paralomis* spp. with precise taxonomic inference, should be pointed out. As for the other occurrence concerning the pertinent genus in hydrothermalism, preliminary report only in the North Fiji Basin ("White Lady" site, approximately 2000 m deep) had been reported (Desbruyères *et al*., 1994; Saint Laurent and Macpherson, 1997). Quite different from the case in bythograeid crabs or galatheid squat lobsters, the occurrence of *Paralomis* individuals may be treated as the consequence of accidental occupation of niche rather than the vent-specific occurrence like in the case of cold seep community (Macpherson, 1994).

1. Taxonomic problem concerning *Paralomis dofleini* and *P. haigae*

Paralomis dofleini had originally been described from Sagami Nada (Balss, 1911, 1913), and so far known only from off central Japan (Sakai, 1976; Takeda, 1984; Macpherson, 1990a). As for *P. haigae*, original description in Eldredge (1976) is based on three specimens from off Guam, 400 - 730 m deep. Macpherson (1990a) reported additional localities, namely, New Caledonia and Samoa Island (also from off Indonesia; Macpherson, personal communication).

After Eldredge (1976) and Macpherson (1990a), the main discriminating characteristics within the relevant species can be summarized as follows: (1) More setose scaphocerite in *P. haigae*; (2) spinulation on entire body, namely, lower and more rounded tubercles in *P. haigae*; (3) more rounded anterior margin of carapace in *P. haigae*. Present material from the C-depression turned out to be almost identical to the relevant definition. However, comparative examination showed no distinction by the characteristics mentioned above, especially in the case between the specimens from Japan, referred to *P. dofleini*, and those from New

Caledonia and Samoa Island, referred to *P. haigae*. The taxonomic basis on the election of the latter should be considerably low, and thus it had better be treated as the junior synonym of the former. On considering (1) the biogeography of *P. dofleini*, herein extended from Japan to Samoa Island, and (2) high probability of accidental occurrence of lithodid individual in hydrothermal fields, it may be safe to conclude that present material represents *P. dofleini*, with first record from hydrothermally active region.

2. Strong segregation in *Paralomis* spp. in the C-depression, and suggestion for the field experiment

The initial purpose to investigate the *Paralomis* faunule in the hydrothermally active region was almost fulfilled through the present results. Unfortunately, present results should be treated as the initial information for the enforcement of field experiment proposed below. I provide here only the speculation and suggestion to (1) the possible biological factors to maintain the segregation, and (2) experimental plan to elucidate it.

On considering the high possibility of non-competitive maintenance of interspecific zonation recognized in the Tokyo Submarine Canyon (see Chapters V and VI), inter-individual competition within different species taxa may be lessened also in the present case. Naturally, to characterize the segregation structure by the multivariate analysis using the explanatory variables like water temperature, concentration of H_2S, or other vent-characterizing ones, must be treated as the cues to explain the relevant phenomena biologically.

Like in the present case, the simplest case, namely, interspecific segregation with no overlapping within two species, can be exclusively appreciated (see also Chapters V and VIII). In the identical condition, direct explanation of maintenance mechanism concerning the relevant segregation can be provided from following planning with control near the experiment site; (1) selective elimination experiment; (2) large-scale transplant experiment.

Selective elimination experiment can be divided into two components; (a) selective elimination at the transition zone of two species taxa; (2) following observation of niche shift expressed by the other species taxon. The feasibility of competitive interaction within different species taxa can be drawn, only when normal species structure in the open niche were recognized. Moreover, it should be cautioned that positive inference could not be gained when the apparent niche shift was not observed (for close discussion, see also Chapter VIII). Large-scale transplant experiment possesses the defect to neglect interaction among the individuals referred to the same species taxon (see also Jensen and Armstrong, 1991).

Especially in the case of the marine decapods, their physiological characteristics had been already reported to be not always concordant with the distribution pattern expressed by the relevant species taxon irrespective of their living depth (Vetter *et al*., 1987).

For the summary of this chapter, I would like to underline the conceptual importance of both the field observation and special experiments mentioned above to the laboratory analysis concerning the physiological and ecological characteristics represented by the pertinent individuals (Vetter *et al*., 1994).

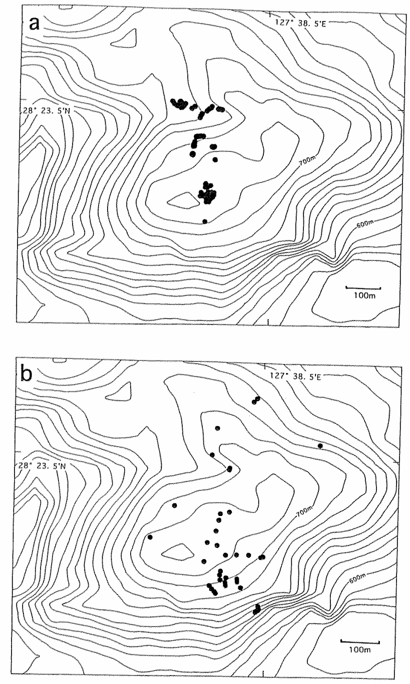

Fig. VII-1. Two species taxa referred to the genus *Paralomis* White, 1856 in the C-depression on the Minami-Ensei Knoll. Solid circles denote the positive site where referable individuals were recognized. a: *Paralomis jamsteci* Takeda and Hashimoto, 1990 b: *P. dofleini* Balss, 1911.

Table VII-1. Two species taxa SP and a morphological phenon MP referred to the genus *Paralomis* White, 1856 recognized from the C-depression in the Minami-Ensei Knoll. The taxonomic result concerning examined lithodid individuals was shown.

name	male	female	undetermined	total
Paralomis dofleini Balss, 1911	29	19	35	83
P. jamsteci Takeda & Hashimoto, 1990	29	16	392	437
P. verrilli (Benedict, 1894)	2	0	0	2
undetermined	2	0	7	9

VIII. EXTRA-HIGH PREVALENCE OF KENTROGONIDS ON BATHYAL LITHODIDS: APPLICATION OF SELECTIVE ELIMINATION

VIII-1. ABSTRACT

Through the accidental establishment of open niche through over-fishing, (1) the primary importance of interindividual interaction within the species taxon and (2) rather small contribution of physiological and ecological characteristics expressed by the individuals could be emphasized to maintain the interspecific zonation among bathyal lithodids. At the entrance of Tokyo Submarine Canyon, central Japan (580 - 740 m deep), the niche shift of *Paralomis multispina* (Benedict, 1894) (original niche deeper than 800 m) into the semi-complete open niche previously occupied by *Lithodes aequispina* Benedict, 1894 was observed with following particulars: (1) Extra-high prevalence concerning *Briarosaccus callosus* Boschma, 1930 (Peltogastridae: Cirripedia) (>98 %); (2) male-biased sex ratio (also >99 %). Moreover, sudden change on species structure (especially sex ratio) of *L. aequispina* occurred with the drastic structural change of *P. multispina* without significant increase of kentrogonid prevalence. Thus, from the present results, the inter-individual interaction within the species taxon, especially associating with reproductive activity, was concluded to be the non-negligible biological factors to maintain the relevant zonation.

VIII-2. INTRODUCTION

In many decapod crustaceans with various ecological characteristics, the unusual interspecific interaction, namely, non-overlapping interspecific zonation, had been reported (Jensen and Armstrong, 1991). In spite of intensive researches with elaborate field experiments for the decapod zonation in intertidal and shallower zones, no example can be found to investigate biologically the positive explanation of its maintenance of zonation in bathyal decapods. It is largely due to the extreme difficulty in (1) finding the relevant zonation and (2) carrying out appropriate field experiment and observation. Especially for the case of lithodid zonation, no previous work had been reported so far.

Among the previous studies, Jensen and Armstrong (1991) on the intertidal zonation shown by two *Petrolisthes* spp. (Porcellanidae: Anomura) is apparently considered not only (1) to provide the most advanced procedure on field experiment, but also (2) to be noteworthy for the physiological and ecological characteristics on maintaining the relevant zonation. However, the experiment program of them seems to possess serious problem closely associated with the interrelationship between species taxon (*sensu* Mayr and Ashlock, 1991) and individual, that is quite appropriately expressed by the definition, "biological species" concept. The conceptual indication of maintaining factor concerning the zonation is unfortunately recognized as the following categorization; (a) biotic factor (indicating the competitive interaction concerning niche or food availability among the porcelain individuals referred to different species respectively); (b) abiotic factor (indicating the physiological and ecological characteristics expressed by the porcelain individual). Thus, they, unfortunately, paid less attention to the special interaction among the porcelain crabs referred to the same species, that exclusively contributes to the maintenance of the species structure usually characterized by reproduction and ontogenic migration (see also Chapters V to VI). Moreover, the more elaborate indication of examined factors should be provided as follows: (a) Physiological and ecological characteristics expressed by the relevant individuals; (b) competitive interaction among the individuals referred to different species respectively; (c) interaction among those referred to the same species. Furthermore, appropriate signifier of (a) - (c) respectively should be selected.

To overcome the deficiencies, appropriate selection of field experiment must be provided with rigorous definition concerning the indicating signifier of species and individual, respectively. Moreover, the ideal condition to examine all of above mentioned biological factors satisfactorily, the (1) selective elimination and the equivalent concerning one species, and (2) successive observation of species structure of migrated species and associated change on individual structure and function, at the periphery of one species, can be presented.

In this chapter, I would like to (1) report the accidental realization of the open niche concerning *Lithodes aequispina* Benedict, 1894, and successive niche shift of *Paralomis multispina* (Benedict, 1894) in the bathyal zone of the Tokyo Submarine Canyon (between the shallower rocky bottom on the steep slope (540 - 700 m deep) and the deeper axial floor (>720 m); see also Chapter II) (Fig. VIII-1). Moreover, I will emphasize the conceptual ideal of (2) the selective elimination to elucidate the most characteristic biological factor to maintain the lithodid interspecific zonation.

Almost complete selective elimination concerning *L. aequispina* happened to be realized between 1977 and 1980, through the onset of commercial pot fishing (see also Chapter II). The initial structure of inter-individual zonation could be inferred to maintain the facing zone at the depth of 800 m (Hiramoto, personal communication; Watabe, unpublished data). The successive but small-scale niche shift of *P. multispina* could be immediately recognized after it from the deeper trough floor (720 - 740 m deep). However, several unusual characteristics, namely, (1) exclusive occurrence of male individuals, and (2) frequent infection of kentrogonid castrators referable to *Briarosaccus callosus* Boschma, 1930 (Fig. VIII-1) on relevant individual only on the shallower continental slope, was observed until 1992. As for the species structure of *P. multispina* in neighboring Sagami Nada, the phenomena above mentioned could never be observed. However, the sudden increase of kentrogonid prevalence at SE off Jogashima, 620 - 750 m deep, concordant with intensive pot fishing was observed from the latter half of 1995 (Kayama *et al*., personal communication).

VIII-3. MATERIALS & METHODS

Main study area, the entrance of the Tokyo Submarine Canyon, was roughly divided into two subareas according to the submarine topography; on the shallower spur (<700 m), and on the deeper trough floor (>701 m). Samplings of lithodid individuals were carried out by the commercial crab-pot fishing there (for the explanation of fishing operation, see Chapter II). Total sampling was carried out from Apr. 1992 to May 1997 (subdivided into 4 terms, T1; Apr. 1992 - Apr. 1993: T2; Nov. 1993 - Jun. 1994: T3; Oct. 1995 - Jun. 1996: T4; Oct. 1996 - May 1997). Usually, pot sampling was not carried out in summer due to the extreme strength of both surface and bottom water movements. Comparative sampling in Sagami Nada was also carried out simultaneously, from off Ninomiya to SSW off Jogashima between depths of 370 and 740 m. Sampling result SW off Jogashima 650-750 m deep, where the sudden increase of kentrogonid infection was observed, was excluded from the data set and shown separately. Five comparative samplings there were carried out at the depth range, 675-740 m, between Apr. - June 1997, using single pot system equipped with 50 crab pots at 50 m interval.

For the lithodid individuals, the taxonomic inference was carried out with special attention to the sex ratio and the rate of kentrogonid infection, (1) to reflect appropriately the biological species concept, and (2) to get stronger inferred results (Mayr and Ashlock, 1991; see also Chapters V-VII). The concrete definition of species category followed Sakai (1976). As for the identification concerning kentrogonid individuals, original description of *Briarosaccus callosus* and successive reports (Sloan, 1984 and else) were used based on the morphology of externa, selection of host, and the geographic range of prevalence recognized there.

For the signifier, (a) individual abundance and sex ratio, and (b) the infection of kentrogonid barnacles itself, were selected as that of the structure and function concerning species taxon and individual, respectively. The abundance of individuals was expressed by Catch Per Unit Effort / 50 crab pots (CPUE). For the determination of sex expressed by lithodid individuals, direct examination of gonad was carried out on board or in the laboratory as accurately as possible (see also Chapter IX). Total sampling results were compiled on the 2D trajectories constructed by the axes (x1, x2), (x1: mean depth (20-m interval for *P. multispina*, whereas binary arrangement concerning topographic characteristics in the Tokyo Submarine Canyon for *L. aequispina*), x2: abundance, sex ratio, or prevalence of kentrogonid individuals).

VIII-4. RESULTS

The kentrogonid-decapod host combination, *Briarosaccus callosus* / *Paralomis multispina*, had not been known so far, and present results is the first report of it.

A large and unusual change on the structures of both lithodid species taxon was observed between T1 and T2 in the Tokyo Submarine Canyon, and described in detail. Extra-high prevalence of kentrogonids was recognized only in *P. multispina*.

1. Abundance

A large change in CPUE of both lithodid species taxon was observed between T1 and T2 in the Tokyo Submarine Canyon. For *P. multispina*, CPUE increased drastically at that time, whereas that of *Lithodes aequispina* conversely decreased considerably (Fig. VIII-2). This trend was constant after T2, in spite of large fluctuation during each sampling term. As for the CPUE of *P. multispina* in Sagami Nada, apparent change during the sampling term was not observed. Thus, only the summation of total sampling results was shown as the indicator of normal structure of the species taxon (Fig. VIII-2).

2. Sex ratio

The trend of sex ratio of *Paralomis multispina* in the Tokyo Submarine Canyon was unusual compared with that in Sagami Nada. The 2D trajectory constructed by the axes, mean depth versus sex ratio, clearly showed a hyperinclination to male individuals. Similarly, that in Sagami Nada also showed similar trend partially (shallower than 640 m) (Fig. VIII-3). At SW off Jogashima, total and each sex ratios were strongly male-biased, namely, ♂/♀ = 7.78 (n = 1546), varying from 6.33 to 11.5, irrespective of depth and the occurrence of ovigerous female individuals.

For *Lithodes aequispina* in the Tokyo Submarine Canyon, drastic change in sex ratio from hyperinclination to female in T1 to insignificant deviation from 1:1 after T2 ($p>0.05$ if the calculation is possible, in each Ti (i = 2 - 4)) was also recognized between T1 and T2. The tendencies continued until T4 (Fig. VIII-3).

The determination of original sex of infected lithodid individual was sometimes difficult in the case of *P. multispina* collected from Sagami Nada on board due to the heavy morphological modification. Thus, here excluded all the infected individuals from all the 2D trajectories concerning the species taxon lest original males and females should be contaminated. Conversely, that concerning *L. aequispina* could be easily carried out because of the slightness of morphological modification (till Stage 2 with complete castration; see also Chapter IX).

3. Infection rate of *Briarosaccus callosus*

As in the case of sex ratio, extra-high prevalence of *Briarosaccus callosus* concerning *Paralomis multispina* was observed throughout the sampling terms (Fig. VIII-4). The prevalence was usually lower in the deeper trough floor. In T1, T2, and T4, each difference in prevalence between shallower (<700 m deep) and deeper (>701 m deep) zones was significant (Zoc=9.408 (T1), 10.08 (T2), and 3.124 (T4), $Z(0.025)$=1.96), whereas not significant in T3 (Zoc=0.4599).

As for the kentrogonid infection rate in *P. multispina* in Sagami Nada, slight contamination within infected male and female turned out to be partially present in the data set, derived from the misidentification of them. Thus, only the total infection rate of the species taxon was shown (Fig. VIII-4). As for the infection rate in SE off Jogashima, close examination was carried out. Total and each infection rates were apparently high, namely, (male, female) (%) = (55.8, 3.4), and (22.1 - 80.6, 0.0 - 15.0), respectively.

Considerably slight increase of kentrogonid infection rate in *Lithodes aequispina* was also recognized after T2, irrespective of depth or sex (Fig. VIII-4).

VIII-5. DISCUSSION

Present results apparently represent the several unusual characteristics. First, (1) the first report of kentrogonid-decapod host combination, *Briarosaccus callosus* / *Paralomis multispina*, (2) the highest prevalence of the kentrogonid barnacles concerning *P. multispina*, (3) conversely low infection rate concerning *Lithodes aequispina* by kentrogonid barnacles in spite of sensitive nature of referable individuals (see Table VIII-1; Sloan, 1984 for Canadian population; Hiramoto, personal communication, for the population in the areas herein examined), can be proposed. Second, the change in sex ratio in both lithodid species taxa, namely, for *P. multispina*, (1) hyperinclination to male in the Tokyo Submarine Canyon and (2) similar but slight inclination to male at SW off Jogashima, and for *L. aequispina*, (3) sudden change into male-biased condition in the Tokyo Submarine Canyon. Here provide the close discussion and comparison with previous reports as follows.

1. Most feasible explanation to the unusual species structure of *Paralomis multispina* in the Tokyo Submarine Canyon

For the biological explanation for the present results concerning *Paralomis multispina* in the Tokyo Submarine Canyon, following two alternatives are present: (1) Constant migration of male individuals and successive infection of kentrogonid barnacles without fail, especially on the shallower spur; (2) the migration of infected male individuals, together with uninfected ones aggregating on the deeper trough floor.

For (1), apparent inconsistencies are not found against the present results and historical premises presented in Introduction. Moreover, on considering the sampling results in Sagami Nada (a: the finding of kentrogonid-prevailing site only at SW off Jogashima from 1995; b: extremely low infection rate in Sagami Nada), the sudden increase of individual abundance may be explained by accidental reason, rather than a certain kind of biological factor. However, following strong basis and premises seem to be satisfied when (2) could be selected: (a) Positive basis for the migratory behavior of infected individuals into relevant site; (b) the special premise to explain the sudden change in prevalence and abundance (especially for the decrease of absolute score of uninfected male individuals); (c) constant generation of infected male individual elsewhere. Thus, the alternative (1) had better be selected based only on the gained results, and the additional premises on explanation should be excluded.

Similar inference can be done to the case of *Lithodes aequispina*, and sudden change only on its species structure (see Figs. VIII-2 to 4) is consistently explained biologically. Moreover, on considering the decrease of individual abundance and concordant change in sex ratio into male, that are closely related to the sudden change on species structure of *P. multispina*, the relevant site may become unsuitable condition as the spawning site for *L. aequispina*. Only from the present results, the biological inference on the abnormal structure of *P. multispina* at SW off Jogashima comes into the same conclusion: The kentrogonid prevalence tends to occur at the disturbed niche in the case of relevant species taxon.

2. Contribution of inter-individual interaction within the species taxon to maintain the inter-specific zonation

From the results, the less competitive interaction among the individuals referable to each different species taxon may explain the inter-specific zonation herein discussed. Here extend the discussion to the assessment of each contribution of (a) inter-individual interaction within a species taxon and (b) physiological and ecological characteristics expressed by individuals.

At first, the case of *Lithodes aequispina* can be explained rather easily. The sudden decrease in abundance of individuals and the inclination to male can be explained by the combination of (a) and (b). On carefully considering the constantly low infection rate of kentrogonid castrators irrespective of high possibility to be infected actually (Hiramoto, personal communication), serious limitation of species niche, especially extending to the immunological defense, derived from the physiological characteristics expressed by the individuals, can not be expected for the species taxon. Actually, the certain kind of sex-specific expression concerning (a) can not be neglected, but they can not help being accompanied by the relating concerning (b). In any way, rather larger contribution of (b) should be proposed for the species taxon.

Second, as for the case of *Paralomis multispina* in the Tokyo Submarine Canyon, it is explained as the proceeding of (a) and successive and severe contribution of (b), when the alternative (a), namely, the immigration and successive infection, were selected in the previous Section a. Moreover, even if the alternative (b), namely, the migration of infected individuals, would be selected, the special interaction among infected and uninfected ones must be considered as soon as the migration happens. On carefully examining the sex-ratio profiles of the species taxon, it can be highly expected to relate the reproductive interaction like the migration to the spawning site or the unusual or disturbed environments herein examined.

From both of above mentioned discussion, the contribution of inter-individual interaction within species taxon, especially relating to reproduction, can be emphasized on maintaining not only (1) species structure of respective species taxon but also (b) interspecific zonation, as the special case of interspecific interaction. Thus, the previous discussion concerning the cause of high kentrogonid prevalence in lithodid species taxon should be largely revised to consider the biological factor previous to (1) the reductive discussion to the individual order corresponding with physical parameter (Hawkes *et al*., 1986), (2) physiologically less resistant nature of lithodids (Shirley *et al*., 1985; Hawkes *et al*., 1986), or (3) less tolerant nature of the lithodids against the kentrogonid larvae due to inefficient cleaning behavior of the lithodids (Sloan, 1984, 1985; Hawkes *et al*., 1986), and compound among them. Especially the results of Sloan (1984) should be appreciated through its partial reference to the reproductive structure of *L. aequispina*. Apart from the exceeding from them on the viewpoint of the height of prevalence (Table VIII-1), the importance of consideration to the inter-individual interaction can be easily understood from the present results.

The conclusion herein provided is considered to provide the concordant results from the analysis concerning physiological characteristics like oxygen-consumption or respiration efficiency among bathyal decapods (Henry *et al*., 1990). Unlike bathyal fishes, the discrepancy between physiological tolerance and the distribution pattern may be common in the relevant taxa (Somero and Childress, 1990; Cowles *et al*., 1991; Vetter *et al*., 1994). It can be considered as the indirect support for the suggestion herein inferred.

3. Problems on selecting the signifier of species structure

In present chapter, (a) individual abundance and sex ratio for the detection of abnormality on species structure, and (b) kentrogonid infection itself for the physiological function expressed by the individuals, were selected respectively. Actually, the other signifiers could be provided, but some of them may express slight problems to deal with, especially for the case of species structure.

For representatives among them, (1) carapace length, (2) modality of morphological modification expressed by the infected lithodids, and (3) the degree of multiple infection of kentrogonid barnacles, are pointed out. However, following awkward condition, closely associated with ecdysis can be directly recognized.

The process of absolute growth expressed by a crustacean individual can be easily modeled by the “going up-stair model” through the linear combination of the product between the Heaviside's function and the size increase at respective stage per ecdysis (Sasaki, personal communication). Thus, if the fundamental parameters like the variance mode of carapace length, duration of ecdysis, and the growth at each developmental stage were fully available, the measurements of a certain body part concerning the field population contributes strongly to elucidate the population dynamics of decapods.

As for the present case of *Paralomis multispina*, the initial information concerning (1) the infected individual: (a) morphological modification per ecdysis; (b) the size of lithodids preferred by kentrogonid larvae; (c) the growth rate (in the simplest case, increase or decrease after the kentrogonid infection), and (2) the initial structure of migrating population should be highly required besides those concerning uninfected individuals. Thus, the characterization of relevant structure of examined species can be realized, but the reductive discussion to the individual order can be unexpectedly conclude only to provide the weak speculation. From the discussion, it seems to be safe that the selection of above mentioned three signifiers and successive analysis on the raw data should be postponed until the basic information concerning the individual available.

For the summary of this chapter, I emphasize the strong contribution of inter-individual interaction within species taxon on the maintenance of not only species structure itself but also interspecific zonation especially in the bathyal lithodids. Moreover, selective elimination, but to be as smallest in scale as possible, can be one of the best ways for its elucidation and qualitative assessment. As for the deep-sea lithodid fishing activity, the new danger associated with over-fishing should be cautioned from present study. Careful planning to prevent the kentrogonid prevalence from spreading may be required in every situation.

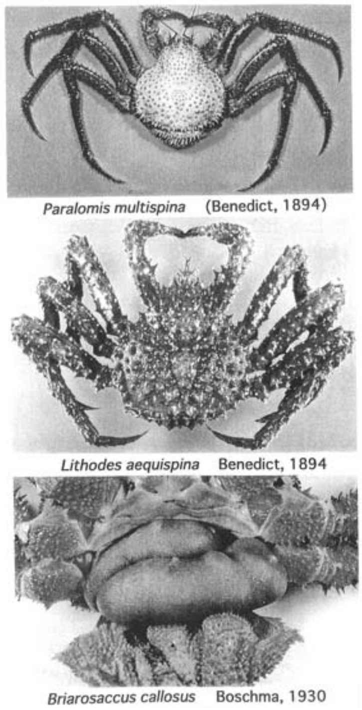

Fig. VIII-1. *Paralomis multispina* (Benedict, 1894), *Lithodes aequispina* Benedict, 1894, and *Briarosaccus callosus* Boschma, 1930. Entire body of referable individuals was shown respectively.

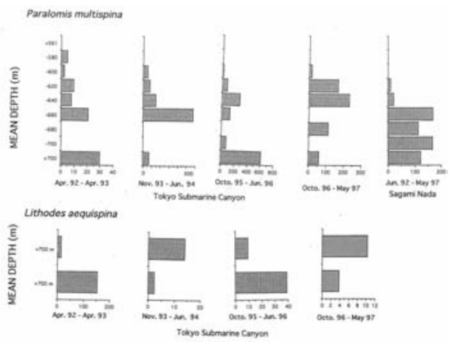

Fig. VIII-2. *Paralomis multispina* (Benedict, 1894) and *Lithodes aequispina* Benedict, 1894 in the Tokyo Submarine Canyon and neighboring Sagami Nada. CPUE profiles against the axis of mean depth of each species were shown as trajectories of system structure of them.

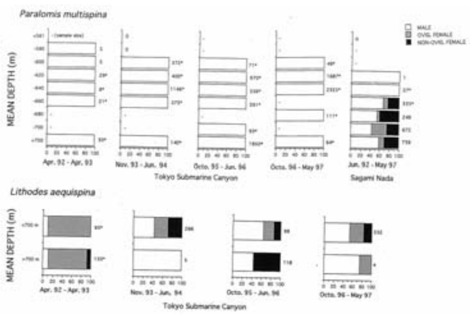

Fig. VIII-3. *Paralomis multispina* (Benedict, 1894) and *Lithodes aequispina* Benedict, 1894 in the Tokyo Submarine Canyon and neighboring Sagami Nada. Sex ratio profiles against the axis of mean depth of each species were shown as trajectories of system structure of them. *indicates the significant deviation from 1:1 (p<0.05).

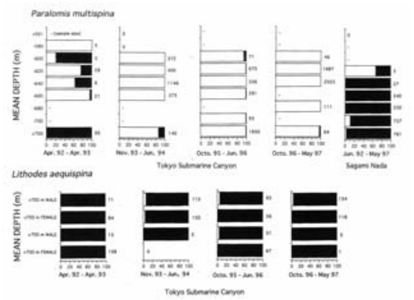

Fig. VIII-4. *Paralomis multispina* (Benedict, 1894) and *Lithodes aequispina* Benedict, 1894 in the Tokyo Submarine Canyon and neighboring Sagami Nada. Profiles of prevalence of kentrogonid individuals against the axis of mean depth of each species were shown as the trajectories of system structure of them.

Table VIII-1. *Briarosaccus callosus* Boschma, 1930. Its higher prevalence on some lithodid species was shown.

host lithodid species	prevalence of *B. callosus* (n)	locality	reference
Lithodes aequispina Benedict, 1894	415 % (133)	Lynn Canal, Alaska	Hawkes *et al*., 1986
	40.5 % (3045)	Portland Inlet System, northern British Columbia	Sloan, 1984, 1985
Paralithodes platypus (Brandt, 1850)	76.9 % (227)	Glacier Bay, Alaska	Hawkes *et al*., 1986
Paralomis multispina (Benedict, 1894)	98.6 % (10875)	Tokyo Submarine Canyon, central Japan	present study

IX. KENTROGONID MATERNALIZATION: MODEL OF SYMBIOSIS

IX-1. ABSTRACT

The unusual interrelationship between kentrogonid barnacles and host decapods was rigorously defined under the term, “kentrogonid maternalization,” mainly through the first finding of complete feminization (in male) and castration (in both sexes) of host in the case of *Paralomis multispina* (Lithodidae: Anomura) / *Briarosaccus callosus* (Peltogastridae: Kentrogonida: Rhizocephala). The term was defined to characterize the following particulars of relevant phenomenon; (1) the exclusion of the case of akentrogonids (the other rhizocephalans) / corresponding host decapods from discussion; (2) the most characterizing interaction between kentrogonids and host decapods, egg mimicry, together with the negative effects on host gonads and the modification on external morphology. The main differences from the nearest case of braconid wasp / prey lepidopteran larva was summarized as follows; (1) the complete loss of autonomic characteristics as individual of kentrogonids; (2) passive suppres-

sion of host immunological response instead of apparent destruction; (3) suppression of death of host decapods as the direct consequence of infection. Several perspectives in decapod endocrinological and immunological studies were also provided.

IX-2. INTRODUCTION

The suborder Kentrogonida Delage, 1884 (Rhizocephala: Cirripedia) is characterized by unusual taxonomic and ecological characteristics on (1) life history concerning referable individuals (Figs. I-1, and IX-1) and (2) host modification (Høeg, 1995; see also Chapter II). In the suborder, three families, namely, Sacculinidae Lilljeborg, 1860, Lernaeodiscidae Boschma, 1928, and Peltogastridae Lilljeborg, 1860, had been macrotaxonomically placed (Høeg and Rybakov, 1992). These characteristics can be recognized only in the suborder, and they can be discriminated from the other families in diverse Rhizocephala, namely, those referable to Akentrogonida Häfele, 1911 (Høeg and Rybakov, 1992). In spite of relatively close studies on ecology, histology, and biochemistry of the former two families, only fragmental reports can be so far found for the third family (Shiino, 1931; Yanagimachi, 1960; Høeg, 1995). Especially for the case of lithodid host, there had been so far no close examination with the exception of simple histopathology in Sparks & Morado (1986).

Recently, the formalization of interrelationship between kentrogonid barnacles and corresponding decapod hosts were carried out by Høeg (1995) with following conclusions: (1) Discussing domain as the interrelationship between diverse rhizocephalans and corresponding decapod hosts; (2) feminization and sterilization of host as characterizing interaction. However, these combinations contain serious discrepancies not only between the previous results but also between his summary and discussion. For the solution of them, (1) rigorous definition of discussing domain, and (2) elaborate examination of the whole series of the relevant interrelationship, and (3) the indication of the most typical example, should be prepared. Besides it, conceptual consolidation especially concerning the terminology, namely, interrelationship / interaction, sex / gender, castration / sterilization, and symbiosis / parasitism, should be provided (Ishikawa, 1994; Margulis and Sagan, 1995). Moreover, clear distinction from the evolutionary discussion should be established to avoid the invalid understanding concerning the relevant interrelationship (Mayr and Ashlock, 1991; Mayr, 1994).

In this chapter, I would like to suggest the term, “kentrogonid maternalization,” for characterizing the unusual aspect of the relevant interrelationship, based on the full set of variety in it. Among the set, the most typical case between *Paralomis multispina* (Benedict, 1894) (Lithodidae: Anomura) and *Briarosaccus callosus* Boschma, 1930 (Peltogastridae) with the complete morphological feminization and castration can be observed. Furthermore, (1) difference from the “parasitic” case of braconid wasp / lepidopteran larva, and (2) future perspective in the decapod endocrinology and immunology, will be also discussed and provided, respectively. Not only the cue to elucidate the relevant interrelationship but also the advanced planning concerning diverse symbiosis will be drawn from the present discussion.

IX-3. MATERIALS & METHODS

The relevant combination was investigated from the materials collected from the bathyal zone in the Tokyo Submarine Canyon and neighboring Sagami Nada, central Japan. The taxonomic inference followed Mayr and Ashlock (1991), and concrete identification was carried out in the manner presented in Chapters III - VIII.

Total 25 combinations were recognized, and 8 of them were closely examined (Table X-1). For the ease of analyses, I exclusively selected the case iv in the following anatomical and histological surveys, and laboratory rearing. However, the existence of reproductive system of infected host individuals was provisionally examined in the case of i-1, i-4, and ii-1, using 5-10 host individuals bearing kentrogonids.

Infected lithodid individuals were closely examined on their external morphology. Especially in males, I took special attention to following characteristics of them; (1) morphological modification of abdominal somites into feminine ones; (2) presence of feminine abdominal appendages on ventral surface of abdomen; (3) opening of feminine gonopores on the coxa of third ambulatory leg; (4) feminine dwarfing of chelae and ambulatory legs; (5) clear distinction between infected male and female individuals. Multiple infection and death after infection (confirmed by the scars left on the abdominal surface of host individuals) of kentrogonid individuals, were based on the direct confirmation of the developmental difference of kentrogonid larvae in the externae.

Anatomical surveys of them were also carried out, especially for (1) the distribution pattern of interna of the individual referred to *B. callosus*, and (2) target organ of host by it. To confirm immunological response, especially through proPO cascade, careful observation of interna condition in pro- and post-detachment of externa from the body of host individual was also carried out.

Histological surveys including TEM observation were carried out by ordinary methods to confirm the invading modality of interna for the host neurosecreting organ, especially for ventral ganglionic mass (VGM), and the structural characteristics of interna.

Five infected lithodid individuals, whose original sex was inferred as male, were introduced into a cold aquarium (4°C), to observe the interaction between them and infecting kentrogonid individuals (Dec. 1996 - Mar. 1997). Moreover, to confirm the final condition among them, starvation experiment till the death of host individuals was also carried out successively.

IX-4. RESULTS

1. Morphological examination and laboratory rearing

Total 3429 originally male (not deductive but inductive sense), and 15 originally female (same in male) individuals were examined, respectively. The position of externa was usually restricted to the ventral surface of abdomen, but sometimes recognized on the connective membrane jointing the plates on the ventral surface of host abdomen. In extreme cases, small externae could be also observed to erupt from the wounds on host sternum (2 cases) and coxa of ambulatory leg (single case). The loss of externa was also observed frequently, it was easily recognized by the presence of scars (Fig. IX-3).

The morphological modification of the host lithodid individuals was inferred and categorized as following sequence of stages (Figs. IX-1-3): Stage 1: slight enlargement of abdomen and feminine dwarfing of chelae and ambulatory legs, Stage 2: emergence of feminine abdominal appendages on inner surface of abdomen, Stage 3: opening of a gonopore, usually on the coxa of left third ambulatory leg, Stage 4: opening of remaining gonopore, the individuals could be hardly distinguished from infected female ones, excluding the absence of setae on coxa of ambulatory legs and sternum.

Multiple infection was described as follows (Fig. IX-4). Class 0: scarred, namely, the loss of externa; Class 1: single infection; Classes 2-4: multiple infection. The class number indicates the number of infected kentrogonid individuals, but Class 4 involves the case of infection by >3 (maximally 20) kentrogonid individuals.

The dependence between morphological modification and multiple infection of infected lithodid individuals was strongly significant (Table X-2, X_0 square = 318.6422, X square (12, 0.05)=21.126, df = 12). However, it was biologically concluded that the morphological modification neither progressed nor suppressed according to the degree of multiple infection.

All the infected male hosts in Stages 1-4 could be observed to express maternal care for the externa through observations in the laboratory. Not only the brushing or cleaning by fifth pereopods and chelae on externae but also positive help for their molting was frequently observed until the death of host individuals. Total 5 infected individuals by single kentrogonid individual were introduced to starvation experiment for 1-3 months, all of them showed above mentioned cares for externae until their death. No detachment of externa due to the attack by host individual and autotomy of infecting kentrogonid individual itself could be observed.

2. Anatomical and histological surveys

Provisional anatomies on the cases i-1, i-4, and ii-1 revealed complete castration, irrespective of the case and the original (inductive sense) sex of host decapod individuals.

The anatomical survey of 5 - 10 originally male infected host individuals at each stage and 15 originally female ones was carried out. Irrespective of the original sex of host individuals, complete castration and following structural and functional characteristics of interna were commonly observed.

The structural and functional differentiation of total interna was never recognized even under a binocular, independent of ontogenic process after the infection into the physical body of host individual. The interna in host's physical body was described as light pea green when the gonadal activity in externa was recognized. However, internae changed into darker green when the activity of kentrogonid individual changed into inferior condition, especially when the detachment of externae from host's body.

The distribution of interna in the physical body of host individual was observed to be (1) restricted to the cavity beneath the intestinal system, and (2) never invaded into any organ referred to intestinal system, sternal muscles or connective tissues, independent from both the progress of morphological modification and the degree of multiple infection (Fig. IX-5). On the contrary, frequent attachment and direct invasion of interna to VGM was always recognized (Fig. IX-6). (1) In the physical body of infected individuals without the eruption of externa, the interna could be frequently recognized to entangle itself with VGM. (2) Independent from both the progress of morphological modification and the degree of multiple infection, the entanglement of interna with VGM was observed to be restricted to the posterior end and the jointing region with giant axons running into third and fourth ambulatory legs and abdomen. The other neurosecreting organs, namely, brain, X organ and sinus gland in the eye stalk, and any other organ and tissue, was never found to be directly invaded or attached (Fig. IX-6). Due probably to the possession of hemoglobin in the hemolymph in the latter, the complete independence on each circulatory system among host and infecting individuals could be easily concluded. The nutrition mode of the latter from host individuals was inferred to be from the surface absorption (probably endocytosis) of interna.

Complete castration of infected male host individuals was inferred to attain in Stage 2. In female host individuals, complete castration was observed in all cases. In both originally male and female individuals (inductive sense), it was also inferred to be irreversible from the unanimous absence of their own reproductive systems even after the death of infecting kentrogonid individuals. In Stage 1, traces of testis and vas deferens were rarely recognized, but they seemed to lose their function compared with those of uninfected male individuals through their apparent structural atrophies. No attachment and invasion of interna to any remaining portion of male reproductive system was also recognized.

From anatomical level concerning the 10 scarred lithodid individuals based on the color of interna, no immunological recognition of invading interna as “non-self” by host’s proPO cascade was recognized until the connecting externa was detached from host’s body (Fig. IX-6). The active operation of proPO cascade was observed through the change of interna from light pea green to darker green due to the generation of melanin (see also Sparks & Morado, 1986). Actually, melanin-enclosure of the interna could be frequently observed at that time.

Histological observation of invaded VGM under a light microscope reconfirmed the slight but direct invasion of interna into the posterior end of VGM, independent from both the progress of morphological modification and the degree of multiple infection (Fig. IX-7). Moreover, any melanin-enclosure through host’s proPO cascade for the interna invading into or entangling to VGM could never be observed in any image, when the gonadal activity of externa could be apparently observed. Unfortunately, that of the case when the externa was detached from host body could not be observed at that time. The microscopic image of toluidine blue staining and TEM images of interna provided (1) its highly reticulate and interstitial histological characteristics, (2) the presence of thick basal membrane directly bathing in the host’s circulatory fluid, (3) the entangling of “pseudopod” from the cells constructing the whole interna, and (4) the presence of small nucleus and few mitochondria, but well-developed and many endoplasmic reticula. Especially for the well-stained granules by toluidine blue in each cell, many ones were observed in every cell without fail (Fig. IX-8).

IX-5. DISCUSSION

Present results are concluded to provide a set of examples fully expressing the unusual characteristics of the relevant interrelationship concerning kentrogonid barnacles. In the following discussion, (1) the most typical status of the case of *Briarosaccus callosus* / *Paralomis multispina*, presently documented for the first time to the science, (2) the definition of the term, “kentrogonid maternalization,” and (3) apparent difference from the case concerning braconid wasp, will be focused. Future perspective derived from them will be also proposed in (4).

1. Most typical status of Briarosaccus callosus / Paralomis multispina

Present finding of the case, *Briarosaccus callosus* / *Paralomis multispina*, provides the first example with the combination of (1) complete feminization of external morphology of male host, (2) enforcement of castration, (3) VGM as the unique target organ, (4) frequent occurrence of multiple infection, (5) rediscovery of passive escape from host immunological response (Sparks and Morado, 1986), and (6) enforcement of “egg mimicry” (*sensu* Ritchie and Høeg, 1981) in infected male individuals. Besides the first elaborate analysis on lithodid case, these findings are apparently concluded as the ripe one in the interrelationship (Høeg, 1995; Høeg and Lützen, personal communication; Takahashi, personal communication).

For complete feminization, the *Paralomis*-specific tendency may be proposed. As had been briefly described in Chapter VIII concerning *Lithodes aequispina* Benedict, 1894 in the Tokyo Submarine Canyon, only the slight modification till Stage 2 could be recognized for the case. On the other hand, the catch of almost feminized (Stage 3) male individuals could be strongly inferred in the case of *P. dofleini* Balss, 1911 and *P. japonica* Balss, 1911 from Sagami Nada (Watabe, unpublished data). For the rigid conclusion and general suggestion as comparative-biological investigation, the preparation of comparative materials should be provided not only for the genus but also for the other host taxa.

The biologically insignificant correlation between the modality of morphological feminization and the degree of multiple infection is suggested to be derived from the complicated endocrinological control of host by kentrogonid individuals. Unfortunately, quite a few studies could be counted so far, and only the SDS-polyacrylamide gel electrophoresis pattern of infected host VGM was investigated (Rubiliani & Godette, 1981). From the present results, simple attribution to humoral induction in proportion to the number of kentrogonid individuals can not be supported.

In the present case, the invasion of interna only into VGM should be emphasized by the slightest attack on host physical structure. The selection of target organ usually spreads from intestinal and genital systems to neurosecreting organs like brain, eye-stalk (Høeg, 1995; Takahashi, personal communication). Thus, in the present combination, the kentrogonid individual can be strongly inferred to compensate nutritional requirement through the surface absorption directly from the host hemolymph. Moreover, the contribution through the humoral endocrinological control may be considerably large together with the direct control of VGM activity associated with mechanical invasion into it. The abundant production of organic polymer quite well stained by toluidine blue may also contribute to the endocrinological pass-way.

The passive escape from host proPO cascade and the unique structure of interna in the present case may offer a good example to investigate precisely the decapod immune system as the case of braconid wasp. Thick basal membrane and entangling of pseudopods might be related to the mechanism to endure the host immunological attack (both the cellular and plasma components) as in the case of braconid wasp. However, considering the scarceness of the previous report in decapod immunology, the total sequence of lithodids should be concretely examined through the same analysis in diverse insects (Wago, 1983; Wago, *in* Natori *et al*., 1992; Ashida, *in* Natori *et al*., 1992; Mori, *in* Natori *et al*., 1992). However, the less feasibility of complete or severe destruction on host immune system like in the case of braconid wasp by elaborate procedure may merely propose the absence of specific epitope on the surface of interna when the kentrogonid individuals keep their healthy condition (Wago, 1983).

2. Definition of the term, “kentrogonid maternalization”

On carefully examining the previous results such as the summary in Høeg (1995), the host selection in the interrelationship is characterized by the following combinations, especially with the crab-shaped decapods equipped with elaborate maternal care: Sacculinidae - Suborder Brachyura (“true crab”); Peltogastridae - Superfams. Paguroidea and Lithodidoidea (or “king crab”); Lernaeodiscidae - Superfams. Galatheoidea, Munidoidea, Munidopsoideda, and Porcellanoidea (or “intertidal porcelain crab”) (see also Chapter V; Watabe, unpublished data). Moreover, the eruption and occupation site of externa of kentrogonids after infection is only at the inner surface of abdomen where the host embryos usually occupy and chelae or cleaning limbs of maternal hosts easily reach. These combinations had not been fully recognized in akentrogonid interrelationship so far. Thus, the discussing domain is defined as the specific combination of kentrogonids / corresponding host decapods, quite appropriately represented by the adjective, “kentrogonid.”

To represent the characterizing interaction, the following terms had been enumerated: For the external morphology of host; (a) feminization (Høeg, 1995); (b) destruction of secondary gender characteristics: For the negative effect on genital system of host; (c) sterilization (Høeg, 1995); (d) castration. Unfortunately, all the possible pair-combinations among a - d contradict the previous results (present results; Shiino, 1931; Okada and Miyashita, 1935; Matsumoto, 1952). In extreme case in Okada & Miyashita (1935), even the gonadal modification of testis into ovary can be recognized. Referring to the establishment of egg mimicry (DeVries *et al*., 1987; Takahashi *et al*., 1997), the term “maternalization” must be most consistent.

The combined term “kentrogonid maternalization” will settle the discussing domain, and provide a sound basis not only for further endocrinological / immunological analysis on the interrelationship, but also for further examination on akentrogonid interrelationship and taxonomy, that expresses the more complicated condition than in kentrogonids (Høeg, 1995).

3. Apparent difference from the case in braconid wasp

The interrelationship defined by “kentrogonid maternalization” shares a lot of characteristics with parasitic case in braconid wasp (Takabayashi and Tanaka, 1995; Yamamura *et al*., 1995). However, besides the resemblance as “parasite,” the apparent difference, especially concerning the autonomy of invading organism, can also be confirmed.

The identical and similar effects on host are summarized as follows: (1) Nutritional exploitation; (2) destructive or passive escape from host immune response; (3) negative effect on host genital system; (4) endocrinological control of ecdysis, and gender maintenance (only for kentrogonid maternalization); (5) passive aid to invader from host physical body like egg mimicry (Takabayashi and Tanaka, 1995).

However, apparent differences can be pointed out, namely, (6) complete loss of autonomic characteristics in kentrogonid maternalization, and (7) host mortality in the case of braconid wasp. Rather, on closely considering the importance concerning host regulation, the kentrogonid individuals can be identified in the structure of host individual as "symbiont" (*sensu* Ishikawa, 1994), whereas the larva of braconid wasp in the physical enclosure of prey lepidopteran larva can be rather considered as the predator or unfavorable "guest" (*sensu* Ishikawa, 1994). Especially for the present case of *B. callosus* / *P. multispina*, the kentrogonid interna occupies the "organ state" in the interactive network among the host organ (Watabe, 2000). Thus, the abuse of "host" for the latter case should be restrained.

Establishment of "loss of autonomy" can be recognized on cellular level: "intracellular symbiont" for the proteobacterian taxa, γ-subdivision and a part of β-subdivision - "guest bacteria" for α-subdivision (Ishikawa, 1994). These conversions on terminological implication can be also recognized in the system-theoretical re-understanding of symbiosis itself (Margulis and Sagan, 1995).

The relevant interrelationship is also characterized by following species interrelationship and interaction conditions, namely, (1) loss of autonomy as individual for the former, and (2) the establishment of mother / off-spring interaction, respectively. This condition is also recognized in the aphidid primary intracellular symbiosis, namely, the loss of free-living nature of the symbiont (for the interrelationship), and nitrogen metabolism (for the interaction) (Ishikawa, 1994).

4. Future perspective

The term, kentrogonid maternalization, provides not only (1) the comparative biological scope in the relevant interrelationship, but also (2) the insight to (a) the sex and gender differentiation among decapod crustaceans, (b) the immunological mechanism like in the case of braconid wasp, and (c) the regulation concerning ecdysis.

Among them, chemical and quantitative analysis concerning recognition or high-density lipoproteins represented by lipopholin or vitellogenin should be initially examined (Spaziani *et al*., 1995). It may provide the direct insight to (1) the endocrinological change into "female" of the internal environment of infected male host (Andrieux *et al*., 1986), and (2) structural coupling among various biochemical cascades, like ecdysis and oogenesis, and associated hormonal regulation. The analysis may contribute directly to the investigation of sex and gender differentiation in both decapod and kentrogonid individuals, like in the case of isopods (Charniaux-Cotton and Payen, 1985; Fingerman, 1987; Suzuki, 1987, 1992; Suzuki and Yamasaki, 1990, 1991a and b, 1995, 1997, 1998).

For the summary of this chapter, several important conclusions concerning the terminological usage should be again proposed as follows: (1) The difference between "sex" and "gender," namely, the generating ability concerning gamete in the former, but the associating characteristics expressed by organ or individual in the latter; (2) "interrelationship" and "interaction," especially on the identifying the "symbiotic" (*sensu* Margulis and Sagan, 1995) condition.

Fig. IX-1. *Paralomis multispina* (Benedict, 1894) and *Briarosaccus callosus* Boschma, 1930. Symbiotic interrelationship among a host and two kentrogonid individuals was shown.

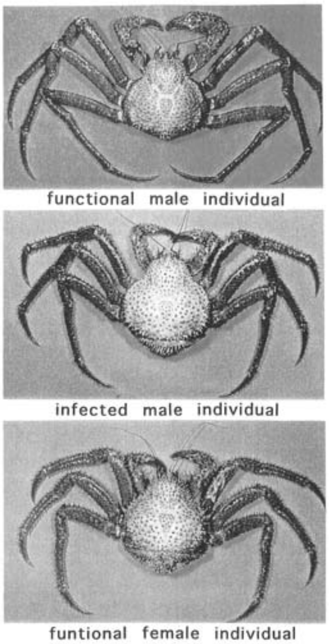

Fig. IX-2. *Paralomis multispina* (Benedict, 1894). The morphological change of originally male individual after the infection of kentrogonid individuals referred to *Briarosaccus callosus* Boschma, 1930, with the presentation of typical morphology of functional male and female individuals.

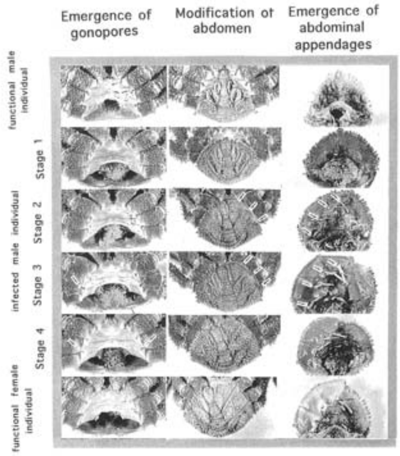

Fig. IX-3. *Paralomis multispina* (Benedict, 1894). The diagrammatic scheme of morphological modification on originally male individuals after the infection of kentrogonid individuals referred to *Briarosaccus callosus* Boschma, 1930. Uppermost and lowermost figures indicate the functional male and female individuals, respectively. Successive modification was shown as follows. Stage 1: slight enlargement of abdomen and dwarfing of the chelae and ambulatory legs; Stage 2: emergence of feminine abdominal appendages on inner surface of abdomen; Stage 3: opening of gonopore, usually on the ventral surface of coxa of third ambulatory legs; Stage 4: opening of gonopore of remaining one.

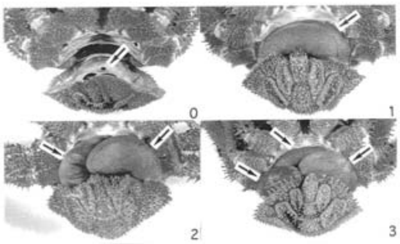

Fig. IX-4. *Paralomis multispina* (Benedict, 1894) and *Briarosaccus callosus* Boschma, 1930. The multiple infection of kentrogonid individuals referred to the latter on the lithodid individual referred to the former. The degree of it was shown and categorized as follows. Class 0: scarred, externa(s) detached from the physical body of host individual; Class 1: single infection; Classes 2 and 3: double and triple infection. Class 4 was actually settled for the infection case by >3 kentrogonid individuals, but figure was not shown.

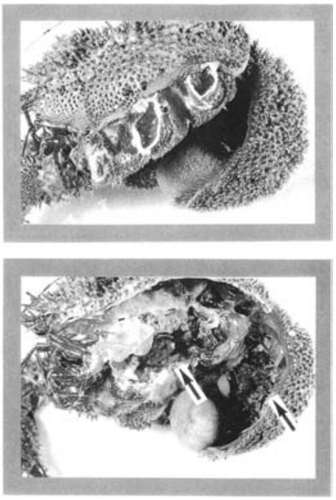

Fig. IX-5. *Paralomis multispina* (Benedict, 1894) and *Briarosaccus callosus* Boschma, 1930. The distribution pattern of interna of infecting kentrogonid individual in the physical body of host lithodid individual was shown. Upper: before the exclusion of exoskeleton; Lower: after the exclusion.

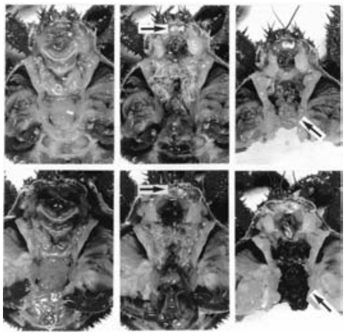

Fig. IX-6. *Paralomis multispina* (Benedict, 1894) and *Briarosaccus callosus* Boschma, 1930. The immunological activity through proPO cascade of host lithodid individual against the interna of infecting kentrogonid individual was shown. Upper: for the interna possessing the externa exhibiting active reproduction; Lower: for the interna without externa. Arrows in the middle indicate the brain of host individual that was not invaded or entangled by interna irrespective of the condition of infecting individuals, those in right indicate the color change of interna.

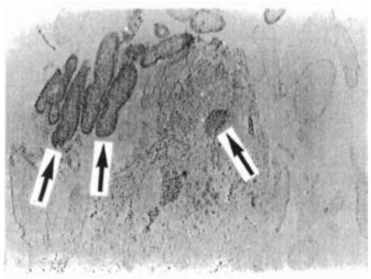

Fig. IX-7. *Paralomis multispina* (Benedict, 1894) and *Briarosaccus callosus* Boschma, 1930. Light microscopic image of VGM of infected lithodid individual. Arrows indicate the invading interna into the tissue of VGM.

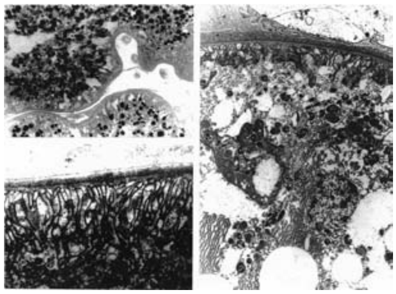

Fig. IX-8. *Briarosaccus callosus* Boschma, 1930. Light microscopic and TEM images of the interna of infecting kentrogonid individuals. 1: light microscopic image stained by toluidine blue, with many well-stained granules in the cells; 2: TEM image of entangling of “pseudopod” from the cells constructing the interna and thick basal membrane; 3: TEM image of whole cells constructing the interna.

Table IX-1. Combination between kentrogonid species and host decapod species. Various modality of morphological modification recognized from the Tokyo Submarine Canyon and Sagami Nada, central Japan, was shown.

i. no apparent modification in both sexes of host individuals
i-1. Sacculinidae gen. sp. 1 / *Trachycarcinus sagamiensis* Rathbun, 1932 (Cancridae: Brachyura)
i-2. ?*Peltogaster* sp. 1 (Peltogastridae) / *Porcellanopagurus* sp. (Paguridae: Anomura)
i-3. ?*Peltogaster* sp. 2 / *Catapagurus doederleini* Doflein, 1902 (Paguridae: Anomura)
i-4. *Lernaeodiscus* sp. (Lernaeodiscidae) / *Munidopsis camerus* (Ortmann, 1892) (Munidopsidae: Galatheidea)
ii. enlargement of abdomen of originally male individuals without any development concerning feminine abdominal appendages nor opening of feminine gonopores
ii-1. Sacculinidae gen. sp. 2 / *Goniopugettia sagamiensis* (Gordon, 1931) (Majidae: Brachyura)
ii-2. Sacculinidae gen. sp. 3 / *Rochinia debilis* Rathbun, 1932 (Majidae: Brachyura)
iii. enlargement of abdomen of originally male individuals without any opening of feminine gonopores
Sacculinidae gen. sp. 4 / *Pleistacantha oryx* Ortmann, 1892 (Majidae: Brachyura)
iv. complete accomplishment for feminine characteristics of originally male host individuals
Briarosaccus callosus Boschma, 1930 (Peltogastridae) / *Paralomis multispina* (Benedict, 1894) (Lithodidae: Anomura)

Table IX-2. *Paralomis multispina* (Benedict, 1894) and *Briarosaccus callosus* Boschma, 1930. The strong dependence between the modality of morphological modification of host lithodid individuals (Stage: St.) and the degree of multiple infection by symbiont kentrogonid individuals (Class: Cls.) was shown (X_0 square = 318.644 > X square (12, 0.05) = 21.126, *df* = 12): Upper, number of individuals; lower in parenthesis, each percentages against the total number of examined individuals. When the host individual possessed both the externas of the symbiont ones and scars, it was counted by the number of externas and categorized into corresponding class.

	St. 1	St. 2	St. 3	St. 4	total
Cls. 0	93 (2.7)	24 (0.7)	5 (0.1)	16 (0.5)	138 (4.0)
Cls. 1	1388 (40.5)	415 (12.1)	183 (5.3)	34 (1.0)	2265 (66.1)
Cls. 2	488 (14.2)	252 (7.3)	25 (0.7)	50 (1.5)	815 (23.8)
Cls. 3	67 (2.0)	40 (1.2)	2 (0.0)	2 (0.0)	111 (3.2)
Cls. 4	70 (2.0)	24 (0.7)	2 (0.0)	4 (0.1)	100 (2.9)
total	2106 (61.4)	755 (22.0)	152 (4.4)	416 (12.1)	3429 (100.0)

X. *CGAT*: AXIOMATIC SYSTEM OF THE AUTOPOIESIS THEORY

X-1. ABSTRACT

To gain the full set of good taxonomic results in diverse living organisms and the coordinated taxonomic system on various level of taxa, axiomatic system of the Autopoiesis Theory, *CGAT* (axiomatic system of Complete Generalized Autopoiesis Theory), was constructed. The system consists of 40 axioms and 2 axioms of inferring rule (2 input axioms+10 universe constructing meta-meta-axioms+2 meta-axioms (declaring of describing possibility of universe with limited number of languages)+12 axioms (regulating the system structure of any autopoiesis system)+2 meta-axioms (declaring of possibility

of construction concerning artificial universe and any autopoiesis system created by 12 axioms) +10 universe-products uniting meta-meta-axioms+2 output axioms). The proofs of completeness and consistency of *CGAT* can be easily given by the nature of *CGAT* itself, namely, “meta-axiomatic system” over any complete and consistent theory including the maximal consistent theory.

X-2. INTRODUCTION

The “Autopoiesis Theory” was originally created from the cognitive physiology of vertebrates, and started as minor biological theory aiming at the understanding of optical mechanism of pigeon or frog (Maturana and Varela, 1980; Kneer and Nassehi, 1995). The theory can be defined as the first theory that defines the “living state” and “living organisms” on earth in modern science, but was unfortunately published in so immature stage (Kawamoto, 1995). However, by the aid of the large contribution by one of the original creator of Chilean physiologist, H. R. Maturana, and successive developer, a system theoretical sociologist in Germany, N. Luhmann, this unique theory was developed into more general, and basic one to diverse biology and sociology of human being. Nevertheless, in spite of larger contribution by Luhmann, the concept of “Autopoiesis,” namely, “self-creating nature,” that can be easily recognized in living organisms and any animal population and society, had not been defined in a concise sequence of limited number of language so far (Kneer and Nassehi, 1995; Kawamoto, 1995). Especially, for the good understanding of the “concept of Autopoiesis,” radical constructivism and axiomatism, that are easily recognized in modern mathematics and logics, are indispensable, but they seem to be neglected or denied in modern biology and taxonomy (Watabe, 1999a, b, and 2000).

The introduction of Autopoiesis Theory into Japan is largely due to H. Kawamoto in the latter half of 1990’s (Kawamoto, 1995). It seems to be largely intended to show the theory as a mere thought of biology or sociology in narrower sense, or mere object of biological thought, and unfortunately, did not develop major trend in not only biology but also meta-science, namely, philosophy of science general. However, Watabe (1999a, b, and 2000) tried the axiomatization of the theory, and could present the prototype of axiomatic system of this unique theory, *cGAT*. It is based on the animal taxonomy and International Code of Zoological Nomenclature (ICZN), and clearly intended the construction of “set theory”-like but quite different foundation in biology general. The axiomatic system, *cGAT*, is characterized by the circular symbol and the unique predicate, “○,” that is the junction of component and higher system structure that is constructed by the generation of component from component, “autopoiesis system.” Moreover, *cGAT* succeeded in the formalized expression of the interrelationship not only (1) between component and autopoiesis system, but also (2) among some autopoiesis systems. In *cGAT*, the completeness and consistency are made sure by the following manner: To make *cGAT* as meta-axiomatic system over any complete and consistent theory including the maximal consistent theory, and to possess Henkin’s Theory, that declares that “any consistent theory has model,” as not “meta-theory” but mere “theory” in system structure. By the aid of *cGAT*, taxonomic inference proposed by E. Mayr can be understood concisely (Watabe, 1999a and b), and the complicated interrelationship in biology, namely, symbiosis, can be understood and studied in a sophisticated manner from the aspect of system theoretical biology (Watabe, 2000).

The unresolved problem in *cGAT* can be summarized as follows.

(1) concise junction between traditional microtaxonomy, which is chiefly based on morphological characteristics, and macrotaxonomy (see also Chapters III and IV)

(2) theoretical unification of traditional microtaxonomy based on morphological examination and taxonomic inference at species level proposed by E. Mayr (see also Chapters V to VIII)

(3) presentation of not found axioms in *cGAT*

(4) more sophisticated junction between naïve biology and formalized biology, and naturally, axiomatic system of biology general (see also Chapter I)

Here, I would like to present the complete set of axioms required by the original implication of the Autopoiesis Theory. For the axiomatic system of the theory, I give the name, *CGAT* (Complete Generalized Autopoiesis Theory).

X-3. CONSTRUCTION OF *CGAT*

The outline of *CGAT* had been already constructed in Watabe (2000). The main characteristics of the axiomatic system are summarized as follows: (1) Usage of "formalized meta-language" on any axiomatic system, including *CGAT* itself; (2) usage of several specific predicates, that join the components and whole the axiomatic system or described autopoiesis system; (3) full description of interrelationships among components, components and described autopoiesis system, and autopoiesis systems; (4) full description of the interrelationship between autopoiesis system and system environment, and the construction of system environment general by *CGAT*; (5) full description of the interrelationship among all axioms in *CGAT*.

1. Definition of language

The definition of language in *CGAT* almost follows the manner of Shimizu (1984) and Takeuti (1994), and Watabe (2000) (defining the language in *cGAT* as formalized meta-language) also follows this manner.

a. Variable

In *CGAT*, two concepts, namely, "component" and "autopoiesis system," are exclusively used to describe autopoiesis system themselves. They construct a "circle." These two concepts are unified by the term, "ｏ" (origin), existing at the center of the circle. Moreover, system environments are considered as a "sphere," on which the autopoiesis system (drawn as circle with a center point, namely, "ｏ" (origin)) are floating, also described by the concepts of "ρ" (fixed point, situating at the center of the spheric system environment), "無" (expressing the spheric system environment), and "＝" (expressing the "object" that can not be described by any language, or "object" that is the "something" before being described by any language). In addition to these terms, input(s) and output(s) of autopoiesis systems should be prepared. Thus, variables are defined as follows:

Component: *COM*1, *COM*2, , ,

Autopoiesis system: *AS*1, *AS*2, , ,

Origin: ｏ1, ｏ2, , ,

System environment of autopoiesis system: 無 1, 無 2, , ,

Fixed point: ρ1, ρ2, , ,

"Objects" that ca not be expressed by any language: ＝

Input(s) and Output(s): *IN*1, *IN*2, , , *OUT*1, *OUT*2, , ,

b. Predicate

In *CGAT*, following 5 types of predicates are used. Each type has two predicates, namely, positive (△, □, ○, ＝, and —) and negative (▲, ■, ●, ≠, and __). The reason of presence of positive/negative predicates is simple, it is resulted from the "spheric" nature of whole the system environment, expressed by the term, "無." The system environment is divided into northern and southern hemisphere, and positive and negative predicate sets are attached on each other. The axiomatic system, *CGAT*, is the result of uniting the northern/southern hemispheres, namely, positive/negative predicates, by limited number of languages.

△ (materialization) and ▲ (de-materialization)

□ (languagenation) and ■ (de-languagenation)

○ (systemization) and ● (de-systemization)

＝ (composite predicate expressing organization, △□○) and — (de-organization, ●■▲)

≠ (composite predicate expressing mechanization, ○□△) and __ (de-mechanization, ▲■●)

c. Logic symbol

In *CGAT*, following logic symbols are used.

∀ (arbitrary), ∃ (existent), ∃! (unique), ¬ (negation)

d. Definition of term and formula

The definition of term and formula follows Takeuti (1994). From the closed formulae, we can construct the axioms of *CGAT*.

2. Axioms

According to the previous definition of *CGAT* language, we can construct following axiomatic system including axioms of Input and Output, axioms, meta-axioms, and meta-meta-axioms, together with axioms of Inferring rule.

The axioms of Input and Output possess the role of junction of any object and universe of *CGAT*. The following meta-meta-axioms (b-e) possess the role to construct the temporal and spacial structure of *CGAT* universe, where any autopoiesis system can operate and develop. The meta-axioms (g) declare that any autopoiesis system can be described by the unique theory, *CGAT*, or any equivalent.

The axioms (h-m) is plain axioms that define (1) the uniqueness of *CGAT* language (h), (2) the interrelationship between component and autopoiesis system (i, j, and k), and the interrelationship among autopoiesis systems (l and m).

The meta-axioms (n) declare the possibility to construct miniature of any autopoiesis system by an autopoiesis system, in other words, functional identity and equivalence among arbitrary autopoiesis systems. The meta-meta-axioms (o-s) possess the role to construct functional equivalent of system environment.

The axioms of Inferring rule (u) defines the axiom itself from univalent autopoiesis system. Thus, these axioms are out of *CGAT* in narrower sense as Inferring rule, like in the case of Gen or MP in the axiomatic system of predicate logic.

a. Axioms of Input

CGATIN+: ∃!〓∃*IN*i(*IN*i＝〓)

CGATIN-: ∃*IN*i∃!〓(〓−*IN*i)

b. Meta-meta-axioms of 〓

CGAT〓+: ∃!ρi∃無 i∃!〓(〓＝無 i＝ρi)

CGAT〓-: ∃!〓∃無i∀ρi(ρi−無i−〓)

c. Meta-meta-axioms of 無

CGAT 無+: ∃!οi∃!ρi∀無i(無i=ρi=οi)

CGAT 無-: ∃無i∃ρi∀οi(οi−ρi−無i)

d. Meta-meta-axioms of P

CGAT P+: ∃!*COM*i∃!οi∀ρi(ρi=οi=*COM*i)

CGAT P-: ∃ρi∃οi∀*COM*i(*COM*i−οi−ρi)

e. Meta-meta-axioms of O

CGAT O+: ∃!*AS*i∃!*COM*i∀οi(οi=*COM*i=*AS*i)

CGAT O-: ∃οi∃*COM*i∀*AS*i(*AS*i−*COM*i−οi)

f. Meta-meta-axioms of Σ

CGAT Σ+: ∃!*AS*k∃!*AS*j∀*AS*i(*AS*i=*AS*j=*AS*k)

CGAT Σ-: ∃*AS*i∃*AS*j∀*AS*k(*AS*k−*AS*j−*AS*i)

g. Meta-axioms of A

CGAT A+: ∃!*AS*i∀*COM*i(*COM*i=*AS*i)

CGAT A-: ∃*COM*i∀*AS*i(*AS*i−*COM*i)

h. Axiom1

CGAT1+: ∃!*COM*j∀*COM*i(*COM*i□*COM*j)

CGAT1-: ∃*COM*i∃!*COM*j(*COM*j■*COM*i)

i. Axiom2

CGAT2+: ∃!*AS*i∀*COM*i(*COM*i○*AS*i)

CGAT2-: ∃*COM*i∀*AS*i(*AS*i●*COM*i)

j. Axiom3

CGAT3+: ∃!*AS*i∀*COM*i(*COM*i△*AS*i)

CGAT3-: ∃*COM*i∀*AS*i(*AS*i▲*COM*i)

k. Axiom4

CGAT4+: ∃!*COM*i∀*AS*i(*AS*i□*COM*i)

CGAT4-: ∃*AS*i∀*COM*i(*COM*i■*AS*i)

l. Axiom5

CGAT5+: ¬∃*AS*j∀*AS*i(*AS*i○*AS*j)

CGAT5-: ∃*AS*i¬∃*AS*j(*AS*j●*AS*i)

m. Axiom6

CGAT6+: ∃!*AS*j∀*AS*i(*AS*i△*AS*j)

CGAT6-: ∃*AS*i∀*AS*j(*AS*j▲*AS*i)

n. Meta-axioms of Ω

CGAT Ω+: ∃!*AS*j∀*AS*i(*AS*i≠*AS*j)

CGAT Ω-: ∃*AS*i∀*AS*j(*AS*j__*AS*i)

o. Meta-meta-axioms of E

CGAT E+: ∃!*AS*k∃!*AS*j∀*AS*i(*AS*i≠*AS*j≠*AS*k)

CGAT E-: ∃*AS*i∃*AS*j∀*AS*k(*AS*k__*AS*j__*AS*i)

p. Meta-meta-axioms of O’

CGAT O’+: ∃!οi∃!*COM*i∀*AS*i(*AS*i≠*COM*i≠οi)

CGAT O’-: ∃*AS*i∃*COM*i∀οi(οi__*COM*i__*AS*i)

q. Meta-meta-axioms of P’

CGAT P’+: ∃!ρi∃!οi∀*COM*i(*COM*i≠οi≠ρi)

CGAT P’-: ∃*COM*i∃οi∀ρi(ρi__οi__*COM*i)

r. Meta-meta-axioms of 無’

CGAT 無’+: ∃!無i∃!ρi∀οi(οi≠ρi≠無i)

CGAT 無’-: ∃οi∃ρi∀無i(無i__ρi__οi)

s. Meta-meta-axioms of ＝’

CGAT＝’+: ∃!＝∃!無i∀ρi(ρi≠無i≠＝)

CGAT＝’-: ∃ρi∃無i∃!＝(＝__無i__ρi)

t. Axioms of Output

CGATOUT+: ∃!*OUT*i∃!＝(＝≠*OUT*i)

CGATOUT-: ∃!＝∀*OUT*i(*OUT*i__＝)

u. Axioms of Inferring rule

CGATIR+: ∃!*COM*i∀*AS*i(*AS*i≠*COM*i)

CGATIR-: ∃*AS*i∀*COM*i(*COM*i__*AS*i)

3. Junction between *CGAT* and empirical results in crustacean taxonomy

By the meta-meta axioms (a-f), operating space of any autopoiesis system can be constructed. Especially, meta-meta-axioms (f) describe and declare the (1) interrelationship of individual-species taxon-higher ecological community in biological implication, and (2) ideal existence of focused taxon. From these axioms, *CGAT* constructs the system theoretical issue on this operating space of various kind of autopoiesis system.

Table X-1 shows the unification of empirical results in crustacean taxonomy and the system theoretical implication of *CGAT*, namely, corresponding of each taxon and meta-description (see also Chapters III and IV). For the ease of understanding, solar system is arranged to the *CGAT* axioms. This will help understanding biological implication of each taxon and meta-description by *CGAT*. Rather, readers should remember the astological implication (meta-astroscientific description associated with human being) of each planet together with the scientific results of astroscience.

4. Theory of *CGAT*: Generation of "temporal concept"

In the previous section 2, we saw the overview of *CGAT*, that starts from the axioms CGATIN and ends in CGATOUT, with inferring rule CGATIR. As a consequence of the original concept of the Autopoiesis Theory, we can recognize the axiomatic system *CGAT* as an autopoiesis system, that is quite similar to a centiped or worm, and characterized by the "exoskeleton" constructed by relevant axioms. If we want to recognize the "temporal concept" in and by *CGAT*, it can be extracted from the system structure of *CGAT* itself. The temporal concept can be internally constructed as the theory, in other words, "internal bone" together with above mentioned "exoskeleton." Then, these "armed" autopoiesis systems are operating in the 3D physical axes with temporal flow, namely, physico-temporal 4D space.

From Table X-1, we can recognize the 15 taxa (with corresponding *CGAT* axioms from CGATΣ to CGATOUT) in any biological hierarchy, together with the taxonomists or observers of this taxonomic results. They are arranged from Σ-taxon to ◎-taxon (representing ones), via primitive, advanced, and atrophied groups (see also Chapter IV). This contains the temporal concept on the taxonomic implication from *CGAT*. If we want to set *CGAT* axioms on the taxonomists or observers, we can set CGATIR on them, and gain the 16-column table. Thus, we can construct taxonomic table (ending in the column with CGATIR) enlarged from Table X-1, that is ending in the taxon characterized by the axioms CGATOUT. This table is constructed on the 2D plain with axes of taxon and temporal concept.

In Chapter IV, taxonomic dendrgram was constructed (see Fig. IV-1). If we wants to see it as phylogram, it can be recognized as monophyletic phylogram with two isolated taxa (◎, Σ-taxa), and 3 groups, namely, primitive, advanced, and atrophied groups at the tree-end of the phylogram. Totally, 5 categories can be recognized in the phylogram, and we can add taxonomists or observer together with them. Then, 6 taxa can be recognized, and CGAT1-6 can be put on them respectively. This is the construction of temporal concept, characterized by the axiom flow from CGAT1 to CGAT6.

The temporal concept is a single circular line armed by CGAT1-6 (arranged on this circle), and then, it can be recognized as an autopoiesis system. Thus, this circle can be characterized by single set of *CGAT* axioms, namely, CGATIR. This autopoiesis sytem is represented as single point without any internal structure. Further operation of *CGAT* can not be carried out.

Above mentioned issue can be reconstructed as following closed formulae, namely, Theory of *CGAT*.

Theory of Temporal concept

TTC+: $\neg \exists COM_l \exists ! COM_k \exists COM_j \forall COM_i (COM_i \neq COM_j \neq COM_k \neq COM_l)$

TTC-: $\exists COM_i \exists COM_j \exists COM_k \neg \exists COM_l (COM_l \_\_ COM_k \_\_ COM_j \_\_ COM_i)$

X-4. CONCLUSION

In present Chapter, I could give the complete set of axioms expressing the concept of "Autopoiesis." The meaning of establishment of *CGAT* for taxonomy general is summarized as follows: (1) Uniting the traditional microtaxonomy based on morphology and the taxonomic inference at species level proposed by E. Mayr, from the aspect of theoretical biology; (2) gaining of full set of meta-description of each taxon, that is fulfilled by each axiom of *CGAT* and *CGAT* itself; (3) elucidation of the interrelationship among the axioms as single axiomatic system, *CGAT*. Here, I would like to show the closer issue of each conclusion.

1. Theoretical junction between traditional microtaxonomy based on morphology and taxonomic inference at species level proposed by E. Mayr

As had been shown in the Chapter III, the objective basis to divide specimen set is theoretically unclear in the traditional microtaxonomy based on the morphological characteristics. It is merely left in the stage of "creation of morphological phenon," and waiting the results of ecological observation like in the case of the Chapter V. The most important point of this problem is to gain the meta-basis to divide specimen set based on the theoretically good reason. It will be gained from the univalent comparison of morphological and ecological differences (especially reproductive characteristics). Thus, the most important point is to find the key-stone specimen in the gained specimen set by the aid of *CGAT*. At least, we can construct a linear arrangement of specimens based on certain taxonomic decision, then, can be applicable of taxonomic dendrogram proposed in the Chapter IV. By the aid of this dendrogram, we can gain the meta-description of each specimen or set of them.

The meta-description of each specimen or set of them is established by the relevant axioms of *CGAT*. In natural environment, animal individuals are major objective of observation by human being, and animal taxonomy is firstly aiming at the recognition of species taxa, that are reproductively isolated autopoiesis systems whose component is inter-individual interaction (see also Chapter V; Watabe, 1999a and b). If the results of observation in natural environment or morphological comparison in laboratory are arranged under the semantics of *CGAT*, theoretically good results of animal taxonomy will be easily gained. The reason is quite simple, *CGAT* is constructed to describe the interrelationship between individual and species taxon, and the higher interaction among species taxa both the manners of (1) taxonomic sentence, namely, genus, family, and so on, and (2) the ecological sentence, namely, guild, regional ecosystem, ecological environment, and so on (see also Chapters V to IX).

2. Gaining of full set of meta-description of autopoiesis system

In Watabe (2000), only the two axioms representing the Autopoiesis Theory had been described as well-formed axioms. In present study, I could present whole the set of axioms drawing the interrelationship (1) between component and autopoiesis system, (2) among some autopoiesis systems, (3) between autopoiesis system and system environment, and moreover, (4) uniqueness of gained axiomatic system, *CGAT*. The main results of construction of present *CGAT* is to formulate all the meta-description as relevant axioms.

The completion of aximatization on the Autopoiesis Theory means following change on our view point concerning the living organisms and their functional equivalents in various fields. By the aid of *CGAT*, we can recognize living organisms and species taxa in natural environment from the aspect of radical constructivism. Additionally, we can recognize the other objects that had not been treated as "autopoiesis system," such as axiomatic system of predicate logic or set theory in modern mathematics and meta-mathematics. The reason is quite simple, they are treated as functionally equivalent, and true "autopoiesis system" together with living organisms and species taxa, and naturally, society of human being as had been declared by Luhmann. Thus, the completion of *CGAT* gives functional meaning of any living organism and species taxon, and naturally, any person and part of human society.

3. Construction of axiomatic system of the Autopoiesis Theory as an axiomatized autopoiesis system (allopoietic system), *CGAT*

In *CGAT*, the Autopoiesis Theory itself is axiomatized from the meta-view point like in the case of axiomatization of predicate logic. The most striking characteristics of *CGAT* is to describe this theory with the context of interaction with system environment by the concepts of "無" and "＝" (both terms denote the "objects" that can not be described and pointed out by any language with the exception of "formalized meta-language"(Watabe, 1999a, b, and 2000)). Frequently, no existence of input/output concerning autopoiesis system had been focused, but it is resulted from the lacking of inclusive view point of interrelationship and interaction between autopoiesis system and system environment. If the relevant axiomatic system constructed to fulfill this demand, the system would declare the interaction between focused object in the system and "observers" or "users of this axiomatic system," and the specific interrelationship between "observers" and "any object described by the axiomatic system," namely, "co-existence through the operation among "observers or users" and "described autopoiesis system." This interrelationship can be easily observed in the macrotaxonomic system of crab-shaped decapods in Chapter IV, that gives large value on human intuition concerning "crabs."

The most important meaning of axiomatization of the Autopoiesis Theory is quite simple, (1) to describe arbitrary autopoiesis system with the context of univalent correspondence between component and autopoiesis system itself, and (2) to clarify the interaction with system environment by the set of meta-meta-axioms (good description of autopoiesis system as "allopoietic" system that has inputs and outputs like ordinary machines (Maturana and Varela, 1980)). According to these two verifications, the Autopoiesis Theory can be used as general system theory based on “taxon-based science,” or “ephemeris” derived from biology, in various fields of science and inclusive human society.

Table X-1. Unification of empirical results of crustacean taxonomy and the axiomatic system of the Autpoiesis Theory, *CGAT*. For the ease of understanding, symbolic objects in astroscience were added. Readers should remember the coordination between described planets and solar system, and the correspondence between planets and meta-desicriptions provided by *CGAT*, and also concrete names of crustacean taxa.

	Symbol	Symbolic object	CGAT axiom	"Living organisms"	Pogonophora-Brachiopoda	Arthropoda	Crustacea	Eumalacostraca
1	Σ	Sun	CGATΣ	Chordata	Pogonophora	Xiphosura	Remipedia	Anaspidacea
2	A	Asteroid belt	CGATA	Archaea	Nematomorpha	Fossile group	Cephalocarida	Waterstonellidea
3	1	Mercury	CGAT1	Bacteria	Nematoda	Trilobita	Sarsostraca	Mysida
4		Jupiter	CGAT2	Fungi	Ectoprocta	Fossile group	Diprostraca	Lophogastrida
5 2		Uranus	CGAT3	Protista	Phoronida	Eurypterida	Notostraca	Thermosbaenacea
6 3		Mars	CGAT4	"chlorophytes"	Annelida	Symphyla	Mystacocarida	Cumacea
7 4	5	Venus	CGAT5	"vascular plants"	Arthropoda	Insecta	Copepoda	Tanaidacea
8		Saturn	CGAT6	Bryophyta	Onychophora	Diplopoda	Thecostraca	Mictacea
9 6		Earth	CGATΩ	Charales	Pentastoma	Pauropoda	Tantulocarida	Speleogriphacea
10 Ω		Pluto	CGATE	Cnidaria-Ctenophora	Sipunculoida	Acarida	Phyllocarida	Isopoda
11 E	O'	Charon	CGATO'	Pogonophora-Brachiopoda	Echiuroida	Aracnida	Hoplocarida	Amphipoda
12	P'	EKB	CGATP'	Echinodermata	Mollusca	Crustacea	Eumalacostraca	Decapoda
13	無'	Neptune	CGAT 無'	Porifera	Tardigrada	Chilopoda	Ostracoda	Euphausiacea
14	='	Comet	CGAT='	Chaetognatha	Priapulida	Opilionida	Brachiura	Amphionidacea
15	◎	Satellite	CGATOUT	Virus	Brachiopoda	Pycnogonida	none	Bathynellacea

	Symbol	Decapoda	Gymnopleura	Brachyura	Anomura	Galatheidea	Caridea	Thalassinidea	Glypheidea
1	Σ	Gymnopleura	Raninoidea	Potamoidea	Lomisoidea	Chylostyloidea	Phycetocaridoidea	Thalassinoidea	Glypheidae
2		Potamoidea	Cosmonotoidea	Homolodromioidea	Cheiroplateoidea	Gastroptychoidea	Stenopodoidea	Calianassoidea	none
3 A	1	Homolodromioidea-Oxystomata	Notopoidea	Dromioidea	Pomatocheloidea	Uroptychoidea	Penaeoidea	Axioidea	none
4		Oxyrhyncha-Scopimeroidea	Ranilioidea	Archaeobrachyura	Pylocheloidea	Eumunidoidea	Sergestoidea	Laomedioidea	none
5 2		Sakainoidea-Hapalocaricinoidea	Notopoidoidea	Oxystomata	Cancellocheloidea	Kiwoidea	Oplophoroidea	Upogebioidea	none
6 3		Hippoidea	Raninoidoidea	Oxyrhyncha	Paguristoidea	Galatheoidea	Stylodactyloidea	none	none
7 4	5	Lomisoidea	Lyreidoidea	Cancroidea	Diogenoidea	Munidoidea	Pasiphaeoidea	none	none
8		Cheiroplateoidea-Cancellocheloidea	Symethoidea	Xanthoidea	Paguroidea	Paramunidoidea	Bresilioidea	none	none
9 6		Paguristoidea-Albuneoidea	none	Scopimeroidea	Parapaguroidea	Bathymunidoidea	Psalidopodoidea	none	none
10 Ω		Porcellanoidea	none	Sakainoidea	Tylaspoidea	Munidopsoidea	Alpheoidea	none	none
11 E	O'	Chylostyloidea-Aegloidea	none	Pinnotheroidea	Probeebeoidea	Shinkaioidea	Palaemonoidea	none	none
12	P'	Caridea	none	Bellioidea	Coenobitoidea	Aegloidea	Crangonoidea	none	none
13	無'	Thalassinidea	none	Carvactaeoidea	Lithodidoidea	none	Pandaloidea	none	none
14	='	Glypheidea	none	Hapalocarcinoidea	Albuneoidea	none	Astacoidea-Nephropoidea	none	none
15	◎	none	none	none	Hippoidea	Porcellanoidea	Eryonoidea-Palinuloidea	none	none

XI. GENERAL DISCUSSION

XI-1. CONCLUSIVE REMARKS

1. Taxonomy

In this study, I presented the concrete example of traditional microtaxonomy based on morphology (the genus *Nephropsis*), construction of macrotaxonomic system (crab-shaped decapods, especially Suborder Brachyura), and taxonomic inference based on the combination of traditional morphology and ecology (the genus *Paralomis* in the Tokyo Submarine Canyon). They were combined by the theoretical background of taxonomy itself, namely, “formalized taxonomy” and “metabiology (foundation of biology).”

2. Faunal zonation

Present results suggested that inter-individual interaction within a species taxon, associating with reproduction, attributed to maintain faunal zonation on the bottom environment (Chapters, V, VI and VIII), as has been also suggested by the definition of “biological species” of Mayr and Ashlock (1991).

The taxonomic inference itself and understanding of its logical structure are very important for the discussion of inter-species interrelationship, characterized by such as interspecific zonation or faunal zonation in certain taxon (Chapters III - VIII).

The interspecific zonation exhibited by the bathyal lithodid species taxa *Paralomis* spp. in the Tokyo Submarine Canyon was described in detail based on strong taxonomic inference (Chapter V). Because the present work was restricted into a narrow one, effort to confirm the generality of present results should be carried out in the other localities or species taxa. The faunal zonation of saprophagous decapods in the same locality was similar to the case of *P.* spp. (Chapter VI)

The submersible operation in a small hydrothermal field proved to be very useful to examine *Paralomis* faunule on the Minami-Ensei Knoll (Chapter VII). Neither the taxonomic examination nor the description of interspecific segregation among lithodids had not been reported so far, present results may open the initial step for the elucidation of species structure and interspecific segregation of non-vent element like larger crab-shaped decapods from the video records.

Unusual aspect of the maintenance of species structure among lithodid taxa was exemplified by the niche-shift of *P. multispina* into the Tokyo Submarine Canyon (Chapter VIII). Though the niche-shift and extremely high prevalence of *Briarosaccus callosus* was associated with over-fishing of the resource, it proved to be an unequaled field experiment, the selective elimination. Furthermore, the results can also provide the new type of danger to exploit the bathyal lithodids as fishery resources, apart from the over-fishing.

3. Kentrogonid maternalization

The adoption of the term, kentrogonid maternalization to characterize the kentrogonid interindividual interaction fixed the contingency around it (Chapter IX). Here the discussing domain and the implication of the term should be confirmed again.

1) kentrogonid maternalization, characterizing the unusual interrelationship recognized between kentrogonids and corresponding host decapods
2) egg mimicry as the most characterizing interaction between kentrogonids and host decapods, additional ones as castration or

feminization on the latter

3) specific taxonomic combination, namely, Sacculinidae – Suborder Brachyura, Peltogastridae – Superfams. Paguroidea/Lithodidoidea (represented by king crab), and Lernaeodiscidae – Suborder Galatheidea (represented by intertidal porcelain crab), quite well characterized by the crab-shaped hosts
4) complete loss of autonomy as individual expressed by kentrogonids, quite different from the case of braconid wasp

As the second issue, present study also found the most typical case in kentrogonid maternalization, namely, *P. multispina* versus *B. callosus*, with the attainment of (1) complete feminization of host external morphology and (2) castration, and (3) the only invaded organ, VGM, together with rich set obtained from the Tokyo Submarine Canyon.

4. CGAT

Present study provides the initial step of automation of taxonomic inference proposed by E. Mayr from the aspect of radical constructivism. According to the establishment of meta-description of each taxon by the axiomatic system of the Autopoiesis Theory, namely, *CGAT*, all the sequence between traditional morphological taxonomy to stronger taxonomic inference based on ecological information can be formalized on the axiomatic system. It will be great aid to study biodiversity in the case of less information and specimen like in the case of deep-sea biology.

XI-2. FUTURE PERSPECTIVE

1. Taxonomy

The most serious problem concerning taxonomy is to gain the objective basis to divide a focused set of specimens, and to provide the reliable taxonomic results, namely, "name of animal." By the aid of *CGAT*, that provides the theoretical background of whole the taxonomy and the definition of species taxon in nature, animal taxonomy will explore new frontier in natural environment or museum collection. For example, the analyses of video record and published taxonomic papers by the manner explored in this study can be proposed.

2. Faunal zonation

Following logical sequences will be suggested to elucidate and specify the most characterizing biological factor of decapod faunal zonation.

1. taxonomic inference based on the concept, "biological species" (*sensu* Mayr and Ashlock, 1991) (Chapters III-VIII)
2. theoretical enumeration of contributing biological factors from the definition of biological species: a. Interaction among the individuals respectively referable to different species taxon, usually understood as competition for niche or food availability (Underwood, *in* Kikkawa and Anderson, 1986); b. interaction among the individuals commonly referable to the same species taxon, usually detected as the reproductive and developmental migration within the species structure (e.g., Sloan, 1984, 1985, and Stone *et al*., 1992); c. physiological and ecological characteristics expressed by the individual, usually discussed through the term, abiotic factor (Abelló and Macpherson, 1989, 1990, and 1991; Jensen and Armstrong, 1991) (Chapters V - VIII)
3. description of the structure of relevant faunal zonation through multivariate analysis with the observation of physical variables throughout

the sampling period, and the finding of representative interspecific zonation from it (Chapters V and VII)
4. selective elimination (equipped with open niche site and untreated site as control), or the finding of equivalent phenomenon in the field (Chapter VIII)
5. interpretation of the results, and the comparison with the other results obtained through the same procedure, concerning different localities or taxa (Chapters V-VIII)
6. confirmation of physical and ecological characteristics expressed by the relevant individuals in the laboratory (e.g., Henry *et al*., 1990; Vetter *et al*., 1994)

Based on the experience of high-resolution description of strong segregation reported in Chapters V and VII on the genus *Paralomis*, the selection of submersible (Burd and Brinkhurst, 1984) and hydrothermally active site (Chapter VII) will provide the best opportunity to carry out the sequence. A part of them had been already started (Vetter *et al*., 1987; Fujikura, personal communication).

Lithodid individuals and species taxa are one of the best materials, because of, sufficiently large size of individuals, easy detection of reproductive interaction within species taxon (Stone *et al*., 1992), and (3) almost fixed taxonomic system.

3. Kentrogonid maternalization

Kentrogonid maternalization can be expected to serve a good material for the following studies of decapod endocrinology and immunology.

1. differentiation of sex and gender in large-sized decapods (Charniaux-Cotton and Payen, 1985; Fingerman, 1987)
2. mechanism of escape from host immune system (Ashida, *in* Natori *et al*., 1992)
3. functional characteristics concerning recognition protein, usually identical to high-density lipoprotein in the hemolymph of host decapods, and its receptor like proteoglycan (e.g., Spaziani *et al*., 1995; Yepiz-Plascencia *et al*., 1995)
4. interlinkage between molting and reproduction-inducing cascade (Schoettker and Gist, 1990; Spaziani *et al*., 1995)
5. finding of hormone releasing hormone like GnRH (Gonadtropin Releasing Hormone) in decapods, that governs the decapod endocrinology of reproduction and molting
6. DNA bar-cording by appropriate gene, especially like GnRH encoding gene and GnRH receptor encoding genes among diverse living organisms, from the basis of reproductive and neurophysical government by GnRH (molecular taxon marker, like the pleopod and thelycum in decapods)

Especially concerning (1) and (4), the biological validity of Androgenic Gland Theory (*sensu* Charniaux-Cotton and Payen, 1985), that had been believed in its generality among diverse crustaceans, turned out to be questioned from endocrinological survey (e.g., Fingerman, 1987; Suzuki, 1987; Suzuki and Yamasaki, 1998). In the case of larger-sized decapods, direct investigation like in isopods will not be realistic, kentrogonid maternalization may provide a good cue for the objective.

4. *CGAT*

The future of *CGAT* will be explored on the Information Technology concerning diverse animal information and the conservation of museum collections. To extract biological implication from video records, faunal check lists, and old photographs, *CGAT* will provide the unique but important results. For a example, the automation of taxonomic inference on computer can be proposed.

At last, but not the least, I would like to emphasize the specialty and generality of deep-sea organisms on studying their interaction and interrelationship. As had been mentioned in respective chapters, the future of the objectives will, I believe, be hopeful and drastic one.

XII. ACKNOWLEDGEMENTS

I would like to express my sincerest gratitude to the Chairman, Mr. M. Akiyama, the Ocean Policy Research Foundation, on the publication of this study and the throughout encouragement on studying the social system on marine bio-community including human being. Moreover, I would like to express my deepest gratitude to Dr. S. Ohta, formerly in the Ocean Research Institute, University of Tokyo ORI, for his not only guidance and encouragement throughout present study but also the direct impression through the description of *Paralomis cristata* Takeda & Ohta, 1979 to make me decided to devote myself to present study. Moreover, the realization of present study should be attributed to the late Dr. T. Sakai, the founder of the Carcinological Society of Japan, the late Mrs. S. Nagai and Y. Hamada, and Dr. S. Suzuki, Kanagawa Prefectural College, for providing me of the initial step concerning the series of present study and encouragement throughout the study.

Moreover, I am greatly indebted to following scientists and persons for the enlightening of the particular discussion and analyses, and laborious land corroboration and intensive sampling: Drs. L. B. Holthuis, Nationaal Natuurhistorisch Museum, Leiden, the late Drs, F. A. Chace, Jr. and R. B. Manning, formerly in the Smithsonian Institution, USA, Drs. K. Baba, formerly in Kumamoto University, P. K. L. Ng, National University of Singapore, M. Takeda, Teikyo Heisei University (taxonomy general); Drs. J. T. Høeg and J. Lützen, Copenhagen University, Denmark, T. Takahashi, formerly in Kyushu University, K. Nagasawa, formerly in the National Research Institute of Far Seas Fisheries, Mrs. M. Marumura, S. Habu, Wakayama Prefecture, the late Dr. S. Miyake, the second president of the Carcinological Society of Japan (taxonomy, systematics, and evolution of kentrogonids); Dr. E. Macpherson, Institut de Ciencies del Mar, España, Drs. T. -Y. Chan and H. -P. Yu, National Taiwan Ocean University, Taiwan, A. Crosnier and N. Ngoc-Ho, Paris Museum MNHN, France, D. J. G. Griffin and H. E. Stoddart, Australian Museum, Australia, H. Sakaji, National Institute of Fishetries Science, K. Fujikura, JAMSTEC, J. Hashimoto, Nagasaki University, K. Hiramoto, formerly in Chiba Prefectural Fishery Station, K.-I. Hayashi, formerly in National Fisheries University, J. Sasaki, Abashiri Fishery Station, the late Dr. Y. Maibara, formerly in the Social Education Center, Tokai University, Mrs. H. Honma, Hokkaido, E. Iizuka, Shizuoka Prefecture, H. Ikeda, Hayama Shiosai Museum, Kanagawa Prefecture, and K. Matsuzawa, Kochi Prefecture (decapod taxonomy and ecology of nephropids and lithodids); Dr. K. Konishi, National Institute of Fishetries Science (early development of lithodids); Dr. H.-M. Yeh, Academia Sinica, Taiwan (cluster analysis, and associated discussion and programming); Dr. H. Nagasawa, formerly in University of Tokyo (sexual differentiation of crustaceans); Prof. T. Mori, Teikyo Heisei University, Assoc. Prof.

K.-M. Park, Miss M. Kyokuwa, and Dr. S. Iwasaka, University of Tokyo (histological analyses and associated discussion); the late Dr. H. Ishikawa, formerly in University of Air, and Y. Hayakawa, Saga University (general discussion concerning symbiosis); Prof. H. Kawamoto, Toyo University and Assoc. Prof. S. Noya, University of Tokyo (system theory general and symbolic logic); the experienced fishermen and executives, Mrs. T. Kayama, K. Kayama, M. Kayama, Y. Maekawa, S. Kayama (No. 3 Ido-inkyo Maru, Nagai Fisheries Co-operation), the late Mr. S. Tanigawa, Mrs. I. Ryuzaki, and S. Hojo, Kanagawa Prefecture (sampling of saprophagous decapods); the officers and crew member of R/V *Tansei Maru*, JAMSTEC/ORI, and DSRV *Shinkai 2000* and mother ship R/V *Natsushima*, JAMSTEC. Especially, I owe the largest part of present study to above mentioned fishermen that instruct me not only the fishing operation and vivid information of studied taxa but also the indispensable cue to system-theoretical viewpoint to carry out present study. Thanks are also extended to the following scientists and persons for their mental and technical supports and encouragements: Curators in Australian Museum and Northern Territory Museum, Australia, Drs. K. Aioi, M. Nakaoka, formerly in the Department of Marine Ecology, ORI, K. Shimizu, Kagoshima Prefecture; diligent students belonging to the departments under the supervision of Prof. T. Mori and H. Ishikawa at that time, respectively.

Finally, I also would like to express my deepest acknowledgements to my parents to allow kindly the completion of present study for nealy 30 years.

XIII. LITERATURE CITED

Abelló, P. and Macpherson, E., 1989. Distribution of *Bathynectes piperitus* (Brachyura: Portunidae) in the Benguela upwelling region and its relationship with some environmental parameters. J. Crust. Biol., 9(3): 373-380.

Abelló, P. and Macpherson, E., 1990. Influence of environmental conditions on the distribution of *Pterygosquilla armata capensis* (Crustacea: Stomatopoda) off Namibia. S. Afr. mar. Sci., 9: 169-175.

Abelló, P. and Macpherson, E., 1991. Distribution patterns and migration of *Lithodes ferox* (Filhol) (Anomura: Lithodidae) off Namibia, J. Crust. Biol., 11(2): 261-268.

Abelló, P., Valladares, F. J., and Castellõn, A., 1988. Analysis of the structure of decapod crustacean assemblages off the Catalan coast (North-West Mediterranean). Mar. Biol., 98: 39-49.

Akamine, T., 1982. On statistical methods in order to classify the distributions of species and the species compositions of stations on benthic organism. Bull. Jap. Sea Reg. Fish. Res. Lab., 33: 117-140. (in Japanese with English abstract)

Alcock, A., 1894a. Crustacea, part II. Illustrations of the Zoology of the Royal Indian Marine Surveying Steamer "Investigator," Calcutta, pl. 8.

Alcock, A., 1894b. Natural history notes from H. M. Indian Marine Survey Steamer "Investigator," Commander R. F. Hoskin, R. N. commanding. On the results of deep-sea dredging during the season 1890-91. Ser. II, No. 1. Ann. Mag. Nat. Hist., ser. 13, 6: 225-245, 321-334, 400-411.

Alcock, A., 1901. A descriptive catalogue of the Indian deep-sea Crustacea Decapoda Macrura and Anomala, in the Indian Museum. Being a revised account of the deep-sea species collected by the Royal Indian Marine Survey Ship Investigator, Calcutta, iv+286 pp., pls. 1-3.

Alcock, A., 1902 (not seen). A naturalist in Indian Seas or, four years with Royal Indian Marine Survey Ship "Investigator." xxiv+238 pp., 1 map.

Alcock, A. and Anderson, A. R. S., 1894. Natural history notes from H. M. Indian Marine Survey Steamer "Investigator," Commander C. P. Oldham, R. N., commanding, Ser. II, No. 14. An account of a recent collection of deep-sea Crustacea from the Bay of Bengal and Laccadive Sea. J. Asiat. Soc. Bengal, pt. 2, 63(2): 141-185, pl. 9.

Alcock, A. and Anderson, A. R. S., 1896. Crustacea. part IV. In Illustrations of the Zoology of the Royal Indian Marine Surveying Ship "Investigator," Calcutta, pls. 16-27.

Anderson, A. R. S., 1897. Natural history notes from the R. I. M. Survey Steamer "Investigator," Com-

mander C. F. Oldham, R. N., commanding, Ser. II, No. 21. An account of the deep-sea Crustacea collected during the season 1894-95. J. Asiat. Soc. Bengal, 65(2): 88-106.
Andrieux, N. and de Frescheville, J., and Herberts, C., 1986. Étude des proteines vitellines de l'hemolymphe et de l'ovaire chez le Crustace Decapode *Carcinus maenas*; incidence du parasite *Sacculina carcini* (Crustace Rhizocephlae). Can. J. Zool., 64: 2279-2287.
Asakura, A., 1998. The sociality in decapod crustaceans (1). male-female relation in the species found in pairs. Bioscience, 49(4): 228-242. (in Japanese)
Baba, K., 1988. Chirostylid and galatheid curstaceans (Decapoda: Anomura) of the "Albatross" Philippine Expedition, 1907-1910. Res. Crust., Spec. No. 2: i-v, 1-203.
Baba, K., Hayashi, K.-I., and Toriyama, M., 1986. Decapod crustaceans from continental shelf and slope around Japan, Jap. Fish. Res. Conser. Assoc., Tokyo, 336 pp.
Balss, H., 1911. Neue Paguriden aus den Ausbeuten der deutschen Tiefsee-Expedition "Valdivia" und der japanischen Expedition Prof. Dofleins. Zool. Anz., 38(1): 1-9.
Balss, H., 1913. Ostasiatische Decapoden I. Die Galatheiden und Paguriden. Abhand. der math.-phys. Klasse der K. Bayer. Akad. der Wiss., Suppl., Bd. 9: 1-85, pls. 1-2.
Balss, H., 1914. Ostasiatische Decapoden II. Die Natantia und Reptantia. Abhand. der math.-phys. Klasse der K. Bayer. Akad. der Wiss., Suppl., Bd. 10: 1-101, pls. 1-9.
Balss, H., 1924. Ostasiatische Decapoden V. Die Oxyrhynchen und Schlussteil. (Geographische Ubersicht der Decapoden Japans) Archiv für Naturgeschichte, 90: 20-84, pl. 1.
Balss, H., 1925. Macrura der deutschen Tiefsee-Expedition I. Palinura, Astacura, und Thalassinidea. Wiss. Ergeb. deutsch. Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898-1899, 20: 185-216, pls. 18, 19.
Benedict, J. E., 1894. Description of new genera and species of the crabs of the family Lithodidae with notes on the young of *Lithodes camtschatica* and *Lithodes brevipes*. Proc. U.S. Nat. Mus., 15: 479-488.
Benedict, J. E., 1902. Descriptions of a new genus and forty six new species of crustaceans of the family Galatheidae, with a list of the known marine species. Proc. U. S. Nat. Mus., 26: 243-334.
Bishop, R. K. and Cannon, L. R. G., 1979. Morbid behavior of the commercial sand crab, *Portunus pelagicus* (L.), parasitized by *Sacculina granifera* Boschma, 1973 (Cirripedia: Rhizocephala). J. Fish Dis., 2: 131-144.
Boschma, H., 1928. The Rhizocephala of the North Atlantic region. Danish Ingolf Expedition, 3(10): 1-49.
Boschma, H., 1930. *Briarosaccus callosus*, a new genus and new species of a rhizocephalan parasite of *Lithodes agassizii* Smith. Proc. U. S. Nat. Mus., 76(7): 1-8.
Boschma, H., 1962. Rhizocephala. Discovery Rep., 33: 55-94.
Bowman, T. E. and Abele, L. G., 1982. Classification of the recent Crustacea. *In*: Bliss, The Biology of Crustacea, Vol. 1, 1-25.
Burd, B. J. and Brinkhurst, R. O., 1984. The distribution of the galatheid crab *Munida quadrispina* (Benedict, 1902) in relation to oxygen concentrations in British Columbia Fjords. J. Exp. Mar. Biol. Ecol., 81: 1-20.
Campodonico, I and Guzman, L., 1981. Larval development of *Paralomis granulosa* (Jaquinot) under laboratory conditions (Decapoda, Anomura, Lithodidae). Crustaceana, 40(3): 272-285.
Cartes, J. E. and Sardà, F., 1993. Zonation of deep-sea decapod fauna in the Catalan Sea (Western Mediterranean). Mar. Ecol. Prog. Ser., 94: 27-34.
Chan, T.-Y., 1997. Crustacea Decapoda: Palinuridae, Scyllaridae and Nephropidae collected in Indonesia by the KARUBAR Cruise, with an identification key for the species of *Metanephrops*. *In* Crosnier, A. and Bouchet, P., (ed.) Résultas des Campagnes MUSORSTOM, Vol. 16, Mém. Mus. natn. Hist. Nat., 172: 409-431.
Chan, T.-Y. and Yu, S. -P., 1993. The Illustrated Lobsters of Taiwan. SMC Pub. Inc., Taipei, x+247 pp.
Charniaux-Cotton, H. and Payen, G., 1985. Sexual Differentiation, *In* The Biology of Crustacea, Vol. 9, Chapter 4, 217-299.
Chen, H.-L. and Sun, H.-B., 2002. Arthropoda Crustacea Brachyura, Marine primitive crabs, Fauna Sinica Invertebrata Vol 30, Science Press, Beijing, China, xiii+597 pp+XVI plates. (in Chinese with English abstract)
Chiba, H., Sakai, H., Gamo, T., Ishibashi, J. -I., Nakashima, K., Minami H., and Dobashi, F., 1992. Chemistry and isotopic composition of bubbles emerging from the sea floor at the Minami-Ensei Knoll, Okinawa Trough. Proc. JAMSTEC Symp. Deepsea Res., (1992): 81-87. (in Japanese with English abstract)
Cowles, D. L., Childress, J. J. and Wells, M. E., 1991. Metabolic rates of midwater crustaceans as a function of depth of occurrence off the Hawaiian Islands: Food availability as a selective factor? Mar. Biol., 110: 75-83.
Dai, A.-Y, 1999. Arthropoda Crustacea Malacostraca Decapoda Parathelphusidae Potamidae, Fauna Sinica, Science Press, Beijing, China, xiii+501+XXX plates. (in Chinese with English

abstract)
Dawkins, R., 1994. The Extended Phenotype: The gene as the Unit Selection, translated by Hidaka, T., Endo, A., and Endo, T., Kinokuniya-Shoten, Tokyo, 555 pp. (in Japanese)
Delage, Y., 1884. Evolution de la sacculine (*Sacculina carcini* Thomps.) crustacé endoparasite de l'ordre nouveau des kentrogonides. Archives de Zool. Exp. Gén., Ser. 2, 2: 417-736.
De Man, J. G., 1917. Diagnoses of new species of macrurous decapod Crustacea from the *Siboga*-Expedition. Zoologische Mededeelingen Uitgegeben Vanwege's Rijks Museum van Natuurlijke Historie te Leiden, 3(4): 279-284.
Desbruyères, D., Anne-Marie Alayse-Danet, Ohta, S., and Scientific Parties of BIOLAU and STARMER Cruises, 1994. Deep-sea hydrothermal communities in southwestern Pacific back-arc basins (the North Fiji and Lau Basins): Composition, microdistribution and food web. Mar. Geol., 116: 227-242.
DeVries, M. C., Rittschof, D., and Forward, Jr., R. B., 1989. Response by rhizocephalan-parasitized crabs to analogues of crab larval-release pheromones. J. Crust. Biol., 9(4): 517-524.
Eldredge, L. G., 1976. Two new species of lithodid (Anomura, Paguridea, Lithodidae) crabs from Guam. Micronesica, 12: 309-315.
Fingerman, 1987. The endocrine mechanisms of crustaceans. J. Crust. Biol., 7(1): 1-24.
Guinot, D., 1977. Propositions pour une nouvelle classification des Crustaces Decapodes Brachyoures. C. R. Acad. Sci., 285: 1049-1052.
Guinot, D., 1995. Crustacea Decapoda Brachyura: Révision des Homolodromiidae Alcock, 1900. *In*: A. Crosnier (ed.), Résultats des Canpagnes MUSORSTOM, Vol. 13. Mém. Mus. natn. Hist. nat., 163: 155-282.
Guinot, D. and Richer de Forges, D., 1995. Crustacea Decapoda Brachyura: Révision de la famille des Homolidae de Haan, 1839. *In*: A. Crosnier (ed.), Résultats des canpagnes MUSORSTOM, Vol. 13. Mém. Mus. natn. Hist. nat., 163: 283-517.
Gordon, I., 1931. Brachyura from the coasts of China. J. Linn. Soc. London., Zool. 37(254): 525-558.
Griffin, D. J. G. and Stoddart, H. E., 1995. Deep-water decapod Crustacea from eastern Australia: Lobsters of the families Nephropidae, Palinuridae, Polychelidae and Scyllaridae. Rec. Australian Mus., 47: 231-263.
Haedrich, R. L., Rowe, G. T., and Polloni, P. T., 1980. The megabenthic fauna in the deep sea south of New England, USA. Mar. Biol., 57: 165-179.
Häfele, F., 1911. Notizen über phylogenetisch interessanten Rhizocephalen, Zool. Anz., 38: 180-185.
Hashimoto, J., Fujikura, K., and Hotta, H., 1990. Observations of deep sea biological communities at the Minami-Ensei Knoll. JAMSTECTR Deep-sea Res., (1990): 167-179. (in Japanese with English abstract)
Hashimoto, J., Fujikura, K., Aoki, T., and Tsukioka, S., 1992. Development of a suction sampler (slurp gun) for deep sea organisms. Proc. JAMSTEC Symp. Deepsea Res., (1992): 367-372. (in Japanese with English abstract)
Hashimoto, J., Ohta, S., Fujikura, K., and Miura, T., 1995. Microdistribution pattern and biogeography of the hydrothermal vent communities of the Minami-Ensei Knoll in the Mid-Okinawa Trough, Western Pacific. JAMSTEC Deepsea Res., 42(6): 577-598.
Hawkes, C. R., Meyers, T. R., Shirley, T. C., and Koeneman, T. M., 1986. Prevalence of the parasitic barnacle *Briarosaccus callosus* on king crabs of southeastern Alaska. Trans. American Fish. Soc., 115: 252-257.
Hayashi, K. I. and Yanagisawa, H., 1985. Zoeae of *Paralomis japonica* Balss (Crustacea, Decapoda, Lithodidae). Nanki Seibutu, 27(1): 23-26.
Henderson, J. R., 1885. Diagnoses of the new species of Galatheidea collected during the "Challenger" Expedition. Ann. Mag. Nat. Hist., (5)16: 407-421.
Henry, R. P., Handley, H. L., Krarup, A., and Harriet M. Perry, 1990. Respiratory and cardiovascular responses of two species of deep-sea crabs, *Chaceon fenneri* and *C. quinquedens*, in normoxia and hypoxia. J. Crust. Biol., 10(3): 413-422.
Hiramoto, H., 1985. Overview of the golden king crab, *Lithodes aequispina*, fishery and its fisheries biology in the Pacific Waters of central Japan. Proc. Int. King. Crab Symp., 297-317.
Hiramoto, K. and Sato, S., 1970. Biological and fisheries survey on an anomuran crab, *Lithodes aequispina* Benedict, off Boso Peninsula and Sagami Bay, central Japan. Jap. J. Ecol., 20(5): 165-170.
Holthuis, L. B., 1974. Biological results of the University of Miami deep-sea expeditions. 106. The lobsters of the superfamily Nephropidea of the Atlantic Ocean (Crustacea: Decapoda). Bull. Mar. Sci., 24(4): 723-884.
Holthuis, L. B., 1991. FAO species Catalogue Volume 13. Marine Lobsters of the World of Interest to Fisheries. An Annotated and Illustrated Catalogue of Species of Interest to Fisheries Known to Date. Food and Agriculture Organization of the United Nations, viii+292 pp.
Holthuis, L. B., 1995. FAO species Catalogue Volume 13. Marine Lobsters of the World of Interest to Fisheries. Macintosh Version 1.0, Biodiversity Center of ETI, UNESCO-Publishing 7, Place de Fantenoy, Paris.
Holthuis, L. B. and Manning, R. B., 1990. Crabs of the

subfamily Dorippinae MacLeay, 1838, from the Indo-West Pacific region (Crustacea; Decapoda; Dorippidae). Res. Crust, Spec. No. 3: i-iii, 1-151.
Horikoshi, M., 1962. Distribution of benthic organism and their remains at the entrance of Tokyo Bay, in relation to submarine topography, sediments and hydrography. Nat. Sci. Rep. Ochanomizu Univ., 13(2): 47-122, 1 map.
Hoshino, K., 1992. On the parasitic castration of shore-crabs caused by *Sacculina*. Cancer, 2: 7-12. (in Japanese)
Høeg, J. T., 1992. Rhizocephala. Microscopic Anatomy of Invertebrates, 9: 313-345.
Høeg, J. T., 1995. The biology and life cycle of the Rhizocephala (Cirripedia). J. mar. biol. Ass. U. K. (1995), 75: 517-550.
Høeg, J. T. and Lützen, J., 1995. Life cycle and reproduction in the cirriped Rhizocephala. Oceanogr. Mar. Biol. : An Annual Review 1995, 33: 427-485.
Høeg, J. T. and Rybakov, A. V., 1992. Revision of the Rhizocephala Akentrogonida (Cirripedia), with a list of all the species and a key to the identification of families. J. Crust. Biol., 12(4): 600-609.
Ikeda, H., 1981. Crabs collected from Sagami Bay, -The catalogue of crab collection of Sagami Bay (1)-. Nat. Hist. Rep. Kanagawa, 2: 11-22.
Ikeda, H., 1991. Crabs collected from Sagami Bay (II). Nat. Hist. Rep. Kanagawa, 12: 41-44.
Ikeda, H., 1998. The deep-sea crabs of Sagami Bay, Hayama Shiosai Museum, Hayama, 180 pp. (in Japanese with English abstract)
Ishikawa, H., 1994. The bacteria manipulating insects, Heibonsha, Tokyo, iv+230 pp. (in Japanese)
Japan Maritime Safety Agency, 1973. Bathymetric Chart #6363-1: Uraga Channel, Japan Maritime Safety Agency, Tokyo.
Jensen, G. C. and Armstrong, D. A., 1991. Intertidal zonation among congeners: factors regulating distribution of porcelain crabs *Petrolisthes* spp. (Anomura: Porcellanidae). Mar. Ecol. Proc. Ser., 73: 47-60.
Kawamoto, H. 1995. Autopoiesis, third generation system, Sidosha, Tokyo, 340 pp. (in Japanese)
Kensley, B., 1981. On the zoogeography of Southern African decapod Crustacea, with a distributional check-list of the species. Smithson. Contrib. Zool., 338: iii+64 pp.
Kikkawa, J. and Anderson, D. J., 1986. Community Ecology, pattern and process, Blackwell Science Publications, Victoria, xi+432 pp.
Kim, D.-S. and Ohta, S., 1991. Submersible observations and comparison of the biological communities of the two hydrothermal vents on the Iheya Ridge of the Mid-Okinawa Trough. JAMSTECTR Deepsea Res., (1991): 221-233. (in Japanese with English abstract)
Kimura, M., Tanaka, T., Kyo, M., Ando, M., Oomori, T., Izawa, E., and Yoshikawa, I., 1989. Study of topography, hydrothermal deposits and animal colonies in the Middle Okinawa Trough hydrothermal areas using the submersible “Shinkai 2000” system. JAMSTECTR Deepsea Res., (1989): 223-244. (in Japanese with English abstract)
Kneer, G. and Nassehi, A., 1995. Niklas Luhmanns Theorie sozialer Systeme, translated by Tateno, T., Ikeda, S., and Nozaki, K., Shinseisha, Tokyo, 244 pp. (in Japanese)
Kobayashi, S., 1995. Multivariate Analysis of Biological Communities, Souju Shobo, Tokyo, 194 pp. (in Japanese)
Lilljeborg, W., 1860. Supplément au mémoire sur les genres *Liriope* et *Peltogaster*, H. Rathke. Nova Acta Regiae Sociatis Scientiarum Upsaliensis, Ser. 3, 3: 73-102.
Lützen, J., 1985. Rhizocephala (Crustacea: Cirripedia) from the deep sea. Galathea Rep., 5: 99-112, pl. 14.
Macpherson, E., 1988a. Lithodid crabs (Crustacea, Decapoda, Lithodidae) from Madagascar and La Reunion (SW Indian Ocean) with descriptions of two new species. Bull. Mus. natn. Hist. Nat., Paris, 4e, ser., 10, sect. A, No. 1: 117-133.
Macpherson, E., 1988b. Three new species of *Paralomis* (Crustacea, Decapoda, Anomura, Lithodidae) from the Pacific and Atlantic oceans. Zool. Scripta, 17: 69-75.
Macpherson, E., 1988c. Revision of the family Lithodidae Samouelle, 1819 (Crustacea, Decapoda, Anomura) in the Atlantic Ocean. Monogr. Zool. Mar., 2: 9-153.
Macpherson, E., 1990a. Crustacea Decapoda: On some species of Lithodidae from the Western Pacific. *In* Crosnier, A. (ed), Résultats des campagnes MUSORSTOM Vol. 6, Mém. Mus. natn. Hist. Nat., 145: 217-226.
Macpherson, E., 1990b. Crustacea Decapoda: On a collection of Nephropidae from the Indian Ocean and Western Pacific. *In* Crosnier, A. (ed), Résultats des campagnes MUSORSTOM Vol. 6, Mém. Mus. natn. Hist. nat., 145: 289-328.
Macpherson, E., 1991. Biogeography and community structure of the decapod crustacean fauna off Namibia (Southeast Atlantic). J. Crust. Biol., 11(3): 401-415.
Macpherson, E., 1993. New records for the genus *Nephropsis* Wood-Mason (Crustacea, Decapoda, Nephropidae) from northern Australia, with the description of two new species. The Beagle, Rec. Northern Territory Mus. Arts and Sci., 10(1): 55-66.
Macpherson, E., 1994. Occurrence of two lithodid crabs (Crustacea: Decapoda: Lithodidae) in the cold

seep zone of the South Barbados Accretionary Prism. Proc. Biol. Soc. Wash., 107(3): 465-468.

Manly, B. F. J., 1997. Randomization, Bootstrap and Monte Carlo Methods in Biology, 2nd ed., Chapman and Hall, London, xvii+399 pp.

Margulis, L. and Sagan, D., 1995. Origin of Sex -Three Billion Years of Genetic Recombination-, translated by Nagano, T., Hara, S., and Nagano, K., Seidosha, Tokyo, 371+xvii pp. (in Japanese)

Matsumoto, K., 1952. On the sacculinization of *Charybdis japonica* (A. Milne-Edwards). Biol. J. Okayama Univ., 1: 84-89. (in Japanese with English abstract)

Maturana, H. R. and Varela, F. J., 1980. Autopoiesis and cognition, The realization of the living, with a preface to 'Autopoiesis' by Sir Stafford Beer, D. Reidel Publishing Company, Dortrecht: Holland/Boston: USA/London: England, 141 pp.

Mayr, E., 1994. Toward a New Philosophy of Biology, Observation of an Evolutionist, translated by Yasugi, S. and Niizuma, A., Tokyo Kagaku Doujin, xvi+545+60 pp. (in Japanese)

Mayr, E. and Ashlock, P. D., 1991. Principles of Systematic Zoology, 2nd ed., McGraw-Hill, Inc., New York, 475 pp.

McLaughlin, P. A., Lemaitre, R., and Sorhannus, U., 2007. Hermit crab phylogeny: A reappraisal and its "fall-out." J. Crust. Biol., 27(1): 97-115.

McMullen, J. C. and Yoshihara, H. T., 1970. An incidence of parasitism of deepwater king crab, *Lithodes aequispina*, by the barnacle *Briarosaccus callosus*. J. Fish. Res. Board. Can., 27: 818-821.

Miyake, S., 1982. Japanese Crustacean Decapods and Stomatopods in Color, vol. I, Macrura, Anomura, and Stomatopods, Hoikusha, Osaka, vii+261 pp., 56 pls.

Miyake, S., 1983. Japanese Crustacean Decapods and Stomatopods in Color, vol. 2, Brachyura, Hoikusha, Osaka, viii+277 pp., 64 pls.

Miyake, S. and Baba, K., 1967. Descriptions of new species of galatheids from the Western Pacific. J. Fac. Agr. Kyusyu Univ., 14: 203-212.

Natori, K., Furuta, E., Muramatsu, S., and the foundation, The Laboratory of Fishery and Invertebrates, 1992. Organic defense among invertebrates, Gakkai-Shuppan Center, Tokyo, 296 pp. (in Japanese)

Nedachi, M., Ueno, H., Ossaka, J., Nogami, K., Hashimoto, J., Fujikura, K., and Miura, T., 1992. Hydrothermal ore deposits on the Minami-Ensei Knoll of the Okinawa Trough. -mineral assemblages- Proc. JAMSTECTR Deepsea Res., (1992): 95-106. (in Japanese and English abstract)

Ohta, S., 1983. Photographic census of large-sized benthic organisms in the bathyal zone of Suruga Bay, central Japan. Bull. Ocean Res. Inst., Univ. Tokyo, 15: 1-244.

Ohta, S., 1990. Ecological observations and remarks on the cold seep communities in Sagami Bay, central Japan. JAMSTECTR Deepsea Res., (1990): 181-195. (in Japanese with English abstract)

Ohta, S. and Kim, D.-S., 1992. Coupling behavior of deep-sea red crab and the nutritional ecology of vent mussel observed during the Shinkai 2000 Dive #542 surveying hydrothermal vent fields on the South Ensei Knoll, Okinawa Trough, Japan. Proc. JAMSTEC Symp. Deep Sea Res., (1992): 279-285.

Okada, Y. K. and Miyashita, Y., 1935. Sacculinization in *Eriocheir japonicus* de Haan, with remarks on the occurrence of complete sex-reversal in parasitized male crabs. Mem. Coll. Sci., Kyoto Imp. Univ., Ser. B, 10(3): 169-208.

Ortmann, A., 1892. Die Decapoden–Krebse des Strassburger Museums. IV. Die Abtheilungen Galatheidea und Paguridea. Zool. Jahrb. (Sys.) 6: 241-326. pls. 11-12.

Phillips, W. J. and Cannon, L. R. G., 1978. Ecological observations on the commercial sand crab, *Portunus pelagicus* (L.), and its parasite, *Sacculina granifera* Boschma, 1973 (Cirripedia: Rhizocephala). J. Fish. Dis., 1: 137-149.

Rasmussen, E., 1959. Behavior of sacculinized shore crabs (*Carcinus maenas* Pennant). Nature, 183: 479-480.

Rathbun, 1932. Preliminary descriptions of new species of Japanese crabs, Proc. Biol. Soc., Washington, 45: 28-38.

Ritchie, L. E. and Høeg, J. T., 1981. The life history of *Lernaeodiscus porcellanae* (Cirripedia: Rhizocephala) and co-evolution with its porcellanid host. J. Crust. Biol. 1: 334-347.

Rubiliani, C. and Godette, G. O., 1981. Radiochemical and electrophoretic studies on the CNS of crabs parasitized with rhizocephalans; comparison with healthy crabs. Comp. Biochem. Physiol., 70B: 415-419.

Saint Laurent, M de and Macpherson, E., 1997. Une nouvelle espèce du genre *Paralomis* White, 1856, des sources hydrothermales du Sud-ouest Pacifique (Crustacea, Decapoda, Lithodidae). Zoosystema, 19(4): 728-727.

Sakai, K., 1982. Revision of Upogebiidae (Decapoda, Thalassinidea) in the Indo-West Pacific region. Res. Crust., Spec. No. 1: 1-106.

Sakai, K., 1987. Biogeographical records of five species of the family Lithodidae from the abyssal valley off Gamoda-Misaki, Tokushima, Japan. Res. Crust., 16: 19-24, pls. I-III.

Sakai, K. & Sawada, T., 2006. The taxa of the infraorders Astacidea, Thalassinidea, Palinura, and Anomura (Decapoda, Pleocyemata) classifieid by

the form of the prepyloric ossicle. Crustaceana, 78(11): 1353-1368.
Sakai, T., 1965. The Crabs of Sagami Bay, Maruzen, Tokyo, xvi+206 pp. (English Part) +99 pls+92 pp. (Japanese Part) +32 pp., with topographic map of eastern part of Sagami Bay.
Sakai, T., 1971. Illustrations of 15 species of crabs of the family Lithodidae, two of which are new to science. Res. Crust., 4 and 5: 1-49, pls. I-XXI.
Sakai, T., 1976. Crabs of Japan and Adjacent Seas, Koudansha, Tokyo, 773 pp.
Sakai, T., 1980. New species of crabs of the families Lithodidae and Calappidae. Res. Crust, 10: 1-11, plate 1.
Shoettker, P. J. and Gist, D. H., 1990. In vitro ecdysteroid production by Y-organs of the blue crab *Callinectes sapidus*. J. Crust. Biol., 10(3): 487-491.
Shiino, S. M., 1931. Studies on the modification of sexual characters in *Eupagurus samuelis* caused by a rhizocephalan parasite *Peltogaster* sp. Mem. Coll. Sci., Kyoto Imp. Univ., Ser. B, 7(2): 63-101.
Shimizu, Y., 1984. Symbolic logic, Tokyo University Press, ii+181 pp. (in Japanese)
Shirley, S. M., Shirley, T. C., and Meyers, T. R., 1986. Hemolymph responses of Alaskan king crabs to rhizocephalan parasitism. Can J. Zool., 64: 1774-1781.
Sloan, N. A., 1984. Incidence and effects of parasitism by the rhizocephalan barnacle, *Briarosaccus callosus* Boschma, in the golden king crab, *Lithodes aequispina* Benedict, from deep fjords in northern British Columbia, Canada. J. Exp. Mar. Biol. Ecol., 84: 111-131.
Sloan, N. A., 1985. Life history characteristics of fjord-dwelling golden king crabs *Lithodes aequispina*. Mar. Ecol. Prog. Ser., 22: 219-228.
Somero, G. N. and Childress, J. J., 1990. Scaling of ATP-supplying enzymes, myofibrillar proteins and buffering capacity in fish muscle: Relationship to locomotory habit. J. Exp. Zool., 149: 319-333.
Sparks, A. K. and Morado, J. F., 1986. Histopathology and host response in lithodid crabs parasitized by *Briarosaccus callosus*. Dis. Aquat. Org., 2: 31-38.
Spaziani, E., Wang, W. L., and Novy, L. A., 1995. Serum high-density lipoproteins in the crab *Cancer antennarius*-IV. Electrophoretic and immunological analyses of apolipoproteins and a question of female-specific lipoproteins. Comp. Biochem. Physiol., 111B(2): 265-276.
Stimpson, W., 1858. Prodromus descriptionis animarium evertebratorum quae in Expeditione ad Oceanum Pacificum Septentrionalem, a Republica Federrata missa, , , . Proc. Acad. Nat. Sci. Philadelphia. 10(4): 31-40.
Stone, R. P., O'Clair, C. E., and Shirley, T. C., 1992. Seasonal migration and distribution of female red king crabs in a southeast Alaskan Estuary. J. Crust. Biol., 12(4): 546-590.
Suzuki, S., 1987. Vitellins and vitellogenins of the terrestrial isopod, *Armadillidium vulgare*. Biol. Bull., 173: 345-354.
Suzuki, S., 1992. A trial of isolation of female hormones inducing sex determination in *Armadillidium vulgare*, Cancer, 2 (1992): 13-15. (in Japanese)
Suzuki, S. and Yamasaki, K., 1990. Vitelogenin synthesis in andrectomized males of the terrestrial isopod, *Armadillidium vulgare*. Gen. Comp. Endocrinol., 77: 283-291.
Suzuki, S. and Yamasaki, K., 1991a. Sex-reversal of male *Armadillidium vulgare* (Isopoda, Malacostraca, Crustacea) following andrectomy and partial gonadectomy. Gen. Comp. Endocrinol., 83: 375-378.
Suzuki, S. and Yamasaki, K., 1991b. Ovarian control of oostegite formation in the terrestrial isopod, *Armadillidium vulgare* (Malacostraca, Crustacea), Gen. Comp. Endocrinol., 84: 381-388.
Suzuki, S. and Yamasaki, K., 1995. Morphological studies on sexual differentiation in *Armadillidium vulgare* (Isopoda: Armadillidae): androgenic gland and male sexual characters, Crust. Res., 24: 93-103.
Suzuki, S. and Yamasaki, K., 1997. Sexual bipotentiality of developing ovaries in the terrestrial isopod *Armadillidium* vulgare (Malacostraca, Crustacea). Gen. Comp. Endocrinol., 107: 136-146.
Suzuki, S. and Yamasaki, K., 1998. Sex reversal by implantations of ethanol-treated androgenic glands of female isopods, *Armadillidium vulgare* (Malacostraca, Crustacea). Gen. Comp. Endocrinol., 111: 367-375.
Takabayashi, J. and Tanaka, T., 1995. “The Eternal Triangle” around Parasitic Wasp, Koudansha, Tokyo, 270 pp. (in Japanese)
Takahashi, T., Iwashige, A., and Matsuura, S., 1997. Behavioral manipulation of the shore crab, *Hemigrapsus sanguineus* by the rhizocephalan barnacle, *Sacculina polygenea*. Crust. Res., 26: 153-161.
Takeda, M., 1985. A new species of *Paralomis*, the crab-shaped Anomura (Crustacea, Decapoda), from the Kyushu-Palau Submarine Ridge. Bull. Nat. Sci. Mus., Tokyo, Ser. A, 11(3): 137-140.
Takeda, M. and Hashimoto, J., 1990. A new species of the genus *Paralomis* (Crustacea, Decapoda, Lithodidae) from the Minami-Ensei Knoll in the Mid-Okinawa Trough. Bull. Nat. Sci. Mus., Tokyo, ser. A, 16(2): 79-88.
Takeda, M. and Miyake, S., 1980. A new species of *Paralomis* (Crustacea, Anomura) from the East China Sea. Annot. Zool. Jap., 53: 42-45.
Takeuti, G. 1994. Introduction to Modern Set Theory,

Nipponhyouronsha, Tokyo, iv+336 pp. (in Japanese)

Tanino, Y. and Kato, H., 1971. The fishing efficiency and selectivity of beni-zuwai crab traps. Bull. Jap. Sea. Reg. Fish. Res. Lab., 23: 101-117.

Toriyama, M., Horikawa, H., and Kishida, S., 1990. Preliminary reports on ten rare caridean shrimps (Decapoda, Caridea) from Tosa Bay and its adjacent waters. Bull. Nansei Nat. Fish. Res. Inst., 23: 13-26.

Vetter, R. D., Wells, M. E., Kurtman, A. L., Somero, G., N., 1987. Sulfide detoxification by the hydrothermal vent crab *Bythograea thermydron* and other decapod crustaceans. Physiol. Zool., 60(1): 121-137.

Vetter, R. D., Lynn, E. A., Garza, M., and Costa, A. S., 1994. Depth zonation and metabolic adaptation in Dover sole, *Microstomus pacificus*, and other deep-living flatfishes: factors that affect the sole. Mar. Biol., 120: 145-159.

Wada, S., Ashidate, M., and Goshima, S., 1997. Observations on the reproductive behavior of the spiny king crab *Paralithodes brevipes* (Anomura: Lithodidae). Crust. Res., 26: 56-61.

Wago, H., 1983. Biodefence of insects, the miracle of phagocyte, Monado Books Vol. 2, Kaimeisha, Tokyo, 96 pp. (in Japanese)

Watabe, H., 1995. Parasitic interrelationships between *Paralomis multispina* (Lithodidae: Anomura) and *Briarosaccus callosus* (Peltogastridae: Cirripedia), Master Thesis presented to the Graduate School of Science, University of Tokyo, 74 pp.

Watabe, H., 1999a. The foundation of taxonomy (1): A trial to formalize the "taxonomic inference" proposed by Erst Mayr. Biological Science, 51(3): 159-167.

Watabe, H., 1999b. The foundation of taxonomy (2): Metaproofs for the consistency and completeness of "formalized Mayrian taxonomy." Biological Science, 51(4): 215-224.

Watabe, H., 2000. Taxonomic system of symbiosis: Application of *cGAT* to general biology. Biological Science, 52(1): 37-48.

Watabe, H. and Hashimoto, J., 2002. A new species of the genus *Rimicaris* (Alvinocarididae: Caridea: Decapoda) from the active hydrothermal vent field, "Kairei Field," on the Central Indian Ridge, the Indian Ocean. Zoological Science, 19: 1167-1174.

Watabe, H. and Iizuka, E., 1999. A new species of the bathyal lobster genus *Nephropsis* (Crustacea: Decapoda: Nephropidae) from Australian waters, with a redecription of *N. holthuisi*. Species Diversity, 4(1999): 371-380.

Watabe, H. and Ikeda, H., 1994. *Nephropsis hamadai*, a new nephropid lobster (Decapoda: Nephropidae) from bathyal depth in Sagami Nada, central Japan. Crust. Res., 23: 102-107.

Watabe, H. and Miyake, H., 2000. Decapod fauna of the hydrothermally active and adjacent fields on the Hatoma Knoll, southern Japan. JAMSTEC Journal of Deep Sea Research, 17(2000): 29-34.

White, A., 1856. Some remarks on Crustacea of the genus *Lithodes* with a brief description of a species apparently hitherto unrecorded. Proc. Zool. Soc. London, 1856: 132-135, pl. 42.

Wood-Mason, J., 1873. On *Nephropsis stewarti*, a new genus and species of macrurous crustaceans, dredged in deep water off the eastern coast of the Andaman Islands. Ann. Mag. Nat. Hist, ser. 4, 12: 59-64.

Wood-Mason, J. and Alcock, A., 1891. Natural history notes from H. M. Indian Marine Survey Steamer "Investigator," Commander R. F. Hoskin, R. N., commanding, No. 21. Note on the results of the last season's deep-sea dredging. Ann. Mag. Nat. Hist., ser. 7, 6: 186-202.

Yamamura, N., Hayakawa, Y., and Fujishima, M., 1995. From Parasitism to Symbiosis - the enemy yesterday into the friend today-, Heibonsha, Tokyo, 229 pp. (in Japanese)

Yanagimachi, R., 1960. The life-cycle of *Peltogasterella* (Cirripedia, Rhizocephala). Crustaceana, 2(3): 183-187.

Yepiz-Plascencia, G. M., Sotelo-Mundo, R., Vazquez-Moreno, L., Ziegler, R., and Higuera-Ciapara, I., 1995. A non-sex-specific hemolymph lipoprotein from the white shrimp *Penaeus vannamei* Boone. Isolation and partial characterization. Comp. Biochem. Physiol., 111B(2): 181-187.

Yokoya, Y., 1933. On the distribution of decapod crustaceans inhabiting the continental shelf around Japan, chiefly based upon the materials collected by S. S. Soyo-Maru during the years 1923-1930. J. Coll. Agr. Tokyo Imp. Univ., 12: 1-226.

十脚甲殻類の超生物学：Autopoiesis 理論の公理系 CGAT の構成

渡　部　　　元*

要　旨

海洋生物、とりわけ採集を含めたアクセスが非常に困難な深海生物を用いた生物学・バイオ産業を実践する場合には、以下の諸問題が存在する。まず、直接観察を実施することが困難である点から、研究計画の策定、実施、産業展開、資源保護などを縦断する形での研究・事業本体の計画管理が容易でないことが挙げられる。さらに、研究実施に関して多額の費用が必要となる一方で、研究そのものが必要経費を生み出すことも重視する必要がある。本研究ではまず、研究の計画管理に関して Autopoiesis 理論を採用し、海洋生物研究の最も基盤となる生物分類学の理論と実際を組織的、統一的に把握・実施した。Autopoiesis 理論は「生命の定義」を明確に実施した理論として認知に関する神経生理学から出立したが、生物分類学への応用はこれが初めてである。具体例として、深海性オキナエビ類、タラバガニ類の分類学、蟹型十脚甲殻類の大分類体系、東京海底谷漸深海域に出現する腐食性十脚甲殻類の分布特性解析、潜水船を用いたタラバガニ類の分布調査、東京海底谷漸深海域での乱獲に基づく駆逐後のタラバガニ類の挙動、十脚甲殻類の共生生物に関する分類学的基盤構築、さらに Autopoiesis 理論そのものの公理主義的観点からの整備も行った。

キーワード：深海性十脚甲殻類、計画管理、分類学、Autopoiesis 理論、公理系

* 海洋政策研究財団

海 洋 政 策 研 究　第5号

2007年12月発行

発行　海洋政策研究財団（財団法人シップ・アンド・オーシャン財団）

〒105-0001　東京都港区虎ノ門1-15-16　海洋船舶ビル
TEL 03-3502-1828　FAX 03-3502-2033

ISSN 1880-0017

Ocean Policy Studies

No.5 2007

OPRF
Ocean Policy Research Foundation