STUDIES ON THE RAJID FISHES (Rajidae) FOUND IN THE WATERS AROUND JAPAN※

By

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(With 3 Plates and 86 Text-figures)

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I. Introduction

The fish referred to the family Rajidae, a well-known natural group in batoids are found in nearly all the seas of the world, especially in the temperate and arctic regions.

General revisional studies of the fish and the relatives have been made by various authorities, viz., MÜLLER and HENLE (1837—1841), DUMÉRIL (1852, 1870), GÜNTHER (1860), HASSE (1878—1885) and GARMAN (1913). A series of painstaking works were written about the fish by CLARK (1926), WHITE (1937) and BIGELOW and SCHROEDER (1934—1953) published much more extensive studies in the fish, which have been acknowledged as giving a basis for the taxonomy of rajids and other batoids found especially in the Atlantic basin. Great progress has recently been made in the taxonomy of many teleosts. Indeed there are several accounts which treat of the discrimination of some common rajids, but Japanese rajids have remained neglected, so far as taxonomy is concerned, for the records concerning the fish, not to speak of other groups of Chondrichthyes, seem incomplete and unsatisfactory to the author. This is why the author has made the present investigation under the supervision of Dr. K. MATSUBARA with a view to obtaining a sounder basis for the taxonomy of this neglected group of fish.

In order to show a more precise method of distinguishing Japanese rajids into genera, species and subspecies, and clarify interrelationship in the family and their genealogical relation to batoids, the author has examined the fish in the following characters, both external and internal, which seem valid to some extent in systematizing the fish: external reproductive organs in both sexes, such as clasper and egg-capsules; snout; tail and its electric organ; placoid scales and their derivatives; vertebral counts; numbers of valves in the heart and the intestine; color and pattern of the integument.

Many elasmobranchs have simpler external features than teleosts, but it is very difficult for us to distinguish species of rajids from one another, especially in their earlier stages, when they remarkably resemble one another in general appearances. Most elasmobranchs in their earliest self-supporting stage are larger in size, as compared with teleosts, and their bodily parts vary a great deal in proportion to their growth. Besides, some pronounced sexual dimorphism presents itself in most rajids. Consequently, these make it difficult for us to identify any particular species of the fish, if we are not provided with minute accounts of the fish characters, such as meristic and dimensional measures, in various stages of the fish.

Fortunately the author has succeeded in obtaining twice as many species as were known to ichthyologist till the time of this investigation of his. The following list represents all the rajids dealt with in the present investigation, including three genera, twenty-one species and four subspecies, some of which will serve for emendation or contribute new information to the science of ichthyology.

In describing the species in the text, the author has used for brevity's sake the Roman alphabet of gothic type ranging from **A** to **W** as the substitutes for their scientific names, and these names belong to the southern form or the northern form, two major groups of species. Some are included in the genus *Raja* of the southern form and others in the genera *Breviraja* and *Rhinoraja* of the northern form, the genera *Raja* and *Breviraja* containing several newly-established subgenera.

	Abbreviations*)
Genus *Breviraja* BIGELOW and SCHROEDER, emend	
Subgenus *Notoraja*, n. subg.	
B. tobitukai (HIYAMA)	A
Subgenus *Bathyraja*, n. subg.	
B. isotrachys (GÜNTHER)	B
B. trachouros, n. sp.	C
B. abasiriensis ISHIYAMA	D
B. diplotaenia ISHIYAMA	E
B. matsubarai ISHIYAMA	F
B. aleutica (GILBERT)	G
Subgenus *Arctoraja*, n. subg.	
B. parmifera (BEAN)	H
B. smirnovi smirnovi (SOLDATOV et PAVLENKO)	I
B. smirnovi ankasube, n. subsp.	I′
Genus *Rhinoraja* ISHIYAMA, emend	
Rh. odai, n. sp.	J
Rh. kujiensis (TANAKA)	K
Rh. longicauda ISHIYAMA	L
Genus *Raja* LINNAEUS, emend	
Subgenus *Okamejei*, n. subg.	
R. kenojei MÜLLER et HENLE	M
R. acutispina, n. sp.	N
R. hollandi JORDAN et RICHARDSON	O
R. macrophthalma, n. sp.	P
R. porosa meerdervoorti GÜNTHER	Q
R. porosa tobae TANAKA	Q′
R. fusca GARMAN	R
R. schmidti, n. sp.	S
Subgenus *Tengujei*, n. subg.	
R. tengu JORDAN et FOWLER	T
R. pulchra LIU	U
R. macrocauda ISHIYAMA	V
R. gigas, n. sp.	W

On the present treatise, as mentioned above, the main purpose is to provide the reader with the criteria of genera and species or subspecies as well as their relationships, and also provide with the author's conclusion as to the validity of the characteristics that have been examined in this investigation. Although racial or population study is of economic importance from a viewpoint of fishery biology, the author wishes to defer future works on minor biological units below subspecies.

However, since nothing is known about concise method for age-determination in any particular species among cartilaginous fishes, a method which functions possible to determine the age of some rajids was first developed by the present author and is amended in the present study.

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* These abbreviations are referred to those given in the preceding paper on egg-capsules (ISHIYAMA, 1958).

II. Acknowledgments

Many gentlmen have assisted me in various ways. First of all I am deeply indebted to Dr. Kiyomatsu MATSUBARA, Professor of the Kyoto University, for his continuous encouragement during the investigation and in giving me many specimens and in critical reading the manuscript. I also sincerely thanks to Dr. Henry B. BIGELOW and Mr. William C. SCHROEDER, of the Museum of Comparative Zoology at Harvard University and the Woods Hole Oceanographic Institution, for their kindness in reading a part of the manuscript and in giving valuable references.

A lot of specimens have been collected by me through the courtesy of many investigators as well as gentlmen mentioned below at various localities in parentheses, for which I wish to thank them most sincerely; Drs. Toraichirô KINOSHITA (Yoichi, Hokkaido), Yoshiteru NAKAMURA (Muroran, Hokkaido), Messrs. Nobuhiko HANAMURA (Otaru, Hokkaido), Seizo IMAI (Wakkanai, Hokkaido), Kiyu KOBAYASHI (Hakodate, Hokkaido), Tatsuji UENO (Tokyo), Motohiro SAKURAI (Kushiro, Hokkaido), Akira SASAKI (Abasiri, Hokkaido), Yoshimitsu TANAKA (Monbetsu, Hokkaido), Tatsuo SARUTA (Tokyo), Kohei KASAHARA (Hachinohe, Aomori), Tsuyoshi KAWASAKI (Shiogama, Miyagi), Kikuzô DOTE (Chôsi, Chiba), Tatsuji MIYAMOTO (Iioka, Chiba), Suekichi KATAYAMA (Maisaka, Shizuoka), Takeo KURAKAKE (Miya, Aichi), Chikashi MASUDA (Miya, Aichi), Mikiji ODA (Miya, Aichi), Yoshiharu HONMA (Sado, Niigata), Yoshinori OGAWA (Kasumi, Hyôgo), Tamotsu IWAI (Maizuru, Kyoto), Takashi KATÔ (Hiwasa, Tokushima), Sinji KUDO (Yawatahama, Ehime), Ichirô FURUKAWA (Kôchi), Sadamu YURINO (Totoro, Miyazaki), Keisuke OKADA (Shimonoseki, Yamaguchi), Kôzô SAISYU (Shimonoseki, Yamaguchi), Tôru TAKAI (Hirao, Yamaguchi), and Seishi Kuwabara (Shimonoseki, Yamaguchi).

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My more specific indebtness is due to Dr. Isao MATSUI, Professor of our college, and Dr. Itsuo KUBO, Professor of the Tokyo University of Fisheries, to whom generous encouragement and many favors I owe a great deal.

I finally return my special thanks to Mr. Hiroshi KOBAYASHI of our college, who assisted me in seeing the paper through the press.

III. Materials and Methods

Rather extensive collection of the rajid fishes and their relatives have been done to be used in the present study. The following table indicates those localities, data of collection and number of the specimens used, which were principally gathered in the landings captured by the motor trawlers operating in the seas covering from the south China Sea to the Sea of Okhotsk.

Deposition of the specimens:- The specimens used in the present investigation were arranged in the three sets, taken from various localities as aforementioned, involving both the younger and the older fishes and egg-capsules of all the members of known and newly described species, except for *Breviraja parmifera* (BEAN), which was collected only one adult male by Dr. K. MATSUBARA from off Muroran in Hokkaido, and the egg-capsules of *Breviraja abasiriensis* and *B. smirnovi ankasube*. Of these three, a set of the specimens including holo- and paratypes of the newly described species together with those hitherto known ones are preserved in the Department of Fisheries, Faculty of Agriculture, Kyoto University, and the other two are preserved in the Museum of Comparative Zoology of Harvard University and in the Zoological Laboratory of the Shimonoseki College of Fisheries, respectively.

Measurements, counts and terminology:- The methods of counts and measurements as well as the terminology of various organs used in this work are followed with illustrations and explanations given by CLARK (1926) and BIGELOW and SCHROEDER (1953) as given in the next lines:

1. All the measurements and counts were taken from the specimens preserved in the formalin (ca. 10%).

2. The observation on the color and pattern of the integument was done in both fresh and preserved specimens.

3. For the histological study of some organs the formalin preserved specimens were used and cut in sections by usual methods.

4. The measurements of the bodily parts were given as follows:

   (1). The total length was measured from the tip of the snout to distal tip of the tail.
   (2). The disc-length was represented by the vertical length from the tip of the snout to the middle between posterior extremities of the pectorals.
   (3). The disc-width is horizontal distance between the two lateral angles of the pectoral fins.
   (4). The length of tail was measured from the center of the cloaca to the tip of the tail, which is subdivided at the insertion of the 1st dorsal fin into two parts, the pre- and procaudal.
   (5). The term of head-length was meant the distance from the tip of the snout to the center of 5th gill slits of the two sides.
   (6). The diameter of eye was indicated by longer axis of the eye-ball inclusive of the integument.
   (7). The interorbital width is the least horizontal distance between the two inner dorsal ridges of the orbits.
   (8). To indicate the degree of notch in the pelvic fin, the distance from the tip of anterior lobe to incised corner between the two lobes was measured and termed it ventral incision.
   (9). The length of the clasper was represented by the distance from the distal tip to a point of emergence from the skin on inner lateral side of the tail.
   (10). To indicate the characteristics of the cranium in each form satisfactorily, the details were given in Fig. 26.
   (11). The vertebral counts were enumerated by the X-ray photographs or by dissections.

5. To show relative growth of the bodily parts the writer has taken the disc-width as the standard dimension substituted for the absolute growth length.

6. In some characters, the biometric study was adopted so as to indicate critical

Table 1. Localities, number of specimens captured of each form and other data related to the collection and examination of the samples. For abbreviations other than followings, see page 2 in the text; E, the East China Sea and the Yellow Sea; In, the Inland Sea; J, the Sea of Japan; O, the Sea of Okhotsk; P, the Pacific; + indicates the occurrance of the species recognized. Other details on the materials examined in the respective scheme will be mentioned later on.

	Species Locality, etc.	A	B	C	D	E	F	G	H	I	I′	J	K	L	M	N	O	P	Q	Q′	R	S	T	U	V	W
No.	Number of specimens	22	34	30	10	31	18	17	1	21	25	17	27	27	102	68	59	72	13	60	67	40	51	89	37	21
	〃 〃 egg-capsules	4	4	5	—	5	2	12	2	4	—	2	6	2	10	6	32	2	2	16	4	4	2	25	7	2
1	Wakkanai, Hokkaido, O	……	+	……	……	……	……	……	……	4	……	……	……	……	……	……	……	……	……	……	……	……	……	15	……	……
2	Esashi, 〃 , O	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	3	……	……
3	Monbetsu, 〃 , O	……	9	……	1	……	……	2	……	17	……	……	……	……	……	……	……	……	……	……	……	……	……	+	……	……
4	Abashiri, 〃 , O	……	……	……	9	……	……	+	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	+	……	……
5	Otaru, 〃 , J	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	+	+	……	……
6	Kushiro, 〃 , P	……	3	……	……	12	16	9	……	……	……	……	2	2	……	……	……	……	……	……	……	……	……	……	……	……
7	Muroran, 〃 , P	……	3	10	……	9	+	4	1	……	……	……	+	……	……	……	……	……	……	……	……	……	……	4	……	……
8	Hachinohe, Aomori, P	……	3	13	……	+	2	+	……	……	……	……	10	10	+	……	……	……	……	……	2	……	……	……	……	……
9	Funakawa, Akita, J	……	10	……	……	……	……	……	……	……	2	……	……	……	14	……	……	……	3	……	……	……	2	29	……	……
10	Shiogama, Miyagi, P	……	+	7	……	8	……	2	……	……	……	……	13	13	……	……	……	……	……	……	1	……	……	……	……	……
11	Chôshi, Chiba, P	……	……	……	……	2	……	……	……	……	……	……	2	2	4	……	……	……	+	+	64	……	……	……	2	……
12	Yokosuka, Kanagawa, P	……	……	……	……	……	……	……	……	……	……	……	……	……	+	……	……	……	……	……	……	+	……	……	……	……
13	Sado, Niigata, J	……	+	……	……	……	……	……	……	……	4	……	……	……	+	……	……	……	……	+	……	……	……	……	……	……
14	Niigata, 〃 , J	……	……	……	……	……	……	……	……	……	1	……	……	……	2	1	……	……	3	……	……	……	……	……	……	……
15	Kanaiwa, Ishikawa, J	……	……	……	……	……	……	……	……	……	+	……	……	……	3	3	……	……	……	5	……	……	……	……	……	……
16	Tsuruga, Fukui, J	……	……	……	……	……	……	……	……	……	+	……	……	……	……	……	……	……	……	……	……	……	+	+	……	……
17	Obama, 〃 , J	……	……	……	……	……	……	……	……	……	……	……	……	……	2	20	……	……	……	12	……	……	……	……	……	……
18	Maizuru, Kyoto, J	……	3	……	……	……	……	……	……	……	16	……	……	……	3	11	……	……	……	16	……	……	……	1	……	……
19	Tsuiyama, Hyogo, J	……	……	……	……	……	……	……	……	……	……	……	……	……	3	1	……	……	4	+	……	……	……	2	……	……
20	Kasumi, 〃 , J	……	……	……	……	……	……	……	……	……	……	……	……	……	7	……	……	……	3	7	……	……	21	29	……	……
21	Maisaka, Shizuoka, P	5	……	……	……	……	……	……	……	……	……	……	……	……	4	……	……	8	……	……	……	……	……	……	……	5
22	Miya, Aichi, P	15	……	……	……	……	……	……	……	……	……	17	……	……	+	……	……	13	……	……	……	11	2	+	23	9
23	Owase, Mie, P	2	……	……	……	……	……	……	……	……	……	……	……	……	2	……	……	……	……	……	……	……	+	……	2	2
24	Oki, Shimane, J	……	3	……	……	……	……	……	……	……	2	……	……	……	……	……	……	……	……	……	……	……	……	+	……	……
25	Senzaki, Yamaguchi, J	……	……	……	……	……	……	……	……	……	……	……	……	……	45	20	3	11	+	5	……	……	……	……	……	……
26	Shimonoseki, 〃 , J, E, In	……	……	……	……	……	……	……	……	……	……	……	……	……	13	12	56	28	……	12	……	……	+	6	……	……
27	Mimase, Kôchi, P	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	12	……	+	……	……	6	……	1	+
28	Yawatahama, Ehime, P	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	3	……	14	……	……	……	……
29	Onomichi, Hiroshima, In	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	+	……	……	……	……	……	……
30	Totoro, Miyazaki, P	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	15	20	……	9	5
	Range of depth captured (ca. m)	300–400	90–230	500–700	80–100	300–500	800–1000	300–700	?	100–200	150–400	330–350	600–800	300–600	20–80	50–90	70–90	80–90	70–100	30–80	20–50	20–50	100–150	50–100	300–400	300–400

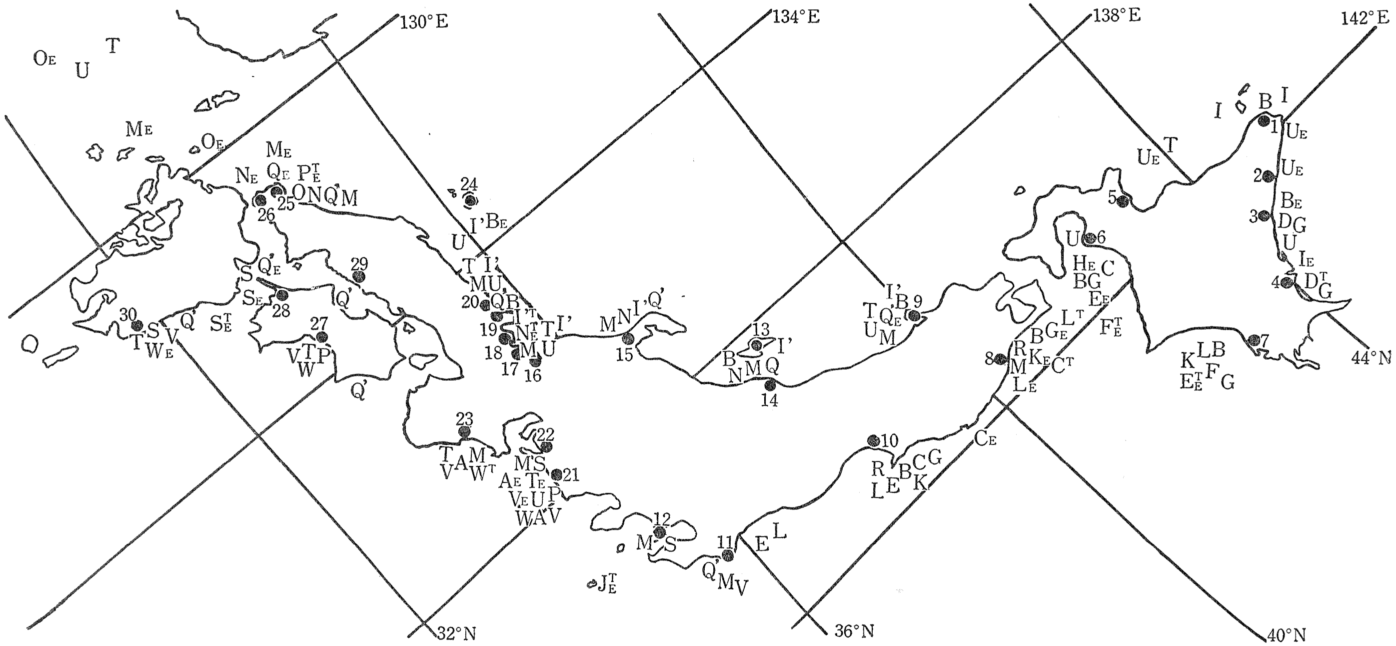

Fig. 1. Distribution of rajid fishes collected during the present study: type localities of species are indicated by T attached to the species symbol; localities of parent fishes with egg-capsules are shown by E attached to the symbol; number given in place of each locality is referred to that in Table 1. For other abbreviations, see p. 2.

basis for the identification or discrimination of the form.*)

Procedure and arrangement of description in general:- With regard to the general part in the present account, the characteristics found in the male organ are offered to provide a fundamental basis on which the phylogenetic classification of Japanese rajids is first developed. Because the single character may not be so reliable as the multiple ones to be used in the taxonomic work such eight characters as mentioned on page 1 which are thought to be important for the present investigation are used together with geographical and other characters. Thus, the present writer has made a comparison of the results obtained from the male organs with those of other characters which are in diversification in greater or less extent.

In the systematic part, the diagnosis in each form is given in the same manner as those given in the previous reports (ISHIYAMA, 1952, '55), viz., the description shall be arranged in order from external to internal and to other characters of the species. As regards the known species, the diagnosis is given by using as many specimens as possible, but in the newly described ones the description shall be made first by the holotype and followed by the paratypes and other notes.

All the drawings were made by the present author, but the photographs were taken by Mr. Sueo HARADA of our college.

IV. Comparative anatomy

A. The external features of organs related to reproduction

a. Clasper or myxopterygium

1. Description in general

In elasmobranchs internal fertilization takes place. The transfer of sperm in the spermatophores from male to female is done by means of the clasper or myxopterygium, which is a specialized organ in male, and is generally considered to be highly specialized modification derived from the pelvic fin. Some worthy contributions have hitherto been made for the purpose of elucidating fine complex and anatomic details in this organ.

PETRI (1867), JUNGERSEN (1899) and HUBER (1901) carried out comprehensive works on internal and external features of this organ. Further, LEIGH-SHARPE (1920-'26) made an extensive study of external character of the organ in various groups of the Chondrichthyes giving many valuable knowledge of the structure and function of the clasper and its associated apparatus. WHITE (1936) also made an important contribution on osteological characters of the organ taken from various representatives within this group. The classification as well as interrelationship within elasmobranchs has been more or less influenced by these characteristics found in the organ thus investigated.

In the present item, the writer has made a comparative study of the characteristics both external and internal of the organ taken from all the members of the Japanese rajids. So far as the present investigation goes, the differences observed in the clasper manifest not only excellent generic and specific features but also apparent

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* For assumption of difference between two closely related forms, a test of mean value of the characters was given by means of t-method under 1% or 5% level of significance, using the following formula: $t = \dfrac{\bar{x} - \bar{y}}{S\sqrt{\dfrac{1}{Nx} - \dfrac{1}{Ny}}}$, where $\bar{x}$ and $\bar{y}$ are means for two forms, N is number of individuals, and S is standard deviation.

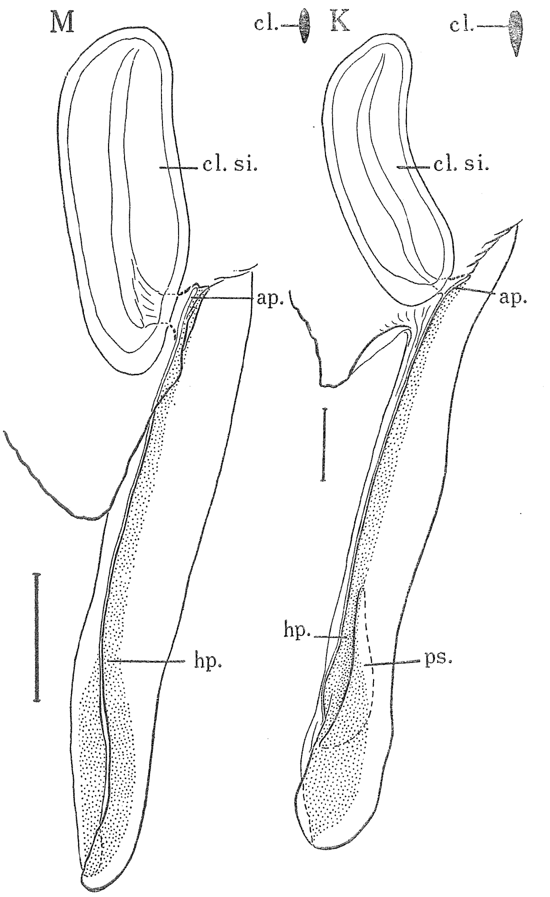

Fig. 2. Dorsal views of two forms in external aspect of clasper and its associated apparatus, based on which the organ was classified into two types, Type-CNE and Type-CSE. ap., apopyle; cl., cloaca; cl. si., clasper siphon analyzed along base of the pelvic fin; hp., hypopyle; K, *Rhinoraja kujiensis;* M, *Raja kenojei;* ps., pseudosiphon; clasper canal is in stippling. Scales indicate 2 cm.

relationship within the group, fully discriminated even between any closely related forms. In fact, the characteristics thus established in the distal portion of the organ are specially noteworthy.

The male organ of the rajid and of other members of the Chondrichthyes in general is composed of two portions, which are distinguished functionally into a bar-like projection, elongated posteriorly from inner lateral side of each ventral fin, the clasper itself in usual meaning, and a large muscular sac, located along the base of clasper, burying each lateral side of the ventral fin, the clasper siphon. These two main apparatus are intercommunicated by the clasper canal or groove, through which the sperm and other reproductive substance pass (Fig. 2).

The clasper is provided with many components in both external and internal structures, nomenclature of which shall be mainly in accordance with those given by LEIGH-SHARPE and other authorities mentioned above. The clasper gland of the rajids, on the other hand, seems to be so similar in the structure throughout all the rajids species dealt here that the organ shall be shown by only short descriptions or figures, if any concern may not show differences between species either in rajids or in related families.

2. Description and comparison of the clasper

(1) External features:

Shape:- From general form in external appearances the clasper may be divided into two types, which are herein called club- and spatula-type, as exhibited in Fig. 2. Club-type is represented by the clasper found in the northern form, in which the organ is usually soft, cylindrical in shape in its main portion and blunt in the glans. Spatula-type can be found in the organ of the southern form, which appears more or less flat, depressed dorso-ventrally and pointed distally.

External structure of the glans clasper*):- The masculinized clasper of the

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* Nevertheless the term 'glans clatper' is newly used here with a functional significance, the structure so named in the fish being not morphologically similar to the glans penis in mammalia.

adult male rajid has a highly complicated structure, especially in its glans clasper. Calling his attention to this fact Leigh-Sharpe (1925 ; p. 567) has claimed that, "the species of this genus fall within well-marked groups, which differs from one another as to their claspers as much, or more than other genera, from Raia ....", and he classified the fish taken from the Atlantic into nine groups, referring to those names as pseudogenera.

The glans clasper of the rajid is made up of dorsal and ventral lobes, which are tightly clasped together and more or less scrolled with each other, to be capable of opening by inner lateral margin toward dorso-lateral or lateral direction when the organ is erected. Many components, of which characteristics of the organ are made, are asymmetrical in structure between both inner and outer borders of the two lobes of the glans clasper. All these figures and descriptions mentioned in this treatise are made from the organ on the left side, from its dorsal aspect or from its opened out two lobes.

The characteristics in external features of the glans clasper are very different between the northern and southern forms, and are divided into two types and herein called Type-CNE and Type-CSE for brevity's sake.

a. **Type-CNE of the glans clasper:-** The fish with this type of the organ is referred to the northern form, where the glans clasper is composed of the following ten components which are lacking in some species and existing in others: pseudosiphon, slit, ridge, pseudorhipidion, scale, spur, pent, funnel, knife, and claw. Of these, pseudorhipidion, funnel and knife are newly termed here. The first five components mentioned above are found on the outer or inner surface of the dorsal lobe, and the rest are developed on the inner border of the ventral lobe or on the mesial plane between the two lobes.

The finding of the apopyle as well as the hypopyle in all the species dealt with here is noteworthy, but, according to Leigh-Sharpe, these two passages for the reproductive substances are supposed to be worthless concerning the present investigation.

Pseudosiphon:- The pseudosiphon is well-developed in the six species, E, F, G, J, K and L. (Figs. 2 and 3)

The apparatus is usually a blindly ending sac, wide aperture of which is pointed at both ends, turning latero-outward, from the anterior portion to the midway in the dorsal border of the glans clasper (Figs. 2 and 3 ; E, F, G, J, K, L). But, the apparatus is very inexplicit in species B (Fig. 3 B), and is much more ill-defined in species H and I (I′) (Fig. 3 H, I, I′), located on the marginal portion or on the inside border of the dorsal lobe.

From the degree of development and the location of the apparatus in these ten forms, the organ may be assorted into three types, which are herein called Types-Ps^1, -Ps^2, and -Ps^3.

Type-Ps^1 is represented by first six species E, F, G, J, K and L, and the pseudosiphon of this type is broadly developed on the dorsal border of the dorsal lobe. With regard to the degree of development and the location of the apparatus we can recognize some differences in these examples: the pseudosiphon in species K (Fig. 2 K) is very large, covering the portion from the base to the midway of the elongated glans clasper, but the apparatus is not so much developed in the five species E, F, G, J and L (Fig. 3) as the preceding species, and the pseudosiphon more or less reduced in size, located on the basal portion of the glans. Type-Ps^2 may be referred to the characteristics found in species B, in which the pseudosiphon is developed in a very obscure state, located along the marginal portion of the dorsal

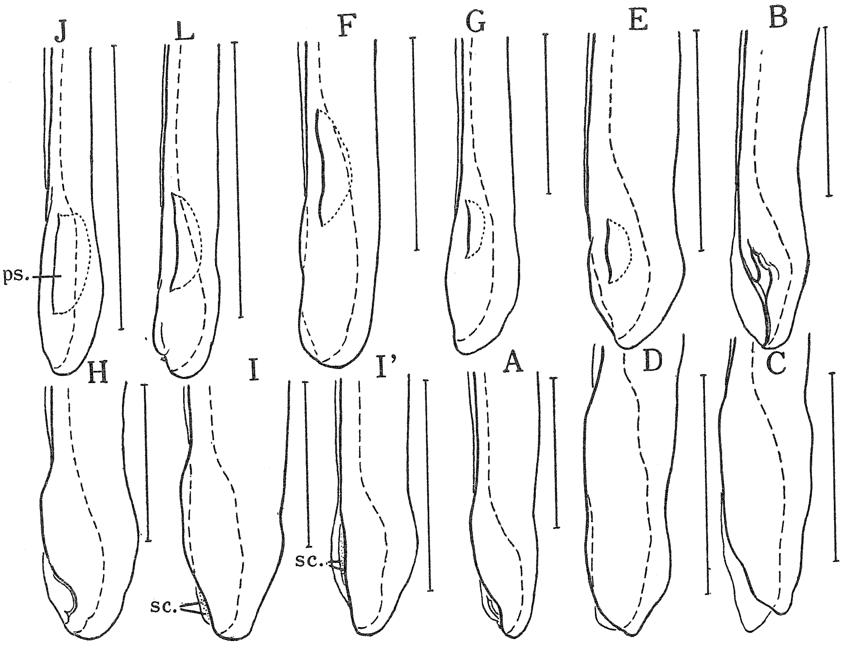

Fig. 3. Dorsal aspects of the glans claspers of twelve forms in Japanese rajids, especially showing differences in the outline of the organ and in the size and location of the pseudosiphon (ps.), based on which three types of the apparatus (Type-Ps^1 to Ps^3) are assorted, and also showing presence and absence of the placoid scales (sc.). Broken line indicates the clasper canal. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I(I′), *B. smirnovi smirnovi* and *B. smirnovi ankasube;* J, *Rhinoraja odai;* L, *Rh. longicauda.* Scale attached to each figure represents 5 cm, but 2 cm in A.

lobe, where a half vestige of the deep-groove (pseudosiphon proper) is present, separated by a longitudinal process. Type-Ps^3 is exemplified by the two species, H and I (I′), which are characterized by having exceedingly degenerated apparatus, shifted to the inside border of the dorsal lobe and represented as a deep-groove as in the species B. Thus, this type is presumably in a more progressed condition than the preceding ones.

Judging from the writers comparison of the pseudosiphon of Japanese rajids in the degree of development and difference of its location, the specialization of the apparatus may have taken place in order from Type-Ps^1 to -Ps^2 and -Ps^3. This hypothetical process in the transformation is sharply seen in the modifications revealed in the dorsal terminals, which are to be explained later on (p. 18).

Slit:- Although the slit is thought to be more or less regularly present along the inside border of the glans clasper of the organ at least in all the Japanese rajids used in the present investigation, it seems very difficult to distinguish it from the pseudosiphon which is also found on the inner surface of the lobe. But, the writer has designated this component as follows: the slit is small, shallow cavity formed by fleshy skin developed on the inner surface of the dorsal lobe, and has no close relation to the dorsal terminal 1. Both number and degree of the development of the component, therefore, seem to have a specific character rather than genealogical significance as shown in the accompanying Figs. (Figs. 4 and 5).

Ridge:- The ridge is developed in the position near the hypopyle with a distinct elevation on the inner surface of the dorsal lobe. The component is present in three species B, H and I (I′), and is supposed to have intimate relation to the degree of development of the pseudosiphon as already mentioned. The ridge is distinct in the species B and H (Fig. 4 B, H), but it is less developed in I (Fig. 4 I). At any rate, such unique development of the component, as seen in these species, is provided with a cartilage referable to the dorsal terminal 2 (cf. Fig. 9).

Pseudorhipidion:- This component is commonly present in the organ of the northern form, and the term is newly alluded in the present study to a structure found on the inner surface of the dorsal lobe. The writer has distinguished the component from the rhipidion termed by LEIGH-SHARPE:- the rhipidion is characteristically developed with porous structure of pitted tissue; but the pseudorhipidion has the smooth skin covering the surface.

The component referable to this character can be discriminated in the groups of species according to the degree of development of the apparatus. The first group, in which the eight species A, C, D, E, F, G, J and K may be involved, and is abbreviated here as Type-Pr^1. The second, in which the four species, B, H, I (I′) and L, are involved, reveals in the component less development, and is termed Type-Pr^2. The degree of development of the component varies as that of development of the distal portion of the dorsal marginal, an axial cartilage of the clasper, as will be described later on (cf. Fig. 12).

Scale:- The most interesting fact that has not yet been found either in the European or Japanese rajids is that the minute scales have been found developed on the dorsal border of the ridge in the species I and its relative I′ (Fig. 3). In all other members of the Japanese rajids no such scales were found.

Spur:- The spur, which is regarded as a component that lies on the mesial plane in the glans, can be recognized as a protrusile process from a socket when the organ is erected. The spur is well-developed in the three species C, D and F, but it is illegible in the two examples B and I (I′). The component is absent in the species A, G, H, J, K and L. (Fig. 4). The presence or absence of the spur depends upon the degree of development of the accessory terminal, as is described later on (cf. Fig. 11).

Pent:- The pent is found to exist only in one species A (Fig. 4 A), and it is provided with a fleshy skin fold attached to the lining of the ventral lobe. The term has been proposed by LEIGH-SHARPE (l. c., p. 23) in naming a component growing on the inner surface of the dorsal lobe of the organ of a sting ray, but the term may be credible to him in view of the fact that the component seems in either case to act as a leading flap of the reproductive substances.

Funnel:- The term ′funnel′ is newly alluded to in this study about a component located on the distal portion of the ventral lobe, having a soft projection something like the foot of bivalve mussel. The development of this component is characteristic of some species in the northern forms, but there are marked intraspecific variations in the degree of development of this component. It is distinctively developed in the five species C, D, F, H and K, but is ill-defined in the three species E, G and L. In other species of the northern members the component is obscure or absent (Fig. 4). The degree of development of the component varies as that of the ventral terminal (cf. Fig. 10).

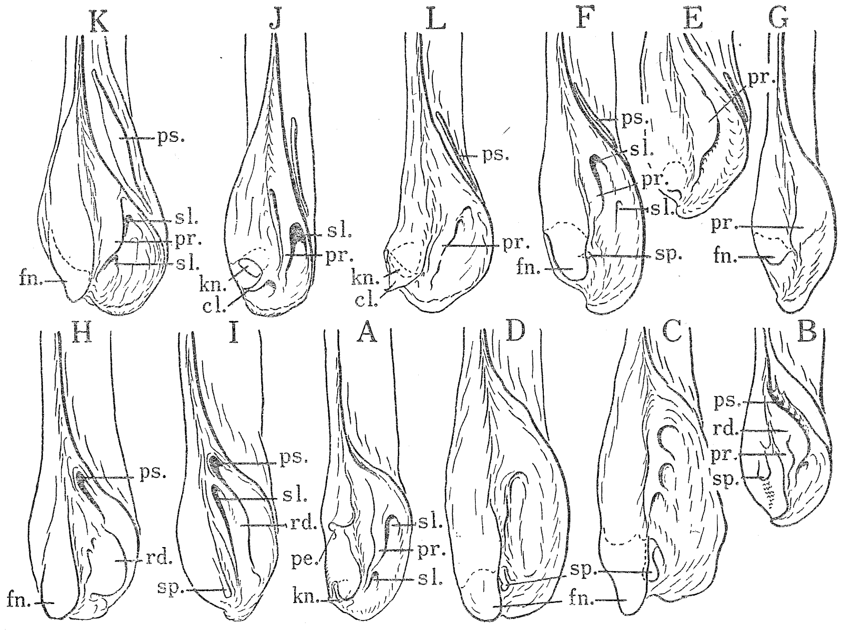

Fig. 4. Showing the arrangement of the structural components developed on inner surface of the glans claspers of eleven forms in Type-CNE of the organ; cl., claw; fn., funnel; kn., knife; pe., pent; ps., pseudosiphon; pr., pseudorhipidion; rd., ridge; sp., spur; sl., slit. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* Magnification is the same to that in Fig. 3.

Knife:- The knife is also newly termed here in naming a component characteristic of the three species **A**, **J** and **L**, which have in common a remarkable structure in the distal part of the ventral lobe, and the structure is of a fleshy skin under which the 'knife' is hidden protrusibly from a socket. The component is furnished with a knife-blade-like edge turning laterally, and is internally the accessory terminal (kn. in Fig. 4 and cf. Fig. 11).

Claw:- The claw is possessed by the two species **J** and **L**, in which the component is furnished with a process sharply pointed, located in the distal part of the ventral lobe. It is significant that this component, which has been given by LEIGH-SHARPE (l. c., p. 26) to an organ of *Rhinobatus productus*, an European guitarfish, can be seen in these species(cl. in Fig. 4). The component can be considered to be a modification of the accessory terminal (cf. Fig. 11).

§§. **Subordinate division of the northern forms on the basis of the external features of their glans claspers (Typ-CNE)**:- The present analytical comparison of external features of the glans clasper may be said to give the following seven distinct types placed under Type-CNE, viz., Subtypes-CNE$^{1-7}$.

Subtype-CNE^{1} is represented by only one species **K**, the organ of which is regarded to be the annexed characteristics: the pseudosiphon is distinct in having Type-Ps^{1}; the two slits are apparently present; the pseudorhipidion is well-developed as in Type-Pr^{1}, and the funnel is remarkably present, but the other components, such as ridge, spur, scale, pent, knife and claw are all absent (K in Figs. 2 and 4).

Subtype-CNE^{2} is modeled after the characteristics revealed in the organ of the species J and L, where the pseudosiphon is moderately developed as in Type-Ps^{1}, pseudorhipidion is obscure as in Type-Pr^{2}, knife and claw are present, though ridge, spur, scale and pent are lacking (J and L in Fig. 4). This subtype seems to some extent related with the preceding subtype in having relatively distinct pseudosiphon and less obscure pseudorhipidion, but the present subtype is well-marked from its relatives in having the both knife and claw.

Subtype-CNE^{3} is found in only one species A. The organ is characterized by having slits, pseudorhipidion as in Type-Pr^{1}, funnel, knife and pent, and by lacking in pseudosiphon, ridge, spur and scale. There is an obscure depression along the marginal portion of the dorsal lobe which may be a vestige of the pseudosiphon. This subtype may be linked up in some respects with the preceding one at least in having the knife, but they may be distinguished from each other externally in the presence or absence of the pseudosiphon (A in Fig. 4).

Subtype-CNE^{4} is represented only by the species B, the organ of which may be defined as follows; pseudosiphon is illegible in having Type-Ps^{2}, pseudorhipidion is of Type-Pr^{2}, slit, ridge and spur are present, though scale, knife, funnel and claw are absent (B in Fig. 4).

Subtype-CNE^{5} is exemplified by the two species C and D. The organ in these species is provided with four annexed components, namely two or three slits, pseudorhipidion (as in Type-Pr^{1}), spur and funnel, but it is devoid of the pseudosiphon, scale, pent, knife and claw (C and D in Fig. 4).

Subtype-CNE^{6} has the characteristics found in the organ of the three species E, F and G, which have the following components, pseudosiphon (as in Type-Ps^{1}), one or two slits, pseudorhipidion (as in Type-Pr^{1}), funnel and spur (except for species E and G), but scale, pent, knife, ridge and claw are all absent (E, F and G in Fig, 4).

Subtype-CNE^{7} is represented by the two species H and I (I′), the organ of which is characterized by the presence of pseudosiphon (ill-defined as in Type-Ps^{3}), slit, ridge, pseudorhipidion (as in Type-Pr^{2}) and scale (except for the organ of the species H), but the other components are not at all developed (H and I in Fig. 4).

b. **Type-CSE of the glans clasper:-** The glans clasper of this type is regarded as the organ of the southern form, which is generally furnished with the six annexed components developed only on the inner surface of the glans; slit, rhipidion, spike, sentinel, shield and dike. Last of these, which is newly termed here, is a component which is found rather regularly on the posterior portion of the mesial plane between the two lobes of the glans.

Slit:- The slit is usually well-developed in the organs of all the fishes of this type, although the number as well as the degree of development of the component varies in the species, as is the case with the preceding type. Generally, two large slits are located on the anterior portion of the dorsal lobe. According to LEIGH-SHARPE (l. c., p. 200), this term was first given to a blind ending fissure developed on the inner side of the dorsal surface of the clasper of *Chiloscyllium punctatum*, but the present writer has accounted for the component, fasing his inferences on the structural evidence so as to avoid its confusion with the pseudosiphon mentioned elsewhere (sl. in Figs. 4, 5 and 6).

Rhipidion:- This component is always present in varying degree, composed of singular structure with pitted, porous tissue, which covers the mesial plane, running rearward from the hypopyle to a midway point of the glans. The rhipidion is monolobed in the seven species (O, Q, S, T, U, V and W), instead of being bilobed in the four species (M, N, P and R). In either case the component is made of the erectile tissue, which is characteristic of the organ of this type (rh. in Figs. 5 and 6).

Spike:- The spike is also usually developed in all the organ of this type, looking like a small or a large projection that lies with the rhipidion. To indicate its degree of development, the writer has assorted the component into three forms which are herein called Type -Sk$^{1-3}$. Type-Sk^{1} is represented by the seven species, N, O, Q (Q′), R, S, T and U, where the spike is more or less obscure, being hardly visible or nearly hidden under the skin or the sentinel. Type-Sk^{2} is modeled after the characteristics of the component in the organ of the species P, in which the spike is a long and slender projection, thrusting itself out posteriorly. Type-Sk^{3} involves four species, viz., M, R, V and W, in which the component is furnished with rear ends more or less hooked (sk. in Figs. 5 and 6).

The different forms of the spike thus distinguished in its external features are due to the differentiation revealed in the cartilage of the accessory terminal 2, which is to be explained later on (cf. Fig. 16).

Sentinel:- The sentinel is located between the rhipidion and the spike, and varies with species more in this type than in the others.

When the features found in this component are compared, the fish in this category may be classified into five types, which are here abbreviated as Type-St$^{1-4}$ (st. in Figs. 5 and 6).

Type-St^{1} involves four species, M, T, V and W, which have each the component elongating posteriorly with or without soft fleshy skin covering the apical portions. In the species M, the sentinel appears to be a bulky projection, but it is long and slender in T, whilst in V and W it is short. Type-St^{2} is found in the feature revealed by the four species (N, Q, R and S), the component of which assumes a very large size, ensuing posteriorly to the rhipidion, being covered with the soft fleshy skin to be taken as a bulky head. Type-St^{3} is found in the two species (O and P); the sentinel is peculiar in these examples, and is distinct from that of the preceding ones, in having the posterior edge with a knife-blade-like margin, which is broadly exposed in the organ of the species P. Type-St^{4} has in it only one species U, in which the sentinel is much more remarkable than in the others,

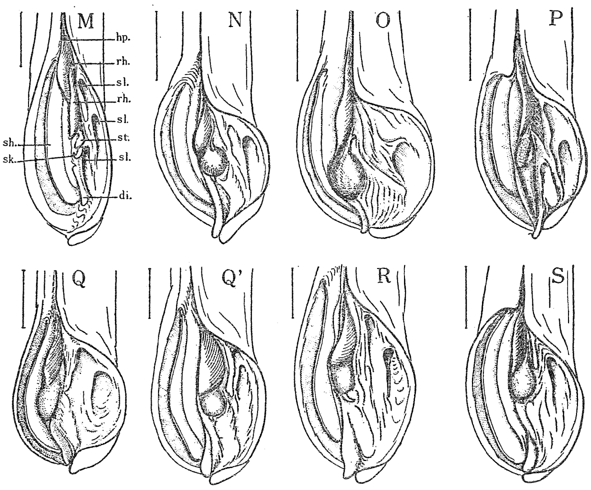

Fig. 5. Showing the arrangement of the structural components developed on inner surface of the glans claspers of eight forms in Type-CSE of the organ; di., dike; hp., hypopyle: rh., rhipidion: sh., shield; sk., spike; sl., slit; st., sentinel. M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; Q′, *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*. Scales represent 1 cm.

being well-developed into an oval shape, and its lateroposterior edge is furnished with a knife-blade-like structure resembling that found in the organ of European skates, *Raja blanda, R. clavata* and *R. rhina* (LEIGH-SHARPE; 1924).

The sentinel is thus specialized into different features, which are conformable internally to the condition in the accessory terminal 1, and is therefore homologous with the spur found in the organ of northern form (Type-CNE).

Shield:- The presence of the shield is characteristic of the organ of this group of the fish (Type-CSE), the component is developed on the inner surface of the ventral lobe. On outside margin of the shield a singular structure with keen edge is present covered with epidermis. The degree of development of the component varies with species, but it seems very difficult to indicate any degree of development of the shield externally as shown in Figs. 5 and 6. Thus, the shield has a very complicated feature as it is closely related internally with the ventral terminal (cf. Fig. 15), which is to be explained later on.

Dike:- The term 'dike' is newly given in the present study to a component found in either distinct or obscure fold covered with fleshy skin, running rearward from basal portion of the sentinel to the symphysis of the two lobes. There are roughly four forms according to the degree of development of the component revealed by the organ of this type (Type-CSE).

The first form which assumes the most prominent feature is developed in the species **N, O, P, Q** (**Q′**), **R** and **S**; the dike reaches posteriorly to, or extends beyond, the symphysis of the two lobes. The second form is represented by the single species **M**; the dike is reduced to a small process, located in the portion far from the symphysis, and reaching the distal edge of the shield. In the third form which involves three species **T**, **V** and **W**; the dike is much more reduced to an ill-defined condition looking like a small ridge, which is connected posteriorly with the extremity of the shield. The fourth form involves only one species **U**, the component of which can hardly be observed externally owing to the enormous development of the

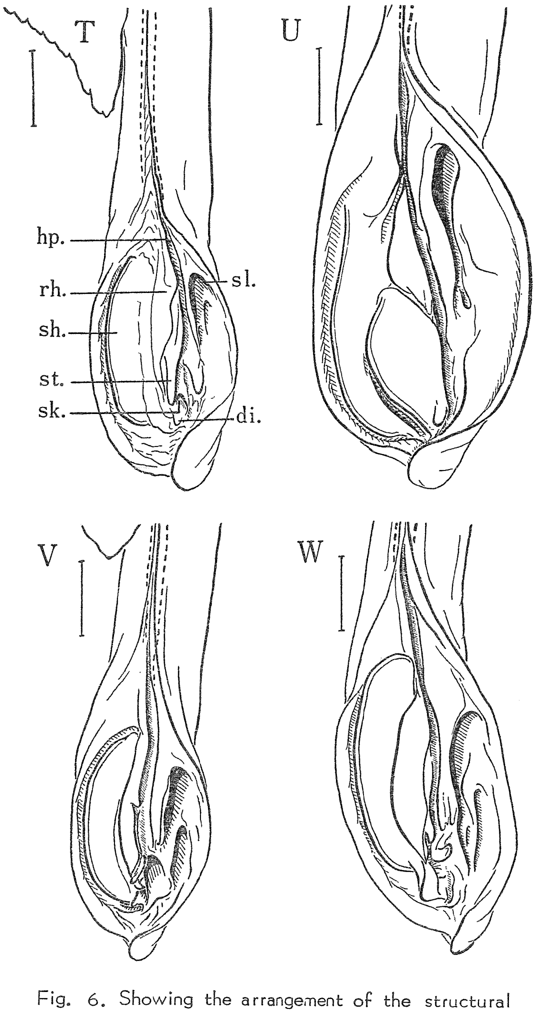

Fig. 6. Showing the arrangement of the structural components developed on inner surface of the glans claspers of four forms in Type-CSE of the organ. T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*; other abrreviations attached to the Fig. are the same to that in Fig. 5. Scales represent 2 cm.

shield (di. in Figs. 5 and 6).

In the four forms thus assorted only the process of the ventral terminal is concerned in the degree of development of the dike as it will be mentioned later on (cf. Figs. 17~19).

§§. **Subordinate division of the southern forms on the basis of the external features of their glans claspers (Type-CSE)**:- By a comparative study of the external features of the glans clasper of the southern members thus examined, the writer has arranged them into six subordinate types placed under the main type (Type-CSE) and abbreviated herein as Subtypes-CSE$^{1-6}$.

Subtype-CSE^{1} is represented by only one species **M**, whose characteristics of the organ are in possession of the following six components; slits, rhipidion bilobed, spike (as in Type-Sk^{3}), sentinel (as in Type-St^{1}), dike with normal shape of second form and shield well-developed (**M** in Fig. 5).

Subtype-CSE^{2} is found in the organ of the four species **N**, **Q** (**Q′**), **R** and **S**; these representatives have features in the components very similar the preceding subtype, but the two subtypes are distinguishable in the following points, spike is reduced to as in Type-Sk^{1}, sentinel is enlarged (as in Type-St^{2}), and dike is well-developed in the first form, in this subtype. The three components, slits, rhipidion and shield, are also present (**N**, **Q**, **Q′**, **R** and **S** in Fig. 5).

Subtype-CSE^{3} is exemplified by the organs of the two species **O** and **P**, whose characteristics in the structure is in the sentinel represented by Type-St^{3}, in addition to the holding of two slits, dike and shield in usual manner. Besides, the rhipidion monolobed in the species **Q** instead of being bilobed in the species **P**, but the spike is of Type-Sk^{2} in the species **P** in contrast with Type-Sk^{3} in the species **O** (**O** and **P** in Fig. 5).

Subtype-CSE^{4} is found in the organ of the species **T**, in which the following characteristics were noticed; dike obsolete in being third form, three slits are present, spike is in Type-Sk^{1}, rhipidion is developed in monolobe, sentinel is in slender proje-

Table 2. Comparison of external features of the glans claspers of the Japanese rajid fishes. Abbreviations refer the reader to the text. + and — represent the presence and absence of the component, respectively.

Types	CNE							CSE					
Subtypes / Components	1	2	3	4	5	6	7	1	2	3	4	5	6
Pseudosiphon	Ps^{1}	Ps^{1}	—	Ps^{2}	—	Ps^{1}	Ps^{3}	—	—	—	—	—	—
Slit, number	2	±	2	1	2－3	1－2	1	2	2	2	3	2	3
Ridge	—	—	—	+	—	—	+	—	—	—	—	—	—
Pseudorhipidion	Pr^{1}	Pr^{2}	Pr^{1}	Pr^{2}	Pr^{1}	Pr^{1}	Pr^{2}	—	—	—	—	—	—
Scale	—	—	—	—	—	—	—; +	—	—	—	—	—	—
Spur	—	—	—	±	—	—; +	±	—	—	—	—	—	—
Pent	—	—	+	—	—	—	—	—	—	—	—	—	—
Funnel	—	—; +	—	—	+	—; +	—; +	—	—	—	—	—	—
Knife	—	+	+	—	—	—	—	—	—	—	—	—	—
Claw	—	+	—	—	—	—	—	—	—	—	—	—	—
Rhipidion	—	—	—	—	—	—	—	+	+	+	+	+	+
Spike	—	—	—	—	—	—	—	Sk^{3}	Sk$^{1;3}$	Sk$^{1;2}$	Sk^{1}	Sk^{1}	Sk^{3}
Sentinel	—	—	—	—	—	—	—	St^{1}	St^{2}	St^{3}	St^{1}	St^{4}	St^{1}
Shield	—	—	—	—	—	—	—	+	+	+	+	+	+
Dike	—	—	—	—	—	—	—	+	+	+	+	+	+
Genus	*Rhinoraja*		*Breviraja*					*Raja*					
Species	K	J ; L	A	B	C ; D	E;F;G	H ; I	M	N;Q; R;S	O ; P	T	U	V;W

ction (as in Type-St^1), and the shield is markedly developed (T in Fig. 6).

Subtype-CSE^5 involves only one species U, whose organ seems to have much specialized features as compared with those of the preceding groups of species or of the forthcoming ones, i. e., sentinel is remarkably developed as represented in Type-St^4, dike is scarcely visible (as in third form), two slits, rhipidion (monolobe), spike (as in Type-Sk^1) and shield is well-marked in large size (U in Fig. 6).

Subtype-CSE^6 involves the two species V and W, where the spike is marked with a hook-like projection (as in Type-Sk^3), and three slits, sentinel (as in Type-St^1), rhipidion monolobed, dike ill-defined (as in third form), and shield enlarged, are all present and characteristics in the organ of the present subtype (V and W in Fig. 6).

The present writer has described and compared external features of the organ of the Japanese rajids, and made the Table 2, which enables any one to distinguish the characteristic feature revealed in the respective representatives.

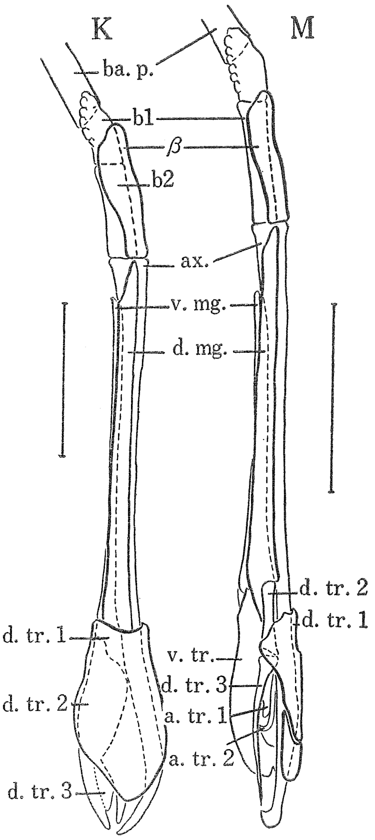

Fig. 7. Dorsal views of two forms in internal structure of the clasper, based on which two types of the organ (Type-CNI and -CSI) were assorted. a. tr. 1—2, accessory terminals; ax., axial cartilage; b$^{1-2}$, intermediate segments; ba. p., basipterygium; β, beta cartilage; d. mg., dorsal marginal; v. mg, ventral marginal v. tr. ventral terminal. K, *Rhinoraja kujiensis;* M, *Raja kenojei.* Scales represent 2 cm.

(2) Internal features:

In the present scheme, the writer has made osteological investigation of the claspers in contrast to those characteristics examined externally in the preceding paragraph.

The cartilages of the claspers are composed of many cartilage elements and vary extensively specifically in the rajid fishes, and are largely divided into three groups, viz., basal, axial and terminal ones, which are either the continuation of the basipterygium modified from the cartilages of the pelvic fin or more probably the modification of the radial cartilage of the fin.

The basal group is composed of three elements termed the pelvic basipterygium, the intermediate proximal segment and the so-called β cartilage; the axial group is composed of the axial, the dorsal and the ventral marginal cartilages, and the terminal group is made of many cartilages connected with the constituting terminal elements of the clasper (Fig. 7).

As illustrated in the Fig. 7 marked differences are found to exist in the cartilginous features of clasper between the northern and the southern forms, especially so distinct in the axial and terminal groups of the cartilages that the two groups seem to be much more important for the present investigation. However, those differences are not so conspicuous in the basal group of the cartilages between the two major forms of the Japanese rajids, so that these cartilages are of little use for distinguishing species and groups of species. Moreover, WHITE (1936) proved the fact that the number of proximal segments and other cartilages in the basal group tend to vary, being contradistinguishable in the large groups of the elasmobranch fishes. Therefore, the basal group of the cartilages may be used in regard to phyletic consideration of the rajids within allied families of batoids.

Comparing those features of the cartilages in both axial and terminal groups which are present in the glans clasper, the present writer has newly divided the Japanese rajids into two types and called them CNI and CSI in contrast to those respective abbreviations defined in the external features of the organ.

§. **Type-CNI of the myxopterygial cartilages:-** The clasper with this type of the cartilages is composed of eight or nine elements; axial cartilage (ax.), dorsal and ventral marginals (d. mg. and v. mg.), three dorsal terminals (d. tr. 1,2,3), and one or two accessory terminal (a. tr. 1,2).

Axial cartilage, ax. :- The axial cartilage is a long, round-bar-like element, and is thickened anteriorly and pointed posteriorly. The cartilage is tightly closed together with the dorsal and ventral marginals throughout its nearly whole length, forming the frame of the clasper canal or groove. On the distal part of the cartilage there are many elements (terminal group) which are a frame of the glans clasper in close contact with each other to form a complex structure.

On the basis of the distal part of the axial cartilage three different forms may be found which the writer has called Type-Ax^1, -Ax^2 and -Ax^3. Type-Ax^1 is found in the eight species (**A**, **B**, **E**, **F**, **G**, **J**, **K** and **L**); the axial cartilage is pointed in its distal tip (Figs. 7, 12 and 13). Type-Ax^2 involves two species (**C** and **D**); the element is spatulate distally (Fig. 12). Type-Ax^3 involves two species **H** and **I** (I′); the distal part of the cartilage is truncated (Fig. 13).

Dorsal and ventral marginals, d. mg., v. mg. :- These elements are long, thin cartilages closely attached to either side of the axial cartilage. The dorsal marginal starts anteriorly on the same level, where the axial cartilage is connected with the intermediate segment, but the ventral marginal rises some distance rearward from that level (*vide* Fig. 7). On the other hand, the feature in the posterior portion of the ventral marginal is somewhat instructive. In the posterior elongation of the ventral marginal, are found two distinct forms in the species examined by the writer, i.e., the ventral marginal is much shorter in the posterior portion than the axial cartilage in the seven species of the northern form except the five species (**C**, **D**, **J**, **K** and **L**), in which the ventral marginal projects posteriorly almost to the equal level to that of the axial element, assuming different features. But, the dorsal terminal has rather the common feature in the posterior portion in the species herein dealt with, though short in the extremity (Figs. 7, 12 and 13).

Dorsal terminal, d. tr. 1 :- This cartilage is located on the dorsal side of the glans clasper, more or less covering the other dorsal terminals, d. tr. 2 and 3. Though marked differences are found in the features of the d. tr. 1 according to the features of the pseudosiphon in the rajids species examined herein, little attention has been paid to the fact up to the present day. Nevertheless, it seems very difficult to show the exact form of the cartilage in the various species of the fish partly owing to the poor calcification and partly to the curious design. By paying the greatest possible care to the anatomy of the cartilage, however, the present writer emphasizes that the characteristics in the cartilage represent remarkable modification in the respective species as seen in Fig. 8.

This fact may probably make us firmly the following conception; 1) the cartilage in the northern members is provided with idiomorphic feature in most cases that may

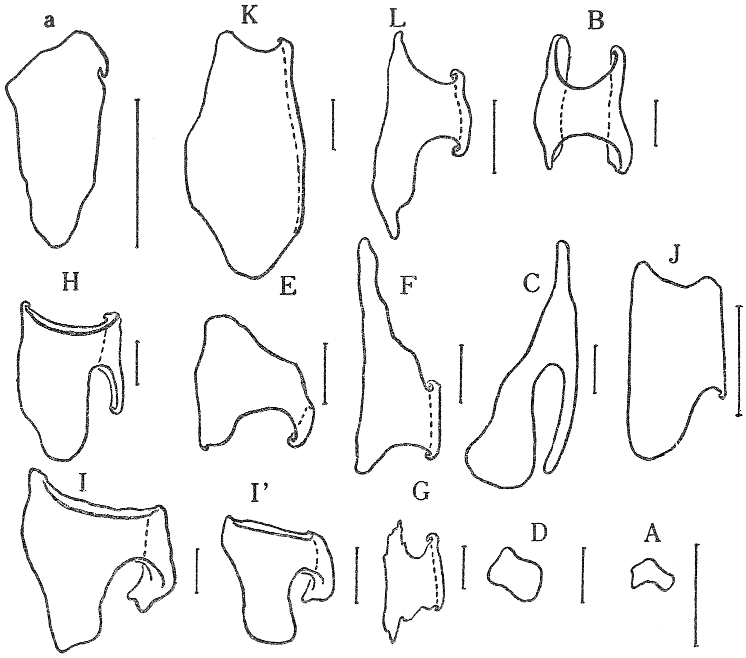

Fig. 8. Dorsal views of the dorsal terminal, d. tr. 1 in thirteen forms in the organ of Type-CNI, coupled with the cartilage of *Rhinobatos schlegeli*, a; especially showing these elements are in species-specific feature, based on which, but conveniently, twelve types, Dt^{A} to Dt^{K} were assorted. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* I', *B. smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* Scales represent 1 cm.

serve for discrimination between species or even between much more related forms, and 2) it may be possible to suppose that there is some linealogical relationship on the basis of these differentiation revealed in the cartilage.

Taking the above into consideration, we give account of these features in the cartilages, using the abbreviations Dt^{A} to Dt^{K}.

It should be noticed herewith the cartilage in the species K is most akin to that of *Rhinobatos schlegeli*, a representative of Rhinobatidae, in which the cartilage is large without any noticeable reduction being seen (a and K in Fig. 8).

Other dorsal terminals, d. tr. 2 and 3 :- These cartilages are developed on the dorsal border of the glans clasper as in case of the preceding element, with the pseudosiphon inserted between the d. tr. 1 and the elements in question. Usually, the two cartilages are coexisting element tightly blended with each other, and are closely stuck basally to the dorsal marginal.

Since the cartilages are very thin and their posterior marginal portions are ill-defined due to the poor chondrification even in the masculinized organ, it may be rather difficult to grasp the exact features of the elements in each species. On the basis of the cartilages the following evidences may be summarized; 1) features in the cartilages seem to show species-specific characteristics, and 2) they are roughly in concord with those linealogical trends found in the d. tr. 1. These evidences could naturally be seen from Fig. 9, if we could guess the courses of the transformation in the cartilages, but in doing so, we should fail to lead to a plausible conception.

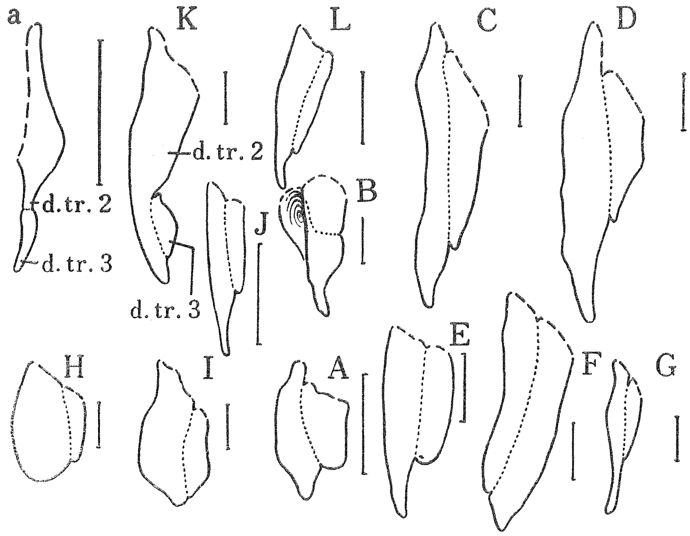

Fig. 9. Dorsal views of the dorsal terminals, d. tr. 2 and 3 in twelve forms of the Japanese rajids, coupled with that of *Rhinobatos schlegeli*, a; broken line indicates the junction of the d. tr. 2 to the d. mg.; dotted line represents the boundary where the two elements are tightly blended. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* Scales denote 1 cm.

Ventral terminal, v. tr.:- On the ventral border of the glans clasper the ventral terminal is located connected with the posterior of the ventral marginal. The differentiations in the cartilage are very complex as in the dorsal terminals, being also taken as idiomorphic in our species, but the element is stiffened and well-outlined in nature (Fig. 10). For further explanation the author has dared to classify the cartilages into five types (Vt^1 to Vt^5), basing them only on those morphological evidences in the elements.

Type-Vt^1 is found in the species K, in which the cartilage is of J-like shape somewhat resembling that of *Rhinobatos schlegeli* (a and K in Fig. 10). Type-Vt^2 is exemplified by the feature revealed in species J, whose element is reduced in its posterior portion (J in Fig. 10). Type-Vt^3 is modeled after the characteristics in the three species (A, C and D); the cartilage is developed in hook-like shape posteriorly (A, C and D in Fig. 10). Type-Vt^4 is found in the six species, B, E, F, H, I (I′) and L; the element is of spoon-like shape with more or less thickened posterior portion (B, E, F, H, I, I′ and L in Fig. 10). Type-Vt^5 is found in the species G; the cartilage is reduced into a very small slender element (G in Fig. 10.).

Accessory terminals, a. tr. 1 and 2;- The accessory terminal is developed with two small cartilages in the three species A, C and D. But in the other species, only

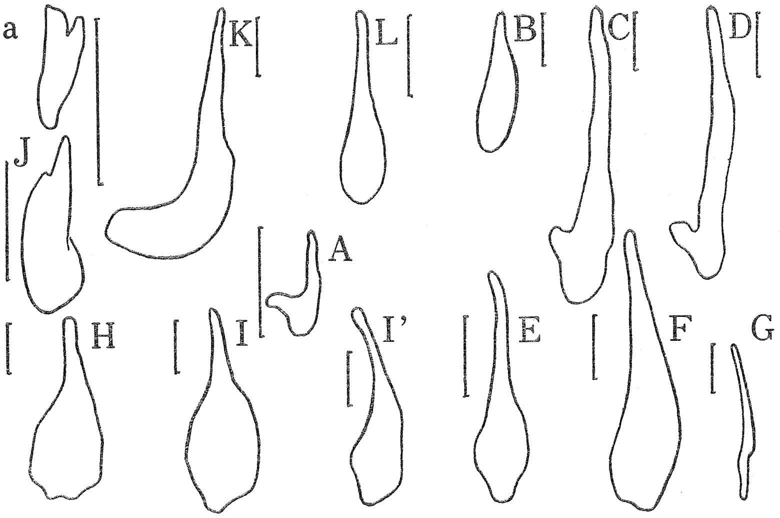

Fig. 10. Dorsal aspects of the ventral terminals, v. tr., of thirteen forms of the Japanese rajids, coupled with that of *Rhinobatos schlegeli*, a; especially showing these elements represent rather idiomorphic feature, based on which, for convenience' sake, five types, Vt^1 to Vt^5, were assorted. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* I', *B. smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* Scales denote 1 cm.

the a. tr. 1 is developed more or less regularly. In either group of the species, the cartilages grow at the emergence of the ventral marginal from the axial cartilage, and the a. tr. 2 is, if present, located on the lateral side of the a. tr. 1. The cartilages are developed in intimate relation to the degree of development of either the spur or the knife in the external structure of the organ.

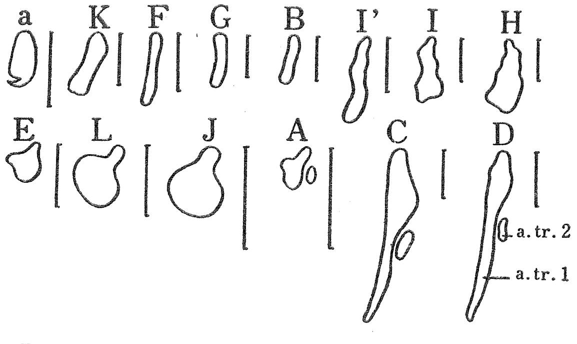

Fig. 11. Dorsal views of the accessory terminals, a. tr. 1 and 2, in thirteen forms of the Japanese rajids, contrasted to that of *Rhinobatos schlegeli*, a; especially notifying these cartilges represent complex outline, on the basis of which six types, At^1 to At^6, were assorted. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* I', *B. smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* Scales denote 1 cm except species a being 0.5 cm.

The features of the cartilages have remarkable interspecific differences as outlined in Fig. 11, which may give us a good idea in distinguishing the fact rather than any information on the form of the elements. For brevity's sake, however, the present writer has defined those characteristics in the cartilages, classifying them into six types called At^1 to At^6.

Type-At^1 involves four species (**B**, **F**, **G** and **K**); the a.

tr. 1 is developed in a small rod with a smooth surface (B, F, G and K in Fig. 11). Type-At^{2} is found in the two species (H, I and its subspecies I′); the element is somewhat thickened with complex configuration (H, I and I′ in Fig. 11). Type-At^{3} is found in only species E, in which the cartilage is very small and broad in shape (E in Fig. 11). Type-At^{4} involves two species (J and L); the element is like a round fan in shape with a keen edge in posterior margin (J and L in Fig. 11). Type-At^{5} has a curious form as found in the species A (A in Fig. 11), where both a. tr. 1 and 2 are present, but the former is furnished with a keen edge as found in the preceding species (J and L). Type-At^{6} is exemplified by the two species (C and D); the cartilage is developed with two elements, of which the a. tr. 1 is very long and stout, while the other is small, looking like a rod (C and D in Fig. 11).

It must be noticed here that the cartilage in the organs of both *Rhinobatos schlegeli* and *Platyrhina sinensis* is highly different from one of the Japanese rajids in having a sharp spine called the claw in the external structure (Figs. 10, 20; a, a″, b).

§§. **Subordinate division of the northern forms on the basis of the internal features of their glans claspers (Type-CNI):-** Judging from the general features of the cartilages which form the characteristics of the clasper in each species of the type CNI, we can emphasize that the organ seems to have unique feature in each species which can not be seen in any other internal features. But, in order to make these differential characteristics in the organ quite distinguishable, the writer has classified this type into seven subtypes abbreviated as Types-CNI^{1} to -CNI^{7} in contrast to those done in the external character.

Type-CNI^{1} has in it only one species K (K in Fig. 12); the characteristics in the organ of this type are found in d. tr. 1 of Type-Dt^{1} and v. tr. of Type-Vt^{1}, which are somewhat alike to those in *Rhinobatos schlegeli*.

Type-CNI^{2} is the characteristics in the organs of the two species J and L (J and L in Fig. 12); the distinguishable features in these examples are d. tr. 1 and a. tr. The d. tr. 1 is somewhat reduced in the species J, but in the L it is more degenerate. This is also observed in the modification of the v. tr. in the organs of the two species. Further, the feature of the a. tr. is conspicuous in this type (as in Type-At^{4}).

Type-CNI^{3} has only one species A (A in Fig. 12); the characteristics in the structural elements are found in remarkably reduced d. tr. 1 and also found in hook-like v. tr., and two accessory terminals connected with a slender posterior projection of the ventral marginal.

Type-CNI^{4}, in which the species B is involved (B in Fig. 12), is distinguished from the other types in having specialized d. tr. 1, 2 and 3, which seem modified from those in the type CNI^{2}, and in having v. tr. of Type-Vt^{4}.

Type-CNI^{5} is found in the organs of the two species C and D (C and D in Fig. 12); these representatives closely resemble each other in both external and internal features of the organ, but they are discriminative internally in d. tr. 1. More exactly, the d. tr. 1 in the species C is in a curious design (as in Type-Dt^{C}) that may have been modified and reduced from that of a species like K. But in the species D which has the element of a small quadrangular shape, the cartilage is much more reduced than in the former species (as in Type-Dt^{D}). The two species may distinctively differ from the others in having specialized dorsal and ventral marginals, and in having axial cartilage of Type-Ax^{2}, ventral terminal of Type-Vt^{3} and accessory terminals composed of two elements belonging Type-At^{6}.

Type-CNI^{6} has in it three species, viz., E, F and G as illustrated in Fig. 13.

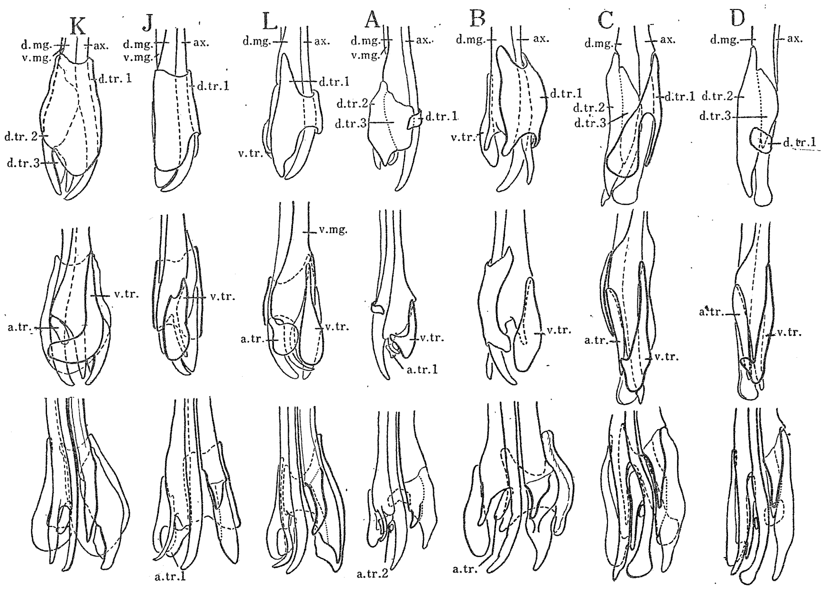

Fig. 12. Showing the arrangement of the cartilages in the glans clasper in seven forms of the organ (Type-CNI), which is subdivided into five subtypes, CNI^1 to CNI^5. Upper row, dorsal aspects; middle and lower ones, ventral and opened views, respectively. a. tr., accessory terminal; ax., axial cartilage; d. mg., dorsal marginal; d. tr. 1—3, dorsal terminals; v. mg., ventral marginal; v. tr., ventral terminal. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* All these Figs. were drawn in the same size for the sake of comparison, and so forth.

These examples are distinguished from any other type in having such similar characteristics in the axial cartilage represented as Type-Ax^1 and in having dorsal and ventral marginals, but the three species are distinguishable each other in some elements, dorsal and venral terminals. Judging from these characteristics in the elements the present writer can safely say that the species E is more related to F than to G.

Type-CNI^7 involves fishes H, I and its subspecies I′ (H, I and I′ in Fig. 13), which are very closely related to both features and arrangement of the cartilaginous elements in the organ, though we can not say much about their congeneric relations between species H and I (I′) recognized in external features of the organs. The present type of the organ may be distinct from the others in having marked peculiarity in features of the axial cartilage of Type-Ax^3, the dorsal terminal and the accessory terminal. It may be worth mentioning here that the differences in the features of such elements are more distinct between the species H and the two subspecies I and I′ rather than that recognized between the latters, in which the features found in the ventral terminal and the accessory terminal are distinguishable each other. The present writer believes that this fact shows a subspecific variation actually originated in the male organ.

§§. **Type-CSI of the myxopterygial cartilages:-** The clasper of this type is found in the organ of the southern form, and is composed of eight elemental cartilages in most species but occasionally more numerous, which are fundamentally of the same composition as those found in the preceding type, although both features and arrange-

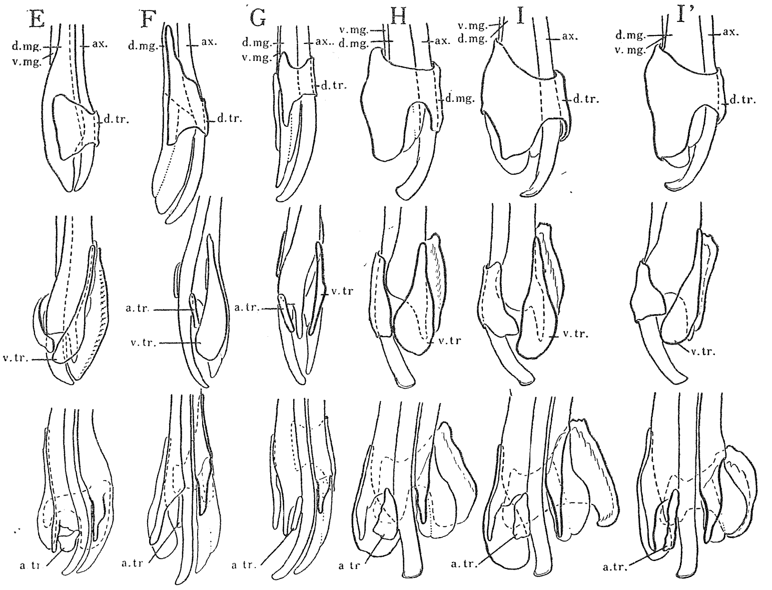

Fig. 13. Showing the arrangement of the cartilages in the glans claspers in six forms of the organ (Type-CNI), which was classified into two subtypes, CNI^6 and CNI^7. Upper row, dorsal views; middle and lower ones, ventral and opened views, respectively. a. tr., accessory terminal; ax., axial cartilage; d. mg., dorsal marginal; d. tr. 1—3, dorsal terminals; v. tr., ventral terminal. E, *Breviraja diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* I', *B. smirnovi ankasube.*

ment of the elements are markedly different between these two types (l.c.). Therefore, the present writer has made first detailed descriptions of the structural elements and followed typification of the characteristics as has been done in the previous section.

Axial cartilage, ax. :- The axial cartilage of this type is the same in its general feature as that of the preceding one, especially in its main portion and the relative position in the organ, but the distal end of the cartilage usually forms a shallow hook in this type except for the species **P**, in which the element ends in a slender and pointed tip (P in Fig. 17). Another difference in the feature of the cartilage between the two types is a projection which more or less develops in the midway portion of the cartilage of this type so as to connect itself with the dorsal terminals, d. tr. 2 and 3. The projection is obscure in the cartilages of the three species **M**, **Q** (**Q′**) and T (ax. in Figs. 17—19), but it is distinctively developed in those of other species of this type, especially so conspicuous in the species **N**, **P**, **U**, **V** and W (Figs. 17 and 19).

Dorsal marginal, d. mg. :- In both feature and location in relation to other cartilages in the clasper, the dorsal marginal of this type is specialized only in the posterior portion as compared with that of the preceding type. The element is broadened posteriorly, ending in an asymmetrical bifurcation (d. mg. in Figs. 17 and 18).

Ventral marginal, v. mg. :- On the ventral side of the glans clasper the ventral marginal is developed, covering the axial cartilage and broadened posteriorly. This cartilage, however, has almost the same feature in this type in question (v. mg. in

Figs. 17 and 18).

Dorsal terminals, d. tr. 1, 2 and 3 :- As in the preceding type the dorsal terminals are composed of three elements. But, there is a marked difference in the features of these three cartilages between the two types. Of the three, the dorsal terminal, d. tr. 1, is remarkable in its size, being scrolled and incurved so as to cover the outermost dorsal border of the glans. Such being the case, the cartilage can be divided into two parts, the dorsal and the ventral half. The dorsal half is usually larger than the ventral one, but the reverse is the case in some instances. More exactly, the dorsal half is well developed in a triangular shape in the five species **M, N, P, S** and **T**, but is tapered in **Q** (**Q′**) and **R**, or is quadrangular (**V** and **W**), and the cartilage is polygonal in its outline in the two examples **O** and **U** (d. tr. 1 in Fig. 14).

So far as the outline of the cartilage is concerned, the element in this group of the fish can be classified into four types, which the writer called Type-Dt^{a} to -Dt^{d} as explained in Fig. 14. Type-Dt^{a} involves the five species **M, N, P, S** and **T**; Type-Dt^{b} is found in the two forms **Q** (**Q′**) and **R**; Type-Dt^{c} involves two species **V** and **W**, and Type-Dt^{d} may be represented by the two forms **O** and **U**.

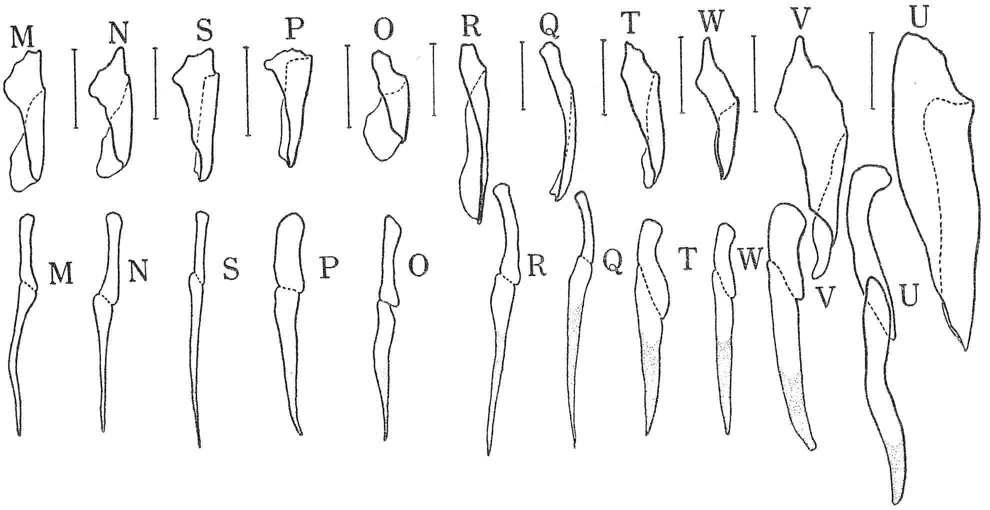

Fig. 14. Dorsal views of the dorsal terminals, d. tr. 1, 2 and 3, of eleven forms of the Japanese rajids, representing Type-CSI of the organ. Upper, d. tr. 1, on the basis of which four types (Dt^{a} to Dt^{d}) were assorted; lower, d. tr. 2 and 3, in which semicartilaginous portion is dotted. M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* R, *R. fusca;* S, *R. schmidti,* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.* Scales attached to Figs. from M to S represent 1 cm, but 2 cm in the rest.

Other dorsal terminals, d. tr. 2 and 3 :- These two cartilages are developed in bar-like elements which ensue rearward from the rear end of the dorsal marginal. It should be noticed herewith that the articulation of the d. tr. 2 to distal end of the dorsal marginal is distinct in this type of the organ. The d. tr. 2 is usually shorter than the d. tr. 3, which becomes gradually slenderer posteriorly, forming semicartilaginous tissue to which the tip of the axial cartilage is attached, making a marginal frame of the dorsal lobe of the glans clasper.

Both shape and size of the cartilages seem to have similar tendencies in the transformation to those noticed in the d. tr. 1, as has been described above. Therefore, the writer has only delineated the cartilages together with the d. tr. 1 (Fig. 14).

It may be of special interest in the cartilages found in the species **U** that a small bar-like element is developed to make a connection between the posterior end of the d. tr. 2 and the projection of the axial cartilage. This unique cartilage is newly termed here 'terminal bridge', which may be an offshoot derived from the accessory terminal described below (t. br. in Figs. 16 and 18).

In summarizing the differentiation revealed in the three dorsal terminals, the writer has presumably found that the evidence worthy of giving specific features leads him to probable relationship in the type.

Ventral terminal, v. tr. :- The ventral terminal of this type of the organ is a very large cartilage with a very complex feature which is markedly differentiated from that in the preceding type, CNI. The cartilage grow in the ventral lobe of the glans to form a frame of the lobe. Anteriorly, the element has a deep notch, in most cases, to which the basal part of the left arm of the accessory terminal 1 is attached. The main portion of the element can be divided into two parts in the ventral aspect; a portion which directs outwards is furnished with a knife-blade-like edge which is called 'shield' in the external observation; the other which is on the inner ventral border of the cartilage more or less developed from a thin cartilage forming an irregular margin on the ventral side of the element. These two parts are bounded by a longitudinal depression.

In the distal part of the cartilage a semicartilaginous projection is developed, tapering off more or less, connecting the posterior tip of the axial cartilage with it. The projection is regarded as a form of the dike in the external.

In order to clarify these complex features revealed in the ventral terminal outlined

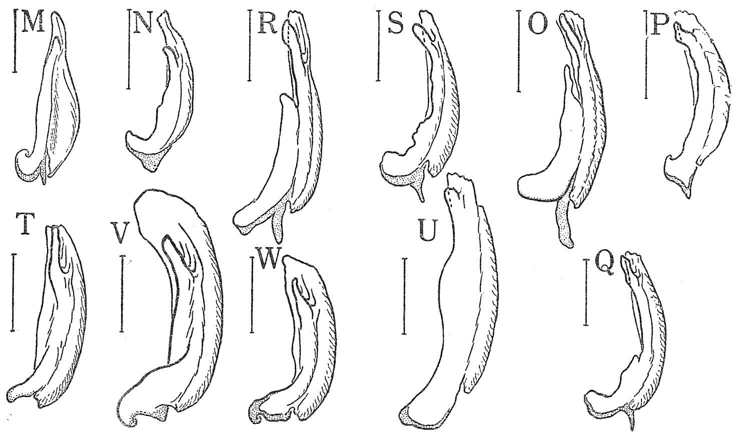

Fig. 15. Ventral aspects of the ventral terminal, v. tr., in the twelve forms of the Japanese rajids (Type-CSI of the organ), especially showing interspecific variations on anterior portion bifurcated, knife-blade-like margin, inner thin cartilage and posterior projection tapering off, based on these characteristics the cartilage were classified into six types, Vt^a to Vt^f. M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi,* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.* Scales denote 1 cm, except those four examples (T—W) with bars of 2 cm.

above, the present writer has assorted the members in this type basing them on, i) feature of the anterior portion with notches, ii) degree of development of the knife-blade-like edge, iii) form of the inner thin cartilage with an irregular outline, and iv) degree of development of the posterior projection tapering off.

Comparing these characteristics in the cartilage that seem to have some validity in speculating the degree of differentiation of the cartilage, the writer has classified species into six groups, as follows, abbreviating them as Type-Vt^a to -Vt^f.

Type-Vt^a involves two species, M and N, whose characteristics in the cartilage are moderately developed in any and every category itemized above (M and N in Fig. 15). Type-Vt^b is found in the feature of the species P, Q and S, where the anterior portion, inner thin cartilage and posterior projection are somewhat conspicuous (P, Q and S in Fig. 15). Type-Vt^c is exemplified by the two species O and R, which are specialized in the features, such as anterior portion, inner thin cartilage and posterior projection (O and R in Fig. 15). Type-Vt^d involves only one species T, in which any of the features in the cartilage can not be noticed as specialization except for the feature revealed with the anterior portion (T in Fig. 15). Type-Vt^e involves the two species V and W, which can be distinguished from the preceding species by having much specialized features in the anterior portion and knife-blade-like cartilage (V and W in Fig. 15). Type-Vt^f is found in the cartilage of the species U, which can be clearly distinguished from any other form mentioned above in having much more specialized features in regard to those four categories itemized above than those in the preceding species (U in Fig. 15).

Accessory terminals, a. tr. 1 and 2 :- The accessory terminals are developed with specialized two elements. Of the two, the a. tr. 1 starts off anteriorly from a portion where the ventral marginal ends in a round margin. The a. tr. 1 assumes Y-like shape in most species in question, bifurcated anteriorly with two symmetric or asymmetric arms. From Fig. 16 we can recognize the transformation in the anterior arm which changes from symmetric form to asymmetric one. The posterior arm, however, is developed in different forms, as simply elongated, broodly pointed or sharply edged.

The accessory terminal 2 is also developed in different design with specialized features in most cases. The cartilage originates together with the right arm of the a. tr. 1, attached to posterior edge of the ventral marginal. Posteriorly, the a. tr. 2 is developed with specialized portions, which are termed here for the sake of convenience to be described as the attachment and the spinal projection (at. and pr. in Fig. 16).

The attachment grows more or less regularly at the midway point of the a. tr. 2, firmly attached to the lateral side of the axial cartilage, except for the species T, in which the attachment is absent. The spinal projection varies with the posterior elongation, which projects posteriorly as a slender and snarled cartilage sharply pointed or hooked at the distal tip. The projection was regarded as the spike in the external observation.

The a. tr. 1 in the organ of the species U is so conspicuous as to be noticed with special mention. Namely, the cartilage in this species is composed of three separate elements; the one with spoon-like shape located on the ventral border of the axial cartilage is newly called here 'detachment' as a substitute for the attachment, (dt. in Fig. 16 U); a boot-like element which ensuing posteriorly from the detachment may be a modification from the spinal projection of the accessory terminal 2 mentioned above (a. tr. 2 in Fig. 16 U); the terminal bridge which has been described in the preceding paragraph may be a fraction derived from the a. tr. 2 (t. br. in Fig. 16

U).

These two accessory terminals which assume markedly diversified features in this type of the organ as outlined above may be co-acting element that render the fish some fundamental service in copulation. In accordance with the characteristics thus mentioned the present writer has classified a group of these two cartilages into six types, viz., At^a to At^f .

Type-At^a is found in the species T, in which the a. tr. 1 is furnished anteriorly with asymmetrical arms and a simply elongated posterior projection, and the a. tr. 2, with a slender projection, but without the attachment (T in Fig. 16). Type-At^b involves three examples (M, V and W in Fig. 16); the a. tr. 1 is developed in the same manner as in the preceding species, but the a. tr. 2 is furnished with the attachment more or less developed, and the spinal projection is hooked posteriorly in some extent. Judging from these facts revealed in the two types mentioned above, the species T may be regarded as the simplest feature of the cartilages, from which those three species represented as the Type-At^b may have been diversified with different features. Type-At^c can be found in the organ of the following four species (N, Q, R and S in Fig. 16); the anterior arm of the accessory terminal 1 is rather in symmetrical form, and the posterior one is broadened with a pointed distal tip; the a. tr. 2 is in moderate degree of development, furnished the attachment and the spinal projection more or less snarled. We must specially mention here the finding of critical difference between the two forms Q and Q′ in structural evidence of the two elements, viz., the spinal projection of the a. tr. 2 in Q is elongated posteriorly reaching as far as the posterior arm of the a. tr. 1, but the projection sticks out posteriorly beyond the distal tip of the posterior arm in Q′ (Figs. 16 and 18). In the writer′s sense this difference in the features of the two cartilages between these two forms may surve as good basis for separating them into two subspecies which

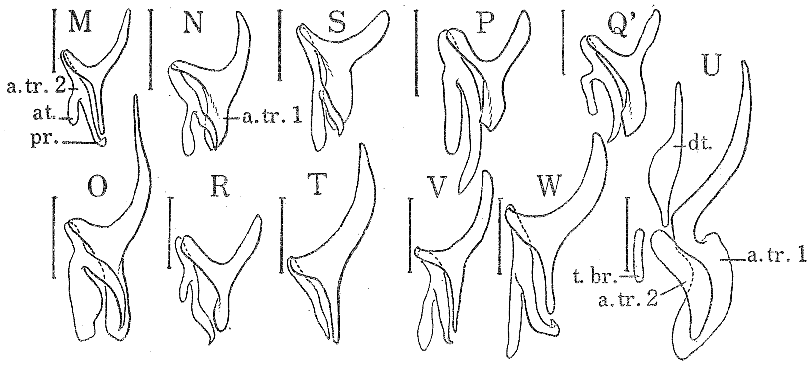

Fig. 16. Ventral views of the accessory terminals, a. tr. 1 and 2 in eleven forms of the Japanese rajids (Type-CSI of the organ), especially showing Y-shaped outline in the a. tr. 1, the attachment (at.) branched out from the a. tr. 2 with or without either hooked or snarled posterior projecton (pr.) and four fractions of the a. tr. 1 and 2 developed in species U (a. tr. 1, a.tr. 2, dt. and t. br.). On the basis of these features the cartilages are assorted into six types as explained in the text. M, *R. kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q′, *R. porosa tobae;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.* Scales represent 1 cm in species from M to R, but 2 cm from T to W.

are closely related to the external features as will be explained elsewhere (cf. p. 173). Type-At^{d} involves only one species **O** as illustrated in Fig. 16; the anterior arm of the a. tr. 1 is asymmetrical due to much elongation in the left arm, and the posterior arm is developed with a long, stout projection which furnishes the distal margin with a keen edge; the attachment of the a. tr. 2 is swollen up, and the spinal projection assumes the form of a very sharp spine like a spindle. Type-At^{e} is exemplified by only one species **P**; the a. tr. 1 has symmetrical arms anteriorly, and the posterior one is thickened with a knife-blade-like edge in its rear end; the a. tr. 2 is remarkably developed with a long attachment and a spinal projection (**P** in Fig. 16). Type-At^{f} involves but one species **U**, whose a. tr. 1 is highly specialized by having a long anterior arm and a large axe-like posterior one which furnishes the outer margin with a knife-blade-like edge; the a. tr. 2 is also curious in having the

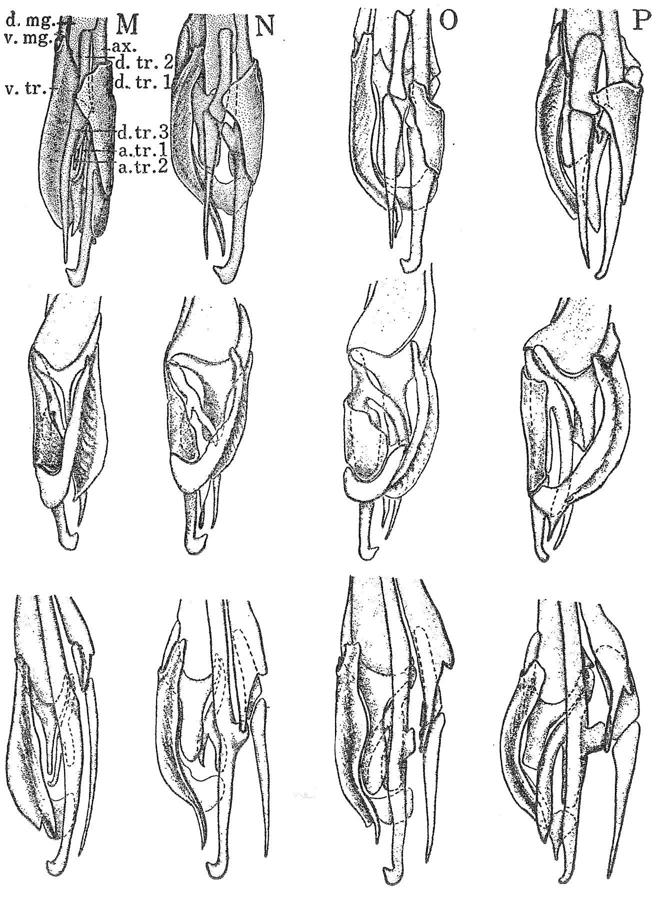

Fig. 17. Showing the structural elements in the glans claspers of four forms of the organ (Type-CSI). Upper row, dorsal views; middle and lower ones, ventral and opened views, respectively. a. tr. 1 and 2, accessoy terminal 1 and 2, respectively; ax., axial cartilage; d. mg., dorsal marginal; d. tr. 1, 2 and 3, dorsal terminal 1, 2 and 3, respectively; v. mg., ventral marginal; v. tr., ventral terminal. M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma.* All these Figs. were given in similar size.

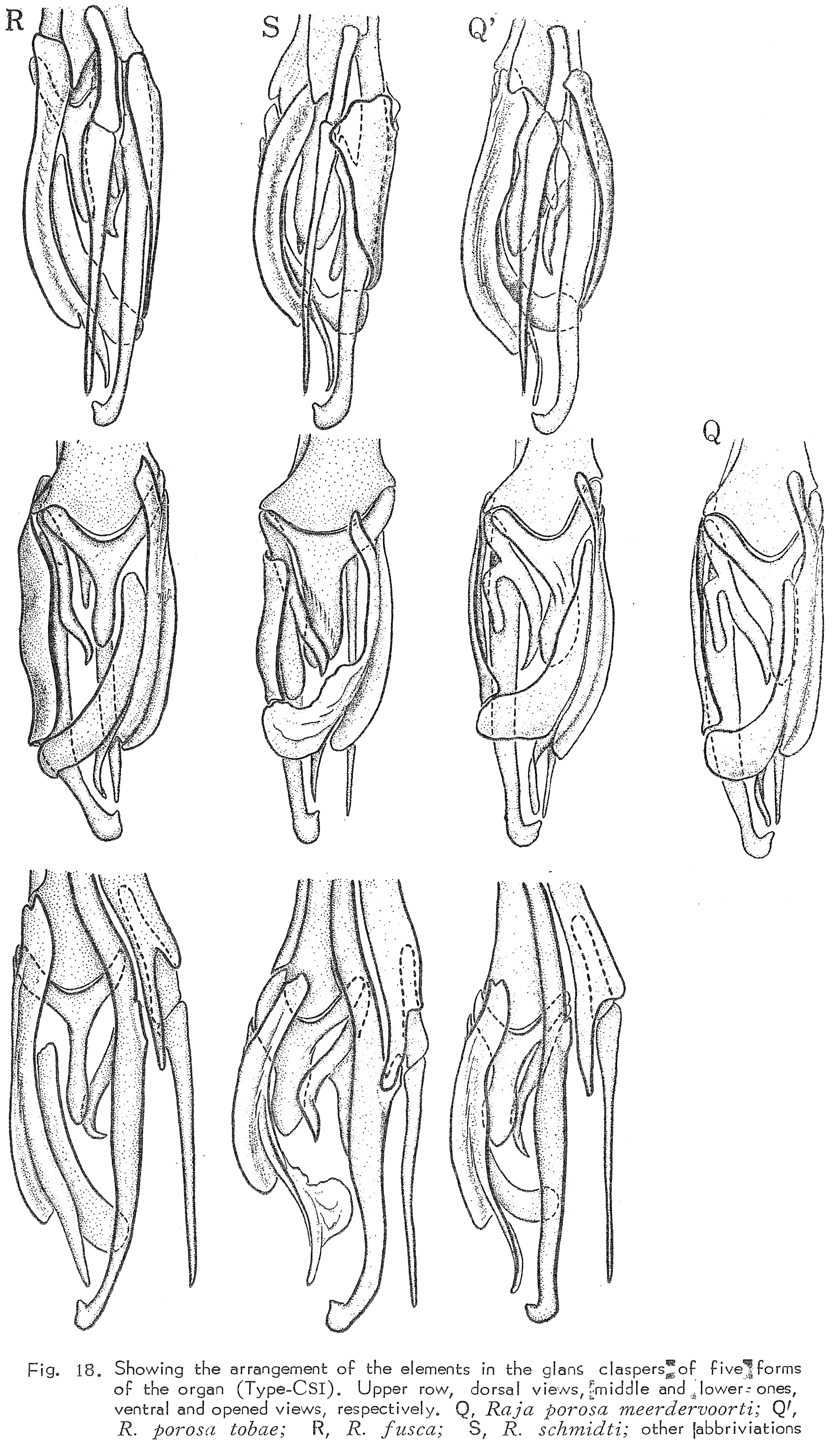

Fig. 18. Showing the arrangement of the elements in the glans claspers of five forms of the organ (Type-CSI). Upper row, dorsal views, middle and lower ones, ventral and opened views, respectively. Q, *Raja porosa meerdervoorti;* Q', *R. porosa tobae;* R, *R. fusca;* S, *R. schmidti;* other abbriviations are the same as in Fig. 17, and all these Figs. were drawn in an equal size.

three fractions derived from the cartilage as mentioned above (U in Fig. 16).

§§. **Subordinate division of the southern forms on the basis of the internal features of their glans claspers (Type-CsI):-** Thus having scrutinized comparatively the internal features found in the claspers of the Type-CsI, the writer has come to the conclusion that any sort of classification of the organ might be difficult to show in complete system because of the greatest diversifications revealed in the organ of this type. But marked differentiations can naturally be recognized especially in the following cartilages, i) both dorsal and ventral terminals, and ii) accessory terminals. According to the differential features of these elements the writer has assorted them into several types.

The following six subtypes may be discriminated in reference to these internal features of the organ concerning the type of glans clasper.

Type-CsI^{1} involves only species **M**, in which the most diagnostic feature may be noticed to the accessory terminals of Type-At^{b}, but the dorsal terminal 1 as well as the ventral terminal is also somewhat attractive (**M** in Fig. 17).

Type-CsI^{2} is modeled after the characteristics of the organs in the four species **N**, **Q** (**Q′**), **R** and **S**. But these examples seem to differ from one another in the characteristics of the dorsal and accessory terminals. In the species **Q** (**Q′**) and **R**, the dorsal terminal 1 tapers off in Type-Dt^{b}, though species **N** and **S** have Type-Dt^{a}, and the accessory terminals of the group of species have been typified as At^{c}, and the features of the ventral terminal are different in these four species belonging to Type-Vt^{a-c} (**N**, **Q** (**Q′**), **R** and **S** in Figs. 17 and 18).

Type-CsI^{3} is found in the species **O** and **P**. These two examples are somewhat analogous in those characteristics, such as the dorsal, ventral and accessory terminals, which clearly make us discriminate this type from any other relatives (**O** and **P** in Fig. 17).

Type-CsI^{4} is exemplified by only species **T**, in which the ventral terminal has Type-Vt^{d} and the accessory terminal shows Type-At^{a}. And this fact is characteristic of this type (**T** in Fig. 19).

Type-CsI^{5} is found in the species **U**, whose organ seems much more specialized than in the former in having the ventral terminal of Type-Vt^{f} and the accessory terminal of Type-At^{f}, and the latter is the most

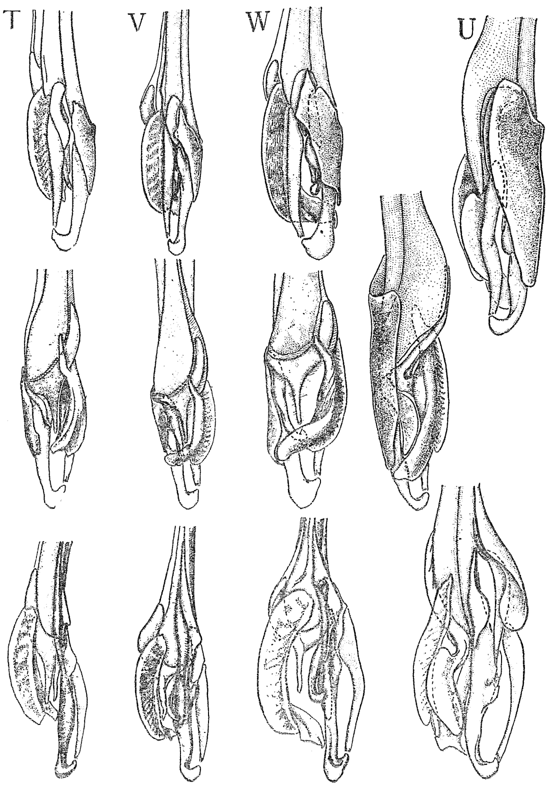

Fig. 19. Showing the arrangement of the cartilage elements in the glans claspers of four forms of the organ (Type-CSI). Upper row, dorsal views; middle and lower ones, ventral and opened views, respectively. T, *Raja tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*.

distinguishable characteristics in the elements (U in Fig. 19).

Type-Csi^6 involves the two species V and W, about which the writer has called the reader's attention to the fact that they are having ventral terminal of Type-Vt^e and accessory terminal of Type-At^b (V and W in Fig. 19).

According to the comparative investigation of the internal feature of the glans claspers of Japanese rajids as aforementioned, the characteristics in the organ of the respective types may be shown in the following Table.

Table 3. Internal characteristics of the glans claspers of the Japanese rajids classified into two major types (CNI and CSI) followed by their subtypes. The abbreviations except followings refer the reader to the text; ax., axial cartilage; a. tr., 1, 2, accessory terminal 1, 2 ; d. mg., dorsal marginal; d. tr. 1—3, dorsal terminal 1—3 ; v. mg., ventral marginal ; v. tr., ventral terminal; + and — represent the presence and absence of the cartilage, respectively.

Type	CNI							CSI					
Subtype / Items	1	2	3	4	5	6	7	1	2	3	4	5	6
ax.	Ax^1	Ax^1	Ax^1	Ax^1	Ax^2	Ax^1	Ax^3	hooked	hooked	hooked or pointed	hooked	hooked	hooked
d. mg.	+	+	+	+	+	+	+	+	+	+	+	+	+
v. mg.	long	long	short	short	long	long	short	+	+	+	+	+	+
d. tr. 1	Dt^K	Dt$^{J;L}$	Dt^A	Dt^B	Dt$^{C;D}$	Dt^{E-G}	Dt$^{H;I}$	Dt^a	Dt$^{a;b}$	Dt$^{a;d}$	Dt^a	Dt^d	Dt^c
d. tr. 2, 3	+	+	+	+	+	+	+	+	+	+	+	+	+
v. tr.	Vt^1	Vt$^{2;4}$	Vt^3	Vt^4	Vt^3	Vt$^{4;5}$	Vt^4	Vt^a	Vt^{a-c}	Vt$^{b;c}$	Vt^d	Vt^f	Vt^e
a. tr. 1—3	At^1	At^4	At^5	At^1	At^6	At$^{1;3}$	At^2	At^b	At$^{d;c}$	At$^{d;e}$	At^a	At^f	At^b
Genus	*Rhinoraja*		*Breviraja*					*Raja*					
Species	K	J;L	A	B	C;D	E;F;G	H;I	M	N;Q;R;S	O;P	T	U	V;W

3. Discussion

(1). Systematic significance of the characteristics related to the clasper:

In elasmobranchs, LEIGH-SHARPE (1926) presumed that "........... genera, and in some cases even species (*Chimaera, Cestracion,* many *Raia*), can be distinguished by those characters ...., and it is abundantly clear that they will in future have to be used for purpose of identification."

By the comparative investigation of the characteristics in both external and internal features of the clasper in each species of the Japanese rajids, the following evidence has been confirmed to be present, which will serve for making out the sound basis formed on: i) features in both external and internal structures of the clasper are species specific without exception; ii) intra-specific variations are seemingly recognizable in minor scale; iii) specific characteristics in the organ worthy of merit for an analytical classification of the fish dealt with in this study; and iv) phyletic relations between genera and between species, or even subspecies in some cases, of the family are conclusively presumed by those transformations of the features in the organs.

(2). Analytical key to genera, species and subspecies of the Japanese rajids:

The following key has been based on both external and internal characteristics of the clasper, and it has been found to exhibit the natural affinities of the species in each group according to their genealogical trends in the characteristics.

1a. Clasper club-type, usually with a blunt distal tip; glans clasper composed externally of ten components, namely, pseudosiphon, slit, ridge, pseudorhipidion, spur, scale, pent, funnel, knife, and claw, some of which are absent in some species, and internally composed of eight or nine cartilage elements, viz., axial cartilage (ax.), dorsal and ventral marginals (d. mg. and v. mg.), three dorsal terminals (d. tr. 1, 2 and 3), and one or two accessory terminals (a. tr. 1, 2); (Figs. 2~4 and 7~12).

2a. Pseudosiphon distinct, broadly opening on the dorsal border apart from distal tip of glans clasper (Type-Ps^1); dorsal terminal 1 large, without remarkable reduction; ventral marginal elongate posteriorly, as long as axial cartilage, of which the distal tip pointed or blunt (Type-Ax^1) .... *Rhinoraja*

3a. Type 1: Both pseudorhipidion and funnel well-developed; knife and claw absent; dorsal terminal 1 complete, covering the whole dorsal side of glans clasper (Dt^K in Fig. 8); dorsal terminal 2 large, connecting with it small dorsal terminal 3; ventral terminal J-shaped (Type-Vt^1); accessory terminal small, rod-like in shape (Type-At^1) .... *Rh. kujiensis* (**K** in Figs. 2, 4 and 12)

3b. Type 2: Both pseudorhipidion and funnel absent or ill-defined; knife and claw present; inner side of dorsal terminal 1 more or less reduced; ventral marginal elongated posteriorly into a slender, curved projection; dorsal terminal 2 and 3 subequal in size, located side by side; ventral terminal not J-shaped but heteromorphic; accessory terminal round, fan-like shaped (Type-At^4).

4a. Slit distinct; dorsal terminal 1 less reduced (Dt^J in Fig. 8); ventral terminal somewhat reduced in Type-Vt^4 .... *Rh. odai* (**J** in Figs. 4 and 12)

4b. Slit absent; dorsal terminal 1 more reduced (Dt^L in Fig. 8); ventral terminal spoon-like is shape (Type-Vt^2) .... *Rh. longicauda* (**L** in Figs. 4 and 12)

2b. Pseudosiphon absent, or reduced, if present, in size, shifted to distal tip of shortened glans, except for species **F**, whose pseudosiphon is rather large, falling far apart from distal tip of glans, or pseudosiphon located on the marginal portion of anterior portion or inside border of dorsal lobe; dorsal terminal 1 reduced in some degree; ventral marginal not so elongate posteriorly as axial cartilage, the distal tip is either pointed or truncated, some times spatulated .... *Breviraja*

5a. Pseudosiphon absent, disappearing from both dorsal and inside borders of glans, so that dorsal terminal 1 reduced to a very small size; two accessory terminals present.

6a. Type 3: Knife and pent present, but funnel and spur absent (Type-CNE^3); distal tip of axial cartilage pointed (Type-Ax^1); dorsal terminal 1 reduced to a small piece (Dt^A in Fig. 8); ventral terminal hooked posteriorly (Type-Vt^3); accessory terminals modified to Type-At^5. .... *B. tobitukai* (**A** in Figs. 4 and 12)

6b. Type 5: Knife and pent absent, but funnel and spur present (Type-CNE^5); distal tip of axial cartilage spatulated (Type-Ax^2); dorsal terminal 1 greatly reduced; accessory terminal 1 very stout, elongated posteriorly (Type-At^6).

7a. Both funnel and spur well-developed; dorsal terminal 1 singular in shape (Dt^C in Fig. 8)................................ *B. trachouros* (**C** in Figs. 4 and 12)

7b. Both funnel and spur less developed; dorsal terminal 1 reduced into a very small quadrangular piece (Dt^D in Fig. 8) .... *B. abasiriensis* (**D** in Figs. 4 and 12)

5b. Pseudosiphon present, reduced in size to some extent, located on the dorsal border or on the marginal, or on the inside border of the glans clasper, so that dorsal terminal 1 more or less reduced in concordance with the degree of development of pseudosiphon; only accessory terminal 1 present.

8a. Pseudosiphon developed on the dorsal border or anterior marginal portion of glans clasper; posterior end of axial cartilage blunt (Type-Ax^{1}); accessory terminal rod-like in shape (Type-At^{1}) except for the species **E**.

9a. Type 6: Pseudosiphon located on the dorsal border of glans clasper; ridge absent; funnel more or less developed; dorsal terminal 2 and 3 flat, reaching the extremity of axial cartilage.

10a. Glans clasper shortened; pseudosiphon reduced to small size; funnel inconspicuous; slit and spur absent; ventral terminal rather large, broadened posteriorly.

11a. Pseudorhipidion distinct; dorsal terminal 1 is of Type-Dt^{E}; ventral terminal spoon-like (Type-Vt^{4}); accessory terminal polygonal in shape (Type-At^{3}) .... *B. diplotaenia* (**E** in Figs. 4 and 13)

11b. Pseudorhipidion moderately developed; dorsal terminal 1 reduced to very thin cartilage with Type-Dt^{F}; ventral terminal spoon-like in shape with thickened posterior portion (Type-Vt^{4}); accessory terminal rod-like in shape (Type-At^{1}) .... *B. matsubarai* (**F** in Figs. 4 and 13)

10b. Glans clasper elongate; pseudosiphon rather large; funnel distinct; both slit and spur present; dorsal terminal 1 less reduced on outer side (Dt^{G} in Fig. 8); ventral terminal greatly reduced to a small, slender bar-like element (Type-Vt^{5}); accessory terminal elongated, rod-like in shape (Type-At^{1}) .... *B. aleutica* (**G** in Figs. 4 and 13)

9b. Type 4: Pseudosiphon degenerate to a deep groove, shifted to anterior marginal portion of dorsal lobe of glans clasper (Type-Ps^{2}); ridge markedly developed; spur slightly growing on ventral lobe; dorsal terminal 1 deeply notched in two sides (Dt^{B} in Fig. 8); dorsal terminal 2 and 3 developed in curious design (**B** in Fig. 9); ventral terminal leef-like in shape (Type-Vt^{4}) .... *B. isotrachys* (**B** in Figs 4 and 12)

8b. Type 7: Pseudosiphon developed on inner border of dorsal lobe of glans clasper (Type-Ps^{3}); ridge present; distal tip of axial cartilage truncated (Type-Ax^{3}); dorsal terminal 1 thickened, forming a deep notch on posterior margin; dorsal terminal 2 large, forming a frame of the ridge; ventral terminal broadened posteriorly (Type-Vt^{4}); accessory terminal with complex configuration (Type-At^{2}).

12a. Ridge distinctively developed, without scale on dorsal surface; funnel large; both slit and spur obscure; dorsal terminal 1 well-notched posteriorly (Dt^{H} in Fig. 8); accessory terminal rather thick (**H** in Fig. 11) .... *B. parmifera* (**H** in Figs. 4 and 13)

12b. Ridge moderately developed, furnished sparsely with minute scales; funnel absent; both slit and spur moderately developed; dorsal terminal 1 less notched posteriorly; accessory terminal slender.

13a. Ridge less developed, so that dorsal terminal 1 low (Dt^{I} in Fig. 8); distal half of both ventral and accessory terminals broadened (**I** in Figs. 10 and 11) .... *B. smirnovi smirnovi* (**I** in Figs. 4 and 13)

13b. Ridge more distinct, so that dorsal terminal 2 relatively high (Dt$^{I'}$ in Fig. 8); distal half of both ventral and accessory terminals rather slender (**I'** in Figs. 10 and 11) .... *B. smirnovi ankasube* (**I'** in Fig. 13)

1b. Clasper spatula-type, depressed dorso-ventrally, with pointed distal tip; glans clasper always composed externally of six components, namely, rhipidion, slit, sentinel, spike, shield and dike, and internally, composed usually of eight cartilage elements except for species U having ten elements, namely, axial cartilage (ax.), dorsal and ventral marginals (d. mg. and v. mg.), three dorsal terminals (d. tr. 1, 2 and 3), and two or four accessory terminals (a. tr. 1, 2, 3 and 4); (Figs. 5—7 and 14—19) .... *Raja*

14a. Spike hooked or blunt posteriorly; sentinel slender or extremely large; anterior arms of accessory terminal 1 asymmetrical.

15a. Rhipidion markedly developed in monolobe; dike ill-defined or obscure; anterior arms of accessory terminal 1 markedly asymmetrical or leaving only the left arm, and the posterior arm slender or otherwise remarkably developed in axe-like projection.

16a. Type 11: Shield moderately large; sentinel growing in a slender projection (Type-St^1); spike small, peeping out from a pocket lying under the sentinel (Type-Sk^1); posterior projections of both accessory terminals lacking bifurcation, elongated into subequal length (Type-At^a) .... *R. tengu* (T in Figs. 6 and 19)

16b. Shield remarkably developed in large size; sentinel inconspicuous, lying with spike bearing hook, if sentinel is large, spike is very obscure, attached to sentinel; posterior projection of both accessory terminals specialized in more or less extent.

17a. Type 12: A large slit present; sentinel very large (Type-St^4); spike obscure (Type-Sk^1); dorsal terminal 1 large and polygonal in shape (Type-Dt^d); ventral terminal represented by Type-Vt^f; accessory terminal highly specialized (Type-At^f) ...... *R. pulchra* (U in Figs. 6 and 19)

17b. Type 13: Two or three slits present; sentinel usually not distinct (Type-St^1); spike apparent, hooked posteriorly (Type-Sk^3); dorsal terminal 1 represented by Type-Dt^c; ventral terminal with Type-Vt^e; accessory terminal with Type-At^b.

18a. Spike slightly hooked posteriorly, so that the posterior projection of accessory terminal 2 not so markedly hooked .... *R. macrocauda* (V in Figs. 6 and 19)

18b. Spike strongly hooked posteriorly, so that posterior projection of accessory terminal 2 deeply hooked, projecting beyond distal tip of accessory terminal 1 .... *R. gigas* (W in Figs. 6 and 19)

15b. Type 8: Rhipidion usually well-developed in bilobes; dike moderately large; anterior arms of accessory terminal 1 less symmetrical, and the posterior arm slender; posterior projection of accessory terminal 2 hooked (Type-At^b) .... *R. kenojei* (M in Figs. 5 and 17)

14b. Spike usually pointed or slightly hooked posteriorly; sentinel bulge developed, covered by fleshy skin; dike clearly seen; anterior arms of accessory terminal 1 usually symmetrical except for species O (*hollandi*).

19a. Type 9: Sentinel devoid of keen edge posteriorly (Type-St^2), so that the posterior arm of accessory terminal 1 broadened; dorsal terminal 1 broad (Type-Dt^a) or tapering off (Type-Dt^e).

20a. Rhipidion bilobed; spike poorly marked as a small spine lying under large sentinel; dorsal terminal 1 with type-Dt^a; anterior arms of accessory terminal less symmetrical, and the posterior arm pointed ...... *R. acutispina* (N in Figs. 5 and 17)

20b. Rhipidion monolobed, but if bilobed, spike distinct, sticking out under sentinel; anterior arms of accessory terminal 1 almost symmetrical.

21a. Rhipidion well-developed with monolobe; spike obsolete; dike elongated posteriorly to symphysis of the two lobes of glans clasper; dorsal terminal 1 narrower as in Type-Dt^b (Q in Fig. 15).

22a. Spike somewhat short peeping out from under sentinel (Q in Fig. 5), so that posterior projection of accessory terminal 2 elongates posteriorly as long as the accessory terminal 1 .... *R. porosa meerdervoorti* (Q in Figs. 5 and 18)

22b. Spike long, thrusting out from under sentinel (Q′ in Fig. 5), so that posterior projection of accessory terminal 2 elongated posteriorly beyond distal tip of the accessory terminal 1 .... *R. porosa tobae* (Q′ in Figs. 5 and 18)

21b. Rhipidion moderate in size with monolobe or bilobes; spike more or less hooked posteriorly, projecting posteriorly beyond distal tip of sentinel; dike well-developed, elongating posteriorly to the symphysis of two lobes; dorsal terminal 1 broad or narrow.

23a. Rhipidion bilobed; two slit present; spike slighly hooked, well-stuck out beyond distal tip of sentinel; dorsal terminal 1 less tapering off (R in Fig. 14); posterior arm of accessory terminal 1 rather slender; posterior projection of accessory terminal 2 crooked and hooked distally with sharply pointed tip (Type-At^c) .... *R. fusca* (R in Figs. 5 and 18)

23b. Rhipidion monolobed; only one slit present; spike slightly stuck out from distal end of sentinel; dorsal terminal 1 broad (Type-Dt^b); posterior arm of accessory terminal 1 thickened; posterior projection of accessory terminal 2 slightly crooked and hooked distally with pointed tip .... *R. schmidti* (S in

Figs. 5 and 18)

19b. Type 10: Sentinel furnished with keen edge (Type-St^3) so that posterior arm of accessory terminal 1 broadened with knife-like margin; dorsal terminal 1 broad but heteromorphic.

24a. Rhipidion monolobed; sentinel distinct; spike obscure, hidden under the sentinel; a large slit present; dorsal terminal 1 polygonal in shape (Type-Dt^d; O in Fig. 14); left arm of accessory terminal 1 greatly elongated; attachment of accessory terminal 2 thickened instead of posterior projection of the element being shortened .... *R. hollandi* (O in Figs. 5 and 17)

24b. Rhipidion bilobed; sentinel moderately developed with keen edge; spike remarkably long, elongated posteriorly to symphysis of the two lobes of glans clasper; two slits present; dorsal terminal 1 broad (Type-Dt^a; P in Fig. 14); anterior arms of accessory terminal 1 symmetrical; attachment of accessory terminal 2 rather large, and the posterior projection greatly elongated posteriorly.......................... *R. macrophthalma* (P in Figs. 5 and 17)

(3). Interrelationships of the Japanese rajids supposed from structural evidence of the clasper:

Differences as well as modes of differentiation in the features of the clasper of rajid fishes are too complex and diversed for us to give those characteristics of each form in the compact system. In other words, it is almost impossible to show them exactly *en bloc*. But, it may be said, on the whole, from the foregoing descriptions and comparisons that noteworthy interspecific differences and genealogical trends have been found in the following characters: i) presence or absence of the pseudosiphon, and degree of development and location of the component, if present; ii) presence or absence of the spur or the spike, and the degree of development, if present, of the components, and iii) form of the knife or the sentinel, and the degree of development of the components, if present, and their associated internal features, such as: (i) form and location of the dorsal terminals, (ii) form of the ventral terminal, (iii) mode of development of the accessory terminals, and (iv) other structural elements marked as worthy for the consideration in view of arriving at a conclusion.

To interpret such differentiations in the suppositional noteworthy characteristics as are mentioned above in several categories, the present writer has arranged the following Table 4, where external and internal characteristics are assorted into thirteen types so as to serve as the characteristics of the respective types of the organ.

𝔞. **The Pseudosiphon related to the features of the dorsal terminal 1** :- As already described in the preceding paragraph, the pseudosiphon in the organ of the northern form of Japanese rajids is assorted into three types (Ps^1, Ps^2 and Ps^3) based on the degree of development and the location of the component, but it disappears in

Table 4. Comparison of important characteristics of the claspers of Japanese rajids, based on their thirteen types of the organ assorted. + or — sign represents presence or absence of the components. For abbreviations, see text.

Characters	Types												
	1	2	3	4	5	6	7	8	9	10	11	12	13
External:													
pseudosiphon (Ps)	Ps^1	Ps^1	—	Ps^2	—	Ps^1	Ps^3	—	—	—	—	—	—
knife (Kn) or sentinel (St)	—	Kn	Kn	—	—	—	—	St^1	St^2	St^3	St^3	St^4	St^1
spur (Sp) or spike (Sk)	—	—	—	Sp^2	Sp^1	Sp^1;-	Sp^3	Sk^3	$Sk^{1;3}$	$Sk^{1;2}$	Sk^1	Sk^1	Sk^3
rhipidion (Rh) and shield	—;—	—;—	—;—	—;—	—;—	—;—	—;—	+;+	+;+	+;+	+;+	+;+	+;+
Internal:													
axial cartilage (Ax)	Ax^1	Ax^1	Ax^1	Ax^1	Ax^2	Ax^1	Ax^3	Ax^a	Ax^a	$Ax^{a;b}$	Ax^a	Ax^a	Ax^a
dorsal terminal (Dt)	Dt^K	$Dt^{J;L}$	Dt^A	Dt^B	$Dt^{C;D}$	$Dt^{E;F;G}$	$Dt^{H;I}$	Dt^a	$Dt^{a;b}$	$Dt^{a;d}$	Dt^a	Dt^d	Dt^c
ventral terminal (Vt)	Vt^1	$Vt^{2;4}$	Vt^3	Vt^4	Vt^3	$Vt^{4;5}$	Vt^4	Vt^a	$Vt^{a;b;c}$	$Vt^{b;c}$	Vt^d	Vt^f	Vt^e
accessory terminals (At)	At^1	At^4	At^5	At^1	At^6	$At^{1;3}$	At^2	At^a	$At^{d;c}$	$At^{d;e}$	At^a	At^f	At^b
Genera	*Rinoraja*		*Breviraja*					*Raja*					
Species	K	J;L	A	B	C;D	E;F G	H;I	M	N;Q R;S	O;P	T	U	V;W

the organs of certain species of the northern form and of the whole members of the southern form. These facts are of primary importance for our studying the genealogical modifications of the organ.

As to the examination and the comparison of the pseudosiphon found in Japanese rajids, the present writer has presumed that the pseudosiphon should have its name in conformity to genealogical relation to the structural features of the clasper in order to be given its compact meaning of the component. This concept concerns the present scheme a great deal because it is suggestive of the relationship in the organs and has great difficulty in our selecting the significance of characters which the organs have.

Thus, the writer has fixed his attention on the following so as to give a reasonable explanation to the present question; (i) as has been repeated in the foregoing description and comparison, the pseudosiphon is developed in different manners in the glans clasper of the northern form, the organ of which is classified into three types. Moreover, in these types the pseudosiphon occupies its position underlying the dorsal terminal 1, or is in close relation to the degree of development of the cartilage. Therefore, in naming and comparing the degree of development of the pseudosiphon, we can reasonably consider that the features of these two components have changed in close relation to the differentiation of the glans clasper; (ii) on the contrary the pseudosiphon in the organ of *Rhinobatos schlegeli* (Fig. 20 a) is markedly developed, found on the inner side of the dorsal border of the glans clasper (since the clasper is dorsal aspect in the Fig. 20), though the component was regarded as a 'slit' by LEIGH-SHARPE (l. c.). However, the dorsal terminal 1 of the guitarfish is highly excellent in its size by having broad, complete outline, and by being located along the ventral side of the glans, and the room which is the pseudosiphon itself is consequently inserted much to ventral side of the clasper. This relation between the position of the pseudosiphon and that of the dorsal terminal 1 observed in the organ of a thornback (*Platyrhina* *sinensis*) is more advanced than in the guitarfish. Namely, the pseudosiphon in the thornback is developed in a large fissure, wholly inserted to the ventral side of the glans, underlying the broad dorsal terminal 1 (Fig. 20).

Such being the case, the present writer is inclined to believe in all probability that the pseudosiphon in the rajids much have gradually shifted to the dorsal border from the ventral of the glans, as is the case with the guitarfish. More exactly, the structural pattern in the glans claspers of the rajids may have changed in congruity with outward twisting capable of turning over the portion, resulting in the differentiation and transmigration of the pseudosiphon together with the dorsal terminal 1. If this view is justifiable, the genealogical trends in the structural pattern in the glans claspers of the rajids may naturally be assumed. That is to say, the pseudosiphon and the dorsal terminal 1 found in the species K may be the most primitive, as these components closely resemble those of the guitarfish. Taking this into consideration, the trend of differentiation of the pseudosiphon can be traced in order from Type-Ps^1 to -Ps^2 and -Ps^3. However, the manner of differentiation of the dorsal terminal 1 seems to be more complex, being in convergence and divergence with changes of the structural pattern in the glans, though each form of the component has great value for taxonomic basis. At any rate, it is very probable that the more specialized organ the species has, the greater degree of differentiation is found in the features of the pseudosiphon and the dorsal terminal 1. Further, this fact that certain species in the northern form and the whole species of the southern form have no pseudosiphon with markedly degenerated dorsal terminal 1 may be justified when we consider that they are offshoots from their ancestral forms in which the pseudosiphon has already disappeared. In this case, therefore, the linealogical trend may be presumed only from the transformation in the dorsal terminal 1.

The consideration on the differentiation of the other terminal components developed in the glans are given below.

§§. **Relationships of the organ classified into thirteen types :-** That general structure in the clasper indicates remarkable difference between the two major forms as has already been noticed. Of the seven types belonging to the northern form, Type 1, to which only the species K is referred, may be the most primitive in having a large pseudosiphon associated with unspecialized dorsal terminal 1. But it is interesting to note that species is found a large funnel, which may be a specialized feature. Presence of large dorsal terminal 2 followed by a small dorsal terminal 3, and J-shaped ventral terminal are also thought to be primitive features, because these elements have close affinity with those found in the guitarfish.

Type 2, may be nearest to the preceding, but it is more highly specialized than the latter in the following points: both dorsal and ventral terminals are somewhat reduced in size, and the accessory terminal is markedly specialized to form the knife associated with the claw, which is modified from distal portion of the ventral terminal. By comparing these characteristics in the two species involved in this type, the species L may be more specialized than the species J, in having more reduced dorsal terminal 1 and ventral terminal, compared with those in the latter.

Type 3, which is represented by only one species A, seems to be an intermediate in structure, resembling partly the preceding type and partly the following one, in having much smaller dorsal terminal 1 without the pseudosiphon, somewhat reduced ventral terminal, and specialized accessory terminals which form the knife of the ventral lobe. The pent in external and the accessory terminal 2 are considered to be special features in this type.

Type 4, which is represented but one species B, may be transitional phase between Types 2 and 5, in having the reduced pseudosiphon located on marginal portion of the dorsal lobe of glans clasper and having the dorsal terminal 1 somewhat similar to that of Type 2. But, the present species is distinct from any other relatives in some characteristics of such components as the dorsal terminal 2 and 3, and the accessory terminal.

Type 5, may be taken as the most specialized phase within the northern form, and is exemplified by the two species C and D, whose organs are marked from those of any other relatives in the following points; presence of large funnel and the spur, and absence of the pseudosiphon associated with greatly degenerated dorsal terminal 1. In spite of these specialized features thus noticed in both external and internal of the glans clasper, the two species involved in this type are quite distinguishable each other in the following respects, viz., the dorsal terminal 1 and the ventral terminal of the species D are thought to have more specialized features than those of the species C, but the features found in the accessory terminal and the distal part of the ventral marginal seem to be in reverse relation between the two species. On the basis of these characteristics the species D may be, on the whole, more specialized than the species C, which is linked partly with the species A on one hand and partly with the species B on the other.

Type 6, involving the three species E, F and G may be related partly to Types 1 and 2, because these species are characterized by having more or less reduced pseudosiphon located on dorsal border of the glans clasper. But this type is discriminated from its relatives in the following features in the organ, i. e. the dorsal terminal 1 and the ventral terminal are the most attractive in the organ of this type. Though the pseudosiphon is distinct and the general structure of the organ is in common in these three species, they can be clearly distinguished from each other according to their differentiations in the organ. These apparent diversifications which presumably may serve for the consideration in question are; differences in size and location of the pseudosiphon, degree of development of the funnel, presence or absence of the spur, and features of both dorsal terminal 1 and ventral terminal. In comparison with these features the species F seems to be the most primitive in this group. But the other two examples may have sprung from the common ancestor in their own way. The fact that the species has some phyletic affinity with the species K, J and L may be owing to the deep sea where the species F is found.

Type 7, involving three forms H, I and I′ seems to be far apart in the degree of differentiation from any other types mentioned above, and it is rather difficult to determine the relationship between them based on the characteristics of the organ. But, it appears to me that this type may be somewhat nearer to Type 4 at least in having further degenerated pseudosiphon followed by the ridge covering the inner surface of the dorsal lobe, and in having the dorsal terminal 1 and the ventral terminal similar to those found in the species B. When the characteristics of the three examples in this type are compared, the species H is distinct from the two subspecies I and I′, the species H may be regarded as a less specialized form of the organ because the degree of outward twisting in the glans clasper of the species H is considered less. The organ of the species H has simpler external feature than the organs of the other relatives. On the other hand, the organs of the two subspecies have a singular character in having the scales developed on the dorsal lobe of the glans. It may be said that the presence of the scales, however, is of unique feature in the organs of the two forms. On the whole, the subspecies I seems to be linked more with the species H than the subspecies I′ in their features of the organ, especially in the accessory terminal.

With regard to the general feature of the organ of the southern form, two phyletic series are assorted on the basis of structural evidence, such as species M-stem and species T-stem. The M-stem contains the three types of organ, ranging from Types 8 to 10, and the T-stem covers from Types 11 to 13.

Type 8, which involves only one species M, represents the most generalized features of the organ of the three types under the M-stem, in having the following character; the sentinel is less developed in Type-St^1, the dike is moderately developed, the dorsal terminal 1 is broad with Type-Dt^a, and the accessory terminals are moderate in development with no sharp edge with Type-At^b. This type of the organ seems to be related partly to Type 9 and partly to Type 11, in their characteristics of the organs.

Type 9, is exemplified by the four forms, N, Q (Q′), R and S, and is nearest to the preceding, but the present type is more specialized than the preceding at least in the following features; the sentinel is broad with Type-St^2, the dike is distinct, and the accessory terminals are thickened. In comparing differentiation of the dorsal tarminal 1, we can surely believe that the two forms Q (Q′) and R may be distinguished from the other two species N and S, in having the element with tape-like shape (Type-Dt^b), while the latter two have broad dorsal terminal 1 (Type-Dt^a) like that of the species M. Such being the case, the species Q (Q′) seems to have the most specialized feature in this type in respect to the cartilage, and may be contiguous to the species R. Moreover, the species Q (Q′) can be clearly distinguished from the species R in having the posterior arm of the accessory terminal 1 more thickened than that of the latter (cf. Fig. 16). It is apparent that the group involving the two species N and S may have originated in the common ancestor of the species like M, because these species have rather similar elemental structures. Further, it should be noticed that the two subspecies Q and Q′ are closely related each other to the structure of the organ, but the two are different from each other in the feature of the accessory terminals, as has been noticed (p. 8). This subspecific difference in the organ can also be seen when we compare the organ of the subspecies Q with that of a form which often has peculiar color pattern as found in *Raja katsukii*. By the way, TANAKA (1916) added *Raja katsukii* to Japanese for the first time. Hence, *Raja katsukii* is identical with the subspecies Q on the basis of their structural components of the organ (cf. Figs. 5, 18 and Pl. II).

Type 10, seems to involve two specialized examples, O and P, which are different each other in the features of some components of the organ. The species P, on the other hand, may be more closely related to the two species N and R than the species O, in having similar dorsal terminal 1 (Type-Dt^a) and the accessory terminal 1, which are highly specialized in the species O (cf. Figs. 14, 16).

Type 11, is modeled after the characteristics of the organ of species T, which seems to have the most generalized feature of the organ in this phyletic series, in having the dorsal terminal 1 of Type-Dt^a, the accessory terminals of Type-At^a, and the ventral terminal with unspecialized posterior portion. On the basis of these characteristics we can see close relation between the organ of the present species and that of the species M (cf. Figs. 14—16).

Type 12, which involves only one species U, seems to be more highly specialized than the preceding or the following types, in having many noteworthy features in the organ, as has been mentioned in the preceding paragraph.

Type 13, is exemplified by the two deep-sea forms, V and W, and is nearer to

Type 11 than to Type 12, as it has a broadly developed dorsal terminal 1 (Type-Dt^{c}), and very asymmetric anterior arms of the accessory terminal 1. But the present type seems to be more specialized than the Type 11 at least in having the accessory terminal 2 which is furnished posteriorly with the hook and the attachment (cf. Fig. 16). On the basis of these characteristics of the elements, the species **W** may be said to be in a more advanced condition than the species **V**.

The writer firmly believes that the organ of the species T may have originated from an ancestral form, from which such two diversifications as represented in Types 12 and 13 may have sprung in different directions in the specialization of the organ. It is very interesting to note that the present hypothesis is also justifiable in the other different characteristics of both external and internal features found in these species, as has already been noticed by the present writer (1955, p. 50).

(4) Relation between the Rajidae and allied families of the batoids, suppossed from the features found in the claspers and its associatd organs:

As to the origin of the Rajidae, it is a general opinion that the family, either the Rhinobatidae or the Platyrhinidae, is most closely related to this family because many features in these groups have something in common with each other. In the author's recent view on this problem in reference to Japanese rajids (ISHIYAMA, 1952, p. 7), a conception has been based on the fact that the fish referable to the genus *Rhinobatos* whose characteristics in the rostrum probably approximate most closely to the fish referred to the genus *Raja*. And, this hypothesis has been precisely argued upon in the foregoing chapter of the present investigation.

In order to emphasize the same point of view, the author has found it necessary to demonstrate some noteworthy facts found in the male organs of these groups related to the Rajidae, and determined which of these families is more closely related to the Rajidae in question, for this is the main function of the present chapter. Discussions are conveniently given in two ways; first on the external features and then on the internal features of the organs.

With regard to the external characters, LEIGH-SHARPE (op. cit.) stated on the form of the clasper in the Batoidei as "the claspers are stout, not denticled, bivalve, and expansible, except in the Rhinobatidae." This statement, however, must be corrected so far as dentition is concerned, inasmuch as the organs of certain species in our rajids are furnished with minute placoid scales, as has been described in the foregoing chapter. Therefore, this feature is not unique to the organs in the Rhinobatidae and the Platyrhinidae, and besides, such feature as the dentition of the organ may provide a sound basis for assuming that there may be some relation between the two related families and the Rajidae. Further, the fact that the degree of dentition in the organ is much less in the *Rhinobatos* than in the *Platyrhina*, as shown in the Fig. 20, may be a safe assumption that the evolutional course may have occurred through the Rhinobatidae from the Platyrhinidae to the Rajidae, so far as the feature in question is concerned. On the other hand, the glans clasper of the Rajidae is remarkably expansible when it is in erection. This phenomenon is not seen either in Rhinobatidae or in Platyrhinidae, because the structural pattern of the glans clasper in these two allied families is not so much twisted outward as in rajids. This fact may have some causal relation to the transformation of the pseudosiphon, as already mentioned (p. 38). Namely, the pseudosiphon is remarkably developed, inserted to ventral side in the *Platyrhina*, and it is relatively reduced, shifted partly to dorsal side in the *Rhinobatos* (Fig. 20 a), but it is less developed on dorsal side or is disappearing in the Rajidae.

Judging from these noteworthy evidences mentioned above, the present writer surely believes that the Rhinobatidae is more closely related to the Rajidae than to the Platyrhinidae, so far as the external features of their claspers are concerned.

Turning to the internal features of the organ, the writer has drawn his attention especially the following two points: i) features of the cartilages composed of the clasper, and ii) degree of development of both clasper siphon and clasper gland.

The cartilages of the clasper are characteristically much more complex in the rajids than in *Rhinobatos* and *Platyrhina*. But, as shown in Fig. 20 a″, a‴, b′, b″, the *Rhinobatos* has its features in the cartilages with general approach to the Rajidae, especially in the northern form of our rajids, at least in having the dorsal terminal with smooth margin, and the ventral terminal with hook, both of which are somewhat related to those of the species K (cf. Figs. 10 and 11). On the other hand, the difference

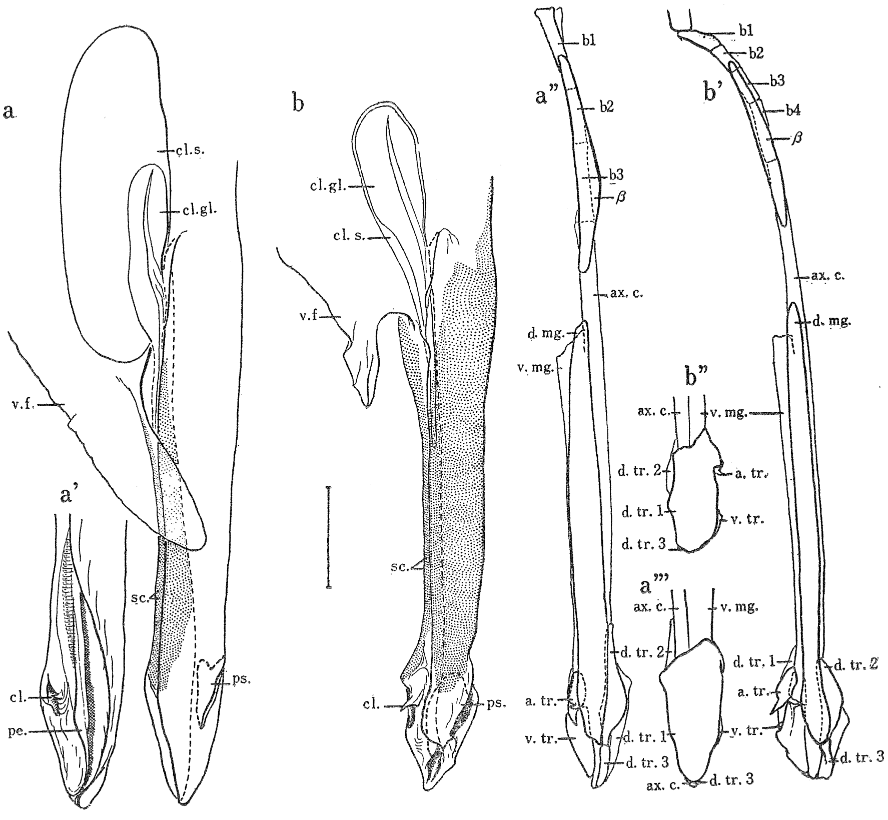

Fig. 20. Comparison of external and internal features of the claspers and associated organ of *Rhinobatos schlegeli*, a — a‴, and *Platyrhina sinensis*, b — b″. a and b, dorsal aspects of the clasper and the clasper siphon dissected; a′, glans clasper when opened; a″ and b′, dorsal aspects of the cartilages of the organs; a‴ and b″, ventral aspects of the cartilages of the glans claspers. Abbreviations in external (a, a′ and b) are; cl., claw; cl. s., clasper siphon sac; cl. gl., clasper gland; pe., pera; ps., pseudosiphon; v. f., ventral fin; sc., scales which are stippling; and internal (a″, a‴, b′ and b″); ax. c., axial cartilage; a. tr., accessory terminal; b_{1-4}, basal segments; β, beta cartilage; d. mg. and v. mg., dorsal and ventral marginal, respectively; d. tr. 1 — 3 and v. tr., dorsal terminal 1 — 3 and ventral terminal, respectively. Accompanying scales, 1 cm.

of these cartilages between the Rajidae and the Platyrhinidae is greater than between the rajids and the rhinobatids. Further, the difference in the number of the basal segments is worthy of being noticed in the three families. Namely, three

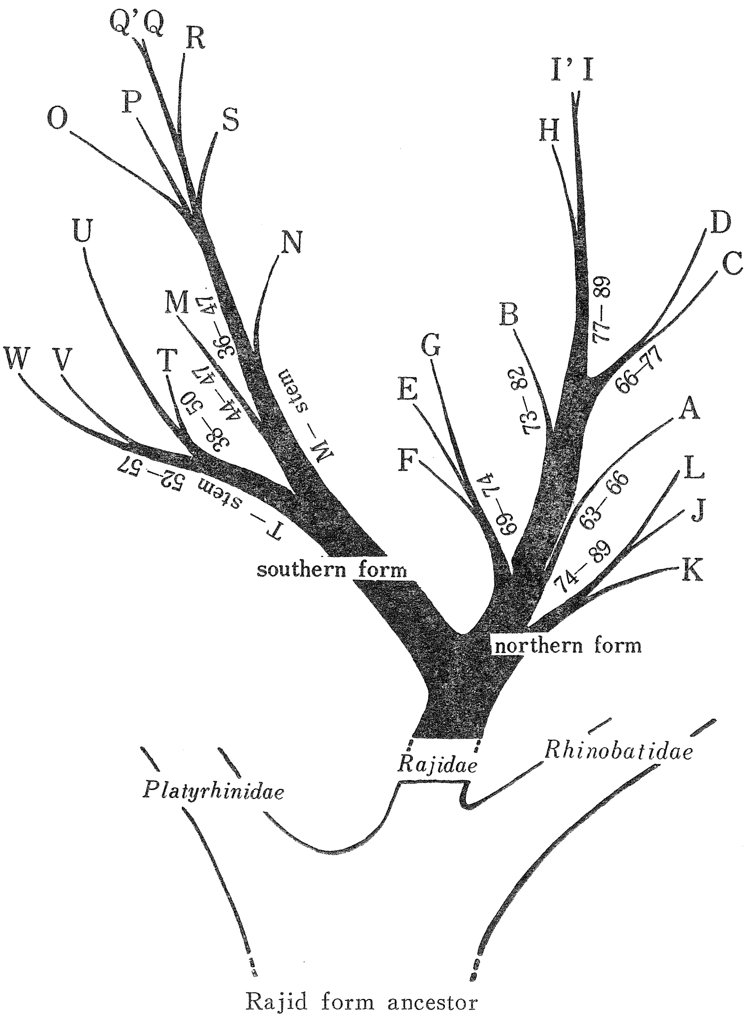

Fig. 21. Suggested interrelationships among the species of Japanese rajids, and between the Rajidae and its allied families, supposed from those structural features in the male organs (clasper and its associated apparatus), and the number of precaudal vertebrae of the rajids. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*; M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; Q', *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*; T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*.

intermediate segments (b_{1-3}) are present in the *Rhinobatos*, instead of four segments (b_{1-4}) in the *Platyrhina*, but two cartilages are always present, in the Rajidae, so far as the writer's knowledge is concerned. Should these relations on the number of the basal segments be correct, the Rhinobatidae may be intermediate between the Rajidae and the Platyrhinidae.

Concerning the clasper siphon and the clasper gland in the batoid fishes, LEIGH-SHARPE (op. cit.) made the following conclusion: "Those, the clasper gland of which has been developed inside the original siphon sac--*Lamna*, *Rhina* and *Batoidei*." And, he further defined the organ of the Batoidei, thus, "The siphon sac always contains a groove, albumen gland confined to the dorsal side of the sac." It is worthy of a special mention that finding of different degrees of development in the clasper gland in the clasper siphon are revealed by the three families. Namely, in the rajid fishes, both organs are markedly developed, and besides, the clasper gland occupies the whole room of the large clasper siphon sac. Whereas, in the *Rhinobatos* the clasper gland is rather small in size, occupying only a part of the space enclosed in the clasper siphon which is relatively as large as that of the rajids. Further, in the *Platyrhina*, both components are less developed, where the gland is small in size, as compared with those in the preceding filling the space ensphering the small clasper siphon. When we consider the fact thus obtained by comparing the degrees of development of the two components, the clasper siphon and the clasper gland which have been revealed among the three representatives in the batoid fishes, we can naturally suppose that the Rajidae has closer relation to the Rhinobatidae than to the Platyrhinidae.

Conclusively, should these studies of the differentiations given from the morphological features of the claspers and its associated organs be accepted and justifiable, the phylogenical relationships in Japanese rajid fishes, and between the Rajidae and its allied families may diagrammatically be illustrated in the foregoing figure (Fig. 21).

The present writer can make some noteworthy remarks on this figure: i) a rajid fish may have arisen from an ancestor like a rhinobatid, ii) the so-called northern form of Japanese rajids may have originated from that ancestral stock, iii) the new-born which resemble the genus *Breviraja* may have again branched in two new forms like the so-called southern form, the genus *Raja*, and the genus *Rhinoraja*, iv) of these two new offshoots the genus *Raja* may have originated deeper in phylogeny than the genus *Rhinoraja*, and v) variation in vertebral count in each group of species can be considered corresponding with the phylogenetic progression along each branch.

b. Egg-capsule

As regard to the egg-capsules of Japanese rajids the present writer has given a revisional study*) by using many specimens referable to 21 species and two subspecies. Therefore, the writer described here merely those keys to species or group of species and summary which were quoted from the foregoing paper, and feature of the capsule in several forms will be given in the systematic part of this account for practical use.

(1) Key to egg-capsules:

1a. Very large in size, measuring more than 100 mm in length exclusive of horns.
 2a. Surface very rough being velvety in texture, Group Eg^4.

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* Observations on the egg-capsules of skates of the family Rajidae, found in Japan and its adjacent waters. Bull. Mus. Comparative Zool., 1958: Vol. 118, No. 1, pp. 1~24, 10 figs. The author's cordial thanks are due to Dr. Henry B. BIGELOW of the Museum of Comparative Zoology, Harvard University, and also to Mr. William C. SCHROEDER of the Woods Hole Oceanographic Institution, for reading the manuscript critically.

3a. Without strong fibroid hairs entirely covering the surface; prickles devoid of small stiff rods at their tips.

4a. Prickles rather long, being perpendicular to surface, Subgroup Eg^{4A}.

5a. Posterior horns longer than width of capsule; capsules 106 mm to 132 mm in length and 76 mm to 86 mm in width .... *Breviraja isotrachys* (Fig. 61 $B_{4,5}$); *B. trachouros* (Fig. 62 $C_{4,5}$)

5b. Posterior horn shorter than width of capsule; length and width being from 106 mm to 120 mm and from 76 mm to 78 mm, respectively .... *B. diplotaenia* (Fig. 64 $E_{4,5}$)

4b. Prickles very long, bending anteriorly, Subgroup Eg^{4B}.

6a. Capsule much larger than those of other northern forms, measuring from about 120 mm to 136 mm and from 73 mm to 90 mm in length and width, respectively; posterior horns longer than width of capsule; capsule-wall, exclusive of prickles, rather thin, being about 0.3 mm in thickness .... *B. aleutica* (Fig. 67 $G_{5,6}$)

6b. Capsule smaller than those of the preceding, about 104 mm to 115 mm in length and from 69 mm to 80 mm in width; posterior horns almost equal to width of capsule; capsule-wall rather thick, measuring from about 0.5 mm to 0.6 mm in thickness exclusive of prickles .... *Rhinorja kujiensis* (Fig. 72 $K_{4,5}$)

3b. Strong fibroid hairs entirely covering prickles, whick are densely furnished with small stiff rods at their tips, Subgroup Eg^{4C}; length and width of capsule being respectively from about 109 mm to 113 mm and from 65 mm to 67 mm; posterior horns longer than width of capsule; capsule-wall relatively thin, measuring about 0.2 mm in thickness exclusive of prickles .... *B. matsubarai* (Fig. 65 $F_{4,5}$)

2b. Surface smooth or somewhat rough, without any velvety texture, Groups Eg^{2}, Eg^{6}, and Eg^{7}.

7a. Surface somewhat rough; horns tape-like in shape or reduced to rudiments, Groups H^{2}, H^{5}, and H^{6}.

8a. Horns rather long, growing slenderer toward tips, pointed at their tips, with a longitudinal slit located at their basal parts, Group H^{2}; capsule-wall composed of two layers, the outer one is furnished with many tubercles over the surface, Group Eg^{2}.

9a. Length and width of capsule about 150 mm and 90 mm, respectively; tubercles covering outermost layer sparsely developed with domed apexes, Subgroup Eg^{2A} .... *B. smirnovi smirnovi* (Fig. 68 $I_{3,4}$)

9b. Length and width of capsule about 120 mm and 90 mm, respectively; the tubercles densely developed with ridged apexes, Subgroup Eg^{2B} .... *B. parmifera* (Fig. 67 $H_{2,3}$)

8b. Horns very short or rudimentary, with a round opening located at their tips or at each of the four corners, Group H^{5} and H^{6}; capsule-wall composed of three layers, the outermost composed of many fibres running lengthwise in series, Group Eg^{7}.

10a. Horns very short, with the opening at their tips, Group H^{5}; broad notches present on lateral sides; length and width of capsule measuring from 140 mm to 185 mm and from 71 mm to 94 mm, respectively .... *Raja pulchra* (Figs. 22 U and 83 U_{4})

10b. Horns reduced to rudiments, with an opening at each of the four corners, Group H^6; notches absent on sides; fibres composing outermost tissue less in diameter than those in 10a; the greatest in size of all capsules examined, measuring about 235 mm and 145 mm in length and width, respectively .... *R. gigas* (Figs. 22 W and 86 W_3)

7b. Surface smooth; horns short, tube-like in shape, Group H^4.

11a. Length of capsule about 100 mm; capsule-wall very thick, measuring more than 1.0 mm, with a very thin pulpy layer which comprises about 13 % of the total thickness of the wall .... *R. tengu* (Fig. 82 T_3)

11b. Length of capsule about 130 mm to 140 mm; capsule-wall relatively thin, measuring about 0.4 mm, with a pulpy layer which comprises about 42 % of the total thickness of the wall .... *R. macrocauda* (Figs. 22 V and 85 V_4)

1b. Usually small in size, measuring less than 70 mm in length exclusive of horns.

12a. Horns long, whip-like in shape, bearing a longitudinal fissure; surface either rather rough or very smooth; Group H^1 and H^3.

13a. Surface rather rough, bearing minute trickles with ridged apexes; capsule-wall divisible into two thickened layers, beind compact in structure, Group Eg^3; moderate in size, measuring from about 57 mm to 68 mm and from 33 mm to 46 mm in length and width, respectively .... *Rh. odai* (Fig. 70 $J_{3,4}$); *Rh. longicauda* (Fig. 71 $L_{4,5}$)

13b. Surface smooth, without any sculpture; capsule-wall translucent, composed of two layers, the outer one very thin, instead of being relatively thick, the inner one parenchymatous in structure. Group Eg^1; very small in size, measuring about 38 mm and 22 mm in length and width, respectively .... *B. tobitukai* (Fig. 60 $A_{5,6}$)

12b. Horns short, tube-like in shape, bearing a round opening at the tip, Group H^4.

14a. Capsule-wall composed of two layers, Group Eg^5.

15a. Capsule-wall about 0.25 mm thick; length and width of capsules measuring from about 51 mm to 57 mm and from 33 mm to 37 mm, respectively ...... *R. fusca* (Figs. 22 R and 80 R_7)

15b. Capsule-wall thin, about 0.15 mm thick; length and width of capsules about 43 mm to 59 mm and from 29 mm to 37 mm, respectively .... *R. porosa meerdervoorti* (Fig. 77 Q_3); *R. porosa tobae*

14b. Capsule-wall composed of three layers, Group Eg^6.

16a. Capsule-wall 0.25 mm to 0.4 mm, with a pulpy layer which is thinner than 50 % of the total thickness.

17a. Pulpy layer comprises about 20 % to 30 % of the total thickness of the wall; length and width of capsules measuring 56 mm to 66 mm and 34 mm to 37 mm, respectively; fibroid hair exceedingly well developed over the surface .... *R. kenojei* (Figs. 22 M and 73 M_3)

17b. Pulpy layer comprises up to 50% of the total thickness of the wall, length and width of capsules measuring from 53 mm to 65 mm and from 27 mm to 39 mm, respectively... .... *R. hollandi* (Figs. 22 O and 75 O_5);

R. schmidti (Fig. 22 S_4)

16b. Capsule-wall less than 0.2 mm in thickness, with a pulpy layer comprising as much as 60% of the total thickness of the wall.

18a. Capsules measure from 49 mm to 54 mm in length; surface densely covered with fine fibres .... *R. acutispina* (Figs. 22 N and 74 N_5)

18b. Capsule the smallest in size, measuring only from 39 mm to 42 mm in length; fine fibres covering the surface less developed than in 18a .... *R. macrophthalma* (Figs. 22 P and 76 P_4)

(2) Summary on egg-capsules:

i. Noteworthy features of the capsule were found in both the external and the histological structure. These characteristics include the shape, horns, fibroid tendrils and configuration of the external surface, and the structure of the capsule-wall, based on which following eight types of the capsules are classified (Table 5).

ii. In the so-called northern form, the capsule is characterized by having a long horn at each corner with a longitudinal respiratory fissure located midway near the tip of the horn, and having a rather simple structure of the capsule-wall (the tertiary egg-envelope) composed of two layers. The outer horny layer, however, assumes a highly specialized appearance, characteristic among different groups and species, having developed a definite form of armor on the surface that may serve a mechanical protection for the developing embryo in the low temperature of its environment.

iii. In the southern form, on the other hand, the capsule has a smooth surface

Table 5. Characters of the egg-capsules in Japanese rajid fishes classified into 8 types For abbreviated letters, see text.

Type	Horn, Group	Capsule-wall				Species and subspecies
		configuration of surface	tissue	Group Eg and its Subgroup		
1	H^{1}	smooth	2 layers	Eg^{1}	—	A
2	H^{2}	rather rough	2 layers	Eg^{2}	Eg^{2A}	I
					Eg^{2B}	H
3	H^{3}	rather rough	2 layers	Eg^{3}	—	J ; L
4	H^{3}	rough	2 layers	Eg^{4}	Eg^{4A}	B ; C ; E
					Eg^{4B}	G ; K
					Eg^{4C}	F
5	H^{4}	smooth	2 layers	Eg^{5}	—	Q ; Q′ ; R
6	H^{4}	smooth	3 layers	Eg^{6}	—	M ; N ; O; P ; S ; T ; V
7	H^{5}	rather rough	3 layers	Eg^{7}	—	U
8	H^{6}	rather smooth	3 layers	Eg^{7}	—	W

and short horns which are usually perforated at the tip, and the wall shows a great variation not only in the inner layer but also, in some cases, in the outer one. Some are formed of only two layers, as is also true of the northern form, but the majority are characterized by having three layers, a pulpy layer being inserted between the two. A remarkable example of this is provided by the two species of *Raja* which produce an egg-capsule (Figs. 22 and 86; U, W) with highly specialized in both histological structure and external form. From all this evidence it

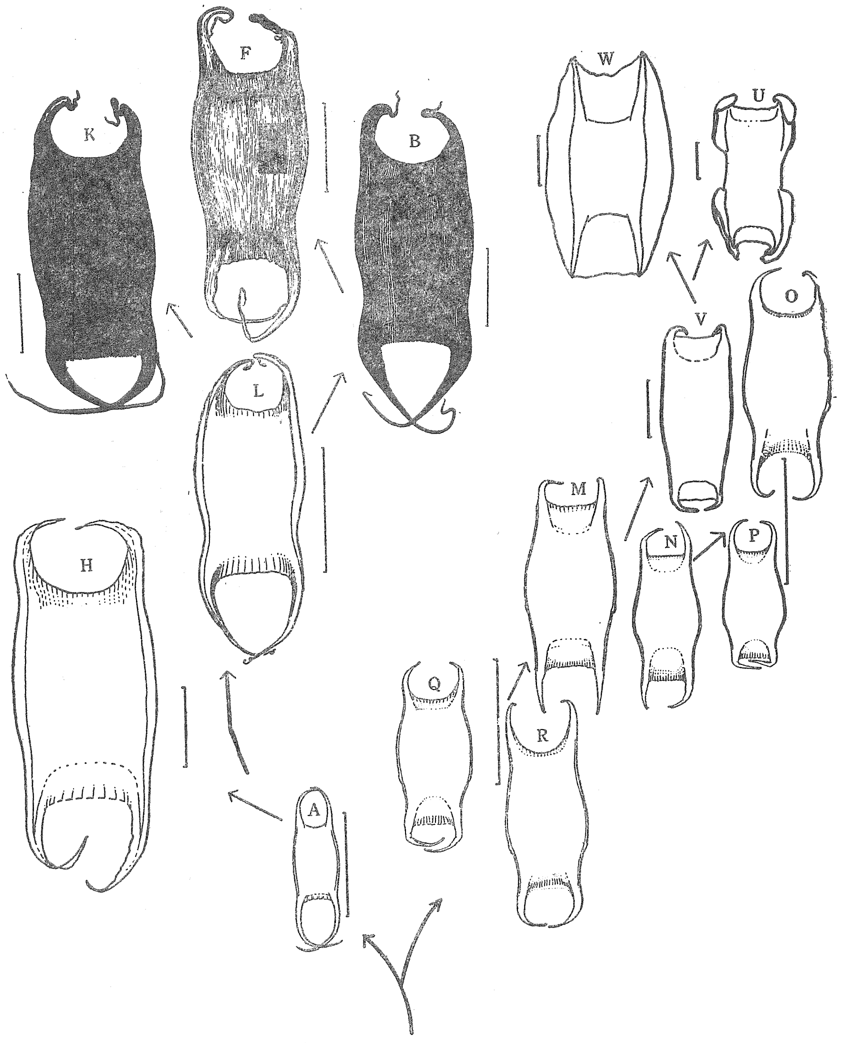

Fig. 22. Dorsal views of the egg-capsules, showing the probable phyletic relationships. As to the details of the surface configuration or of the structure of the capsule-wall, see Fig. given in each species. A, *Breviraja tobitukai;* B, *B. isotrachys;* F, *B. matsubarai;* H, *B. parmifera;* K, *B. Rhinoraja kujiensis;* L, *Rh. longicauda;* (northern form in the left series); M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* R, *R. fusca;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas;* (southern form in the right series). Scales attached represent 5 cm.

seems conclusive that the external form and histological structure of the capsule case are important either mechanically or physiologically, or both, for the development of embryo which develops under relatively high temperature.

iv. This concept, based chiefly on the geographical distribution and the manner of breeding of the adult in relation to the features of the egg-capsules, of different groups and species, suggests that the divergence in pattern of these features have been due to environmental adaptation, in conformity with the two functional roles of the capsule.

v. Should this hypothesis be justifiable, successive changes in the features of the egg-capsules of Japanese rajids may be classified into 8 types (Table 5).

vi. These phenomena, an interesting instance of promorphological adaptive differentiation, foreshadow the general characteristics of the future embryo.

vii. This trend in the manner of differentiation within the capsules (Figs. 22 and 23)

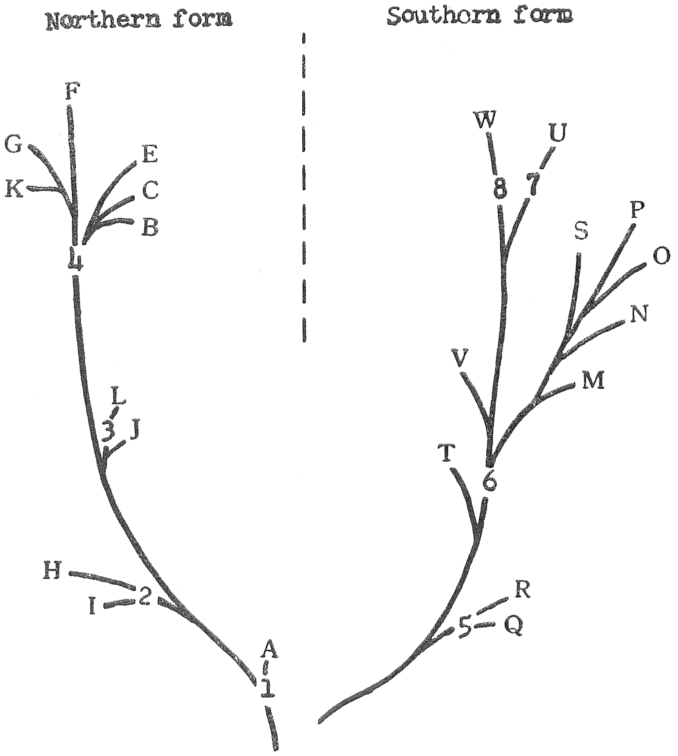

Fig. 23. Interrelationships of the egg-capsules of Japaneses rajids, supposed from both external and histological feature of the capsules, based on which 8 types were assorted. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* R, *R. fusca;* S, *R. schmidti* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda,* W, *R. gigas.*

is related in the main to the phylogeny deduced from the claspers of this group of fish. From this fact it may be emphasized that the character of the capsule bears a significance of fundamental phylogenetic importance, though in some cases extreme accomodation to the conditions of the environment precludes an exact parallel between the two trends. Further, these evidences may make clear the general idea that the organ concerned with the reproduction of the animal is usually quite for the systematic classification of the animal.

C. Bearing of the external features of organs related to reproduction on systematics of the Rajidae

Regarding the organs of the male and the female sexes which serve to distinguish the species easily, the so-called rock-and-key relationship which goes by the name of the mechanical isolation today is not so much evaluated in the present day as before (GOLDSCHMIDT, 1940; DOBZAHNSKY, 1941). But, it has been known in some groups of fishes and animals that the organ of the male of one species is distinguishable from that of other species when it has complex features in the copulatory organs (MAYR et al., 1942; UCHIDA, 1955), such as, the penis in the Muridae (TOKUDA, 1941) and in the xiphophorin fishes (GORDON and ROSEN, 1951), the petasma in the penaeid shrimps (KUBO, 1949), and many insects having such organs. Thus, HUBBS and TURNER (1938) laid stress on the conception; "it is quite in line with recent advance in the taxonomy of fishes, and of animals in general, to find again that the characters associated with reproduction provide the most reliable indication of relationship."

Evidently, the present author has recognized that the characteristics in the external male organ (clasper) of the Japanese rajids seem to give, as described above, the most reliable basis for the systematics of this group of fish, and stated some conceptions on the heading.

On the other hand, the writer has found several noteworthy facts in the external female organ (egg-capsule) of our rajids, and confirmed that the trend in the mannner of differentiation within the capsules is related in the main to the phylogeny deduced from the male organs of this group of fish. But, it must be noticed that an exact parallel between the two trends is precluded in some cases from extreme accomodation to the conditions of the environment where the egg was laid.

As the elasmobranchs bring about internal fertilization by means of the specialized copulatory organs which are thought to have direct relation in less degree to the physico-chemical condition of the environment, the external male organ seems to be more highly evaluated as a taxonomic character than such an organ of the female as the egg-capsule, which varies with different features due to adaptive differentiation as mentioned above, and also more than any of other external or internal organs of the fishes, except for internal character related to reproduction. However, we taxonomists would all desire in distinguishing species to find out the most reliable diagnostic character which has some feature easy of identification with but little variability, though it may be impossible to do so in any particular species in animals in general, since a good taxonomic character of a single species cannot be constant without the least variation. Therefore, there are two different extreme ways in making a taxonomic category for a given species, i. e. one is to use the most reliable diagnostic character, idealistic as it is so far if present, and the other is to deal with a number of characters with limited variability useful for separating species.

In the present study, the procedure similar to the former of the two stated above is attempted by the writer as he has confirmed that the external male organ seems to have the most reliable basis for the systematics of Japanese rajids when he has compared the characteristics in the organ with those in other external and internal parts of the body, important for the taxonomy of the elasmobranchs in most cases.

It is a matter of great interest that trend of the variation in the number of vertebrae in the groups of the fish agrees well with that deduced from the male organs (Fig. 21).

B. Characters other than those related to reproduction

a. Snout, its external and internal features

1. Description in general

The feature of snout has generally been used in taxonomy of various groups of elasmobranchs. In fact, the features of both external and internal parts of the snout in rajids have served for one of the marks worthy for diagnosis of some groups. But it has frequently been noticed that the variation in external feature of the snout is rather extensive even in a single species. Accordingly, various features of the snout, such as shape, flexibility, angle, degree of undulation on both sides and relative length of the snout have been examined so as to clarify the variability of this organ. Some features of these, however, are variable, especially with the growth of the body and between the sexes, in some cases. In the present study, therefore, a good many specimens of each species were examined in both external and internal characters of the snout. Then, the writer has obtained some compact knowledge of the features of the snout which may be worth in our finding a clew in taxonomy of the rajids dealt here.

2. Description and comparison of the snout

1). **External:**

(1). **Outline of the snout:-** In most of the rajid fishes, the snout is triangular in shape, which is so highly modified as to be adapted for the bottom life. The marginal sides of the snout are undulated in some degree. Degrees of undulation along the margin from the tip of the snout to the angle of pectoral fin have been believed to be very important by several authors. But the feature varies so much with the growth of the body, and with the sexes. Generally, the degree of undulation becomes greater with the growth of the fish, and it is greater in the male than in the female. Further, these tendencies are more pronounced in the southern form than in the nothern one.

The difference in the angle of the snout has also been considered by various authors as one of the important features, viz., GÜNTHER (1887), GILBERT (1896), EVERMANN and GOLDSBOROUGH (1907), SOLDATOV and PAVLENKO (1915), TANAKA (1916, '26), JORDAN and HUBBS (1925), SCHMIDT (1931), FANG and WANG (1932), HIYAMA (1940), FOWLER (1941) and BIGELOW and SCHROEDER (1948). This character, however, bears little use as to make it appreciable a clear distinction in any species as well as genera, due to not only obscurity in its measurement but also to no small variation with growth of the body and between the sexes. In short, the angle of the snout is greater in the young and in the female than in the adult and in the male. These differences are in close relation to differential growth of the length of the snout. Accordingly, the degree of the angle and the undulation in the margin of the snout may act as a specific character, but it is generally taken as an index of general external discrimination in some species.

The flexibility of the snout recognizable by external touch is one of the most attractive features in the snout, by which the two main stocks of our rajids can be separated (ISHIYAMA, 1952). This shall be discussed later on in combination with the internal character of the snout.

(2). **Proportion of the length of snout**:- The proportional measurement of the snout to various parts of the body, especially to the length of the head has usually served for taxonomic criterion of the fish. But, it should be noticed that this character usually tends to vary with age or sex even in the same species. As seen in Fig. 24 and Table 6, the proportional measurement of the snout to the length of the head in relation to the width of disc which is substituted for the standard dimension may show the following general tendencies; i) mode of ontogenic change in the relative length of the snout seems to differ to some extent between the northern and southern forms. To be more exact, the relative length changes in linear relation with the growth of the body in the northern form, but it is curvilinear in the southern form as in the case with the tail (cf. pp. 66 and Figs. 31 and 32); ii) sexual difference in

Table 6. Ratio of proportional measurement of snout measured in head-length in three stages of Japanese rajids. For abbreviations, see text.

Stage and ratio / Species	Juvenile		Adolescent				Adult			
			male		female		male		female	
	range	aver-age	range	aver-age	range	aver-age	range	aver-age	range	aver-age
A	—	—	2.09—2.20	2.12	2.10—2.26	2.17	2.03—2.18	2.13	2.12—2.24	2.17
B	1.95—2.32	2.11	1.92—2.04	1.95	1.88—1.99	1.94	1.94—2.06	1.96	1.90—2.03	1.94
C	1.73—2.25	2.02	1.99—2.12	2.07	1.84—1.94	1.87	2.00—2.25	2.09	1.83—2.03	1.91
D	—	—	—	—	—	—	2.19—2.26	2.22	1.94—2.03	1.99
E	2.00—2.09	2.03	1.92—2.25	2.05	1.89—2.04	1.97	1.92—2.32	2.15	1.92—2.06	2.00
F	2.08—2.35	2.27	2.50—2.60	2.55	2.48—2.25	2.51	2.50—2.63	2.56	2.44—2.52	2.48
G	1.81—1.86	1.83	1.92—1.97	1.94	1.83—1.86	1.85	1.92—2.05	1.98	1.64—1.90	1.74
H	—	—	—	—	—	—	2.06	—	—	—
I	1.96—2.04	2.00	—	—	1.94—2.04	1.99	2.10—2.33	2.19	1.87—2.10	1.98
I′	1.96—2.08	2.01	1.87—2.07	1.90	1.90—2.01	1.97	2.08—2.30	2.19	1.91—2.30	2.05
J	—	—	2.23—2.31	2.28	2.10—2.31	2.16	2.39—2.61	2.48	2.15—2.20	2.18
K	2.23—2.50	2.32	2.03—2.58	2.22	2.08—2.37	2.22	2.26—2.30	2.28	2.11—2.45	2.26
L	2.52	—	1.89—2.48	2.30	2.27—2.39	2.29	2.33—2.68	2.46	2.24—2.38	2.31
M	1.86—2.70	1.92	1.94—2.20	2.08	1.74—2.04	1.95	2.11—2.35	2.23	2.00—2.09	2.03
N	1.82—1.95	1.89	1.84—2.00	1.92	1.76—1.97	1.86	2.06—2.27	2.12	1.74—2.06	1.93
O	1.81—1.90	1.98	1.84—2.00	1.93	1.82—1.94	1.87	1.88—2.13	2.02	1.80—1.94	1.89
P	1.90—2.00	1.96	1.89—2.12	1.99	1.87—2.11	1.97	2.05—2.65	2.17	1.84—2.14	1.99
Q	1.80—1.92	1.86	1.94—2.09	2.00	1.82—2.18	2.06	2.02—2.40	2.15	1.85—2.17	1.95
Q′	1.69—2.16	1.82	1.81	—	1.80—2.00	1.88	2.11—2.16	2.13	1.58—2.00	1.88
R	1.89—2.07	1.96	1.95—2.16	2.07	1.84—2.15	2.00	2.12—2.43	2.22	2.02—2.14	2.16
S	2.04—2.06	2.05	2.11—2.21	2.16	2.07—2.18	2.12	2.29—2.49	2.42	2.17—2.62	2.42
T	1.69—1.80	1.74	1.62—1.76	1.68	1.55—1.71	1.62	1.75	—	1.59—1.68	1.63
U	1.95—2.23	2.14	1.73—1.93	1.81	1.66—1.88	1.77	1.80—1.94	1.95	1.69—1.75	1.72
V	1.72—2.04	1.81	1.67—1.78	1.71	1.62—1.73	1.66	1.77—1.84	1.79	1.62—1.64	1.62
W	1.61—1.70	1.63	—	—	1.65—1.66	1.65	1.81—1.84	1.82	1.60—1.83	1.68

the relative length is rather obscure or negligible in the northern members, though apparent in the southern ones; and iii) in most cases, the snout is shorter (the ratio is greater) in the adult male than in the adult female in the southern form, and the similar tendencies are seen in the proportional length of tail.

The proportional length of the snout and its ontogenic trend seem to have no more than a specific importance to each species in the northern form, considering that the snout has a very complex structure. On the other hand, the trend in the southern form may represent not only specific feature but also generalogical significance owing to rather common structure in the snout, as is described later on.

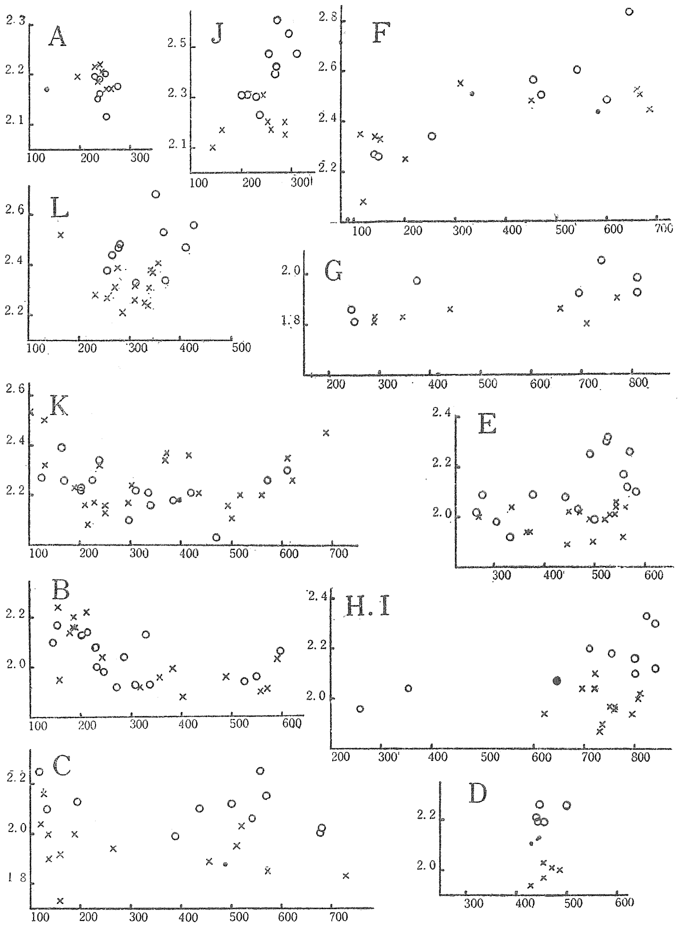

Fig. 24. Ratio of snout in length against head in relation to disc-width (in mm) in the northern form. Ratio, ordinate; disc-width, abscissa; circle, male; cross, female. Black spot represents the ratio in species H (*Breviraja parmifera*). A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.*

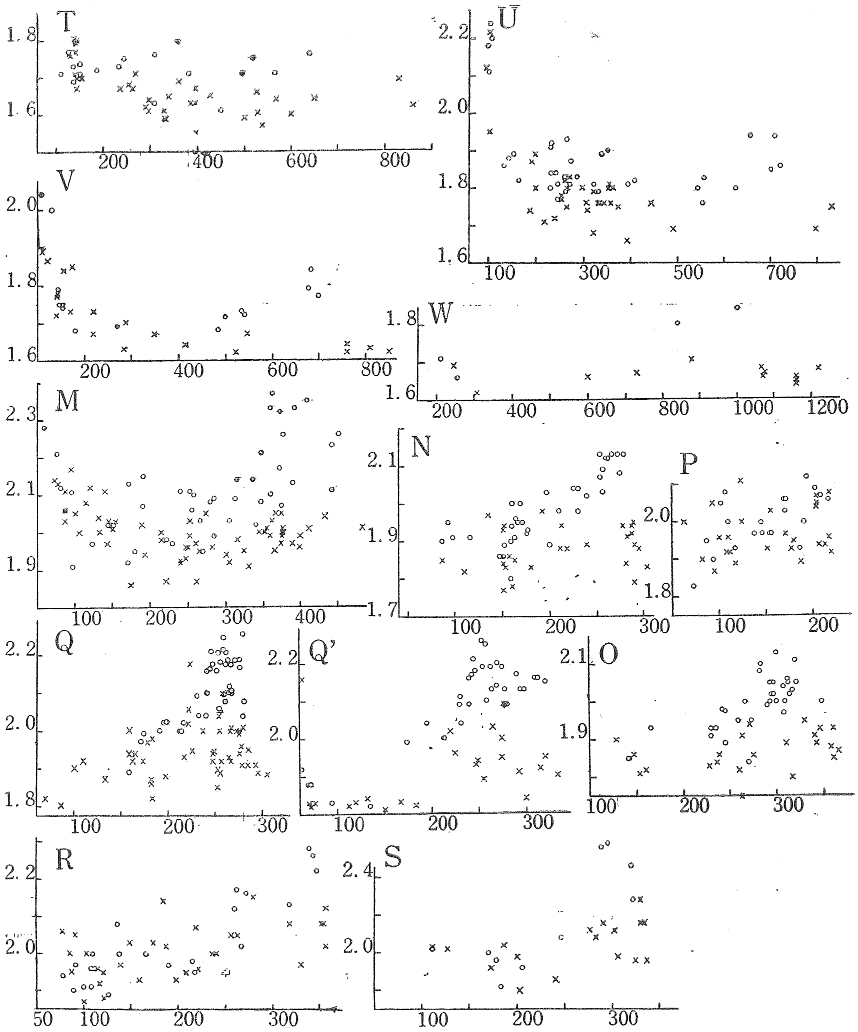

Fig. 25. Ratio of snout in length against head in relation to disc-width (in mm) in the southern form. Ratio, ordinate; disc-width, abscissa; circle, male; cross, female. M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* Q', *R. porosa tobae;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

2). Internal:

Although anatomical characters of the snout have proved to be fundamentally important for our settling taxonomic criteria above the rank of genera of the Rajidae, the differences in principal features are important for distinguishing some related forms referred to the same genus. By principal features are meant the rostral cartilage and its appendices, the degree of forward extension of the pectoral fins on both sides and the shape of anterior fontanelle of the cranium.

(1). **Rostral cartilage and its appendices**:- In the Rajidae, the snout is generally supported internally by a cartilage with some degree of development that originally arises with forward prolongation of the skull. With regard to the feature of the cartilage in rajid fishes a number of noteworthy works have already been done by several authors. The present writer has recently classified the Japanese rajids into three genera according to the characters of the rostral cartilage, agreeing with a view made by BIGELOW and SCHROEDER (1948). Namely, the so-called northern form which involves two genera is characterized by having a delicate rostral cartilage extending to the tip of the snout. The two genera are separated by the presence or absence of a basal segment developed at the base of the cartilage. In the southern form, on the contrary, the rostral cartilage is developed in a stout, rod-like projection caused by heavy calcification recognizable by external touch. Taking the feature of the cartilage into consideration, the Japanese rajids can be clearly assorted into three types, which are called herein Type S^A, S^B and S^C (Fig. 26), respectively, following the critiques mentioned above, viz.: Type S^A, which is referable to the species of the genus *Raja*, is characterized by having a stout, rod-like median bar without a basal segment (W in Fig. 26). Type S^B exemplified by species referred to the genus *Breviraja* is marked by a delicate rostral cartilage without a basal segment (B in Fig. 26).

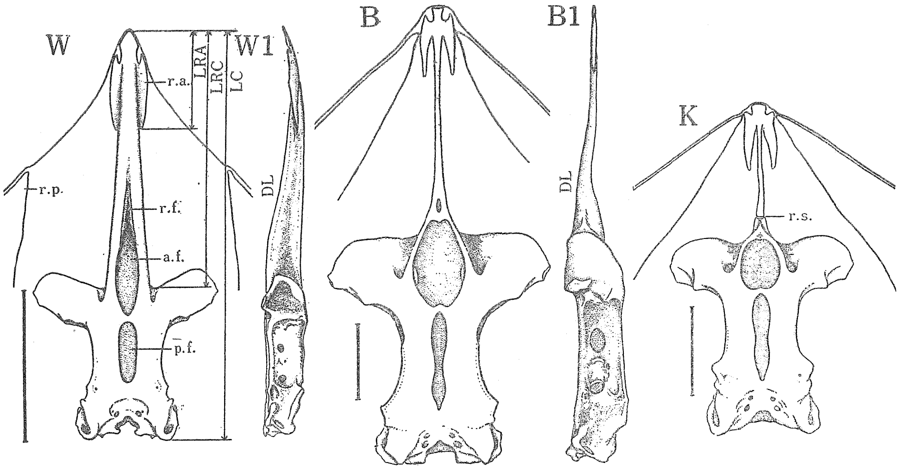

Fig. 26. Showing three types of the rostral cartilages of Japanese rajids, with the terminology and method of measurement. B. K and W, dorsal view; B_1 and W_1, side view; especially notifying the differences in degree of development of the rostral cartilage with or without the rostral segment and in shape of the rostral appendices. a. f. anterior fontanelle; DL, dorsal side; LC, length of cranium; LRC, length of rostral cartilage; LRA; length of rostral appendix; p. f., posterior fontanelle; r. a., rostral appendix; r. f. rostral fossa; r. p., radial cartilages of pectoral fin; r. s., rostral segment. B and B_1, *Breviraja isotrachys;* K, *Rhinoraja kujiensis;* W *and* W_1, *Raja gigas.* Scales represent 3 cm.

Type S^C is modeled after the characteristics of the cartilage observed in species of the genus *Rhinoraja*, whose rostral cartilage is developed with a basal segment at the base of the delicate cartilage (r. s. in Fig. 26 K).

At the distal part of the rostral cartilage a rostral appendix is attached on each side. Anterior tip of the rostral cartilage is inserted from a notch between the appendices. Feature of posterior portion of the appendix in relation to the rostral axis is very different between the northern and the southern forms. Namely, posterior end of the appendix fuses to or closely contacts with the side of the anterior part of rostral cartilage in the southern members without exception, but it is free in the northern ones (ISHIYAMA, 1952). In either case, however, degree of development of the appendix sometimes differs so much in species specifically that it may act to serve as specific demarcation, or as linealogical consideration in some cases. In addition to this, the shape and relative length of the rostral cartilage in relation to width or length of the cranium are more or less important for the taxonomy of this group.

(2). **Degree of forward extension of the pectoral fins:-** One of the great structural differences which exists between the two major forms of Japanese rajids is the degree of forward extention of the pectoral fins. Of this matter, however, a fairly good description was given dy BIGELOW and SCHROEDER (1948), followed by the present writer (1952), so that a brief note with biological significance shall be given in the present study.

In the southern form, the radial cartilages of the pectoral fins fall far from the tip of the snout, leaving a large semicartilaginous portion on both sides of the rostral appendices (Fig. 27). On the other hand, in the northern form the radial cartilages are very close near the rostral appendices without noticeable space (Fig. 28).

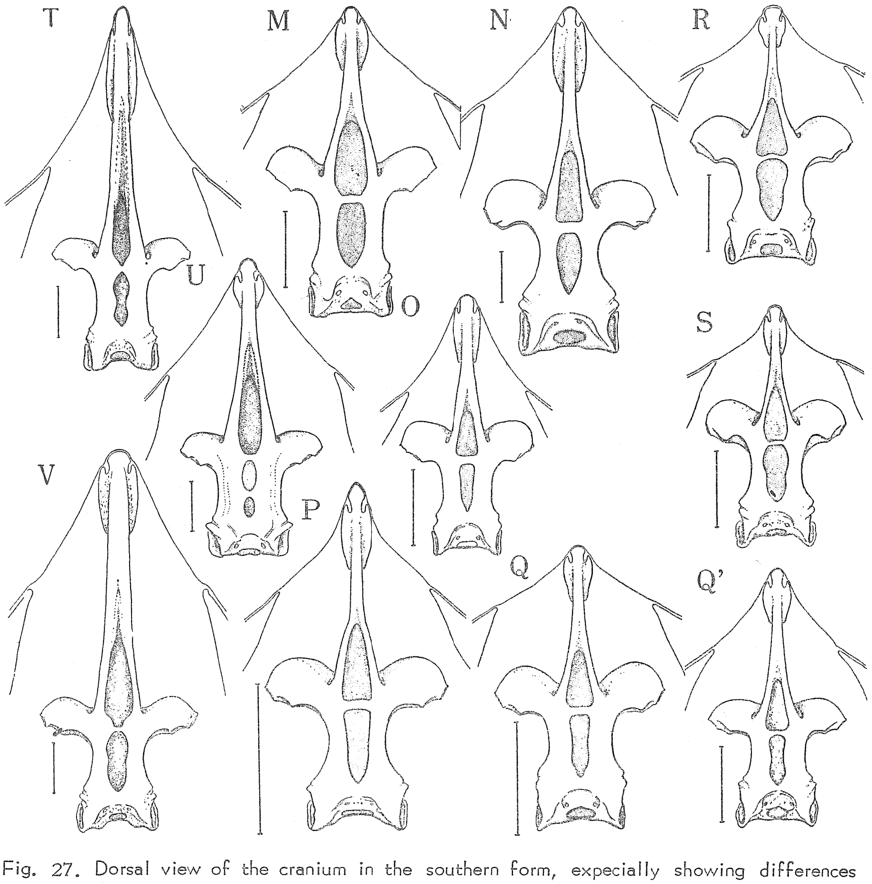

Fig. 27. Dorsal view of the cranium in the southern form, expecially showing differences in relative length of the rostral cartilage and the shape of the anterior and posterior fontanelle. M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* Q', *R. porosa tobae;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda.* Scales represent 3 cm.

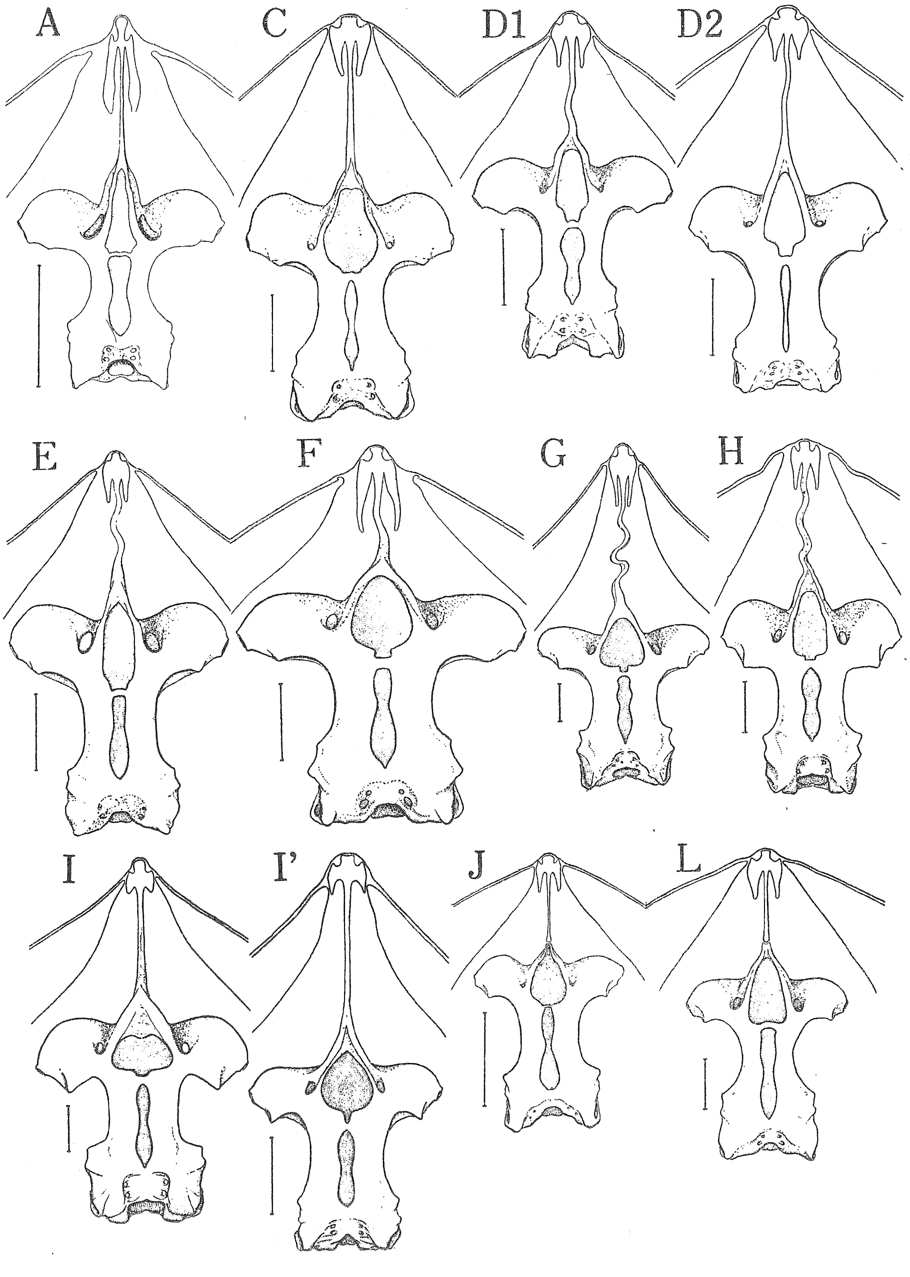

Fig. 28. Dorsal view of the cranium in the northern members, especially showing differences in the degree of development of the rostral appendix and presence or absence of the rostral segment developed at the basal portion of more or less elongated rostral cartilage, and in undulation of the cartilage and shape of the fontanelle, and also in remarkable forward extension of pectoral fines. A, *Breviraja tobitukai;* C, *B. trachouros;* D_1, D_2, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi,* I′, *B. smirnovi ankasube;* J, *Rhinoraja odai;* L, *Rh. longicauda.* Scales represent 3 cm.

Remarks:- A peculiar undulation of the rostral cartilage was observed in some species of the northern form when these preserved specimens or fresh ones were thoroughly dissected. This fact, however, is found to exist to some extent in all the members of this form, but it is characteristically revealed in species **G** (**G** in Fig. 28), whose rostral cartilage is very long and tapers. The phenomenon is thought to be unique in the northern members, especially so distinct in species referred to the genus *Breviraja*, and no such case could be seen in the southern members, (Fig. 27) as well as in a specimen involved in the northern form preserved in the formalin solution after the fresh specimen was dissected out (cf. Fig. 28 **C**, **I**, **I′**). Thus taking this fact into consideration, the phenomenon is forced upon the writer to take the following speculation as to this interesting feature in the rostral cartilage.

In most part of the pectoral fins of rajids, gentle undulatory vibrations of the margins may take place so as to give the fish the wave motions, by which pushing effort against water may be made. That is known as the pectoral type of locomotion (UCHIDA, 1930, pp. 9—10, Fig. 4). The wave motion, therefore, may be given in the greater part of the snout in the northern form so that the radial cartilages extend to distal part of the snout. On the contrary, the motion may be restricted only to the portion rearward the anterior tip of the radial cartilage that fall far from the distal tip of the snout in the southern one.

Then, it may be worthwhile to meet with a reasonable speculation as to the fact in question that synchronous vibratory function possible bending and rebending motions in the greater part of the snout of the northern form may have a possibility of shortening or lengthening to greater or less extent affecting combined effort from the two sides in the snout. If such a hypothesis be justifiable, the wave motion on both sides of the snout may dynamically oppose between the two major forms, and further, a segment developed on the basal part of the rostral cartilage of species belonging to the genus *Rhinoraja* may have been specialized from that of genus *Breviraja* so as to facilitate such mobility in the snout. If this view is really true, we may conceive that rather extensive individual variation in the length of the snout of the northern form may be caused by such elastic structure in the snout as mentioned above. And, it may also be considered that the strong undulation of the rostral cartilage is caused by elongated snout as is found in species **G** (**G** in Fig. 28).

b. Discussion

1. Analysis of genera and species of the Japanese rajids

The following key of genera and species of our rajids has been prepared in aid of clear separation of the fish by using such characters of the snout as: i) flexibility; ii) relative length measured in external; iii) features of the rostral cartilage and its appendices as well as their relative lengths; iv) degree of forward extention of the radial cartilages of the pectoral fins; and v) location and shape of both anterior and posterior fontanelle of the cranium.

1a. Snout usually blunt, but elongated and flexible in touch, and can easily be bent vertically in its most parts. Rostral cartilage very weak, slender rod or tape-like projection, reaching extremity of the snout, where the rostral appendix broadly developed with delicate cartilage on both sides (Type $S^{B,C}$); posterior ends of the appendix apparently free from the lateral sides of rostral bar. Anterior tips of radial cartilages of the pectoral fins very close to, or nearly contacted with, lateral edge of the appendix. Anterior fontanelle usually polygonal or curious in shape, excavating anteriorly covered with a cartilage without shallow depression.

2a. Rostral cartilage without segment .... *Breviraja*

3a. Rostral cartilage about as long as or longer than skull; rostral appendix very long or moderately long, or even very small.

4a. Snout shorter than, or almost equal to, half the length of head. Rostral cartilage developed in slender, more or less undulated bar, almost as long as skull.

5a. Rostral cartilage much slender, bearing a pair of long, delicate rostral appendices or wings, which extend to half way to base of the rostral bar. Anterior fontanelle elongate into long furrow .... *B. tobitukai* (Fig. 28 A)

5b. Rostral cartilage moderately thickened, bearing a pair of relatively small rostral wings, which are shorter than one-third of the length of rostral cartilage.

6a. Anterior tip of snout commonly blunt. Rostral cartilage developed in rod-like projection.

7a. Rostral appendix longer than one-fourth the length of rostral cartilage. Anterior fontanelle usually ellipsoid or pear-like in shape .... *B. isotrachys* (Fig. 26 B); *B. trachouros* (Fig. 28 C); *B. abasiriensis* (Fig. 28 D)

7b. Rostral appendix shorter than one-fourth the length of rostral cartilage. Anterior fontanelle usually broad .... *B. smirnovi smirnovi* (Fig. 28 I); *B. smirnovi ankasube* (Fig. 28 I′)

6b. Anterior tip of snout broadly blunt. Rostral cartilage rather flat .... *B. parmifera* (Fig. 28 H)

4b. Snout always longer than half the length of head. Rostral cartilage developed in a long, tapered and exceedingly undulated bar, much longer than skull .... *B. aleutica* (Fig. 28 G)

3b. Rostral cartilage much shorter than skull; rostral appendix long, longer than half the length of rostral cartilage .... *B. matsubarai* (Fig. 28 F)

2b. Rostral cartilage with a segment at the basal portion .... *Rhinoraja*

8a. Rostral cartilage rather thickened, bearing large rostral wings, which are half as long as rostral cartilage .... *Rh. kujiensis* (Fig. 26 K)

8b. Rostral cartilage very slender, bearing small wings, which are shorter than half the length of rostral cartilage .... *Rh. odai* (Fig. 28 J); *Rh. longicauda* (Fig. 28 L)

1b. Snout usually pointed anteriorly and apparently axiled in touch, and scarcely bent at the base. Rostral cartilage stout with heavy calcified rod, reaching extremity of the snout; distal portion of the cartilage bears a rostral appendix on both sides (Type S^{A}); posterior end of appendix fused to, or closely contacted with, the lateral side of the rostral cartilage. Anterior tips of radial cartilages of pectoral fins falling far from the tip of snout, leaving large semicartilaginous portion in front of the skull. Anterior fontanelle usually long, pointed anteriorly, elongated into shallow depression .... *Raja*

9a. Snout much longer than half the length of head in stage above 100 mm of disc-width. Rostral cartilage stout and long, much longer than cranium.

10a. Rostral appendix in adult equal to, or longer than, one-third the length of cranium. Posterior fontanelle not divided into two holes.

11a. Rostral appendix in adult about half as long as rostral cartilage, the furrow of the latter elongated anteriorly, reaching beyond posterior end of the appendix .... *R. tengu* (Fig. 27 T)

11b. Rostral appendix in adult shorter than half the length of rostral cartilage, the long furrow of the latter long, but not reaching posterior end of the appendix .... *R. macrocauda* (Fig. 27 V); *R. gigas* (Fig. 27 W)

10a. Rostral appendix in adult much shorter than one-third the length of cranium. Posterior fontanelle divided into two holes.................................. .... *R. pulchra* (Fig. 27 U)

9b. Snout short or moderate in length, shorter than, or subequal to, half the length of head in stage above 100 mm of disc-width. Rostral cartilage somewhat longer, or shorter than the cranium.

12a. Rostral cartilage a little longer than or equal to length of cranium... .... *R. kenojei* (Fig. 27 M); *R. acutispina* (Fig. 27 N); *R. hollandi* (Fig. 27 O); *R. macrophthalma* (Fig. 27 P); *R. porosa meerdervoorti* (Fig. 27 Q); *R. porosa tobae* (Fig. 27 Q′)

12b. Rostral cartilage shorter than the cranium...................................... .... *R. fusca* (Fig. 27 R); *R. schmidti* (Fig. 27 S)

2. Consideration of the differentiation of the snout

One of the most important things in the systematics of rajids is found in both external and internal features of the snout. The evidences noticed by the present writer has led him to the following hypotheses in regard to the differentiation of the snout, which may have evolved in the two lines. i) specialization shown by gradual changes in the length of snout without noticeable structural differentiation, which may be revealed in the southern form; and ii) specialization shown by structural modification of the snout, which is revealed in the northern form. These hypotheses were developed based on the following facts.

1). **Length of the snout largely correlated with the depth of habitat:-** The depth of habitat observed in the species belonging to the genus *Raja* ranges from exceedingly shallow coastal waters down to about 200 fathoms. For example, the species which have a relatively shorter snout, such as species R and S (Fig. 25 R, S), usually inhabits the coastal waters, the adjacent regions at a depth of about 20 to 50 fathoms, or shallower waters. On the contrary, the species having longer snout such as T, V and W (Fig. 25) are generally found at a depth of about 100 fathoms or in the deeper regions. Further, the examples having moderate length of the snout such as M, N, O, P, etc. (Fig. 25) were fonnd to occur in the intermediate zone between the two extremes mentioned above.

Judging from these facts, the transformation in the relative length of snout of the southern form may presumably have occurred in close relation with depths of their habitats, though there may exist rather large geographical and also seasonal variations of the depths even in the same species. But it is interesting to note here that the similar tendency has been known to occur in the European rajids (CLARK, 1922).

If the above supposition on the specialization of the snout in the southern form is justifiable, there are two possible lines in assuming the course of transformation in the organ, i. e. whether the snout with greater length is thought to be more primitive or advanced form. More exactly, whether the species T which has a longer snout is more primitive than the species S which has a shorter one, or the reverse is the case. In consideration of these two cases, the present writer has inferred the following two evidences:

(a). In comparison of the features of rostral cartilage between two rajids, T and S, and a guitarfish, *Rhinobatos schlegeli*, there are found some noteworthy facts, viz., the anterior fontanelle of the guitarfish is a long and deep furrow lying from

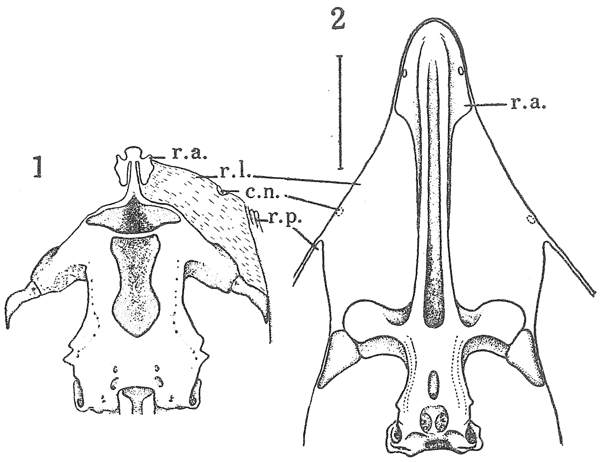

Fig. 29. Dorsal aspects of the crania of the two representatives; 1, *Raja clavata*, 90 mm in total length of a embryo, after HOLMGREN (1940, Fig. 147); 2, *Rhinobatatos schlegeli*, with scale of 3 cm. c. n., cartilage nodule; r.p., cartilages of pectoral fin; r. a., rostral appendix; r. l., rostral ligament.

the base to the distal tip of the long and stout rostral cartilage (2 in Fig. 29), which resembles more that of the species T than that of species R or S (Fig. 27). Further, the rostral appendix of the guitarfish is very broad and thin anteriorly, originating posteriorly near the midway point of the rostral cartilage, which seems to be a reminiscence of the appendix found in the species like T.

(b). It will be seen in Fig. 25 that in the southern form relative length of the snout is nearly the same in the young stages of various species whatever it shows remarkabele difference in their adult stages (cf. Fig. 25).

The key to these two cases mentioned is a realization that the reduced snout of the adult is a neotenous condition*) of the elongated snout, i. e. the snout is masked in adult species T by subsequent lengthening, and is retained in adult M with moderate length, and is less produced in that of species S with much shorter snout, as has stated by de Beer (1951) according to Nichols and Breder (1928) for the evolution of flying fishes.

If this hypothesis is really true, the longer snout a species has, the more primitive condition it is in. In this case, therefore, species S may be in a more advanced condition than T, so far as their features of the snout in the southern form are concerned. It may be said that the snout may have been diversified into two directions in accordance with the depth of the habitat, viz., ones with relatively short snout are found in the fishes inhabiting either the deep seas or rather shallow waters, such as species V, W and U, and the other's which retain still shorter snout are represented by the fishes inhabiting the waters of shallower or coastal regions, as is observed in species M, N, R and S (cf. Table 1).

Thus, we can infer on the transformation of the snout in the southern form, basing the characteristics in both external and internal parts of the organ, that the differentiation of the snout may have taken place from the elongated snout to the shorter one, making an evolutional step upward with the changes of their habitats from moderate depth of the sea to either deep sea or shallow regions.

2). **Structural modification revealed in relation to change of the utility of snout:-** In the northern form, however, the rostrum has such complex structure that it is difficult for us to suppose their linealogical trends on the basis of the above mentioned hypothesis, but another hypothesis is needed for explanation. In this case, the flexible snout is surmised to have excellent advantage of seeking and blanketing food, such as

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* Neoteny meaning the case where the adult retains larval character, or the case where the adult descendant resembles the young stage of the ancestor (de BEER, 1951, p. 68).

fishes, crustaceans, etc. This specialization in the snout may have been caused by the forward expansion of the pectoral fins in the rostral region, undergoing retrogressive differentiation of the rostral cartilage. It is worth mentioning that a comparison of the rostral cartilage of Type S^B (Fig. 26 B) with that of a embryo of *Raja clavata* described by HOLMGREN (1941) shows us the homologous feature though these are referable to different genus. In other words, the feature of rostral cartilage of the species referred to the genus *Breviraja* may be in a neotenous condition in species of the genus *Raja*, the cartilage of which much resembles that of the guitarfish (2 in Fig. 29.) We may well believe that the rostral cartilage with Type S^B may be destined to the stoppage of succesive development of the old character which Type S^A accords, so as to make remarkable change in the rostrum with great influence of forward expansion of the pectoral fins. The present writer has developed the two following hypotheses partaining to the differentiation of the snout in the northern form:

(a). We may reasonably suggest that the species of poorly developed rostral cartilage with small appendix may be in a more advanced condition than that of rather strong cartilage with remarkable appendix. If this is really the case, species **H** and **I** (**I′**) may be regarded as more specialized than **A** and **F**, so far as the feature of rostral cartilage is concerned (cf. Fig. 28). The hypothesis seems also to hold true in the species referred to the genus Rhinoraja, i.e. species **J** of much more delicate rostral cartilage with less developed rostral appendix (**J** in Fig. 28) is thought to be in a more specialized condition than species K (K in Fig. 26).

(b). We may safely surmise that the anterior fontanelle is originally developed on the anterior portion of the chondrocranium, as seen in the guitarfish. But, as a rule, the shape and location are much varied in the Rajidae, especially in the northern members. As the similar features of the fontanelle occur rather consistently in closely related species and do not occur in widely separated ones, the features relating to the development of this organ may be used as linealogical consideration. Is it not possible to consider that the longer and the more anteriorly the fontanelle is, the more primitive condition it is? If this view is accepted, the fontanelle of the species **H** and **I** (**I′**) may reasonably be considered to be more specialized than those of **A** and **E** (cf. Fig. 28), although the condition of the organ is more or less variable not only in related species, but also in the sexes of a single species.

Granting the foregoing conception to be justifiable, however, it may be a far-fetched interpretation to suppose that further linealogical trends may exist in the snout of the northern form, especially in the genus *Breviraja* with much more diversification in the structure.

The degree of undulation, or serpentine feature of the rostral axis annotated elsewhere may be congruous with the mobility of the snout in some degrees, which seems to occur in parallel with the flatness of the cartilage. Such being the case, this character may be useful for a specific or superspecific demonstration in some species, but not for phyletic pedigree.

Summarizing the above, the characters thought to be important for phyletic evaluation in the snout of the Japanese rajids thus far examined are; i) relative length of the snout; ii) features of the rostral cartilage and its appendices; iii) presence or absence of the rostral segment; iv) degree of forward expansion of the radial cartilages of the pectoral fins; and v) shape and location of the anterior fontanelle. Of these features, ii), iii) and iv) may be valid for the generic relation, but i) seems important only for the subgeneric relation of the southern form, and v) may be very important for the consideration of interspecific relationships in the northern form.

Thus the characteristic features distinguished as specialization or degeneration are well seen in both external and internal parts of the snout. Such relations as specialization and reduction in characteristics of the snout and of the tail are apparently recognized as antagonical ones, as has been stated by the present writer (1952, '55). Namely, as in case of the southern form, when the specialization occurs only with modification by reduction of the snout from their ancestral form, the extreme specialization of the tail is recognized as will be explained later on (p. 66). On the contrary, the significant specialization in the snout which may be correlated with less specialization of the tail is revealed in the northern form. Further, such relations thus antagonizing each other between the specialization of the snout and of the tail may generally be confirmed in the sexes of the southern form, which provides sexual difference to some extent. To be more exactly, the relative length of the snout is usually greater in the female than in the male, while the tail is in most cases relatively shorter in the female than in the male (cf. Figs. 25, 31 and 32). Conclusively, the snout and the tail may have been evolved in counter relation each other in Japanese rajid fishes.

Finally, it should be noticed that the trend of the differentiation in the features of snout of Japanese rajids thus mentioned above seems to be in parallel with that supposed from the male organ, as a whole. But, the characteristic features even in both external and internal of the snout are not always evaluated as a specific constant of each species because the organ show much similar features in closely related forms, in some case.

b. Tail, its external features with special reference to the electric organ

1. Description and comparison of the tail and its electric organ

1). **External features of the tail:-** In taxonomy of batoid fishes, external features of the tail have generally been used for distinguishing each group of the fishes. In general feature, the tail of rajid fishes has been thought to be rather intermediate between those of the guitarfish and the sting ray.

In the present item, the shape, the length of tail relative to standard dimension (width of disc), the degree of development of the dermal folds on both sides, and the reduction of the distal portion are especially taken into consideration. In detail, the tail of rajid bears either depressed or rolled elongation in external appearance. Individual variations as well as sexual differences in relative length of the tail are more or less salient. The degree of development of the fleshy dermal folds on sides of the tail is closely related to that of the electric organ, except for one species (species A), but the reduction in length of the distal portion of the tail is of specially interesting phenomenon in the young stage throughout all the species dealt with here.

These external features should be considered to be in close connection with internal ones, but here, as for the sake of convenience for description, some points of greater importance in externals have been alluded to as well.

(1). **Outline of the tail:-** Though it may be stated that the tail of the rajid seems originally to be for locomotion, the organ remains at a stage of development insufficient for propelling the body, and is in the state of reduction to some extent. When the tail is cut off at the insertion of the first dorsal fin, the outline in cross view shows two rather defined features, and is called herein respectively round- and depressed-type.

Round-type (A in Fig. 30): In this probably primitive form, the tail is largely cylindrical and rod-like in shape, with round upper border and flattened under surface. Fishes with this form of the tail accompanied by general elongation are characteristically referred to the northern members with exceptions of three examples, such as **H**, **I** and **I′** (Fig. 35 **H**, **I**).

Depressed-type (**U** in Fig. 30): Still more advanced form is found in the depressed-type of the tail, in which the tail is much lower than wide, in most cases. Fishes with this form of the tail remarkably reduced in length are represented by the southern form and three examples of the northern one aforementioned, and this makes us infer that the form of the tail may be more conventional for the bottom living than that of the preceding.

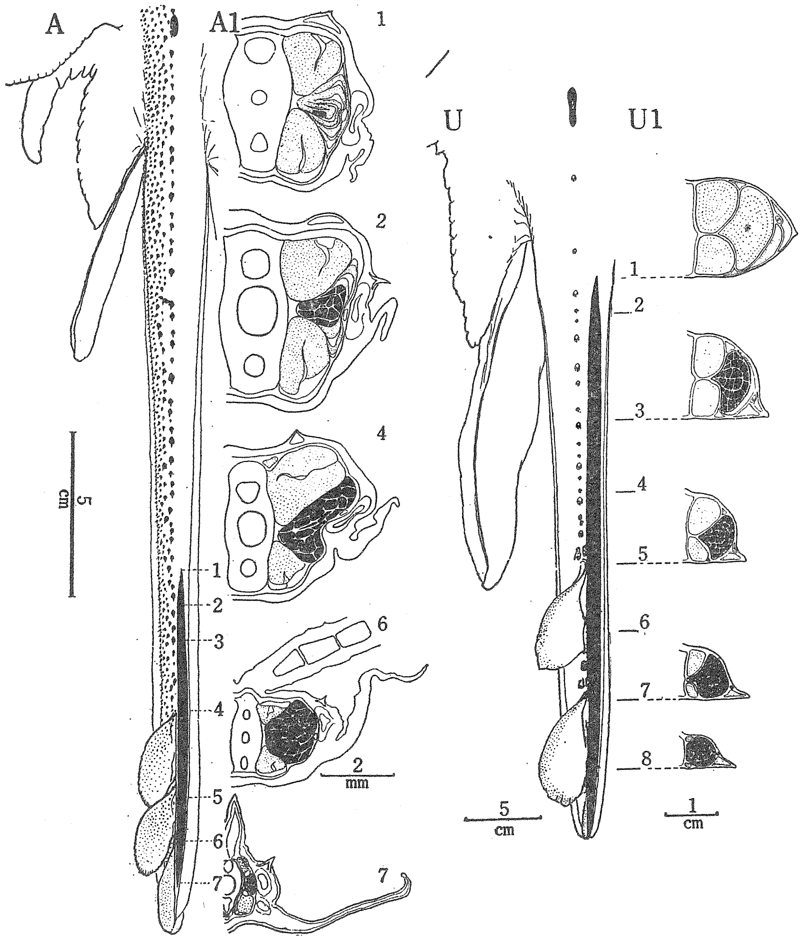

Fig. 30. Showing the two representatives in the outline of tail and in the manner of location of the electric organ exposed by dissection, or shown by cross section at several portions where the organ lies. Black spindle in A (*Breviraja tobitukai*) and U (*Raja pulchra*) represents dorsal aspect of the electric organ when exposed from the surrounding tissue; cross view in the two forms is arranged in the two series (A_1 and U_1), ranging vertically 1, 2 .... 7 or 8, which correspond to those numbers assigned in A and U.

At any rate, though there appears to be two types of the tail mentioned above in its external view, the anterior portion in both types of the tail is similarly thickened as is the case with that of the shark. From this fact it may be said that the diverge in the form of the tail has occurred from anterior portion to rearward.

Tails can be divided in two types, so far as external features are concerned, but this distinction is a conventional way of dividing tails at a glance, because between the two extremes there are some forms intervening, making it almost impossible for us in strict sense to draw a border line between the two types mentioned above.

(2). **Length of the tail:-** In the RAJIDAE, as in some other features, the length of the tail is defined in two diversed groups. In one group the tail is long irrespective of sex, which is characteristic of the northern form, whose proportional ratio of the tail in the adult against the width of disc is from 0.8 up to 1.2, with some exception, such as three examples **H, I** and **I′**, where the ratios are from about 1.5 up to 1.7. In the other group is reduced in length, which is characteristic of the southern form, its ratio being from about 1.0 up to 2.0. Furthermore, in the southern form, the tail undergoes sexual difference to some extent in its length, being usually longer in male than in female if compared with the same-sized fish of the species. Although the relative length of tail in the rajids may be attributed to a high degree to classification

Table 7. Ratio of proportional measurement of tail measured in disc-width in three stages of Japanese rajids. For abbreviations, see text.

Stage and ratio / Species	Juvenile		Adolescent				Adult			
			male		female		male		female	
	range	average	range	average	range	average	range	average	range	average
A	—	—	0.48—0.89	0.87	0.48—0.90	0.87	0.87—0.92	0.89	0.81—0.89	0.84
B	0.99—1.18	1.09	1.17—1.25	1.20	1.11—1.23	1.17	1.23—1.28	1.25	1.22—1.25	1.23
C	0.94—1.24	1.04	1.08—1.18	1.12	1.05—1.09	1.07	1.15—1.25	1.21	1.13—1.38	1.21
D	—	—	—	—	—	—	1.12—1.61	1.28	1.16—1.32	1.24
E	1.04—1.17	1.10	1.12—1.26	1.18	1.13—1.28	1.19	1.21—1.28	1.24	1.18—1.33	1.25
F	0.91—1.13	0.98	1.04—1.16	1.08	1.07—1.08	1.07	1.09—1.16	1.14	1.10—1.12	1.11
G	1.07—1.13	1.09	1.04—1.22	1.13	1.05—1.18	1.11	1.19—1.29	1.23	1.20—1.37	1.26
H	—	—	—	—	—	—	1.41	—	—	—
I	1.50—1.69	1.53	—	—	1.63—1.67	1.65	1.50—1.75	1.56	1.47—1.69	1.59
I′	1.37—1.73	1.50	1.56—1.75	1.63	1.55—1.66	1.62	1.66—1.78	1.72	1.66—1.75	1.72
J	—	—	0.95—1.05	0.99	0.92—0.99	0.95	0.99—1.07	1.01	0.99—1.06	1.02
K	0.86—0.98	0.91	0.88—1.11	1.01	0.95—1.28	1.03	1.12—1.20	1.16	1.05—1.26	1.18
L	0.87	—	0.94—1.12	0.99	0.88—0.96	0.92	0.96—1.08	1.01	0.92—1.01	0.96
M	1.05—1.48	1.37	1.33—1.48	1.39	1.37—1.58	1.46	1.26—1.42	1.34	1.36—1.50	1.41
N	1.24—1.37	1.32	1.34—1.54	1.44	1.27—1.50	1.39	1.36—1.43	1.39	1.42—1.62	1.50
O	1.26—1.34	1.29	1.23—1.40	1.31	1.27—1.40	1.35	1.16—1.36	1.25	1.35—1.52	1.44
P	1.18—1.44	1.32	1.26—1.42	1.33	1.24—1.68	1.47	1.18—1.28	1.23	1.23—1.48	1.34
Q	1.23—1.46	1.36	1.32—1.52	1.42	1.35—1.56	1.41	1.16—1.48	1.32	1.33—1.50	1.44
Q′	1.12—1.38	1.26	1.29	—	1.33—1.42	1.36	1.20—1.38	1.26	1.31—1.48	1.40
R	1.30—1.49	1.40	1.43—1.58	1.49	1.34—1.55	1.43	1.34—1.52	1.42	1.40—1.54	1.49
S	—	—	1.23—1.46	1.33	1.32—1.46	1.37	1.18—1.29	1.23	1.30—1.50	1.37
T	1.19—1.39	1.30	1.41—1.75	1.58	1.39—1.78	1.56	1.65	—	1.67—2.04	1.84
U	1.05—1.73	1.19	1.32—1.76	1.56	1.24—1.78	1.57	1.41—1.69	1.57	1.70—1.73	1.71
V	1.00—1.43	1.15	1.31—1.59	1.49	1.23—1.60	1.40	1.55—1.70	1.61	1.67—1.82	1.74
W	1.27—1.48	1.34	—	—	1.53—1.62	1.56	1.55—1.57	1.56	1.57—1.67	1.62

of this group, it varies to some extent with sexes and even with growth of the fish (Table 7).

(3). **Relative length of the tail in sequence of growth of the fish:-** The relative length of tail varies rather extensively with the growth of the fish throughout the species here dealt with through a considerable number of specimens. A comparison of the variation indicated by the ratios against the width of the disc shows three types in their trends, viz., Types T-1, T-2 and T-3. The proportional ratio rather simply increases without any sexual differences with the growth of the body in Type T-1, in which all of the species belonging to the northern form may be comprised (Fig. 31). The ratio first suddenly increases, either constantly or slightly, and then, remarkable sexual difference occur in most cases of Type T-2, in which almost all of the species referred to the southern form may be included with the exception of the species R. (Fig. 32).

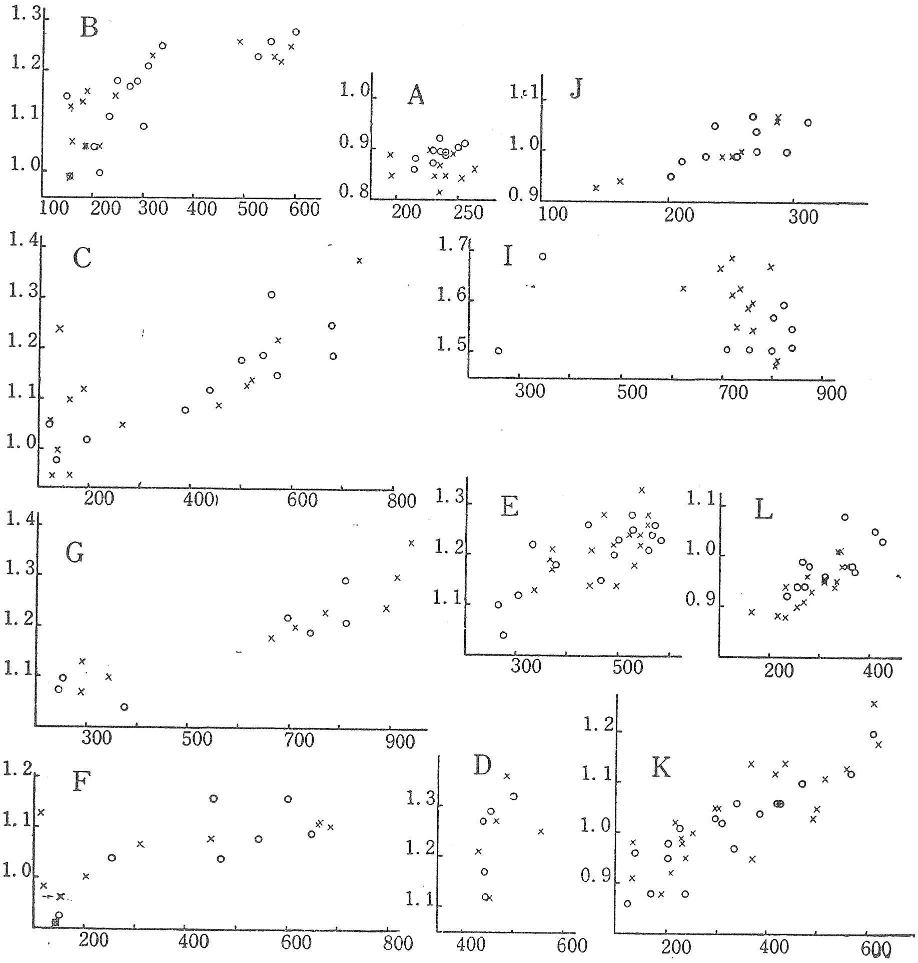

Fig. 31. Ratio of tail in length against width of disc in relation to the width (mm) in the northern form; ordinate, ratio; abscissa, disc-width; circle, male; cross, female. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica,* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.*

The curve gradually changes, at first, increasing its ratio, then followed by an easy grade in Type T-3, to which four species of the southern form belong. (T, U, V and W in Fig. 32).

Thus, the mode of the change of the proportional ratio of the tail may be classed into three types, which may be regarded as intricate problems. The tail of the rajid, however, may not grow evenly throughout the entire portion but differential growth occurs locally, and is eventually destined to diminish in its distal part as described later on. In either event, it may generally be pointed out from these figures that the mode of transformation in the relative length of the tail portion, if compared biometrically, may be classed into three types as mentioned above with some exceptions (Table 7).

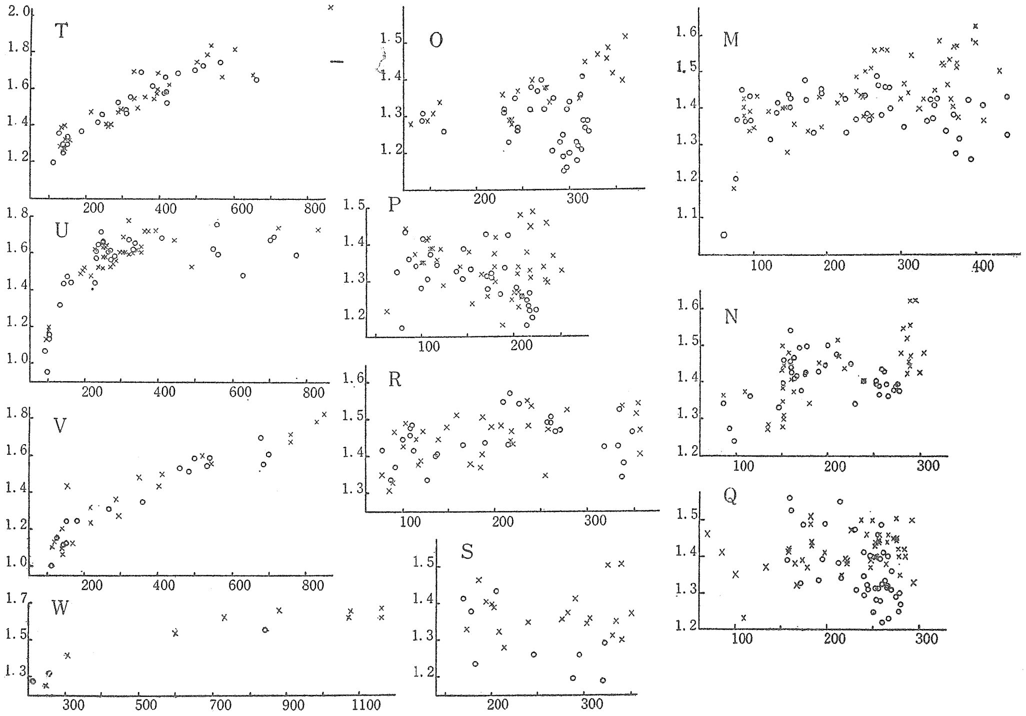

Fig. 32. Ratio of tail in length against width of disc in relation to the width (mm) in the southern form; ordinate, ratio; abscissa, disc-width; circle, male; cross, female. M, *Raja kenojei;* N, *R. acutispina,* O, *R. hollandi,* P, *R. macrophthalma,* Q, *R. porosa meerdervoorti;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

(4). **Metamorphosis of the tail in later embryos of some species:-** Four stages of the embryo of *Rhinoraja kujiensis**) were illustrated to show especially the change in the proportion of tail and its external feature. In addition to the above

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* These specimens were secured by a motor-trawler of the Hachinohe Branch Station of Tohoku Regional Fisheries Research Laboratory during the survey of the deep seas off the Pacific coast, and were kindly placed at the writer's disposal.

mentioned materials, several specimens of the post-embryos and the young of *R. kenojei* and of other species taken by the writer have also been treated here. All of these embryos were extruded from those egg-capsules. In order to compare briefly these specimens under the present scheme, it may be convenient to give an account of the principal features at each stage of the embryo of *Rhinoraja kujiensis*, which are to be mentioned in the first place.

Rhinoraja kujiensis:- Body is very slender, bearing an enormously large yolk-sac; head is greatly delated eminence, bulking over the snout region; the eyes are well formed; the external gills are apparent, protruded from incomplete gill-slits; the spiracles are developing into conspicuous clefts immediately before the gill-slits. Both pectoral and pelvic fins are distinct but small, being in outward expansion on lateral

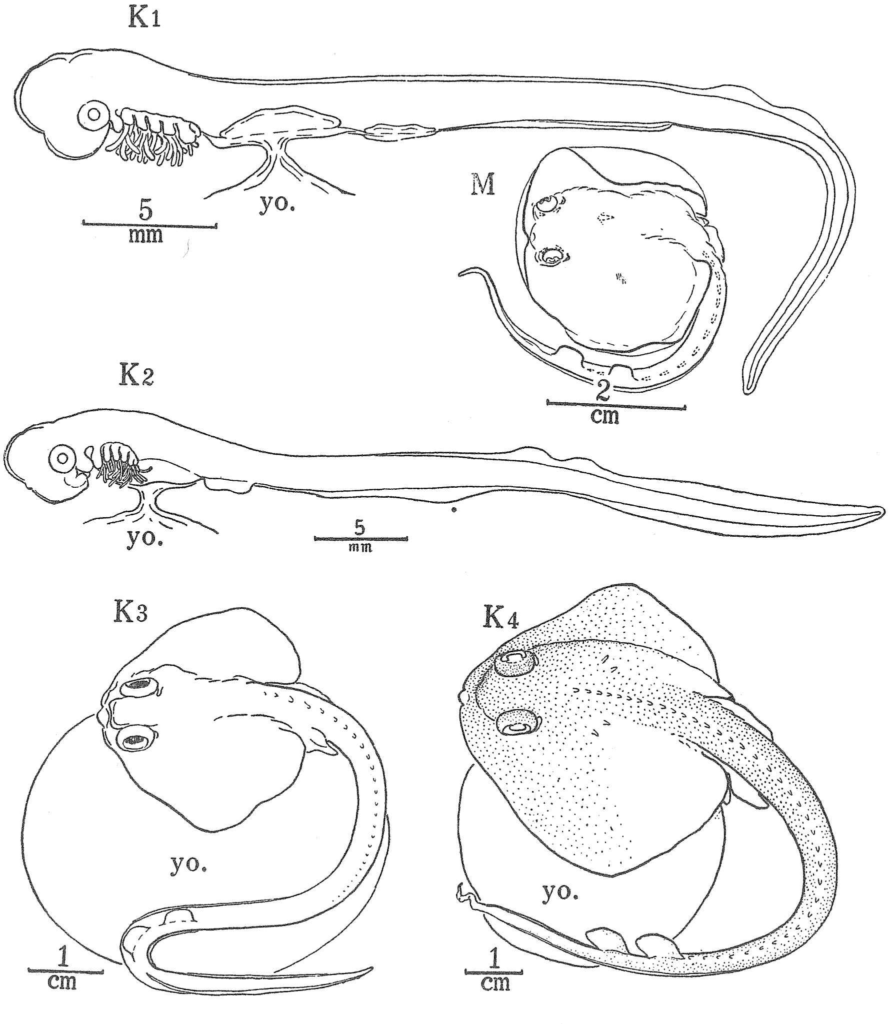

Fig. 33. Later embryos in the two species, K_1—K_4, *Rhinoraja kujiensis*, and M, *Raja kenojei*, especially showing long caudal portion, which is complete in K_1 — K_3 and M, but it is in process of shrinkage in K_4. yo., yolk-sac.

sides; dorsals are well-established, inserted ensuring far back between head and rear end of the tail. The tail behind dorsals is long, measuring about one-fourth times as long as total length of the boby. This specimen may be corresponding approximately to BALFOUR's stage N in the shark, (Fig. 33 K_1).

The embryo (Fig. 33 K_2) has essentially the same feature as that of preceding one, but it calls our attention particulary to the following: The pectorals and pelvics are even precociously larger; the two dorsals are rather distinct, located anteriorly on the notably long tail; the tail portion measured from posterior end of the 2 nd dorsal to rear end is about one-third times as long as the total length. It may be meaningful to find a elevation of the fin-fold lying far behind the pelvic fins. This may be a vestige of the anal fin, which is called herein tentatively anal fold.

The further advanced embryo shows a form decidedly like a skate, as can be seen from the figure; it has well-established pectoral fins, their anterior tips being closed together, interposing a short projection of the snout between them; the dorsals are located far back on the tail as in the case of the foregoing specimen; the pelvics are already notched. The characteristic features of this embryo are that the long caudal tip behind the second dorsal is complete without a sign of reduction, and the caudal and the membraneous folds on lateral sides of the tail are still distinct. The anal fold in question is also evident. The embryo is yet attached to a large mass of the yolk-sac. A series of tubercles or rudiments of the thorns is running from opposite side of the cloaca to posterior, but the tubercles are becoming smaller toward midway of the tail. The eyes are pigmented, and the disc is margined with faint gray. The embryo may be corresponding approximately to BALFOUR's stage P in the skate (Fig. 33 K_3).

The embryo (Fig. 33 K_4) has a very similar appearance to the specific features of the species; the spination characteristic of the species has well developed as large spines on the mid lines of the disc and of the tail and on the shoulder, by means of which we can most readily distinguish this species from other relatives. Upper surface of the body is gray in color instead of being white on under surface. The most attractive feature in this embryo is that a long distal portion of the caudal fin still remains behind the second dorsal, being in process of reduction, and its extreme tip has begun to show signs of shrinkage, undulating irregularly. Further, it may be of note that the said anal fold still remains as a very thin membraneous fold occurring midway between the cloaca and insertion of the first dorsal fin. As the embryo approaches a stage of emergence from the egg-capsule, the reduction of the tail behind the base of second dorsal becomes remarkable, and the phenomenon occurs only in the embryonic tail end, where the horizontal dermal folds on the lateral sides of the tail are not developed. At the stage where the caudal region has assumed to have similar appearance to that of the adult, the young attains to about 230 mm in total length.

As described above, the metamorphosis in the caudal portion of *Rhinoraja kujiensis* occurs gradually at about the end of the post-embryonic stage, and is found sometimes to continue to the stage after the embryo has hatched out.

Breviraja isotrachys:- Several specimens of the young of this species, measuring from 222 mm to 253 mm in total length, which were also trawled in the seas off the northern Hondo, have showed to occur the metamorphosis of the caudal portion in question in the same manner as in the preceding species. Namely, the tail of young fish measured 253 mm still keeps its caudal portion long, being curl and shriveling in the tip (Fig. 34 B). At the stage when the fish attains 300 mm in total length, however, the caudal tip in question almost assumes adult form in its general appearance (cf. Fig. 62 B_3).

Raja kenojei:- The latest embryo illustrated together with its young specimen of this well-known species may well exhibit the metamorphosis in the caudal tip. In Fig. 33 M, the tail region is still long, somewhat slenderer toward its rear end, and measures at the 2nd dorsal rearward about one-third times as long as the tail-length, and besides, the yolk-mass remains, though reduced in size, with a fully-developed external form approaching the adult of this species. In the youngest specimen measuring 100 mm in total length, which must have been lately hatched out from the egg-case, the metamorphosis of the tail is much progressed as compared with the foregoing one. It is a noteworthy fact in this case that the proccess of metamorphosis in the caudal region may have acceleratively taken place after the embryo has emerged from the egg-case with rapid shrinkage and dropping-out of the distal part of the tail.

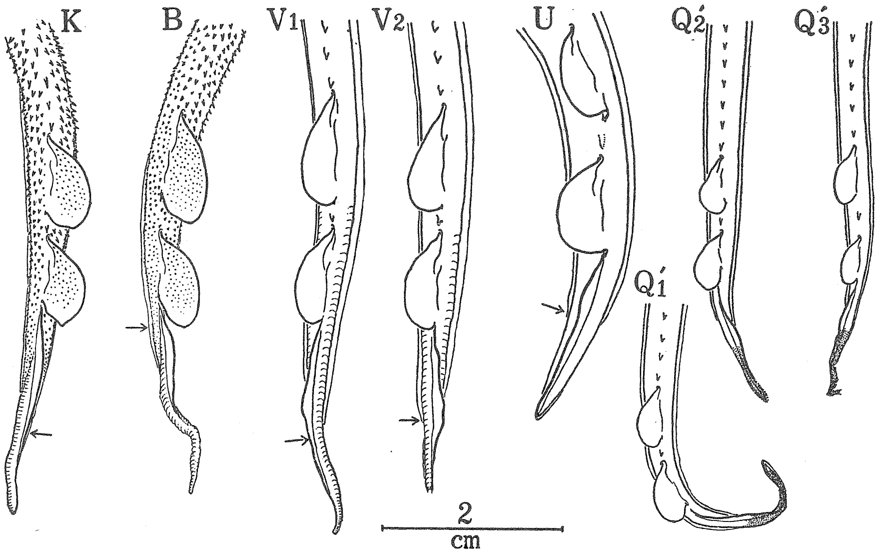

Fig. 34. Dorsal aspect of distal part of the tail in the young and the late embryos of five species, especially showing long caudal portion behind 2nd dorsal fin, where the portion is in process of shriveling or dropping out. Accompanying arrows indicate the portions where the electric organ was found to extend from anterior portion (cf. Fig. 46). B, *Breviraja isotrachys;* K, *Rhinoraja kujiensis;* Q'_1—Q'_3, *Raja porosa tobae;* U, *R. pulchra;* V_1--V_2, *R. macrocauda.*

Raja pulchra:- Of the embryo of this species only the latest one known to the writer is available for the present study, and this still has a small, spherical yolk-sac, which shows us that it is just before the times of its hatching-out from the egg-case. Noteworthy in this specimen is the fact that the said caudal portion still remains, and is plump in its general appearance. It must also be mentioned that the long caudal portion shows the obvious metameric segmentation and the horizontal dermal folds on both sides do not extend to the posterior extremity of the tail (U in Fig. 34). This condition is peculiar in contrast to that of the younger specimen of *R. macrocauda* which inhabits the deep seas. The caudal tip of the species still remains, the portion is about one-half time as long as that of the adult (Fig. 34 V_1, V_2).

From the foregoing observation on various stages in the late embryonic development of a number of rajid fishes, it may be summarized that; i) remarkable metamorphosis occurs in the distal part of the tail; ii) the metamorphosis in the tail takes place by means of shrinkage and dropping-out only in the portion behind the dermal folds not at all developed on both sides of the tail; iii) the duration for the metamorphosis seems to differ between the northern and the southern form, i. e. the embryonic tail in the northern form remains longer after the young has emerged from the egg-case than seen in the southern one, and iv) the deep-sea inhabitants even in the southern members appear to need longer time for the metamorphosis of the tail than the shallow inhabitants.

2). **Internal features of the tail with special reference to the electric organ:-** The existence of the electric organ in the rajid fishes has hitherto been little noticed from systematic viewpoints of ichthyologists, though we have a good many contributions concerning both anatomical, physiological and biochemical studies on this strange organ. As already known, the electric organ in rays and skates is found in the two families of the batoids, placed in the disc of the torpedo and in the tail of the skate. The organ of the torpedo is generally thought to be more advanced in its structure than that of the skate, and the skate's organ is practically recognized to represent some primitive features somewhat similar to histological features of the fish muscle*). In the present account, the writer has limited only to gross anatomy of the organ with a view to arriving at some conclusion under the subject.

(1). **On some aspects of the electric organs of rajid fishes:-** As I have already described previously in other reports (ISHIYAMA, 1955), the electric organs of Japanese rajids are found to be classified in two distinct forms from electrical elements constituting this organ, the cup- and disc-form, respectively, which have long been known to exist in European skates. Of these forms of the organ, the former type is found to mark the organ of the northern form, and the latter characterizes that of the southern one. The difference in minute structure between these two types of the element is remarkable as is the case with the European skates which have been well mentioned by several authorities, especially by EWALT (1888, '92) and ROBIN (1865).

(i). General feature of the electric organ:- The electric organ of the skate may largely be observed as spindle-shape in outward appearance when it is exposed from under the muscle and dermal tissues on both sides of the tail (Fig. 30). On the other hand, difference in horizontal location of the organ in the tail between the two forms is remarkable. In the northern form, the organ is found to exist only in the posterior portion of the tail, falling far from the cloaca or from the emergence of pelvic fins (A in Fig. 30). In this case, moreover, it should be borne in mind that the organ gradually migrates forward as the greater it becomes, the less the portion where the organ lies in the procaudal portion, and, on the whole, the shorter the tail (Fig. 35).

In the southern form, however, the organ usually lies in the place from near the base of tail to its distal end (U in Fig. 30). The transpecific forward migration of the organ as notified above is also found to exist in this form, viz., the increase of relative size of the organ accompanies not only some changes of outward growth of the organ and gradual increase of the organ located in the precaudal portion, but also gradual decrease of the organ in the procaudal one as can be best understood from those contradistinguishing figures (Figs. 35, 36 and 37).

The relation of the electric organ to its surrounding parts of the body is clearly

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* For minute structure of the skate's organ, see ISHIYAMA and KUWABARA, 1955 and '56.

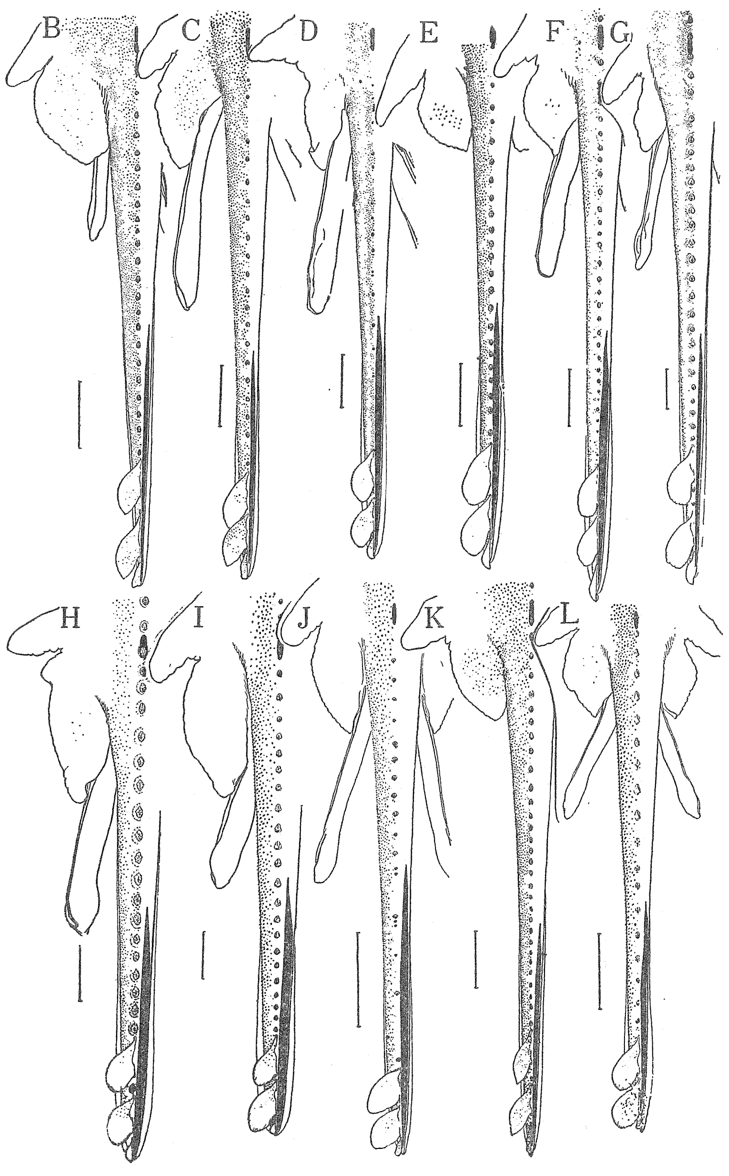

Fig. 35. Semidiagrammatic illustration of the dorsal view of the tail in eleven northern species, especially showing both the electric organ and the spination. The electric organ is shown by black on right side of the tail; the spination is shown only on the left side; the black slit in the anterior end in each figure represents the cloaca on opposite side; all these figures accompanying scales of 5 cm were arranged in equal size by way of comparison, and so forth in the following figures. B, *Breviraja isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.*

observed in outline when a transvers section of the tail is made where the organ lies, and is seen under the microscope with a low power (A_1 and U_1 in Fig. 30).

(ii). The number and the mode of distribution of electric elements in the elctric organ:- It is practically difficult to compare the degree of development of the electric organ in each species of rajid fishes because the transpecific differentiation of the organ accompanies not only changes in size, but also differences in structure. But the

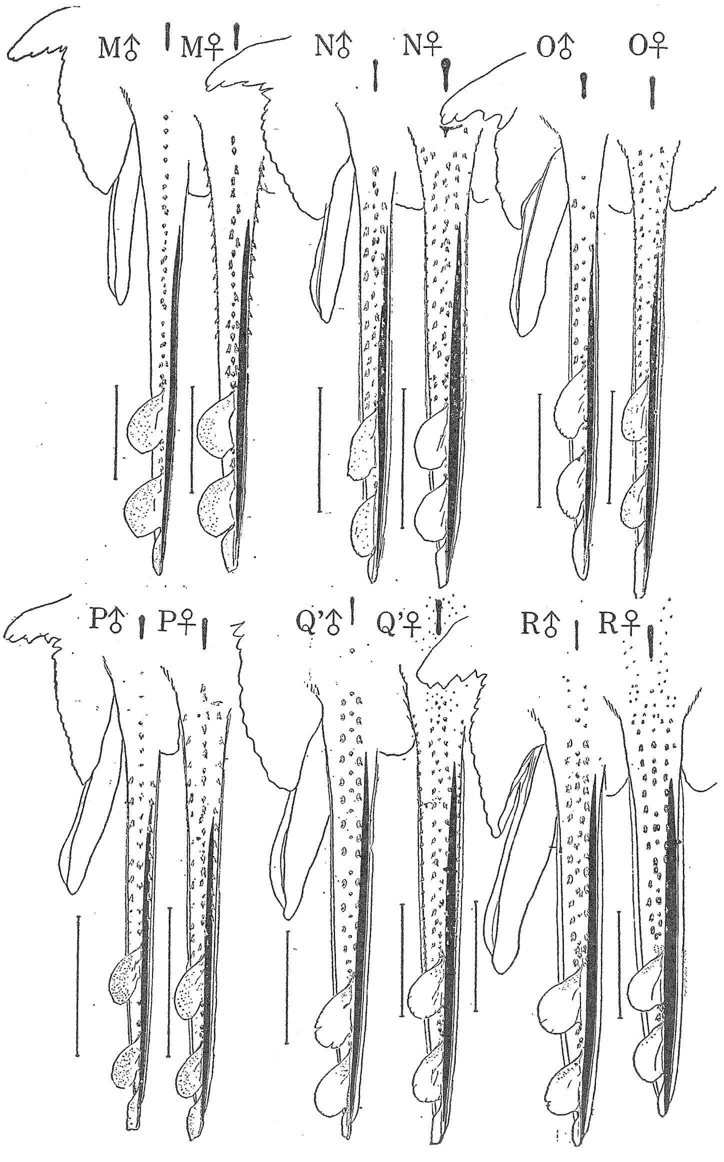

Fig. 36. Semidiagrammatic illustration of the dorsal view of the tail in six southern species, especially showing the distributions of both the electric organ and the spination. The method of illustration is the same as in Fig. 35. M♂, M♀, *Raja kenojei;* N♂, N♀, *R. acutispina;* O♂, O♀, *R. hollandi;* P♂, P♀, *R. macrophthalma;* Q'♂, Q'♀, *R. porosa tobae;* R♂, R♀, *R. fusca.*

present writer has estimated, for brevity's sake, the number of elements existing in an organ of each species by means of cutting sections of the organ (ISHIYAMA, 1955).

Concerning the number of the elements in an organ of the skate several accounts have been given. In *Raja batis*, about 10,000 discs on each side of the organ were estimated by EWALT (l. c.). The method of estimation taken in this study may be

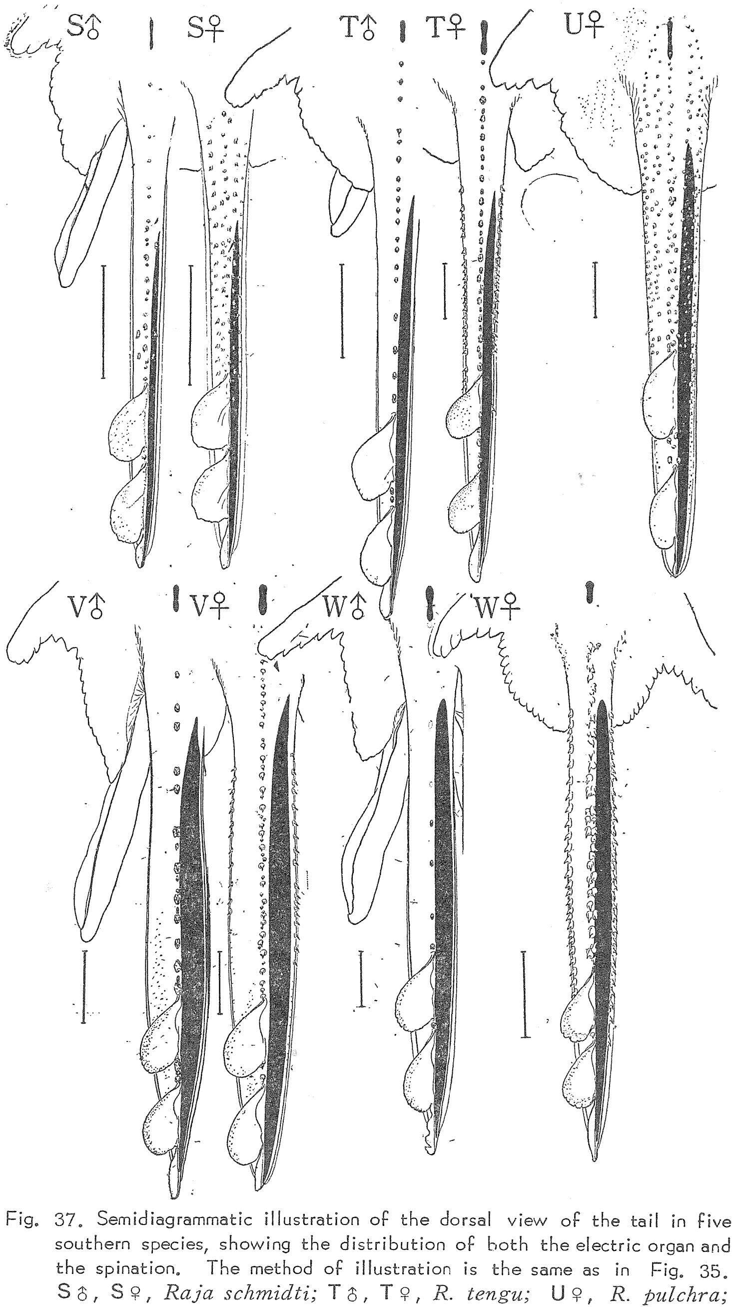

Fig. 37. Semidiagrammatic illustration of the dorsal view of the tail in five southern species, showing the distribution of both the electric organ and the spination. The method of illustration is the same as in Fig. 35. S♂, S♀, *Raja schmidti;* T♂, T♀, *R. tengu;* U♀, *R. pulchra;* V♂, V♀, *R. macrocauda;* W♂, W♀, *R. gigas.*

rather rough, but it would be of some use in appreciating the comparison of degree of development of the electric organ between species or group of species in combination with other characteristics of the organ.

As a step to the method of estimation given by the writer as aforementioned, the number of elements in an organ should be noticed: i) the elements are more numerous in larger species than in smaller one belonging to either the northern or southern form, in most cases, i. e. the least number was in the species A and P of each form, amounting to about 3400 and 4800, respectively, both species (A and P) represent the smallest in size in the each group. The maximum number, on the other hand, was found in large species, such as species I and V, in which the number is 27000 and 80000, respectively, ii) the numerical ratio of the elements between the two portions of tail divided represents close relation to the degree of development of the organ in the external feature. Namely, the procaudal elements are apparently more numerous than the precaudal ones in species A, P and O, whereas the reverse is the case in species I, V and W, and almost the same number of procaudal and precaudal elements is found in species B, C and F, but in the other species the precaudal elements are larger in number than the procaudal ones, and iii) in the southern form, the numerical ratio between the precaudal and the procaudal elements is different in more or less extent between two sexes; usually the procaudal elements relative to the

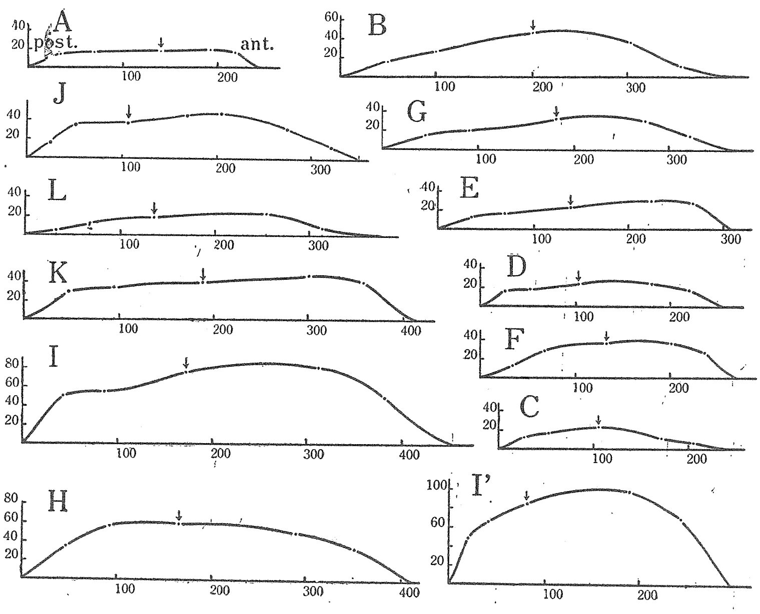

Fig. 38. Curves showing the distribution of electric elements in an organ of twelve forms of the northern members. Number of the elements given by cross sections at five or seven positions of the organ was plotted on vertical axis, and that in longitudinal sections at the same positions of the organ was given on horizontal axis. The arrow indicates the origin of 1st dorsal fin. ant. and post. being anterior and posterior extremity of the organ. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* I', *B. smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.*

precaudal ones are more numerous in female than in male, though there exist some exceptions to these facts (Table 8).

As regards the mode of distribution of the elements in the organ by far estimated the writer has noticed that, i) the curve representing the mode of distribution of the elements in an organ is smooth in its main portion without any remarkable elevation in species **A** and **L** of the northern form, and in species **O**, **P** and **U** of the southern one, which have relatively smaller electric organs in their relatives; ii) the height of curve increases firstly in the precaudal portion as in the case of the species **B**, **D**, **E** and **G** in the northern members, and **N**, **Q** and **T** in the southern ones, in which the organs are moderate in the degree of development; iii) the height of curve becomes higher throughout the organ in species, of which the organ is remarkably large, as represented by **H**, **I** (**I′**), **V** and **W** within respective form (Figs. 38—40); and iv) the transpecific changes in the mode of distribution mentioned correspond largely to retrogressive reduction in number of the elements involved in the procaudal,

Table 8. Number of electric elements in precaudal and procaudal portions of the tail and the dimension in three bodily parts in Japanese rajids. In the northern form (A—L), samples were used either the male or the female of adult fish of each species, but in the southern form (M—W), both of male and female of each species were treated.

Item Species and sex	Total length (mm)	Disc-width (mm)	Tail-length (mm)	No. electric elements			
				precaudal		procaudal	
				♂	♀	♂	♀
A, ♀	496	248	300	—	1383	—	2096
B, ♂	794	520	423	6080	—	5298	—
C, ♂	832	542	456	1869	—	1680	—
D, ♂	703	446	396	3325	—	2067	—
E, ♀	797	556	430	—	4326	—	2265
F, ♂	946	600	515	4280	—	3217	—
G, ♂	1280	811	672	4648	—	3527	—
H, ♂	941	645	455	11321	—	7357	—
I, ♂	1105	800	530	17825	—	9265	—
I′, ♀	868	665	379	—	17555	—	4473
J, ♂	520	311	293	8380	—	2891	—
K, ♂	680	420	395	7905	—	5656	—
L, ♂	606	365	370	3743	—	1521	—
M, ♂ ; ♀	585 ; 543	409 ; 400	290 ; 248	5519	6068	4316	3830
N, ♂ : ♀	399 ; 405	266 ; 278	195 ; 200	4685	4322	2754	3495
O, ♂ ; ♀	493 ; 486	321 ; 340	245 ; 243	5151	7473	12879	9222
P, ♂ ; ♀	350 ; 345	224 ; 232	183 ; 173	2615	2270	3426	3070
Q′, ♂ ; ♀	480 ; 485	320 ; 320	245 ; 241	7428	3932	2426	2442
R, ♂ ; ♀	487 ; 325	339 ; 236	245 ; 252	8672	6175	5760	2620
S, ♂ ; ♀	465 ; 446	288 ; 303	241 ; 225	3268	2983	3225	3429
T, ♂ ; ♀	728 ; 1130	562 ; 850	322 ; 470	17340	11532	10620	19404
U, ♂ ; ♀	965 ; 1119	710 ; 830	420 ; 491	8107	5232	5008	6624
V, ♂ ; ♀	1000 ; 1250	700 ; 800	435 ; 465	37440	52416	15744	28448
W, ♂ ; ♀	1210 ; 1540	840 ; 1160	540 ; 693	45326	45216	21324	32030

and progressive development in that found in the precaudal.

(2). **Later embryonic development of the electric organ in some rajids:-** The early development of the electric organs of certain skates has been sufficiently studied by EWALT (l. c.). Therefore, there is a little escape in question in our rajids from those valuable accounts made by the past savant on the subject.

Under the present item a histological study has been made with the study of probable relation between degree of development of the electric organ and the metamorphosis in the caudal portion by cutting section using those materials placed for external observation.

Rhinoraja kujiensis:- In Fig. 41 K, we can see that the vestigial elements, which were said by EWALT (1888, p. 543) to be the primary club, are in process of conversion into the electric cup from the muscle fibers. It should be noticed herewith that the vestiges are not developed in the distal tip of the tail, and that only a small number of the vestiges are feebly seen in the portion falling far before the tip, and a large number of cups in some advanced stage of development are found anteriorly in front of the 2nd dorsal fin. Such being the case, none of the electric elements which might be converted from the muscle fibers is found to rise in the caudal tip, which shows that the tip is in the representative state of shriveling and dropping-out of the tissue therein.

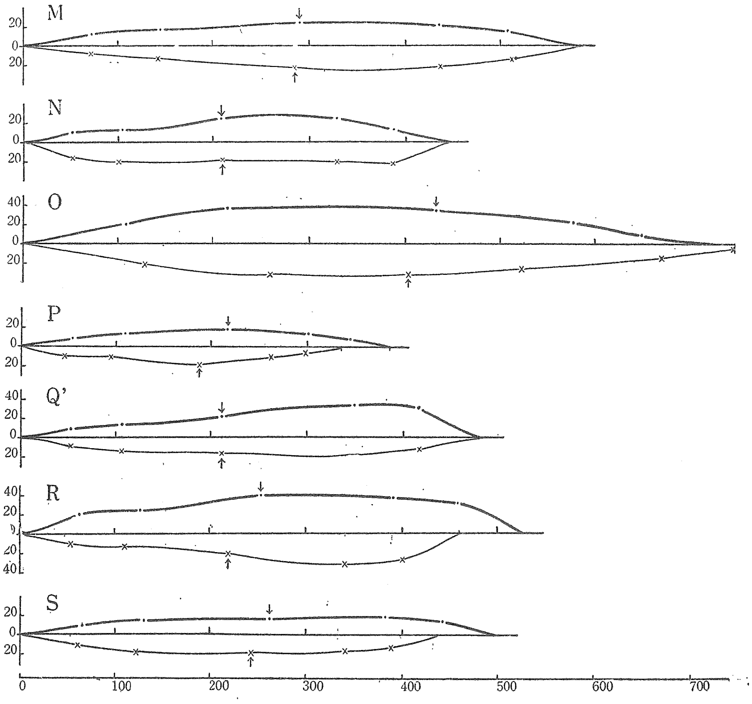

Fig. 39. Curves showing the distribution of electric elements in an organ of six forms of the southern members. Upper in each figure is regarded to that in the male, the lower in the female. Method of illustration is the same as in Fig. 38. M, *Raja kenojei*, N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q', *R. porosa tobae;* R, *R. fusca;* S, *R. schmidti.*

Supposing from these facts which were introduced from ontogenetic development of the electric elements in the caudal tip and of the reduction of the portion in the later embryo of this species, we may conceive that the reduction of the distal portion of the tail may have close relation to the development of the electric organ.

On the other hand, when the facts given above are compared with the metamorphosis observed in the external of the tail (p. 69; Fig. 34), that the occurrance of the vestigial elements seems to have extended *in situ* to the portion indicated by the arrow in that figure. Further, it will be evident to observe the facts

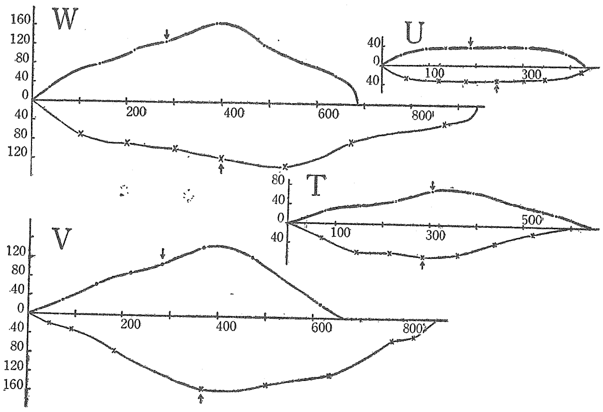

Fig. 40. Curves showing the distribution of electric elements in an organ of four forms of the southern members. Method of illustration is the same as in Fig. 38. T, *Raja tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

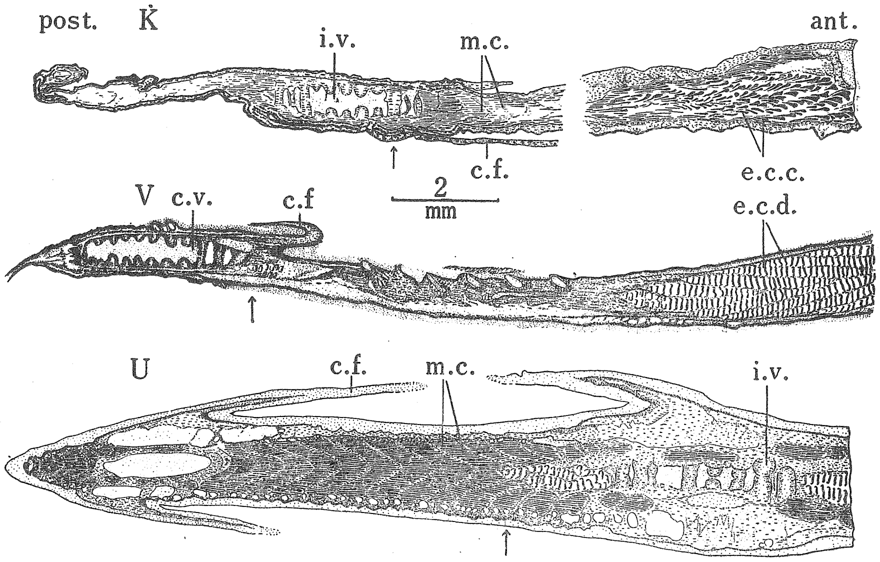

Fig. 41. Longitudinal vertical sections of the caudal tips in the two representatives of the electric organs of the post embryos, especially showing the development of the cup-form elements which are in conversion from the muscle fibres falling far from the tip in K (*Rhinoraja kujiensis*), and that of disc-form ones in U (*Raja pulchra*) and V (*Raja macrocauda*), in which exuviation and reduction of the caudal tip are in progress to form the elements from the muscle fibres falling far from the distal tip. The arrow indicates the posteriormost part where the electric elements are distinct in its development (sea also Fig. 34). ant., anterior; c. f., caudal fin; e. c. c., electric cone of the cup-form elements; e. c. d., electric cone of the disc-form elements; i. v., incipients of the vertebrae; m. c., muscle cone; post., posterior.

that the portion of shriveling and dropping-out in the distal portion of tail is naked from any armatures.

It should be expected from these evidence mentioned that the long caudal tip might be a purely temporary organ which has been developed during post-larval life, and disappears as the young grows or even before, and that this phenomenon may be correlated not only with its sheer necessity for their bottom life but also with the development of its electric organ.

Raja pulchra:- The post-embryo used in this study is the same material with what was referred to the external (cf. Fig. 34 U). The electric organ in the relatively long caudal portion in question is found to lie posteriorly near the middle of the portion when cut in the same way with the preceding species. We can evidently observe that the electric elements are in complete development, and that the organ is decidedly distinguished from its surrounding tissues. It may hence be said in this case, as has already been mentioned by EWALT (1892, p. 403) that the organ may reach to almost complete development in the latest embryo, followed by the reduction of the rear portion which continues for some time till after the embryo has emerged from the egg-capsule (U in Fig. 41).

Raja macrocauda:- Noteworthy in this specimen is that the great length of the caudal portion is still found remaining in the young stage (V in Fig. 34). And, the posterior extremity of the electric organ is found to exist nearer to the end of second dorsal than to the tip of the tail (cf. V in Fig. 41). However, it must be noted herewith that the specimen is thought to indicate more precocious features in its outward appearence than does *R. pulchra* mentioned above though the specimen was secured in the open sea. From this fact the reduction of the long caudal portion may continue for some time after the young has begun to get its own living.

A specimen of this species at its more advanced stage shows the scar marked on the extremity of the long caudal portion, where the organ is still falling far from the distal tip of the tail (V_2 in Fig. 34).

Raja porosa tobae:- The extremity of the electric organ is also found to exist, lying nearer to the end of second dorsal than to the tip of tail, which is still long and tapered in shape. A specimen in somewhat metamorphosed stage has some interesting feature in its caudal tip. The reduction in the caudal tip, as seen in Fig. 34 Q′, is in the stage of dropping-out by shrinking and segmenting into several pieces. The electric organ is, of course, found to lie not reaching to the extremity of the tail, as expected from the foregoing facts (cf. Fig. 34 Q'_{1-3}).

Taking those facts into consideration which show the relation between the reduction of the caudal tip and the degree of development of the electric organ, we may safely infer that, though there are more or less difference in the developmental history of the organs between the northern and the southern forms as well as between species, the later embryonic development of the organ may have caused the reduction or dropping-out of the caudal portion. Such hypothetical conception of the reduction in the tail as are formed from those ontogenical developments in relation to the degrees of development of the electric organ must not be overlook in finding clue to some systematic significance of the tail in rajid fishes.

Discussion

1). Use of the tail in taxonomy

On the basis of some important characteristics in both external and internal parts of the tail observed in this study, the present writer has made an analytical key to species or groups of species of the Japanese rajids, in order to make out the systematic significance of the tail of the fish. Of course, the tails of rajids bear some important characters, such as the patterns of distribution of the placoid scales and the number of vertebrae. From this key, however, one may clearly grasp in classifying the fish the use of the tail to them, and the writer has later on clarified all those characteristics revealed in the tail for the students to rely on in determing species in the systematic part of the present investigation.

1a. Tail usually long, round-type in external view with some exceptions; dermal fold on both sides of the tail distinct posteriorly, but anteriorly it reaches to midway of the tail, falling far behind from the root except for the species A; electric organ more or less developed on both sides of the tail, characterized by constituting the cup-form elements.

2a. Tail very long, 0.8 to 1.2 times as long as the width of disc even in the adult; electric organ small or moderate in its development, lying from distal tip to far rearward of middle point of tail.

3a. Tail much more elongated, always longer than length of disc; electric organ less developed, polygonal in cross view of main portion, falling anteriorly far rearward from the middle of tail.

4a. Dermal fold on both sides of tail distinct throughout whole length of the tail; electric elements smallest in number, enumerated about 3400 in an organ, and the elements are more numerous in procaudal than in precaudal portion .... *Breviraja tobitukai* (A in Figs. 30 and 38)

4b. Dermal fold on both sides of tail developed only on posterior half; electric elements involved in an organ somewhat more numerous than in the preceding, enumerating more than 5000 in number; number of elements in the precaudal more numerous than that in the procaudal .... *Rhinoraja odai* (J in Figs. 31, 35 and 38); *Rh. kujiensis* (K in Figs. 35 and 38); *Rh. longicauda* (L in Figs. 35 and 38)

3b. Tail rather long, almost as long as or slightly longer or shorter than length of disc; electric organ more or less well developed than that in the precedings, triangular or roundish in cross view, scarcely extending forward halfway to base of tail.

5a. In adult, tail about as long as or slightly longer than length of disc; electric organ rather small, the part lying in precaudal portion one-third time shorter than the length of that portion; number of electric elements in the precaudal except for species D, more numerous than in procaudal, but is reverse in species D .... *Breviraja isotrachys* (B in Figs. 35 and 38); *B. trachouros* (C in Figs. 35 and 38); *B. abasiriensis* (D in Figs. 35 and 38)

5b. In adult, tail slightly shorter than, or nearly equal to, length of disc; electric organ somewhat advanced in its development, the length lying in the precaudal almost one-third time as long as that portion; electric elements in the precaudal slightly more numerous than in the procaudal .... *Breviraja diplotaenia* (E in Figs. 35 and 38); *B. matsubarai* (F in Figs. 35 and 38); *B. aleutica* (G in Figs. 35 and 38)

2b. Tail short, depressed-type, about 1.50 to 1.75 times as long as width of disc; electric organ much more developed than in 2a, round in cross section of the main portion, extending from distal tip to near or beyond half way to base of tail; electric elements much more numerous in the northern members, the ratio of precaudal ones to procaudal ones more than 1.5 times .... *Breviraja parmifera* (H in Figs. 35, 38 and 68); *B. smirnovi smirnovi* (I in Figs. 35, 38 and 68); *B. smirnovi ankasube* (I′ in Figs. 38 and 69)

1b. Tail relatively short, depressed-type in external view; dermal fold on both sides of tail more or less distinct, covering from base of tail to the distal tip; electric organ characterized by having disc-form elements.

6a. In adult, tail less reduced, about 1.2 to 1.6 times as long as width of disc; electric organ very small or moderately developed, running from distal tip to near or far behind the center of posterior ends of pelvic fins.

7a. Procaudal part of tail relatively long; electric organ very small, falling the anterior tip far from posterior ends of pelvic fins.

8a. Procaudal portion more than one-third time as long as tail, holding more than half the length of electric organ .... *Raja hollandi* (O in Figs. 36, 39 and 75); *R. macrophthalma* (P in Figs. 36, 39 and 76)

8b. Procaudal portion as long as or a little longer than half the length of tail, holding about one-half the length of electric organ .... *Raja kenojei* (M in Figs. 36, 39 and 73); *R. schmidti* (S in Figs. 37, 39 and 81)

7b. Procaudal portion moderately reduced in length; electric organ moderately developed, reaches or extending to near posterior ends of pelvic fins, the length almost half as long as tail .... *Raja acutispina* (N in Figs. 36, 39 and 74); *R. porosa meerdervoorti* (Q in Figs. 36, 39 and 77); *R. porosa tobae* (Q′ in Figs. 36, 39, 79 and 80)

6b. In adult, tail more reduced, about 1.35 to 2.0 times as long as disc-width; electric organ relatively large or enormousely well developed, covering from distal tip of tail to near or far beyond posterior ends of pelvic fins.

9a. Procaudal length of tail somewhat longer than or nearly as long as one-half length of tail measured rearward from posterior ends of pelvic fin; electric organ relatively large, reaches to posterior ends of pelvic fins (female) or farther beyond (male) .... *Raja fusca* (R in Figs. 36, 39 and 80); *R. tengu* (T in Figs. 37, 40, 81 and 82)

9b. Procaudal portion of tail longer or much shorter than one-half length of tail measured posteriorly from posterior ends of pelvic fins; electric organ more or much more developed, reaching anteriorly to, or beyond posterior ends of pelvic fins in both sexes.

10a. Procaudal portion more than half as long as tail measured posteriorly from posterior ends of pelvic fins; electric organ better developed with two subequal portions divided .... *Raja pulchra* (U in Figs. 30, 37, 40, 83 and 84)

10b. Procaudal portion much shorter than the half length of tail measured posteriorly from posterior ends of pelvic fins; electric orgn much better developed in size in southern members, extending beyond distal ends of pelvic fins.

11a. Procaudal portion nearly as long as or shorter than one-third length of tail; distal portion of tail reduced into small flap of the caudal fin; electric organ developed in enormous size, occupying almost whole room of muscular tissue in the tail .... *Raja macrocauda* (V in Figs. 37, 40, 85 and 85)

11b. Procaudal portion more than one-third times as long as tail; distal portion of tail somewhat long, holding distinct caudal fin ....

.... *Raja gigas* (W in Figs. 37, 40, 84 and 86)

2). Consideration on the utility of the tail

In general, forward movement of the body in the elasmobranch fish may largely be classified in two fundamental types, one is found in the shark and called caudal-type, and the other is found in the batoid fish and called pectoral-type. In skates and rays, the caudal portion is so atrophied that the fin may act as a rudder, but not as a powerful propelling organ. In fact, the dorsal fins are usually falling and ensuing far back on the tail, and the caudal fin usually keeps up its position with only a small flap, which almost disappears in some species. These features found in the tail of rajid fishes may be outstanding negative specialization toward diminution in opposition to positive specialization developed with pectoral fins. But a point of great importance is the presence of the electric organ which might subserve for the rajids some such favors as special function. The present writer has given a working hypothesis on the natural function of the electric organ (Ishiyama, 1955).

In the present scheme, the writer will discuss further from ontogenical and genealogical viewpoints the use of the tail relating principally to the correlation found between the reduction in tail and the degrees of development of the electric organ, though it still remains to be proved how the skate′s organ subserves in practice.

Judging from the characteristics observed upon morphological and embryological evidences in the tail of rajid fishes, the tail has two different uses. One is its original function, or we should rather say fundamental use, for movement of the body. The other, inferred from genealogical evidences of the organ is the tail being used as a defensive weapon responsible for special external stimuli. Of these two hypothized functions of the tail, the former may be believed to be still remaining in a greater number of tails of the round-type, in which almost all members in the northern form are included. But, since the depressed-type, to which the southern form and some of the northern one belong, has been reduced in its length in greater or less degree, its tail may have been kept at more retard than that of the round-type in its original function. At any rate, we can surely believe that the effective power in the original function may be gradually increased from the distal portion to the base of the tail, where the muscular tissue is great.

On the other hand, a special function of the tail may be presumed from the fact which has been confirmed by physiological studies of the electric organs of certain skates (Robin, 1865; Sanderson and Gotch, 1888). The existence of rather weak electrical shock discharged from the skate′s organ at the distal end of the tail seems to have some use for orientation. In fact, the electromotive force can be increased from the anterior portion where the organ lies rearward to the tip. In this case, taking into consideration all the facts given in the foregoing chapters showing the relations between the reduction or dropping-out of the tip of tail and the degree of development of the electric organ, and between the relative length of the tail and the degrees of development of the electric organ, we cannot but conceive that the organ must have some causal relation to the growth of the tail. In other words, the electric organ may be a special organ, which is presumably very useful for the conservation of the activity of the tail, probably necessary for the bottom living.

If this is really the case, the tail may have two different roles: its original function of propelling the body and a function as the special organ or as a special feeler. This concept that the original and the special functions of the tail form a reciprocal relation may be understandable from ontogenical and genealogical viewpoints mentioned above.

Further, a evidence that the electric organ grows in its weight as the body does (according to EWALT, 1892; p. 402) with its sudden increase in the skate when it attains its maturity may, therefore, suggest that the organ may have some use in the probable strife for existence among the species.

Though it may be still now impossible to interpret the real biological function of such a peculiar organ in the tail of the skate, the hypothetical view so far mentioned may imaginatively be extended to our explanations of the tail as an organ of avoiding inter- and intraspecific competition or as that of species selection rather than a defensive weapon against natural enemies' attack from behind the body. Likelihood is that the skate's organ may act a role similar to what has generally been considered about the natural function of the luminescent organ in the fish and other animals*).

3). **Consideration of the differentiation of the tail**

Having examined comparatively important features in both external and internal of the tail of Japanese rajid fishes, the present writer has concentrated his particular attention on the following points, with a view to arriving at a conclusive opinion on the present scheme, thus; i) general shape of the tail, ii) relative length of the tail and its change with growth of the body, iii) structural characteristics of the electric organ, and iv) reduction of the tail-length or exuviation of the caudal tip in relation to degree of development of the electric organ.

On the basis of i) to iii) categories mentioned above, the rajid fishes can be divided in two main groups. But the phyletic relationship of the two groups is so diversified in their courses of differentiation that it may be difficult to interpret reasonably such a complex structure. However, in order to solve this puzzle, the writer has considered the problem within the limits of the following bases helped by some working hypotheses given in the preceding scheme.

(i). From both phylogenical and ontogenical viewpoints of the batoid fishes, it is generally believed that the long tail of the round-type, which appears to be its primary modification in the shark, may be considered to be more primitive than the short tail of the depressed-type. Consequently, the so-called southern form may be more specialized than the northern form in respect to the general shape and relative length of the tail. Similarly, the tail in the species **H** and **I** (**I'**) may be in more advanced condition, and the species **A**, **J**, **K** and **L** may be less specialized, in the northern form.

(ii). In comparison of ontogenetic change of the relative ratio of the tail with the growth of the body, the northern form appears to show congeneric trend with linear relation without any sexual difference even in the adult, but the southern form may be divided in two groups in this respect, viz., one, which involve the six species (**M**, **N**, **O**, **P**, **Q** and **S**), shows sexual difference in the adult to some extent, representing curvilinear relation, and the other, exemplified by the five species (**R**, **T**, **U**, **V** and **W**) reveals imperceptible sexual difference with curvilinear relation.

(iii). As a hypothetical conception on successive changes of relative length of the tail in both ontogenical and linealogical series in relation to the degree of development of the electric organ which may have some causal relation to the reduction of the tail or exuviation of the caudal tip, we can suppose that the existence of relatively long tail with relatively small electric organ may be considered primitive than that of relatively short tail with large electric organ.

Granting that these views were true, purely hypothetical as it is, the phyletic

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* On this matter, the present writer will give an accounts in future.

relationship in the two major groups of Japanese rajids may be expected to be through the two confronting features of each species, i. e. relative length of the tail and numerical ratio of the electric elements between the precaudal and procaudal portions.

Conclusively, the following figure obtained from these two morphometric evidences in the tail of each species shows systematic relationship in the different groups of Japanese rajids, concerning the successive changes of relative length of the tail and degree of development of the electric organ (Fig. 42).

It is worthy of special mention that the figure coincides fairly well with the inter-relationship deduced from the features of the clasper of this group of the fish (cf. Fig. 21).

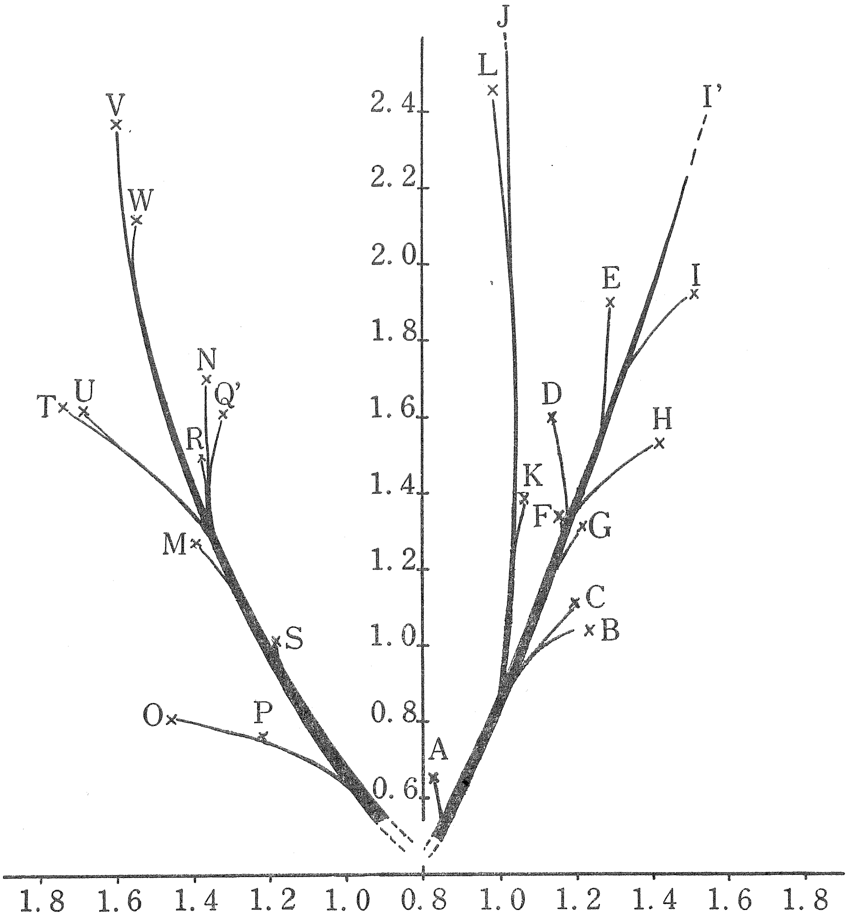

Fig. 42. Supposed relationships based on ratios of the length of tail in disc-width (horizontal axis) and of the number of electric elements of precaudal portion in procaudal ones (vertical axis), especially showing parallel evolution in the two major groups of Japanese rajids in respect to the two morphometric importances. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi sminovi;* I', *B. smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei,* N, *R. acutispina,* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti,* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

This fact may enable us to infer that the characteristics of the tail are highly valued in the systematic classification of rajid fishes.

C. Vertebrae

1. Description in general

The vertebral characters in elasmobranch fishes have been subjects of discussion from the past, being used in the taxonomy as well as in the phylogeny of various groups of the fish (HASSE, 1879 ; REGAN, 1906 ; WHITE, 1936). HASSE has distinguished three types of vertebrae in the Elasmobranchii, based principally on the structure and the condition of calcification, thus: the cyclospondylic, the asterospondylic and the tectospondylic. Of these, the last type of vertebrae, which involves the batoid fishes, is characterized by having centrum with numerous concentric calcified cones*). We, in general, agree with the above critique for the separation of such three types of calcification.

In all batoids the larger part of the anterior region of the vertebral column has a solid vertebral plate fused, to which the scapular portion of the shoulder girdle is attached. Yet many differences have been noticed in the form of the plate within groups of the batoids (GARMAN, 1913), and the character is not so remarkably different among Japanese rajids dealt with. The vertebral centra of rajids are gradually reduced in size anteriorly, being embedded in the vertebral plate. Posteriorly, they extend near the tip of the tail, where the segmentation is incomplete owing to the reduction in its distal portion, as mentioned elsewhere (cf. Fig. 41).

The present writer has given an account of Japanese rajids on the number of the vertebrae divided into three groups, as follows; abdominal, precaudal and procaudal (ISHIYAMA, 1952). In the present study, he has made a analytical comparison between counts in the abdominal and precaudal regions of all the species. But the procaudal vertebrae are kept outside of this comparison due to the inclusion of the incomplete segmentation of the distal portion. The reason why the boundary between precaudal and procaudal regions can be determined arises at this point, and the writer has adopted the following hypothesis to interpret this question.

It has generally been widely assumed that the modification in the feature of the caudal vertebrae in some elasmobranchs may have come about for greater freedom and strength of movement in the caudal portion (RIDEWOOD, 1899 ; REGAN, 1906 ; DANIEL, 1928). In fact, according to CAMPBELL (1951), the undulatory pattern of movement in the tail of *Rhinobatus productus* has been proved to have a different threshold responsible for external stimuli between anterior and posterior portions of the first dorsal fin. Further, the present writer(1955) mentioned in the Japanese rajids that the distributional pattern of the electric elements markedly changes starting at the insertion of first dorsal fin. On the basis of these facts it seems reasonable that the subdivision of the caudal vertebrae in this group of fish may be justifiable according to the functional meaning.

At any rate, it is rather difficult to count the vertebrae covering the two region,**) and counts vary in some degree in the same species. Nevertheless, the present writer has ascertained that noticeable differences are found between the counts in the two

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* Of this matter, the present author has given several accounts (ISHIYAMA, 1951 a,b, '55, '56), where he claimed that the concentric calcified rings of the centrum of the vertebra in some rajids are regarded as annual growth rings as is observed in many teleosts, and also see p. 119 in this article.

**The counts were made by means of X-rays or dissection.

regions of the vertebrae, which has enabled us to separate the Japanese rajids into two phyletic groups.

2. Comparison of the vertebral counts

By the total number of the vertebrae of the two regions, the two groups, one with a larger count about 90 and above, and the other with a fewer counts, less than 90, are regarded, respectively, to the northern and southern forms. In comparing the two series of vertebral counts thus divided, the writer has scrutinized the fish in regard to the counts for the purpose of subdividing it into four groups. As seen in Table 9, the differences between those two groups in the two series of counts are more pronounced in the precaudal than in the abdominal groups. More exactly, the number of abdominal vertebrae shows less magnitude in its range of variation than that of the precaudal ones. Further, it should be noticed that the tendency in the variation of vertebral counts in the two regions of the backbone classifed shows a regularity in the differences between those counts in species or groups of species.

Table 9. Counts of abdominal and precaudal vertebrae in Japanese rajids, especially showing smaller counts with less variability in the abdominal vertebrae than in the precaudal ones. Number of specimens examined of each species is parenthesized. C. V., coefficient of variation; S. D., standard deviation; for other abbreviations, see Fig. 43.

Species	Abdominal vertebrae		Precaudal vertebrae		Species	Abdominal vertebrae		Precaudal vertebrae	
	range	mean±S. D.	range	mean±S. D.		range	mean±S. D.	range	mean±S. D.
A (11)	24—27	25.4±0.78	63—70	65.6±1.90	M (6)	27—28	28.3±0.74	44—47	44.8±0.69
B (10)	34—40	36.1±1.61	73—82	77.4±2.83	N (5)	26—29	27.4±1.02	20—42	41.2±0.97
C (9)	32—36	33.4±1.06	71—77	74.3±1.88	O (5)	28—29	28.4±0.49	38—42	40.8±2.13
D (5)	31—33	32.4±1.02	66—70	67.6±1.58	P (5)	25—26	25.4±0.49	38—43	40.4±1.87
E (11)	31—37	33.6±1.50	70—74	71.1±1.62	Q, Q′(13)	25—30	27.3±1.45	36—43	40.1±1.85
F (5)	34—36	35.0±1.00	71—73	71.8±0.75	R (5)	28—29	28.8±0.40	29—43	41.0±1.41
G (7)	35—38	36.0±1.19	69—74	70.8±1.82	S (5)	27—29	28.0±0.63	42—45	43.4±1.01
H (1)	39		82		T (5)	31—32	31.4±0.15	46—50	47.6±1.35
I, I′(8)	35—40	37.4±1.86	83—88	85.0±2.05	U (7)	30—32	31.2±1.03	38—42	39.1±1.16
J (10)	33—36	34.1±1.04	85—91	88.4±2.1	V (8)	30—33	31.2±1.17	53—59	55.3±1.98
K (8)	33—38	35.1±1.76	76—83	79.3±2.33	W (4)	30—34	32.5±1.50	59—61	60.0±1.00
L (7)	30—32	30.5±0.73	74—80	75.5±2.06					
Total range	24—40		63—91		Total range	25—34		36—61	
C. V. (%)	11.5		9.8		C. V. (%)	7.9		11.5	

It will be seen from these figures that the abdominal counts may be considered less variable than precaudal ones in successive changes from species to species.

The Japanese rajids thus may be classified into four groups of species on the basis of the counts of the precaudal vertebrae, viz., those with about 75 and below, those with about 75 and above which can be related to the two groups of the northern form, those with about 45 and below, and those with about 45 and above which can be related to the southern form. The following five species **A**, **D**, **E**, **F** and **G** belong to the first group. The second includes the following seven species **B**, **C**, **H**, **I** (**I′**), **J**, **K** and **L**. The third includes seven species **N**, **O**, **P**, **Q** (**Q′**), **R**, **S** and **U**. The remaining four species **M**, **T**, **V** and **W** are referred to the fourth group.

As indicated in Fig. 44 accompanying the above description, successive changes in vertebral counts of precaudal groups seem to indicate some tendency in the respective group of species.

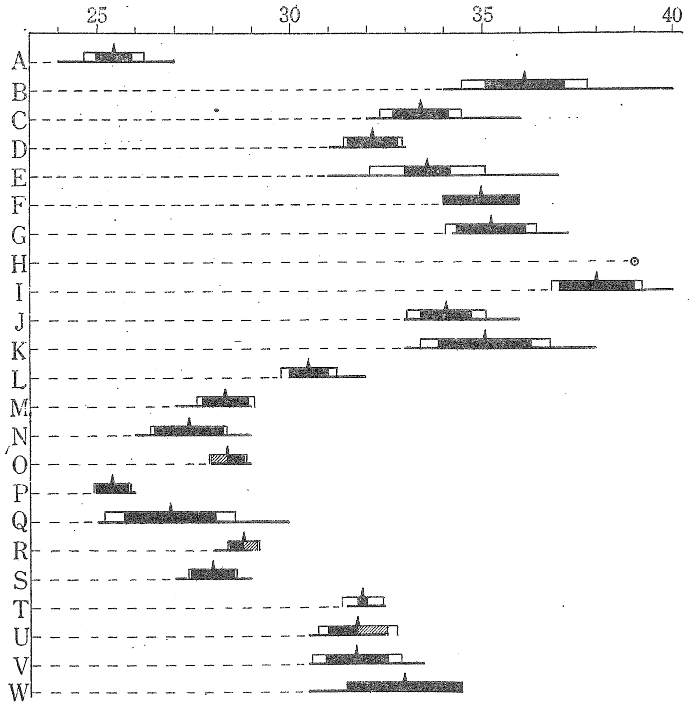

Fig. 43. Showing variation in number of abdominal vertebrae of Japanese rajids. In each species, the horizontal heavy line indicates total variation of the sample; the mean is indicated by a small triangle which projects upward; the solid area is the extent of 2 standard errors on each side of the mean; the hollow area delimits one standard deviation on each side of the mean; the hatched area indicates 2 standard errors in case the extreme range of total variation is yet smaller than the extent of 2 standard error; the guide line is broken. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi* including *smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti* including *porosa tobae;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

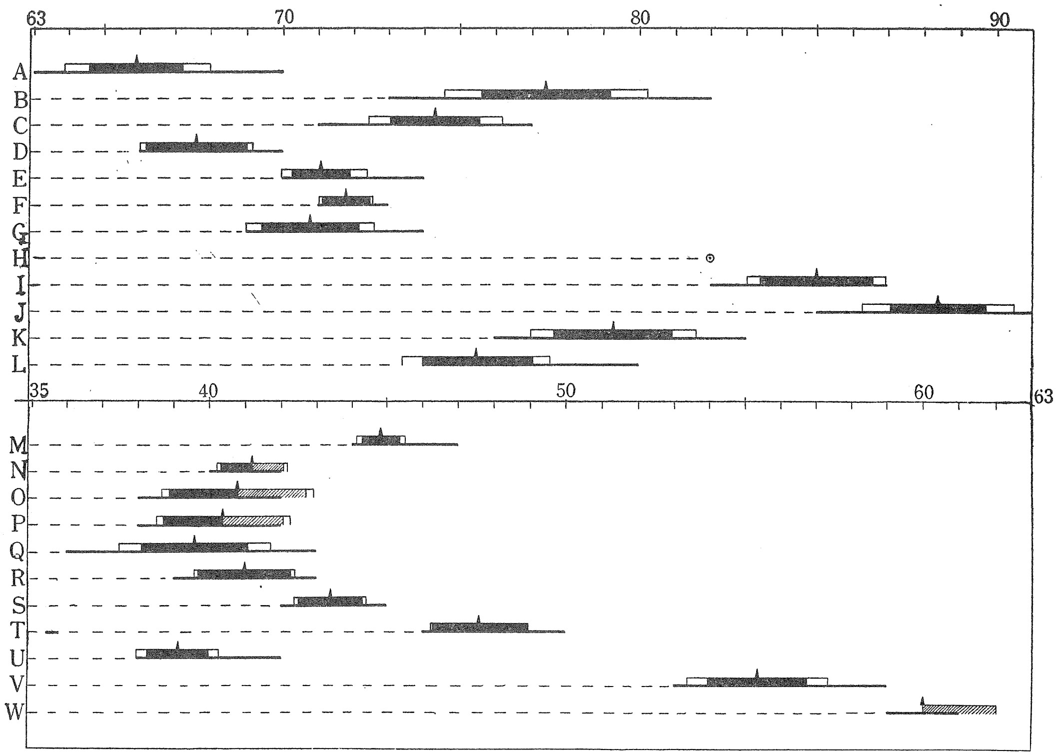

Fig. 44. Showing variation in number of precaudal vertebrae of Japanese rajids. The graph is illustrated by the same method as in case of Fig. 43. In this Fig., especially in comparison with the preceding Fig., the range of transpecific variation is distinct between the two major forms of the rajids with a boundary of about 60 in number of the vertebrae. For abbreviations, see Fig. 43.

3. Discussion

1). Use of the vertebral counts in taxonomy

It is a well known fact in the teleosts that the variation in the vertebral counts tends to change with more or less regularity according to the physical condition of the environments where the fish inhabits. The character, on the other hand, is usually found to be a fundamental phylogenic rather than physiological one within the limits of the variations. In distinguishing the character either phenotypically or genotypically, the writer believes that the characteristics in question in the case of our rajids may serve at least to provide a designation of subgeneric ranks, which were classed into four groups on the basis of precaudal counts aforementioned. Nevertheless, the counts cannot be used for establishing a specific demarcation since the character shows gradual change from species to species, overlapping some frequency in each subgenus.

When these characteristics are examined, the differences between groups of species seem valid for the taxonomy and phylogeny of Japanese rajid fishes, because such important features as found in their claspers are generally parallel with the traits which are maintained in this character (cf. Fig. 21). Whereas, as may be expected, the counts do not appear as a specific constant, but are generally useful as a partial index of the overall fundamental character.

2). Variation in the vertebral counts in relation to geographical distribution

Fish taxonomists have accumulated a good deal of useful knowledge on this subject in establishing a modern species concept, notably in teleosts which inhabit different localities and which have evolved many differentiated forms. But we possess much less literature on this subject, since the best research has not dealt with elasmobranch fishes.

It may obviously be assumed from the present work that the colder water members of Japanese rajids have more numerous vertebrae than the warmer water representatives. Further, this phenomenon seems to have some relationship to their geographical distribution as is the case with various teleosts, in which the number of vertebrae depends upon the physico-chemical condition at the time when vertebral organization takes place. Applying the theory in this case, we may consider the relation between the water temperature at which the adult females with egg-capsules were caught and their vertebral counts (Fig. 45). As indicated in this figure there seems to be a positive correlation between the numbers of abdominal and of precaudal vertebrae and the water temperature where those parent females were caught. Further, from this figure it is also apparent that the precaudal rather than abdominal segments of the backbone vary from species to species, and seem to show the decrease of the vertebral counts with the increase of temperature. Although the precaudal counts may be used as a subgeneric character, as already mentioned in the preceding section, the character seems to correlate more or less with its geographic distribution.

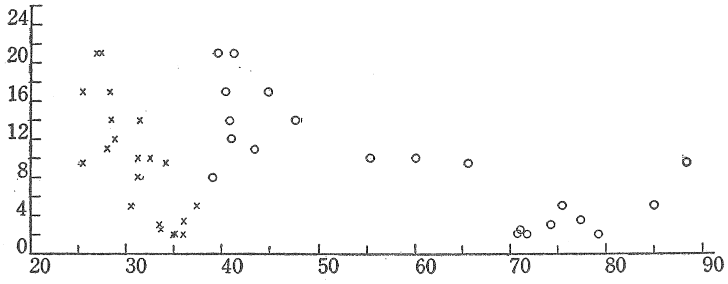

Fig. 45. Showing relationships between the water temperature where the parent females of 21 forms of Japanese rajids were caught and the numbers of abdominal and of precaudal vertebrae. Temperature (°c), ordinate; vertebral counts, abscissa; cross, abdominal; circle, precaudal.

Another aspect of variation in the character concerns the question of the range of valency with which the two forms do not intermingle between each other.

Thus, the character of the diverse forms that constitute Japanese rajids suggests two main phyletic lines, but the interpretation of this matter cannot be regarded as certain.

3). Correlation between number of vertebrae and other internal character

In the present item the writer has only dealt with the relation between the number of vertebrae and that of turn of the intestinal valves. It is found that the species having a relatively higher number of vertebrae tend on the whole to have larger number of turns of the intestinal valves, and this parallelism between the two characters seems to be dependent on the condition where the meristic organization takes place. Further, the degree of correlation between the number of the abdominal vertebrae and that of the intestinal valves is considered to be greater than that between the number of the precaudal ones and the number of the intestinal valves (Fig. 46). The writer must make a plausible interpretation of these facts in the future, taking up a good many more experiments. But as to the reason why successive changes in number of the vertebrae are attributed more to genealogical pedigree than to adaptive process, as compared with the changes in the intestinal valves, the present writer argues in favour of the following evidence. It is clearly found in the foregoing description that the number of vertebrae is divided into two series of groups of species, which are divergently radiated with a boundary of 60 in the number of precaudal vertebrae. The number of intestinal valves, on the contrary, varies in direct proportion between the two groups of Japanese rajids, from five to thirteen or fifteen, of the number of the valves (cf. Table 10). Such being the case, the present writer can safely affirm that the variations in number of the vertebrae in species or groups of species of Japanese rajids are indicated principally as phyletic pedigree rather than as adaptive differentiations.

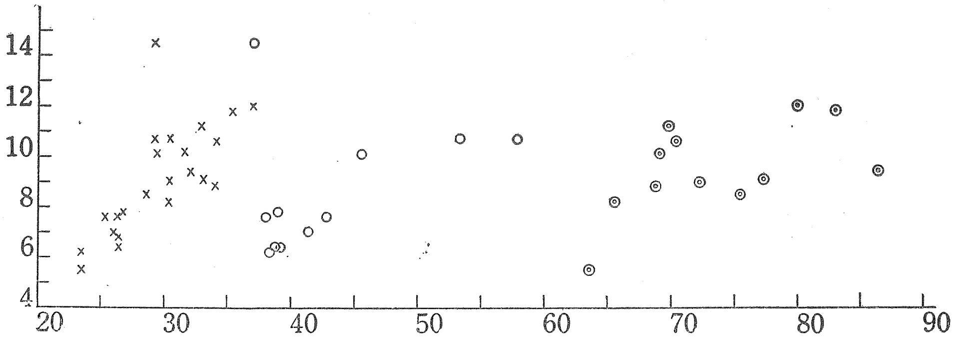

Fig. 46. Relationships between mean value in number of the intestinal valves (ordinate) and those in the abdominal and precaudal vertebrae (abscissa), especially showing parallel relation between numbers of the valves and of the abdominal vertebrae (cross). Circle and double circle represent precaudal vertebrae of southern and northern form, respectively.

In conclusion, therefore, the observed differences in the degree of gradational variability in the vertebral counts may have basically been caused by genetic factors on one hand and partly influenced with less regularity by the effect of the environmental conditions on the other.

d. Intestinal valves

1. Description in general

The knowledge of the spiral valves and its application to the taxonomy of Japanese rajids is scanty up to the present day, except for the findings made by the present writer (Ishiyama, 1952, '55). As regards the organ of the elasmobranchs, however, a number of valuable contributions have been given by several authors, such as Gegenbauer (1870), Parker (1879), Mayer (1897), Garman (1913) and White (1936, '37). White has classified the elasmobranchs into three types according to the manner of the spire of the valves, such as scroll, spiral and ring. Of the three, the spiral type has been regarded as referable to the Heterodontea, the Squalea and the Platosomeae.

The number of turns or gyrations of the spiral valves of the fish varies greatly among the elasmobranchs as has already been noticed in the past. But, since the valves are thought to have developed from the typhlosoles of cyclostomes and invertebrates to increase the surface of the intestinal canal by which absorption and digestion of food take place, it would be assumed that the principle affecting the variation of number of the valves might be similar to that in the pyloric coeca of the teleosts. Whereas, actually the variation in the number of the spiral valves in any species is usually slight. Accordingly, it is the main purpose of the present study to obtain an adequate answer to the question whether or not the feature of the intestinal valves is useful for separating Japanese rajids into species or some groups. Further, the category so far used to separate, if possible, any form with considerable certainty will be considered to be valid or not depending on the phyletic meaning of the groups of the fish.

With regard to this organ, the present writer has examined particularly the features as well as the number of gyrations of the valves in different species, from a viewpoint of taxonomy, and drawn the conclusion on the differentiation of the organ.

2. Comparison of the intestinal valves

The intestinal valves in Japanese rajids are found to be of the "spiral type", according to the scheme given by WHITE, and the organ is made up of a very thin membrane covered with microscopic villi, excepting the species **U**, in which the valves are much thickened (**U** in Fig. 47).

So far as the present investigation is concerned, the number of gyrations of the valves varies 5 to 15 in Japanese rajids, the variation not being remarkable not only in the groups but also in the same species. It is worthy of mention here that the trend

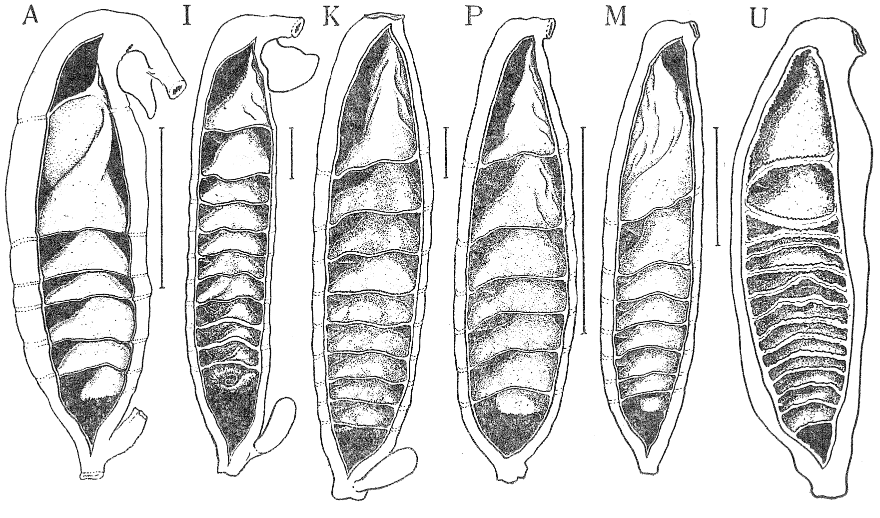

Fig. 47. Spiral valves of the intestine in six forms of Japanese rajids, especially showing interspecific variations in features and in number of the valves based on which six groups were classed. A, *Breviraja tobitukai;* K, *Rhinoraja kujiensis;* I, *B. smirnovi smirnovi;* M, *Raja kenojei;* P, *R. macrophthalma;* U, *R. pulchra.* Scales represent 2 cm.

in fluctuation of the valves and the range in number has little difference between the northern and southern forms, though they vary much in several other characteristics mentioned elsewhere. Namely, the least number of valves among Japanese rajids thus far examined is found in species A of the northern form and in species P of the southern form, and the greatest number is found in the species F, H, I (I′) and U, ranging from 11 to 13 and from 14 to 15 in the respective form. Further, it appears that the number tends to increase from species to species in the northern form more rapidly than in the southern one. For convenience′ sake Japanese rajids may be classed into six groups in respect to the number of valves: one with few valves (from 5 to 6), another with intermediate number of valves (from 8 to 9), and a third with numerous valves (from 10 to 13) in the northern form; a group with few valves (from 5 to 7), another with intermediate number of valves (from 8 to 10), and a third with numerous valves (from 11 to 15) in the southern form. These are respectively called here groups 1, 2, 3, 4, 5 and 6, which are to be assigned to the species belonging to each group (Table 10).

Table 10. Variation in number of the spiral valves of the intestine in Japanese rajids. Number of specimens examined in each species is parenthesized. S. D., standard deviation; other abbreviations, as follows: A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G. *B. aleutica;* H, *B. parmifera;* I, I′, *B. smirnovi smirnovi* including *smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, Q′, *R. porosa meerdervoorti* including *porosa tobae;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

Species	Range	Mean ± S. D.	Group	Species	Range	Mean ± S. D.	Group
A (13)	5 — 6	5.5 ± 0.50	1	M (5)	7 — 8	7.6 ± 0.48	4
B (10)	10 — 11	10.6 ± 0.49	3	N (5)	5 — 7	6.4 ± 0.80	4
C (7)	8 — 10	9.0 ± 0.54	2	O (5)	6 — 7	6.8 ± 0.40	4
D (5)	8 — 9	8.2 ± 0.40	2	P (5)	5 — 7	6.2 ± 0.75	4
E (9)	10 — 11	10.2 ± 0.41	3	Q, Q′ (12)	7 — 8	7.6 ± 0.47	4
F (5)	11 — 12	11.2 ± 0.40	3	R (5)	7 — 8	7.8 ± 0.40	4
G (5)	8 — 9	8.8 ± 0.40	2	S (5)	7	7.0 ± 0.0	4
H (1)	12		3	T (6)	9 — 11	10.1 ± 0.28	5
I, I′ (6)	11 — 13	11.8 ± 0.89	3	U (6)	14 — 15	14.5 ± 0.15	6
J (5)	8 — 10	9.4 ± 0.80	3	V (8)	10 — 11	10.7 ± 0.18	5
K (7)	9 — 10	9.1 ± 0.35	2	W (7)	10 — 11	10.7 ± 0.14	5
L (6)	8 — 9	8.5 ± 0.50	2				
Total range	5 — 13			Total range	5 — 15		

3. Discussion

1). Use of number of the intestinal valves in taxonomy

Though considerable differences of the intestinal tract are expected in various physiological process and in relation to the correlated organs in the same species which ranges all over the world from tropics to the temperate zone, as Rensch (1931) has shown in the intestinal tract, the characteristics related to nutrition have often been confirmed to indicate a taxonomic integrity in some groups of the teleosts (Hubbs and

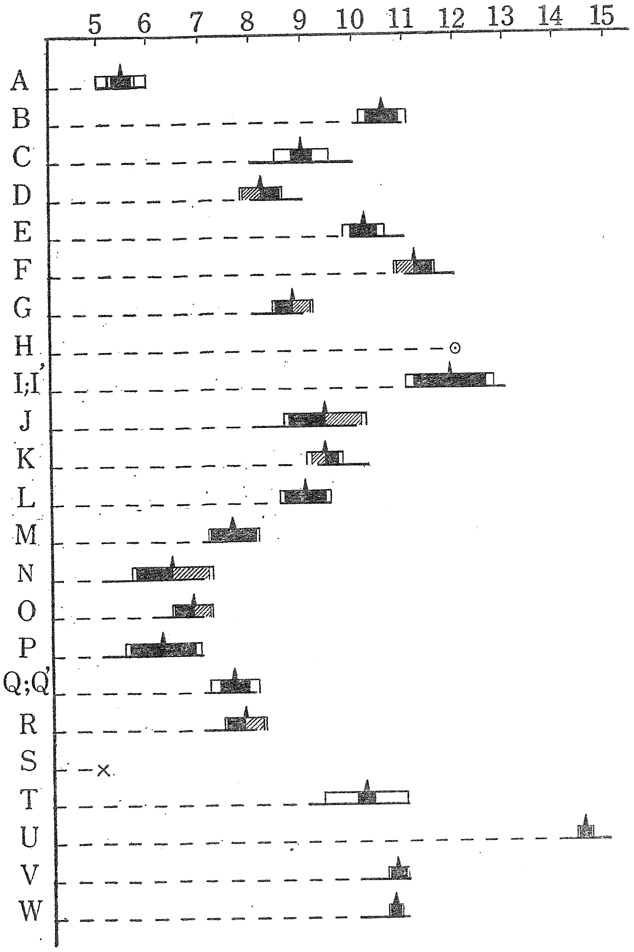

Fig. 48. Showing variation in number of the intestinal spiral valves of Japanese rajids. The graph is illustrated by the same method as in case of Fig. 42. In this Fig., especially in reference with the preceding table, the variations in both intra- and interspecific relations are less than those found in the number of vertebrae (Figs. 42 and 43). For abbreviations, see Table 10.

TURNER, 1939; BERNER, 1948; KAFUKU, 1952).

Differences in the number of the spiral valves of Japanese rajids are believed to be less important than other internal features in separating the genera or the species among the related forms because it has been discovered that the number must have the range of almost the same degree in many species, and varying degrees of overlapping or separation between any related species may fail to give a fine distinction if a lot of specimens are examined. But, it may be taken as certain that the species having such variant characteristics in question as those in the two species **A** and **U** can be used in clearly distinguishing their relatives.

2). Geographical variation of the number of intestinal valves

GEGENBAUR has pointed out that the small number of valves in *Chimaera* *monstrosa* shows its being in a primitive condition. However, WHITE has stressed that this tendency may be a puzzle because of finding either a tendency toward multiplication or toward reduction in the derived families. And, she has suggested that the variation in the number of the valves in the spiral type, in which the Platosomeae is included, is paralleled with the variation in the heart valves.

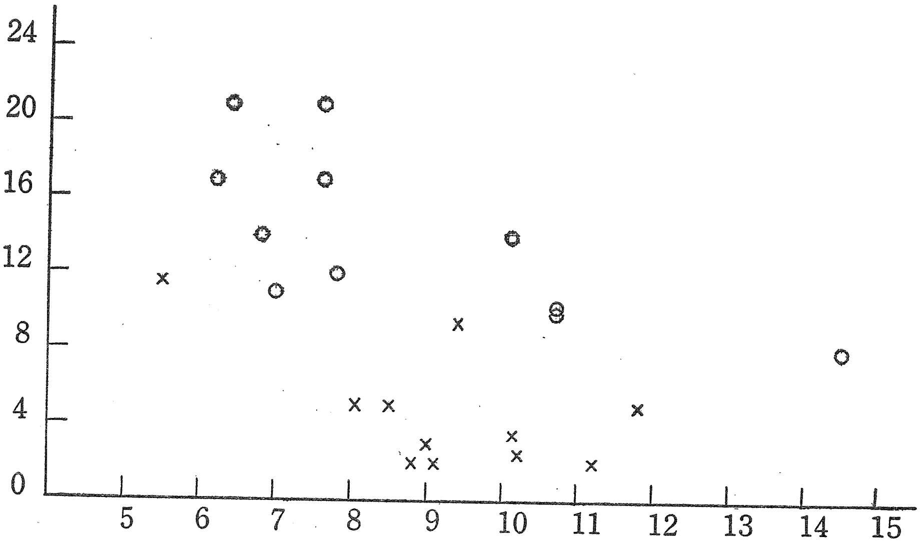

Fig. 49. Showing relationship between the mean number of spiral valves of the intestine and the water temperature (°c) where the parent females were caught. Temperature, ordinate; number of the valves, abscissa; cross and circle, the northern and southern form, respectively.

What is important for this discussion is whether such variation indicates the phyletic relation or merely an adaptive process. To solve this question the present author has examined the number of the intestinal valves of some fishes of the related families of batoid fishes obtained in our waters. Based on his examination with a comparative investigation of the variations in the features, the writer has come to the assumption that the variation in the number of the intestinal valves must be considered as a series of geographical characters which may have been acquired by the needed specialization in an adaptive zone.

As already mentioned in the preceding section and as shown in Table 10, Japanese rajids may be classified into six groups according to the number of valves, and the grouping is seemingly related to the geographical distribution of the fish. For example, the first group, which involves only one species A in the northern form and is characterized by having the smallest number of valves, is found only in the southernmost region, as stated elsewhere. The second and the third groups, which involve the remainders of the same form and have larger number of the valves, inhabit either the deep-sea region or the extreme north. The similar relation is also found in the two groups of the southern form. These facts may contribute much in formulating the hypothesis that the number of valves is an adaptive character probably correlated with the climatic factor. But, it is interesting to note here that a fish with a smaller or larger number of valves is occasionally found in the species thought to be either primitive or specialized as a whole.

With regard to the reason why the valves are more numerous in the northern or deep-sea species than in the southern or shallow-water ones we have to quote the hypothesis proposed by MATSUBARA (1943, p. 158) on the variation of the pyloric coeca in Japanese scorpaenoid fishes: "The stronger or larger amount of the ferments are fundamentally necessitated in fishes inhabiting in the colder waters than in warmer waters to facilitate normal digestion. The fact that the coeca are more numerous in northern form is originated to increase such value." This may also be applicable in this case. This hypothesis may be supported by the fact that successive changes in the number of the intestinal valves seem to correlate to some extent with changes of the temperature in the sea where parent females with matured eggs were caught (Fig. 49).

Taking these into consideration, the number of the intestinal valves in Japanese rajids may be estimated as a specific character to be used to some extent in our classification of the fish.

e. Heart valves

1. Description in general

The heart valves of the elasmobranchs have been studied by some ichthyologists from viewpoints of taxonomy and phylogeny of the fish. GARMAN (1885, 1913) gave a somewhat extensive description of the organ. WHITE (1936, '37) made a much more intensive study of this organ leading to her conclusion, when she had examined a large number of species of each group of the animal taken from all the seas in the world. These works have made valuable contributions for establishing the knowledge of higher categories in the systematism of this group of fish. We are rather lacking in the knowledge of dealing with such a small group as Japanese rajids. Therefore, it is the main aim of this chapter to determine whether or not the characteristics found in the heart valves of Japanese rajids are important for the systematism of this group, and how much the results obtained from this study will agree with the past authors.

The conus arteriosus of the ventricle, which is formed by a relatively thickened muscular wall in the rajids, is furnished internally with several rows of the semilunar valves, as in other elasmobranchs (Fig. 50). In the preparation of the samples examined, the ventral border of the conus arteriosus was dissected on the mesial line,

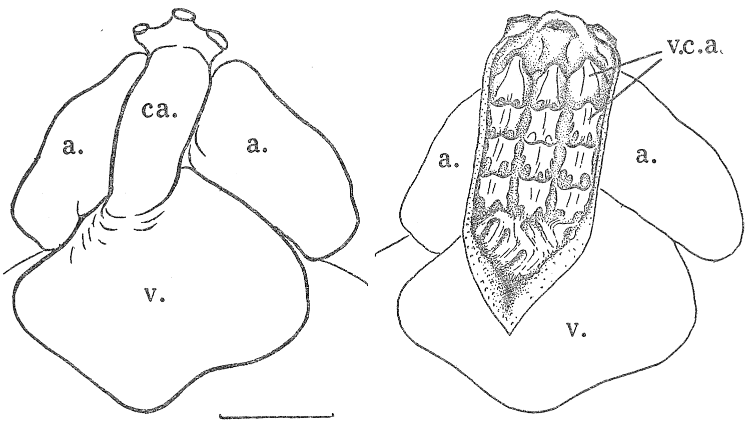

Fig. 50. Ventral aspect of the heart and its valves in the conus arteriosus of *Raja kenojei*. a., auricle; ca., conus arteriosus; v., ventricle; v. c. a., valve of conus arteriosus. Scale represents 1 cm.

and then stained with a dye, cyanine 5 R (KUSAKABE, 1953), for a few seconds. The heart valves thus arranged in both longitudinal and transverse series were clearly observed *in situ*.

The heart valve varies to some extent even in members of the same species. The variations are found in the number, location and feature of the valves. Accordingly, it must be emphasized that a considerable number of specimens of the same species should be examined so as to be useful for determining even one of the contributing characteristics in establishing a classification.

In the present study, the author has examined the features of the heart valves using a considerable number of specimens of all the Japanese rajids, and the results obtained were compared with the characteristics found in the organ of other batoid fishes in order to develop a hypothesis that would seem to correlate with differentiation of this organ throughout batoids.

2. Comparison of the heart valves

From the number and the manner of arrangement of the heart valves in the Japanese rajids dealt with, the following four groups may be assorted, abbreviated herein as Group-V^1, -V^2, -V^3 and -V^4, respectively. Group-V^1 involves fishes referable to the two species 𝔸 and 𝕃. In this group (Fig. 51 𝔸), the organ is in

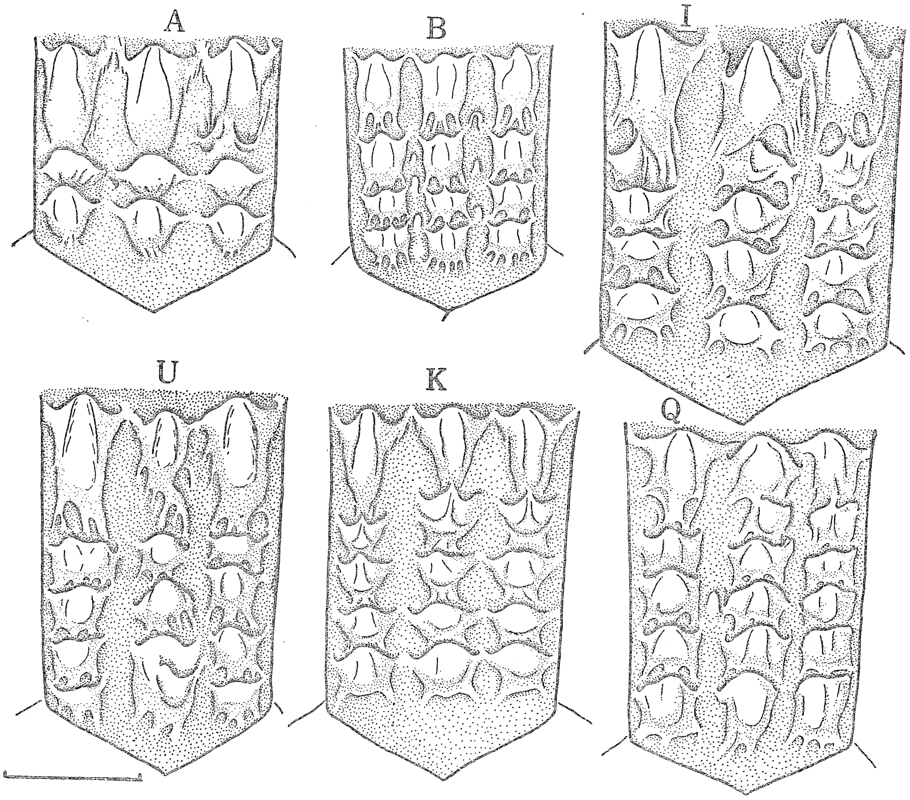

Fig. 51. Heart valves in six forms of rajids, especially showing interspecific variation in the number of valves in a longitudinal row. A, *Breviraja tobitukai*; B, *B. isotrachys*; I, *B. smirnovi smirnovi*; K, *Rhinoraja kujiensis*; Q, *Raja porosa meerdervoorti*; U, *R. pulchra*. Scale represents 1 cm.

many cases composed of three tiers of valves, but sometimes has four tiers in a longitudinal row. Group-V^2 is exemplified by the following many species which are regarded as both northern and southern forms, namely B, C, D, E, F, H, I (I′), M, N, O, P, R, S, T, U, V and W (Fig. 51 B, I, U). In these species, the valves are developed as four tiers in three rows in most cases. Group-V^3 may be referred to such three species represented herein as G, J and K, whose organs possess four or five tiers in three distinct rows (Fig. 51 K). Group-V^4 involves only one example referred to Q(Q′), in which the organ is observed to have from four to five or even to six tiers in three rows (Fig. 51 Q).

In most of Japanese rajids, the heart valves are thus found to have four tiers of valves in three rows, and the fish may be arranged conventionally into four groups as mentioned above. The least number of tiers in the valve is found in Group-V^1, in which the species A has three tiers of valves in a row in most cases. On the other hand, the greatest number of tiers is represented by Group-V^4, in which the species Q usually has from four to five tiers and occasionally six in a row. The counts of tiers of the valves in each species of Japanese rajids may vary as shown in the following table.

Table 11. Frequency distribution in number of tiers in the longitudinal rows of the valves of conus arteriosus in Japanese rajids. Number of specimens in each species is parenthesized. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, I′, *B. smirnovi smirnovi* including *smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, Q′, *R. porosa meerdervoorti* including *porosa tobae;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

Tiers Species	3	4	5	Tiers Species	3	4	5	6
A (12)	10	2	—	M (9)	—	7	2	—
B (8)	—	8	—	N (8)	—	8	—	—
C (9)	—	9	—	O (10)	—	7	3	—
D (4)	—	4	—	P (10)	—	9	1	—
E (6)	—	6	—	Q, Q′ (13)	—	7	5	1
F (5)	1	4	—	R (8)	—	5	3	—
G (5)	—	2	3	S (9)	—	7	2	—
H (1)	—	1	—	T (8)	—	5	3	—
I, I′ (7)	—	7	—	U (10)	—	8	2	—
J (9)	—	5	4	V (4)	—	4	—	—
K (5)	—	2	3	W (4)	—	4	—	—
L (4)	3	1	—					

3. Discussion

Use of the heart valves in taxonomy

As regards the heart valves of the Japanese rajids, the present writer has focused his attention on, (i) the number of tiers in a longitudinal row, and (ii) intra- and interspecific variations of features of the valves. These characteristics, however, seem to be less important for specific definition than other anatomical features treated from a viewpoint of taxonomy because we have found imperceptible variations between species and even between groups of species, and found many individual variations. However, the features of the organ thus far examined may be supposed to have the following traits: i) the number of distinct longitudinal rows is three without exception; ii) the number of tiers in a row ranges from three to six, and this low counts predominates in the northern form as compared with the southern form; and iii) the valves have rather well-defined features in the southern form than in the northern one.

Consequently, the features of the heart valves, so far as the Japanese rajids are concerned, may be recognized as mere characteristics in distinguishing larger groups of species in the batoids. The hypothesis may be applied to the following items.

(1) Relation of the features of the heart valves to phyletic trends supposed from other anatomical features:-

GARMAN (1913) conjectured that "rather generally the number of rows of valves in the conus of the Antacea decreases with advance in rank, with increase in specialization. In the Platosomeae the rule does not hold so well." This opinion has been generally accepted by DANIEL (1928). On the other hand, WHITE (1937) stated that: "In the Platosomeae, the number of tiers in each longitudinal row is rather increased, reaching six and sometimes even seven, but in some species they are very few in number. The tendency in the elasmobranchs is for duplication of valves rather than reduction, and this duplication may take place transversely as well as longitudinally." Such being the case, the conclusions of the two authorities are opposite each other especially in respect to the Antacea but they are rather in agreement in respect to the Platosomeae. It is also the case with our rajids. Namely, in the northern form, which is thought to be more primitive on the whole than the southern one, the heart valves are relatively small in the number of tiers in a row with a few exception. Further, it may be noticed here that the least number of tiers in a longitudinal row is represented by the species **A**, which is believed to have many generalized features, as mentioned elsewhere. Besides, the largest number of organs is found to exist in the subspecies Q and its relative Q′, whose characteristics are generally the most specialization in the related members.

(2) The heart valves may be supposed to represent a mutable feature:-

In the present item, the writer has attracted attention to the following two facts: i) The specialization of the heart valves may have occurred in the species specifically:- Although the features of the heart valves of Japanese rajids are seemingly expected to show phyletic trait in some cases, as already mentioned, the organ, on the contrary, may be assumed to have evolved species specifically. For example, in the species referred to the northern form is one having the characteristics of the organ without any phyletic relation, but of seeming importance in the species specifically. To be more exact, although the two groups of species, such as **F** and **G**, and **K** and **L** belong different phyletic stems in the northern form, they are assorted into another two groups, such as F and L, and G and K, in respect to the characteristics of the organ (cf. Table 11). A similar phenomenon is noticed in the southern form, the two groups of species O and P, and T and U, for instance, have mostly four tiers in a longitudinal row, though the two groups have no close relation to other anatomical features. It may be thought, therefore, that the features relating to the heart valves in rajid fishes must have resulted from much more complex causes than were originally supposed. ii) Variations of the heart valves in other batoid fishes:- In order to make a comparison of the characteristics of the organ between the rajids and other batoids, the present writer has examined several representative species of the families of the batoids as shown in Table 12 and Fig. 52.

Table 12. Showing the characteristics of the heart valves in nine species of five representatives. Number of specimens examined is in parenthesis.

Family	Species		Heart valves	
			No. row	No. tiers in a row
Rhinobatidae	*Rhinobatos schlegeli*	(2)	3 — 4	4
	Rhynchobatus djiddensis	(2)	3 — 4	6
Platyrhinidae	*Platyrhina sinensis*	(2)	3	4
Dasyatidae	*Dasyatis akajei*	(2)	3	4
	Urolophus aurantiacus	(2)	3	4
	Gymnura japonica	(2)	3	5
Myliobatidae	*Holorhinus tobijei*	(2)	3 — 4	5
Torpedinidae	*Narke japonica*	(2)	3	2

It may be seen from these table and figure that the characteristic in question varies a little as a rule even in different families, except for the Torpedinidae. In *Rhinobatos* (1, 2 in Fig. 52), there are four tiers set in three or four longitudinal rows with small accessory valves. But, there are six tiers set in three distinct longitudinal rows with incomplete valves forming a row, in other species of the same

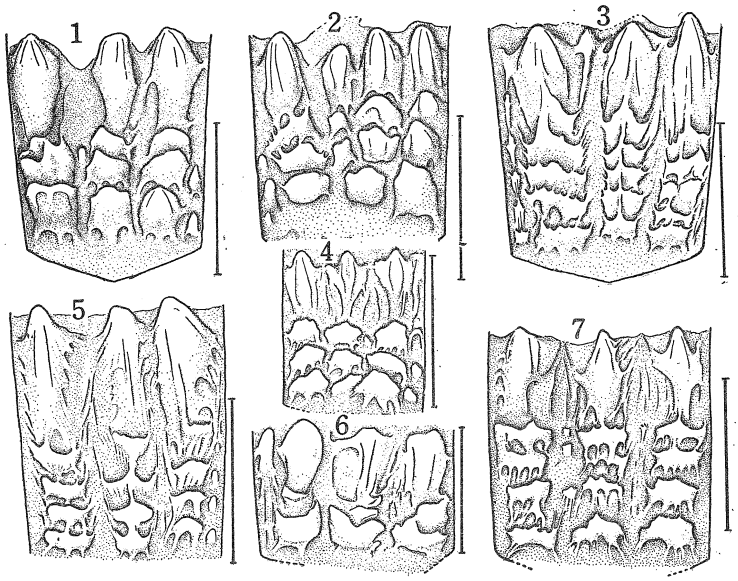

Fig. 52. Heart valves in six representatives in batoid fishes, especially showing intra- and interspecific variations in number and arrangement of the valves. 1 and 2, *Rhinobotos schlegeli;* 3, *Rhynchobatus djiddensis;* 4, *Platyrhina sinensis;* 5, *Gymnura japonica;* 6, *Narke japonica;* 7, *Holorhinus tobijei.* Scales denote 1 cm other than 6 with 5 mm.

family, *Rhynchobatus* (3 in Fig. 52). Further, in both *Gymnura japonica* and *Holorhinus tobijei*, the heart valves are found to have five tiers of three longitudinal rows though these two representatives are thought to have diverged greatly in their phyletic relation (5, 7 in Fig. 52). Moreover, there exist in *Platyrhina sinensis* (4 in Fig. 52) four tiers of three longitudinal rows with undifferentiated valves in a row, and there are very irregular valves with two or three tiers of three or four longitudinal rows in *Narke japonica* (6 in Fig. 52).

To summarize the above, the author has come to the conclusion that the feature of the heart valves may be no more than a variable characteristic which is merely of specific importance in some species and in some particular group of the batoids as its diagnostic sometimes. As the two cases mentioned are well relevant to our rajids, the writer has inferred that the variation is doubtless an indication of mutating feature without any relationship suggestive of a tendency associated with genealogical trends.

f. Placoid scales and its derivatives

1. Description in general

Some information on the placoid scales of the elasmobranchs has been given by many authorities, and the features in the scales have been regarded as most important characters in the taxonomy of the fish. In fact, many elasmobranchs have their skin covered with placoid scales or its derivatives to some extent, varying from group to group. In the Rajidae, the body is usually covered with scales on both surfaces more or less regularly, but the dorsal side is more setose with small or spine-like denticles than the ventral, where a small area is furnished with minute scales or is smooth, in most cases.

To the best of the present writer′s knowledge, the feature or genetic regularity in the scales of rajid fishes has not been treated of in the taxonomy to a comprehensive system. The main aim of the present scheme is, on one hand, to give some noteworthy knowledge of identifying species or group of species, and, on the other, to arrange those characteristics found in the scales in a compact system.

2. Comparison of placoid scales

1). Features and tracts of placoid scales in Japanese rajids:

A thorough examination and comparison of the scales of all the species dealt with in this study including many specimens ranging from the adult to very young fish has shown that there is a remarkable difference in both features and tracts of scales between the northern and southern forms. Usually, the scale has a broad base and sharply pointed process in the northern form, whereas in the southern one the scale mostly has a spiny process with no broad base.

As regards the tract of scales, it is much diversified between the two forms. In the northern members, the entire dorsal surface of the body is usually crowded with scales, visibly so in the tail, which is conspicuous in the young fish, but in the southern members scales are sparsely present on the body, on the whole, retaining some definite tracts and leaving a large smooth area in the disc.

It some species of rajid fishes, some of the scales on the dorsum develop into large spines with more or less regularity, and the characteristics in number and in arrangement of the enlarged scales are among the most important marks of a species or groups of species. Generally, large spines are developed on the nuchal and shoulder regions, on upper margins of the orbits, and on mid-dorsal line running backward from the nuchal to the dorsal fins. Besides, a pattern of backlar spines, the so-called alar spines, never fail to occur on the marginal portion of each pectoral fin of the matured male. Of these, the spines developed on orbit, shoulder region and mid-dorsal line are more or less different in the mode of development between the two major forms of Japanese rajids. These differences in the features and tracts of the scales between the two forms are mentioned in detail with the following scheme.

2). Mode of genesis of the scale in both ontogenic and genealogical series:

As already annotated above in the northern form, the scales are developed on the whole dorsal side of the body in the young or at least on the tail in the adult, whereas in the southern form the denticles mostly occur in much less degree even in the adult. Although these diversities in the spination are found to exist between the two aforementioned, there are many phases in the degree of development, varying from species to species or with the growth of the body even in a single species in the respective form. Thus, on the basis of the characteristics in spination outlined, Japanese rajids may be divided into two types and called herein Types Sc^N and Sc^S, which are referred respectively to the northern and southern forms.

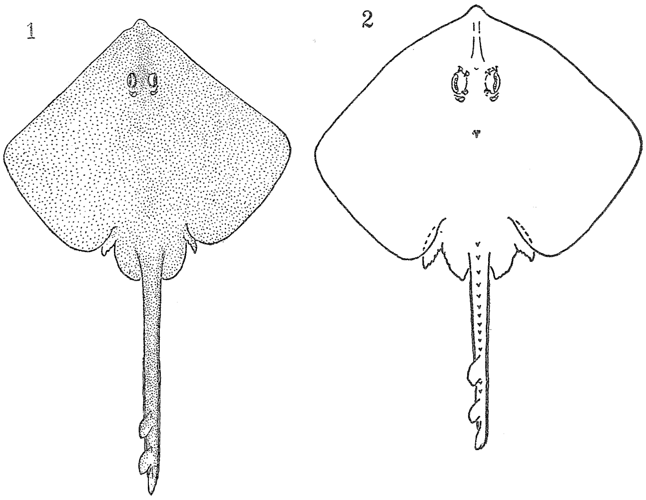

Fig. 53. Showing two types of the spinations in the young of Japanese rajids. 1, northern form; 2, southern form.

Type Sc^N is characterized by having the scale with a broad, stellate base and sharply pointed process, and in the fishes of this type the dorsal surface is entirely covered with denticles at least in the young and the tail, in the adult. The spination of the disc including the pelvic fin, however, becomes either sparse or setose in the adult in some degree, and the degree of spination is more or less different in species or between the sexes. Further, this type may be subdivided into six subtypes, Sc^{NA} to Sc^{NF}, mainly based upon the degree of development of the prickles, the number and the mode of arrangement of enlarged spines or thorns found in the adult.

Subtype Sc^{NA} is modeled after the characteristics in the spination found in the species A (Fig. 60 A$_1$); the spination on the whole dorsal surface of the body is always uniformly and densely covered with numerous prickles without enlarged spines, and no differences are found in spination regardless of the age and the sex even in the adult, excepting the alar spines*). Subtype Sc^{NB} is exemplified by the two species B and C (Figs. 61, 62; B_1 and C_1); the dorsal surface of the disc is also covered with numerous pricklly scales even in the adult stage, but this subtype is distinguished from the preceding in most cases by having a row of nuchal and tail spines and one shoulder spine. Some differences in the mode of development of the prickles and the spines are found to exist between the two species referred to this subtype; the prickles covering dorsal surface of the body in the species B are denser and smaller in size than those in the species C, and enlarged spines developed on nuchal and shoulder regions are usually well marked in the species B, though they are obscure in the species C. These differences in the spination between the two species are more distinct in their adult stage than in their young stage.

Subtype Sc^{NC} involves the two species J and L (Figs. 70, 71; J_1 and L_1); the spination characterizing this subtype is the presence of a row of large spines running along mesial line of the tail together with numerous prickles covering dorsal surface of the body even in the adult. When the species J is compared with the species L in spination, the former is distinguished from the latter by having mid-dorsal belt of somewhat enlarged prickles developed on the disc, though the latter has no such pattern of enlarged scales, but has a row of nuchal spines, which the former has not.

Subtype Sc^{ND} may be referred to the spination revealed by the three species D, E and F (Figs. 63, 64; D_1, E_1 and F_1); the spination characteristic of this subtype is noticed by remarkable reduction in the disc of the adult, leaving the mid-belt and marginal pattern of the prickles, and by a row of enlarged spines set on the tail. But the three species are different from one another in spinations as follows: the nuchal and shoulder spines are absent in the two species D and E, while they are present in the species F, and in the species E and F the tail spines are usually well developed set regularly in a row, but in the species D they are obscure, occurring at places. The degree of reduction in the spination revealed in the dorsal surface of the body with the growth of the fish appears greater in order of D, E and F.

Subtype Sc^{NE} involves the three species G, H and K (Figs. 66, 67, 72; G_1, H_1 and K_1); the spination in this subtype is rather distinguished from those in the relatives by having a row of large spines running continuously from the center of disc to the dorsal fins, and by having one or two spines on each shoulder. By those patterns of the prickles and enlarged spines developed on the dorsal surface of the disc and on the tail, the three species can be distinguished from one another as follows: dorsal surface of the disc is more or less densely covered with numerous prickles in the adult of the species G and K, though it is smooth in its main portion in the species H, and the prickles of the species K are larger in size than those of the species G, but in the species H they are much more distinctively developed with a broad stellate base on the head; number of the large spines set on the shoulder is measured as two in the species H and K, but mostly one in the species G.

Subtype Sc^{NF} is modeled after the characteristics in the spination of the two subspecies I and I′ (Figs. 68, 69; I_1 and I'_1); the mode of spination in these examples appears similar to that of the species H, but the members of this subtype are discriminated from the latter; dorsal surface of the disc becomes almost smooth in the adult and subadult stages of this subtype, except for those prickles developed on the anterior marginal portion of the disc, the frontal and interorbital spaces of the eyes and on the

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* The occurrence of the pattern of the enlarged thorns is so generalized in the matured male of Japanese rajids that the thorns are excluded from the characteristics of this subtype, and so on.

basal portion of the tail. A group of two or four nuchal spines and a shoulder spine are also present in this subtype. A remarkable fact in this subtype is the occurrence of minute prickles on the dorsal lobe of the glans clasper, as mentioned elsewhere (cf. I and I′ in Fig. 3).

Type Sc^{S} is referred to the features of spination in the southern form; the scale is usually developed in spiny or enlarged prickle with no broad stellate base, and in young stage the spines developed with definite positions on dorsal surface with common tracts are much fewer than in the adult stage except the species W, and the body becomes more setose with age, giving specific and sexual differences. On the basis of these characteristics, this type may be classed into six subtypes, Sc^{SA} to Sc^{SF}.

Subtype Sc^{SA} involves those three species represented by M, T and V (Figs. 36 and 37; M, T, V); the spination characteristic in this subtype is revealed principally by the mode of development of the spines on the tail, i. e. a row of spines in the male and three rows of the same in the female run along the upper surface of the tail, and one nuchal spine mostly occurs in the center of the disc. Comparing the three species of this subtype in the degree of development, the manner of arrangement of the spines and prickles developed on the tail and the disc, the author has found some differences and discriminated them one another, viz., in the species M and T the spines running in irregular series along the mesial line of tail are numerous and well-developed (Figs. 36 M and 37 T), though they are rather few and weak in the species V (Fig. 37 V), and the nuchal spines in the adult of the species M are more numerous, varying from one to four in number in most cases, but in the other two species the spines occur usually as one, and the ventral side of the head is thickly furnished with minute prickles in the adult of the species T, though in the species M and V the distal portion of snout is only setose.

Subtype Sc^{SB} is represented by only one species U (U in Figs. 30 and 37); the spination in this subtype is rather similar to the preceding case, especially so in the male, but the female is distinguished from the relatives by having five rows of spines on the dorsal surface of the tail when matured. The manner of development of prickles and spines developed on dorsal border of the disc appears to resemble especially that of the species T.

Subtype Sc^{SC} involves but one species W (Fig. 86 W); the spination is singular in both young and adult stages, i. e. minute prickles are entirely but sparsely developed on the disc and the tail in the young in addition to the common tracts of large spines characteristic of the young of the southern form (W in Fig. 84), but the minute prickles disappear when the fish get into the adolescent stage. Further, the row of large spines set on the tail of the adult male is worn away in most cases or is reduced to a vestige in some occasions, but the spines in the adult female become thicker, set in three distinct rows (Fig. 37 W). Dorsal surface of the disc in the adult of both sexes is provided with rather similar tract of the prickles and spines, as in the case of the species T and V, but the present species bears numerous prickles on the snout and interorbital space.

Subtype Sc^{SD} is modeled after the spination revealed in the adult of species R (Fig. 36 R); the degree of development of the armature on the tail and nuchal regions is rather the same between the two sexes, having three rows of the tail spines and three to five nuchal ones, whereas anterior margin of the disc is more setose in the male than in the female, as is usual in this form. Ventral surface of the body is devoid of the spination except the distal portion of the snout.

Subtype Sc^{SE} is exemplified by the two species N and S (Figs. 36 and 37; N, S); the spination characteristic in this subtype is marked in the following respects; the spines on tail are set in three rows in the male, but in many irregular rows in the female which are numerous, irregularly covering the tail. Tail spines in a row are fewer in the species S than in the species N, but the reverse is the case with the orbital spines.

Subtype Sc$^{\mathrm{SF}}$ is referred to the manner of spination revealed by the three species, O, P and Q (Q′) (Figs. 75—79); the features of the spination of the adult male are rather similar to those found in the preceding subtype, in having three distinct rows of tail spines, but the present subtype can be distinguished from the preceding one in having five rows of spines arranged regularly on the tail of the adult female, in usual cases. The number of nuchal spines decreases in order Q (Q′), P and O, measuring respectively from 3 to 6, from 2 to 3 and from 1 to 2, in most cases, whereas the tail spines become thicker in order O, Q (Q′) and P (Fig. 36). The nuchal spines of species P is developed in a triangular position in many cases.

3. Discussion

1). Systematic significance of the scales in Japanese rajids

Although the features of the scales may provide us with some informal ways of finding a clever method of separating species or group of species in rajids, the characters vary so much even within a single species that it is not an easy task to obtain a compact knowledge responsible for a practical index in distinguishing any species including younger and older specimens. But on the basis of the characters mentioned in the foregoing section, the present writer has given the following key that may be useful for the heading of the present section.

1a. Type Sc$^{\mathrm{N}}$: Entire dorsal surface of the body more or less thorny with numerous prickles bearing stellate broad bases in the young stage without exception, but the spination of the disc in the adult is either as thick or fewer than that of the young, and the dorsum of tail is always wholly furnished with numerous scales even in the adult; sexual difference in the spination of the disc more or less obscure except the alar spines.

 2a. Subtype Sc$^{\mathrm{NA}}$: Dorsum of body entirely setose even in the adult stage; regardless of age and sex, present in spination without enlarged spines set on nuchal, shoulder and tail regions.............................. *Breviraja tobitukai* (A in Figs. 30 and 60)

 2b. Dorsum of the disc more or less setose in the adult stage, having either numerous prickles or smooth portion, but the tail is always covered with prickles with a row of enlarged spines.

  3a. Dorsum of the disc entirely setose even in the adult; a number of large spines set either on nuchal or shoulder region, or on both regions present or absent, the spine on nuchal, if present, is interrupted from that of the tail.

   4a. Subtype Sc$^{\mathrm{NB}}$: Both nuchal and shoulder spines present.

    5a. Prickles covering dorsal surface of the body very thick, but minute; both nuchal and shoulder spines apparent in most cases ....
    .... *B. isotrachys* (B in Figs. 35 and 61)

    5b. Prickles covering dorsal surface of the body rather sparse and large in size; both nuchal and shoulder spines somewhat obscure in many cases ....
    .... *B. trachouros* (C in Figs. 35 and 62)

   4b. Subtype Sc$^{\mathrm{NC}}$: Shoulder spine absent; if nuchal spines present, dorsum of disc is provided with prickles without noticeable pattern of modified scales.

    6a. Nuchal spines absent, but with a mid-belt of somewhat enlarged prickles running from nuchal to basal portion of tail .... *Rhinoraja odai* (J in Figs. 35 and 70)

6b. One to four, mostly three, nuchal spines present; basal portion of the pectoral fin somewhat sparse in matured male .... *Rh. longicauda* (L in Figs. 35 and 71)

3b. Dorsum of the disc partly setose in the adult due to reduction of the spination; nuchal and shoulder spine, or either present or absent, the nuchal one, if present, interrupted from that of tail.

7a. Subtype $\mathrm{Sc}^{\mathrm{ND}}$: Shoulder spine absent; if nuchal spine present, main portion of the dorsum of disc entirely naked when matured.

8a. Nuchal spine absent; basal portion of the pectoral fins more or less smooth when matured.

9a. Enlarged spines of the tail obscure, set at places; basal portion of the pectoral fin and posterior end of the pelvic fin sparsely thorny even in the adult stage, leaving a broad mid-belt of the prickles .... *B. abasiriensis* (D in Figs. 35 and 63)

9b. Enalrged spines of the tail distinct, set in a regular row; basal portion of the pectoral fin as well as the pelvic fin almost smooth, leaving a mid-belt of the prickles .... *B. diplotaenia* (E in Figs. 35 and 64)

8b. Two to four nuchal spines present; dorsum of the disc entirely smooth except anterior marginal portion, mid-belt and snout, which are sparsely armed in the adult .... *B. matsubarai* (F in Figs. 35 and 65)

7b. Both nuchal and shoulder spines present; dorsum of the disc wholly smooth or setose in the adult, if setose, row of nuchal spines is connected with that of tail, reaching to the dorsal fin.

10a. Subtype $\mathrm{Sc}^{\mathrm{NE}}$: A row of large spines presnt, running continuously rearward of nuchal region to dorsal fin; clasper devoid of prickles.

11a. Dorsum of the body thorny even in the adult, bearing numerous prickles, but basal parts of the pectoral fins are sparser in the adult.

12a. Prickles of the body somewhat thickened; a pair of large spines present on each shoulder; ventral side of the head smooth, excepting distal portion of the snout; a row of large spines set along mesial line of the disc always distinct ...... *Rh. kujiensis* (K in Figs. 35 and 72)

12b. Prickles on the body very small; one shoulder spine present on each side; ventral side of the head thorny; a row of large spines set along mesial line of the disc obscure, in some cases, reduced on its halfway point .... *B. aleutica* (G in Figs. 35 and 66)

11b. Dorsum of the body wholly naked on its main portion except for anterior marginal portion of the disc and inner margins of the orbit, where the prickles with broad stellate bases are sparsely developed .... *B. parmifera* (H in Figs. 35 and 67)

10b. Type $\mathrm{Sc}^{\mathrm{NF}}$: Two to four, usually 4, nuchal spines present; dorsum of disc wholly smooth except those portions with prickles marked in the preceding species; dorsal lobe of the glans clasper developed few minute prickles... *B. smirnovi smirnovi* (I in Figs. 35 and 68); *B. smirnovi ankasube* (I′ in Fig. 69)

1b. Type Sc^{S}: Dorsal surface of body in the young entirely smooth with the exception of large spines set on definite positions, except the species W, but the spination becomes more thorny with the growth of body, giving remarkable sexual difference to the character especially of the tail, in most cases.

13a. A row of large spines present on dorsal mid-line of tail in adult male, but three or five rows in adult female; only one nuchal spine present in most cases.

14a. Subtype Sc^{SA}: Three regular rows of spines present on the tail in female.

15a. Spines on tail sharp and thickened, developed in numerous number when matured.

16a. Nuchal spines two to four; ventral surface of head smooth except tip of the snout in adult fish .... *Raja kenojei* (M in Figs. 36 and 73)

16b. Nuchal spines one to two in most cases; ventral surface of head thorny by having minute prickles when matured .... *R. tengu* (T in Figs. 37, 82 and 84)

15b. Spines on tail rather few and reduced in size: nuchal spine mostly one or two: ventral side of head almost smooth except tip of snout ....*R. macrocauda* (V in Figs. 37, 84 and 85)

14b. Five or three rows of spines distinctly developed on the tail in matured female.

17a. Subtype Sc^{SB}: Spines on tail rather small in both sexes, but numerous in the adult, bearing five rows in female; spination in the young developed with common tract in the southern form ...... *R. pulchra* (U in Figs. 30, 37, 83 and 84)

17b. Subtype Sc^{SC}: Spines on tail usually reduced, worn out in adult male, but they remarkably thickened and set in three rows in adult female; numerous prickles present on dorsum of body in the young, but they almost disappear with growth of the fish.........*R. gigas* (W in Figs. 36, 84 and 86)

13b. In adult, three rows of spines present on tail in male, but three or five rows in female; nuchal spines usually numerous.

18a. Subtype Sc^{SD}: Three rows of spines present on tail in both sexes; nuchal spines three or five followed by numerous somewhat enlarged scales in female ....*R. fusca* (R in Figs. 36 and 80)

18b. Five or irregular rows of spines developed on tail in matured female, but three rows in male.

19a. Subtype Sc^{SE}: Numerous spines in irregular rows thickly covering tail in female.

20a. Tail spines very few in adult male, but orbital ones more numerous than in that of 20b. .... *R. schmidti* (S in Figs. 37 and 81)

20b. Tail spines developed in three distinct rows, but orbital ones about five to six developed on each side .... *R. acutispina* (N in Figs. 36 and 77)

19b. Subtype Sc^{SF}: Five rows of spines set regularly on tail in matured female...... *Raja porosa meerdervoorti* (Q in Figs. 36, 77 and 78); *R. porosa tobae* (Q′ in Figs. 36, 78 and 79); *R. hollandi* (O in Figs. 36 and 75); *R. macrophthalma* (P in Figs. 36 and 76)

2). Relation between the degree of development of the spination and the geographical distribution of Japanese rajids

It is generally known in fish and in other animals that the features of scales tend to vary from species to species with their geographical distributions. Such geographical variations of a character as occur in close relation with niches of the fish in a group must not be overlooked and must be considered important for distinguishing species, and it should also be noticed whether or not the feature is useful for assuming genealogical pedigree in the group of animals.

In the Rajidae, scale features differ very much between the northern and the southern forms, as mentioned in the foregoing section. These differences in the feature are opposed not only in the ontogenic development of the fish, but also in the genealogical trend between the two series of Japanese rajids. In the northern members, there is a tendency that the more northward or the deeper the sea is where a species lives, the greater degree of diminution in the number or the less degree of specialization in the feature of scales takes place. For example, the species **A**, which is referred to subtype Sc^{NA}, is found to inhabit southernmost area of the region where the northern members are distributed, and the species **B**, **C**, **J** and **L**, which are characterized by having the spination of the subtypes belonging to either Sc^{NB} or Sc^{NC}, are found only to inhabit more northerly regions than the preceding species. Subtype Sc^{ND} of the spination is represented by fishes which range still farther northward or in deeper waters with gradual changes of degree of diminution of the scales developed on the disc. Thus, we can generally confirm the opinion given above.

In the southern form, the transpecific variations of the character in relation to geographical distribution show rather a similar tendency to that of the northern form mentioned above, though the change of spination during ontogenic development is quite antagonical between the two forms as afore-explained. Namely, the degree of development of the spination becomes greater with changes of the habitat either direction from north to south or from deep waters to shallow ones. For example, the three species, **M**, **T** and **V**, which are referred to subtype Sc^{SA}, inhabit the region ranging from moderate to deeper waters in parallel with change of the degree of development of spination in their adult stage. Further, the species **N**, **O**, **P**, **Q** and **R** are more setose than those preceding ones, and are dwellers in the shallower waters or in the south of an area distributed by the southern members. Thus, we may recognize many cases which agree with the hypothesis mentioned above concerning the degree of development of the spination and geographic distribution of the fish, though some cases are found contradictory to this phenomenon.

As regards the reason why such geographical variation in the features of spination takes place in some degree of correlation, the present writer has ventured the following phypothesis in order to interpret the question concerning a suggestion given by WHITE (1937, p. 62), that "the history of denticle in general shows that their development is more directly affected by the environment than is that of other external characters. There is definite similarity ...., and while it is impossible to test the condition of the environment in all cases, it is probable that temperature, depth and exposure are all concerned." Indeed, these factors may affect directly or indirectly the differentiation of the denticles of rajid fishes, but the writer should like to add a biological factor to these physical ones. Discussions shall be given below.

3). Relation between the degree of development of the spination and that of the electric organ of the tail

It is worth finding that the degree of development of the scales of the tail to some extent seems related to that of the electric organ, and besides, the two organs reveal a remarkable sexual difference in the southern members in most cases, but the difference is very slight or absent in the northern members.

Usually, sexual dimorphism in the spination is developed in some degree in several portions of the body of rajids. In the matured fish, a patch of backlar spines, such as alar and malar ones, is distinctively developed only in the male, but the spination is greater in the female than in the male in most cases, and this tendency is remarkable especially in the tail of the southern form.

It was formerly suggested by the present writer that the scales are developed in order to protect the body, and that the electric organ may serve for a similar biological function or may be used as the sex-relating apparatus. In other words, the two organs seem to have a single but complex biological significance in the tail of rajids.

As already mentioned elsewhere, the degree of development of the electric organ is positively correlated with that of reduction of the length of the tail, but the degree of development of the spination appears to affect the length of the tail in less degree.

In the northern members, for instance, the successive change of relative length of the tail is supposed to occur in direct proportion only to the degree of development of the electric organ, and regardless of sex, the fishes are all dressed in numerous scales on the tail with slight difference in the spination among species.

In the southern members, on the contrary, the successive change of the length of the tail seems to be associated not only with that of the electric organ, but also with that of the spines on the tail. In fact, both electric organ and spination are better developed in the female than in the male, the former having a longer tail in most cases. If both organs are almost the same in their degree of development between the sexes, as in the case of the species **R**, the length of tail is not so different between the sexes (cf. **R** in Fig. 32), as is the case with the northern form, where the two organs are developed in the same degree between the sexes partaining to the same length of tail (cf. Fig. 36 **R**). Further, the electric organ becomes enormously large in size, as is observed in the species **V** and **W** (cf. Fig. 37 **V**, **W**), whose spinations of the tails are reduced or eventually lost, accompanying remarkable sexual differences in the length of tail. This fact makes us infer that the less the spines on the tail are developed, the more the electric organ is developed. The development of the electric organ positively affects the reduction of the tail, as already explained elsewhere. In another instance, however, the degree of development of the spination of tail appears negatively correlated with that of the electric organ, as in the case of the species **N**, **O**, **P** and **S** of the southern form, and **A**, **J**, **L** and **K** of the northern form. In these examples, the spination and the length of the tail are remarkable, though the electric organ is developed in less degree. These evidences mentioned above may give us a conception that relative length of the tail in the rajids dealt with here seems to have causal relation to the degree of development of either spination or electric organ, or of both, through very complex biological functions of the two related organs.

4). Consideration on differentiation of the features of spination in Japanese rajids

As already mentioned in the foregoing paragraphs, the feature of the scale varies much not only with genealogical pedigree, but also with ontogenic series of rajid fishes, giving remarkable specific and sexual differences of the character. On the basis of characteristic features of the scale, the present writer has classed Japanese rajids in two main types, which contain six subtypes, respectively (Table 13).

Table 13. Characters of the spination of Japanese rajids, classified in two major types with subtypes respectively. For abbreviations, see text.

Type	Subtype	Characters					Species and subspecies
		dorsum of disc		nuchal spine	shoulder spine	spines on tail of adult fish; sexual difference	
		young	adult				
Sc^{N}	Sc^{NA}	setose	setose	absent	absent	absent	A
	Sc^{NB}	setose	setose	present	present	present; without sexual difference	B ; C
	Sc^{NC}	setose	setose	absent or present	absent	present; without sexual difference	J ; L
	Sc^{ND}	setose	setose or smooth	absent or present	absent	present; without sexual difference	D ; E ; F
	Sc^{NE}	setose	setose or smooth	present	present	present, continuous with nuchal; without sexual difference	G ; H ; K
	Sc^{NF}	setose	smooth	present	present	present; without sexual difference	I ; I′
Sc^{S}	Sc^{SA}	smooth	smooth	present	absent	present; with sexual difference, one row in male, three rows in female	M ; T ; V
	Sc^{SB}	smooth	smooth	present	absent	present, with sexual difference; one row in male, five rows in female	U
	Sc^{SC}	setose	smooth	present	absent	present; with sexual difference; one row or absent in male, three rows in female	W
	Sc^{SD}	smooth	smooth	present	absent	present; without distinct sexual difference, three rows in both sexes	R
	Sc^{SE}	smooth	smooth	present	absent	present; with sexual difference, three rows in male, irregular numerous rows in female	N ; S
	Sc^{SF}	smooth	smooth	present	absent	present; with sexual difference, three rows in male, five regular rows in female	O ; P ; Q ; Q′

Of the features of scale given in the preceding sections, the characteristics considered to be important for phyletic relationships of the organ of Japanese rajids are, i) general shape of the scale, ii) degree of development of the scales in the adult stage, and iii) trend of the change of spination revealed in ontogenic series of the fish. With regards to these hypothetical bases, the author has drawn his attention to the following viewpoints, so as to arrive at the conclusion of the present subject.

(i). It has generally been known that the placoid scale and its derivatives are originated from a hard armour of four layers of tissue covering the surface of body of the earliest vertebrate, from which an ancestor of the modern elasmobranchs has been derived. In fact, many of the elasmobranchs are clad in armour of placoid scales to some extent, and the condition is generally well modified in the modern batoid fish. In the Rajidae, the scale usually has spiny type which is, according to WHITE(1937), modified from the plate-like one, and the degree of reduction in thickness of the scales parallels in the main with specialization of the fish.

Observing a similar tendency in our rajid fishes, we have found that the more numerous denticles of a flattened form a species has, the more generalized condition it is in. If this hypothesis is justifiable, we may infer that the feature characteristic in the scales of the northern form, Type Sc^{N}, may be considered to be in more primitive condition than that of the southern one, so far as the shape of the scale and general feature of the spination are concerned.

(ii). As regards the successive change in the number of large spines developed on the body of the northern form, the present writer has considered it in the same manner as given in the above mentioned hypothesis. It is naturally believed that the enlarged spines or thorns developed with definite tracts on body surface are modified from the minute prickles so as to protect the body or to allow the fish to survive. This modification of the scales into large spines occurs along dorsal-mid line of the tail with few exceptions, and on nuchal and shoulder regions in some species. The absence of prickles, on the other hand, is mainly seen in the disc inclusive of the pelvic fins, except marginal and mesial portion of the disc, and snout and interorbital portions. The relation between the degree of development of the enlarged spines and that of reduction of prickles is considered to be very complex. However, we can reasonably assume that the species with more numerous scales without any noticeable large spines even in the adult stage seem to maintain more generalized condition than those with fewer scales with many enlarged thorns. Such being the case, the species **A** referred to subtype Sc^{NA} may be interpreted to be most primitive in spination, followed by either subtype Sc^{NB} or Sc^{NC}. It may be said, therefore, that these two subtypes may be diverged offshoots from the common ancestor similar to the preceding subtype. Subtype ScND, which is represented by the three species **D**, **E** and **F**, may be linked with subtype Sc^{NB}, though these representatives are pretty well reduced in the number of scales. Although those three species (**F**, **H** and **K**) having a row of large spines set continuousely along the mesial line of disc are referred to the subtype Sc^{NE}, the category of the feature seems to involve somewhat conventional measure, because there is some variation in the feature of the spination among the three species. However, the present writer is inclined to proposed here the following idea that may be justifiable in this case. The outward resemblance in the feature of spination revealed by the three species of this subtype may be caused by either convergence or divergence of the character of different stock. Namely, the three representatives referred to this subtype belong to from each other different phyletic stem. At any rate, subtype Sc^{NF}, which involves the subspecies **I** and **I′**, is considered to be the most specialized phase characterized by having very few scales on the dorsum of disc and the prickles on the dorsal lobe of glans clasper.

(iii). As to the successive development of the scales in the ontogeny of the fish referred to the southern form, Type Sc^{S}, the hypothesis which has been adopted in the northern form is not justifiable but another one must be derived. On the theory of evolution in animals a character can be lost again in a phyletic line, and a similar or equivalent character can be required (MAYR et al., 1953). In favour of this theory, the present writer believes that Type Sc^{S} must have arisen from an ancestor which has almost lost the character of scales similar to Type Sc^{N}, and the equivalent character may have been developed in Type Sc^{S} with the advance of specialization of the fish. If this view be true, the successive development of scales with the growth of the body in the southern form may be considered to be equivalent but analogous to the successive reduction of the spination in the northern form. Based on this theory, Type Sc^{S} may be considered to be in a more advanced condition than Type Sc^{N}.

According to the writer's idea, it may generally be accepted in the southern members, therefore, that the more numerous scales a species has in the adult stage, the greater degree of differentiation in the spination occurs. Regarding the differentiation of the spination in this type, however, the writer believes that polyphyletic development has taken place, and the divergent or convergent variation of the character is further exhibited by the existence of remarkable sexual difference. At any rate, the subtype Sc^{SA}, which is represented by the three species **M**, **T** and **V**, is probably nearer to the original form than any other, because very few large spines are found on the tail with much smaller degree of sexual difference. Of the three, the species **T** may be accounted for as an intermediate between the two other species in respect to the degree of development of the spination. Is it not far-fetched to say that the characteristics in the spination developed in those referred to all the subtypes in the southern form except subtype Sc^{SA} may have evolved from something like the three species **M**, **T** and **V**, developing in three different directions ? From this viewpoint we may reach the conclusion that subtypes Sc^{SB} and Sc^{SC} seem to be offshoots from subtype Sc^{SA}, diverged into different form. To be more exact, the subtype Sc^{SB} may have directly sprung from a form which has a character similar to that found in the spination of the species **T**, but subtype Sc^{SC} may have diverged from the species **T** through the species **V**. We have to introduce herein again the statement made by MAYR et al. (l. c.) that the numerous prickles found in the young of the species **W** may have recovered the old character which has disappeared in the young of all species in the southern form (cf. **W** in Fig. 84). On the other hand, the species referred to subtypes Sc^{SD} or to Sc^{SF} may have been specialized from a species bearing the spination similar to that of the species **M**, by gradual increase of the scales in both sexes. Such being the case, is it not very logical to interpret that the degree of development of the spination revealed in the species **R** referred to subtype Sc^{SD} may be regarded as having the most intimate relation to that revealed in the species **M**, because three rows of large spines are developed on the tail of both sexes?

We generally agree in considering that the placoid scales are originally developed everywhere on the surface of the body without any regular arrangement. In comparison of the manners of arrangement of the spines developed on the tail of the species involved in the subtypes Sc^{SE} and Sc^{SF}, we may safely believe that the subtype Sc^{SF} seems to possess more specialized phase than Sc^{SE}, because the females of Sc^{SF} have their tail furnished with five rows of spines in regular arrangement, when the females of Sc^{SE}, with numerous rows of spines irregularly arranged. If the writer is right in presuming the differentiation of the spination, subtypes Sc^{SA} and Sc^{SF} are considered to be the two extremes in the phyletic lineage of the spination revealed in the southern form.

When we accept the foregoing conception on the courses of differentiation of the spination thus supposed, we may say that the trend in phyletic relationship especially of the southern form in Japanese rajids is generally parallel with that which has been inferred from the fact found in the clasper, but in the northern form the two trends are in discord with each other to some extent, as is the case with other adaptive characters, such as the snout and the egg-capsule.

Remarks: In many works on taxonomy of elasmobranchs, both feature and number of teeth are among the noteworthy characters. In fact, the characteristics of teeth on both jaws are frequently very different even in a group of the fish. In the Rajidae, the features which have heretofore been used in taxonomy are the number of rows and the manner of arrangement of the teeth on both jaws.

In the present study, where many specimens of all the species of Japanese rajids have been examined, the two characters of the teeth are taken into due consideration.

The principal results thus obtained in this investigation may be summarized as follows:

i). The number of teeth in rajids undergoes remarkable intra- and interspecific variations, and the method which has been customarily used may be inaccurate to some extent, because the teeth of an embryo set originally in pavement arrangement change in some degree with the development of the organ giving distinct sexual dimorphism of the teeth.

ii). From the above reason, the present writer has been able to obtain the following result: (i) the teeth on both jaws are generally more numerous in the southern members than in the northern ones, being measured 35.1-50.0 and 22.5-44.0 on the average, respectively, (ii) the difference between the species in the two major groups of Japanese rajids may not show any noticeable specific character (Table 14), and (iii) the teeth are arranged in pavement style in young fish, but in quincuncial way in the adult, being very sharp or prehensile in form in the male, though the teeth of the female are less pointed.

Table 14. Counts of teeth on the upper jaw of Japanese rajid fishes, especially showing smaller counts in the northern members (A—L) as compared with those in the southern ones (M—W). Number of specimens of both sexes examined are parenthesized. For other abbreviations, see text.

Species (♂ : ♀)	Number of teeth				Species (♂ : ♀)	Number of teeth			
	male		female			male		female	
	range	average	range	average		range	average	range	average
A (8 : 8)	41—45	43.6	38—50	44.0	M (40 : 48)	27—40	35.5	32—40	35.9
B (12 : 15)	24—28	26.5	25—31	27.0	N (31 : 29)	42—50	45.5	41—55	46.1
C (7 : 7)	21—27	24.4	20—27	24.1	O (34 : 20)	39—50	43.4	40—48	46.3
D (6 : 5)	20—27	23.8	26—27	26.0	P (13 : 14)	33—45	39.1	36—46	40.2
E (15 : 15)	26—35	29.8	29—35	31.7	Q (6 : 7)	42—54	46.4	41—51	44.6
F (5 : 5)	21—25	24.2	20—25	22.6	Q′ (9 : 13)	41—51	46.0	37—51	44.7
G (5 : 5)	33—35	34.4	30—36	32.6	R (15 : 26)	48—52	50.0	37—54	47.5
H (1 : 0)	29	—	—	—	S (8 : 16)	42—46	43.2	39—47	44.0
I (9 : 12)	22—26	23.8	19—26	22.5	T (20 : 31)	30—41	36.5	32—41	36.8
I′ (8 : 6)	22—25	23.6	21—29	24.8	U (30 : 22)	39—48	43.1	34—52	44.2
J (10 : 4)	30—36	32.4	31—33	32.2	V (9 : 12)	33—37	34.4	33—38	34.4
K (11 : 12)	23—30	27.1	20—31	27.0	W (4 : 8)	33—37	35.2	33—37	35.1
L (10 : 15)	28—33	30.0	27—33	29.8					
Total range	20—45		19—50		Total range	27—54		32—55	

Conclusively, so far as Japanese rajids are concerned, the teeth are not so important in taxonomy. The teeth similarly developed may have resulted from very similar food habits and related behaviors of the fish.

g. Color and pattern

1. Description in general

The color of integument in elasmobranchs is not usually so much conspicuous as in the teleosts, but it considerably varies in species, and the characteristics in both color and pattern found in some sharks and skates have often been noticed. In fact, features of the color and its pattern on both sides of the body are subject to remarkable source for taxonomy of this group together with those of the spination, and are among the most convenient measures of distinguishing any particular species of rajid fishes. However, the character, on the other hand, has been known to change with the growth of the body to some extent even in a single species, and certain authorities have demonstrated that the variability of the character, which is known as metachrosis in a skate, is influenced by the physiological condition of the body (HOGBEN et al., 1936; ENAMI, 1936).

The present writer has examined in his present study, i) whether or not characteristics of the color and pattern developed on the skin of the body are useful in distinguishing species or groups of species of Japanese rajids, and ii) whether or not the characteristics in question of any group of species have any relation in the fish, and he has obtained a conception enabling him to conclude these questions.

2. Comparison of color and pattern

On the basis of color and its pattern found in both fresh and preserved specimens of Japanese rajids, young or old, which have hitherto been collected by the present author, the five following groups are conventionally recognized and called here groups 1 to 5. Group 1 involves the four species **A**, **T**, **V** and **W**, which have unitary color of either grayish brown or dark gray with no spot or pattern developed on the dorsum. But there are some differences in the ground color in these four species, viz., in the species **T** the dorsum is grayish brown though the color is lighter in the venter than in the dorsum, but the species **A** and **V** are lead-gray on both sides of the body, and the species **W** appears blackish gray on both surfaces. Group 2 is exemplified by the six species, **B**, **C**, **G**, **H**, **I** (**I′**) and **K**, their dorsums are characterized by having a common ground color of golden drab when fresh, but the color becomes lead-gray as the fish are preserved in the formalin solution. The color of venter appears white except the tail and marginal portions of the disc and the cloaca where they are dark brown. But, in the species **G** the venter is scattered by several large black blotches (**G**$_4$ in Fig. 66). Group 3 may be referred to the color found in the species **E** and **F**, the former being provided with a faint rosy color dorsally though the venter bears its color in very paler, while the species **F** is deep darkish purple on both sides of body. The ground color developed in these two species is rather stable even in their preserved condition. Group 4 involves five species, **D**, **J**, **L**, **O** and **P**, and they are dorsally of a complex hue with many spots and patterns of dark chocolate color, but the so-called pectoral ocellus is absent in the young stage except for the species **J**, in which two pairs of white marks are usually developed in the basal portion of the pectoral fins (Pl. I). The venter in these species is generally white excepting the marginal portions of the disc and the tail, where dark color and occasionally brown blotches are developed. Group 5, in which the six species, **M**, **N**, **Q** (**Q′**), **R**, **S** and **U** are involved, has the characteristics of the color and pattern which resemble those of the preceding group in having many variations in the character. But the fish of this group can be distinguished from that of the preceding group in having more or less developed pectoral ocellus margined with dark color, especially in their young stage. The venter is usually white, but occasionally several dark blotches are seen on it with the exception of the species **M**, in which the whole surface of the venter is covered with unitary color of gray.

Although there are some remarkable variations in detail other than those mentioned above in color and pattern developed on both dorsum and venter of the body of Japanese rajids, the features in every instance are too complex to be arranged in any clever system. Therefore, the author has deferred minute descriptions of the variations of the character in some species until he treated of taxonomy in this investigation later on.

Discussion

1). Systematic significance of the color and pattern of Japanese rajids

Rather extensive variations of the color and pattern are found to exist mainly owing to environmental and physiological factors, and the character is generally apt to be regarded as ignored in separating species in any group of fish. But it may be more or less important for the author to clarify whether or not these features are useful for critical identification of the species. As to various features of the color and pattern found in Japanese rajids, the following may be useful for discriminating species or groups with some certainty, i) whether or not the color of the integument is developed in unity or variety, ii) what kind of ground color is found on either dorsum or venter of the body in both fresh and preserved specimens ?, iii) presence or absence of any color mark or pattern, or of blotch on either surface of the body, and iv) presence or absence of the pectoral ocellus margined with either darker or fainter color especially in the young. Based on these categories, the annexed key to Japanese rajids has been arranged as a great help to the workers for their rapid identification.
1a. Color of dorsum unitary, with neither darker nor paler pattern.
  2a. Group 1 : Dorsum gray or grayish brown in both fresh and preserved specimens.
    3a. Dorsum grayish brown, but the venter is faint gray .... *Raja tengu*
    3b. Both dorsum and venter lead-gray or blackish gray .... *Breviraja tobitukai* (Pl. I; A); *Raja macrocauda*; *R. gigas*
  2b. Group 2 : Dorsum golden drab in fresh, but it becomes lead-gray when preserved.
    4a. Venter somewhat lighter than dorsum without dusky blotch, but marginal portions of disc, cloaca and occasionally of tail are developed with dark color .... *B. isotrachys*; *B. trachouros*; *B. parmifera*; *B. smirnovi smirnovi* including *B. smirnovi ankasube*; *Rhinoraja kujiensis*.
    4b. Venter having several large dusky blotches .... *B. aleutica* (G_4 in Fig. 66)
  2c. Group 3 : Dorsum faint rosy or darkish purple in both fresh and preserved condition.
    5a. Dorsum faint rosy when fresh, but venter is paler than the dorsum .... *B. diplotaenia*
    5b. Dorsum darkish purple in both fresh and preserved condition .... *B. matsubarai*
1b. Dorsum rich in numerous spots and patterns of darker or lighter color.
    6a. Group 4: Without pectoral ocellus margined with dusky color in young excepting the species J, in which a pair of white ring present on each side of pectoral fins; venter generally pale, but tail and marginal portion of disc dusky .... *B. abasiriensis*; *Rhinoraja odai* (Pl. I; J); *Rh. longicauda*; *Raja hollandi*; *R. macrophthalma*
    6b. Group 5: pectoral ocellus margined with dusky color present on basal portion of each pectoral fin, being distnct in young.
      7a. Venter generally gray .... *R. kenojei* (Pl. II; M)

7b. Venter generally white excepting tail and marginal portion of disc inclusive of pelvic fins being dusky.

8a. Numerous spots of chocolate color scattered on dorsum .... *R. fusca*; *R. schmidti* (Pl. III; S)

8b. Color very variable, usually mottled with dark and yellowish brown .... *R. acutispina*; (Pl. II; N) *R. porosa meerdervoorti* (Pl. II; Q) inclunding *R. porosa tobae*; *R. pulchra* (Pl. III; U)

2). **Relation between coloration and geographical distribution of the rajids**

As regards the characteristics of color and pattern of the integument, the present writer has classified Japanese rajids into five groups which are introduced in Table 15, based on the four categories aforementioned.

Here, it is worthwhile to mention that these variations in species or groups of species are found to occur somewhat regularly with the changes of the habitat in both horizontal and vertical ranges. An example of such geographical variation of the character is found in the rajids inhabiting the sea off Aich Prefecture, the so-called Kumano-nada: the color and pattern of the fish change with the depth of the habitat. The vertical range of the depth of habitat, where any species of rajids is found, is from about 50 meters down to about 400 meters. Within this range a depth at which the color of the dorsum of a rajid changes from variety to unitary tone appears to be about 100 meters. The variety of the color and pattern of the integument of dorsum occurs above this threshold depth, though some variations of depth of the habitat of certain species were found according to vertical migration of the fish. For instance, the species **M**, **P**, **S** and **U**, which are involved in Group 4 or 5, are found to inhabit the region less than about 100 meters deep, whereas the species **A**, **T**, **V** and **W**, which are referred to Group 1, are found in the waters below that threshold depth, changing their vertical distribution from shallow to deep in order **T**, **A**, **V** and **W** (cf. Table 1). Species J may be an exceptional example to the trend mentioned above, because the color and pattern develop in this species, which inhabit the sea more than 300 meters deep in the neighbouring region (cf. Fig. 1).

Table 15. Characteristics of the color and pattern of Japanese rajid fishes classified into five groups. For abbreviations, see text.

Group	Characters			Pectoral ocellus	Species and subspecies
	color tone	kinds of colors			
		dorsum	venter		
1	unity	grayish brown or lead-gray	light brown or gray or blackish gray	absent	A; T; V; W
2	unity	golden drab in fresh, lead-gray when preserved	white or black blotches present	absent	B; C; G; H; I (I′); K
3	unity	faint rosy or darkish purple	light rosy or darkish purple	absent	E ; F
4	variety	spots and patterns of dark chocolate present	white or faint gray	absent except species J	D; J; L; O; P;
5	variety	spots and patterns mottled with dark and yellowish brown	gray or white with or without dark blotch	present	M; N ; Q ; (Q′) R; S ; U

Another instance which seems to show a good example of vertical change of the coloration has been observed in some rajids inhabiting the Pacific and the Sea of

Okhotsk, around Hokkaido. In these regions, the depth where the color and pattern of the integument change from variety to unitary tons seems to occur in rather shallow waters about 50 to 70 meters deep. Downward this threshold depth the color of the dorsum changes with the increase of the depth of habitat from species to species in order from unitary color of gray to golden drab and to faint rosy, and finally to darkish purple developed on both sides of the body. This final phase in the coloration is referable to the species **F**, which lives in very deep waters, so far as Japanese rajids are concerned (cf. Table 1).

Judging from these facts, the successive changes of the color and pattern with the increase of the depth of habitat of rajid fish may prove the principle concerning the protective or the concealing coloration (HUBBS, 1947; COTT, 1956), as in instances of other aquatic animals. Therefore, the characteristics of the color and pattern may be accounted for as an adaptive sequence with survival value in the niche of respective rajid species. As regards the unitary coloration of the deep-sea form without any color pattern, the characteristics in question may help critical identification of the species, because the light condition in the deep is very stable. However, when the niche of a species is restricted to shallow waters with a depth above the threshold in a region, the color and pattern of the skin of body are found to exist a very complex hue, which can be changed in a short time, being affected somehow through the sense of light. In fact, it has been noticed that many different color patterns are seen even in a single species of rajids inhabiting shallow waters, as in case of the species Q. By the way, this species has been given by TANAKA (1916) as a new species *Raja katsukii*, distinguished from *R. porosa* on account of its strikingly different color patterns (Pl. II; Q).

Conclusively, we should take care with delicate sense so as to use the features of color and pattern in the taxonomy of rajid fishes, as in the case of the teleosts and other aquatic animals in general. The writer surely believes that the color and pattern of the integument of rajid fishes are among the really phenotypical characters responsible for environmental factors regardless of phyletic relationship.

C. Sexual dimorphism

There is more or less pronounced sexual dimorphism in most groups of elasmobranchs, in which an outstanding sexual difference is the presence of the clasper in the male. Besides the clasper, the principal sexual dimorphism of subadult or adult rajid may be found in the following: total length of body, shape and length of snout, length of pelvic fin, length of tail, dermal denticles and teeth, and electric organ. These are summarized below one by one.

1. Usually the female is larger than the male to some extent as in other elasmobranchs. The difference in size between the two sexes, as a whole, is not so much conspicuous in the northern form as in the southern one. The greatest difference between the sexes of the same species has been found in the species **W**, the matured female of which is the largest (about 1800 mm in total length) in our rajids, measuring about 1.4 times as long as the male. So far as the species of Japanese rajids are concerned, sexual difference in total length of the adult fish may be seen in the following table.

These differences in size between the sexes may largely be correlated to differencial growth in the body, as explained on the snout and the tail of the fish.

2. Front margin of the body anterior to lateral angles of the pectoral fins is more

Table 16. Comparison of average total body-length of the adult in Japanese rajids. For abbreviations, see text.

Species, northern form	Total length, mm		Species, southern form	Total length, mm	
	male	female		male	female
A	430— 479	440— 507	M	564— 622	557— 660
B	810— 930	875— 900	N	400— 425	396— 435
C	900—1023	897—1070	O	411— 493	451— 540
D	622— 715	684— 714	P	315— 350	304— 365
E	820—850	791— 817	Q(Q′)	388— 440 (432— 480)	398— 425 (392— 495)
F	1063	1097—1165	R	448— 517	470— 518
G	1106—1280	1470—1510	S	452— 507	492— 523
H	941	?	T	900—1020	1010—1130
I (I′)	1030—1138 (902— 930)	1062—1160 (907— 943)	U	966—1052	962—1119
J	406— 480	458— 502	V	920—1000	1082—1250
K	894— 910	920—1043	W	1180—1345	1860
L	606— 688	602— 620			

or less undulated in the two sexes of matured male. The degree of undulation is more remarkable in the male than in the female, and the sexual dimorphism is more differentiated in the southern members than in the northern ones. Generally, the shallower the waters are where a species lives, the greater is the degree of undulation. The author may be justified in saying this, when he has found that the deep-sea forms, such as V and W, reveal lesser degree of undulation than the shallow-water ones, such as M, O, P and Q, even among those southern forms.

The degree of sexual difference in relation to the length of the snout is also witnessed between the two major forms of Japanese rajids, as illustrated in Fig. 25 and Table 6. In short, the length of the snout relative to the head is apparently longer in the female than in the male of southern forms with the exception of one species P, but this is not so obvious in the northern members except the species D, E, I (I′) and J (cf. Fig. 24 and Table 6).

3. Sexual difference can be seen in the elongation of the posterior lobe of the pelvic fin of the male, accompanied by the growth of the clasper. For this reason, in the length of disc the pelvic fin should not be included in making a comparison of the length of disc between the sexes. The remarkable elongation of the posterior lobe of the fin in the rajids is intimately attributable to the enormous development of the clasper siphon, embeded in the posterior lobe of the fin (cf. Fig. 2).

4. Sexual difference in the rajids especially of the southern form can also be seen more or less in the length of the tail, as shown in Fig. 32 and Table 7. The difference, however, is less conspicuous in many species of the northern form. Sexual difference in the length of the tail of the southern form seems to have been developed in close correlation with the electric organ and spines of the tail, mostly longer in the male than in the female.

5. Sexual difference in the spination is developed in two different ways, which contradict each other between the two major forms of Japanese rajids, viz., sexual difference of the northern form is revealed by the diminution of those downy prickles covering the disc, and the reduction of the spination with growth of the body is more

rapid in the male than in the female. On the other hand, in the southern form the difference is seen in the increase of spines in the tail with the growth of the body, and in most cases the degree of development of the spines becomes greater in the female than in the male. In both cases, however, it is common to the species that the alar spines are found to be developed more or less in the matured male, while the malar spines are developed only in the southern form except the species W.

In the male, the teeth on both jaws are well-developed with sharp pointed cusps, while in the female they are in pavement style with shorter cusps.

6. The electric organ of the male is more or less well-developed in most species of the southern form, when compared with that of the female. But there is no difference in the organ between the two sexes of the northern form. Some complicate structural evidence may exist in regard to the causal relation between the length of tail and the degree of development of the organ as well as of the spines on the tail. It is probable that the degree of development of the electric organ and the length of the tail are a negatively correlated between the sexes of the southern form.

V. Ecological and geographical reconnaissance on Japanese rajids

A. Age and growth of some rajids

It is essential to fishery biology for us to know how to find out the age of fish. Many biologists have long been trying to determine the age of fish, especially of teleosts, but no reports on elasmobranchs have been made public except the author's detailed studies in Japanese rajids (ISHIYAMA, 1951, 1957). The growth of the fish is closely related with their age, and the author has treated of it in this chapter, followed by some respects on fishery biology.

a. Age-determination

The age of fish is determined by three general methods, namely; length-frequency distribution, recovery of marked fish, and interpretation of the layers that are laid down in the hard parts of the fish (ROUNSEFELL and EVERHART, 1953, p. 297), the last of which is the most generally accepted method for this purpose.

Otolith and scales are used more frequently than the vertebrae in determining the age of teleosteans, but it is not so with elasmobranchs, so that only vertebrae are used in this pursuit, thus: concentric rings composed of different layers are constructed in the centrum, so number of rings as to the three kinds of rajids having economic importance, which belong to the so-called southern form, were pursued by histoloigcal method.

The author (1951) has already set forth his studies in *Raja fusca* and *Raja hollandi*, so it is intention to make a further study in *Raja kenojei**) in addition to the two species.

1. **Vertebrae to be used in the age-determination:** The vertebra in rajids has a clearly distinguishable centrum, whose size varies by the different positions of the

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* The specimens were gathered at Shimonoseki fish market from Dec., 1952 to Sept., '53 in aid of the Shimonoseki Branch of Seikai Regional Fisheries Research Laboratory. The collection as well as preparation of the samples was carried out in assistance of Mr. Keisuke OKADA, to whom I wish to express my hearty thanks.

vertebral column, i. e. several centra situated most anteriorly, which are smaller than those posteriorly, are buried in the so-called anterior vertebral plate. Therefore, the centra have rather the constant measure in diameter and may be used in the age-determination, relating to the size of the fish, and are located at the range from 10th to 20th of the vertebral column (Fig. 54 R_1).

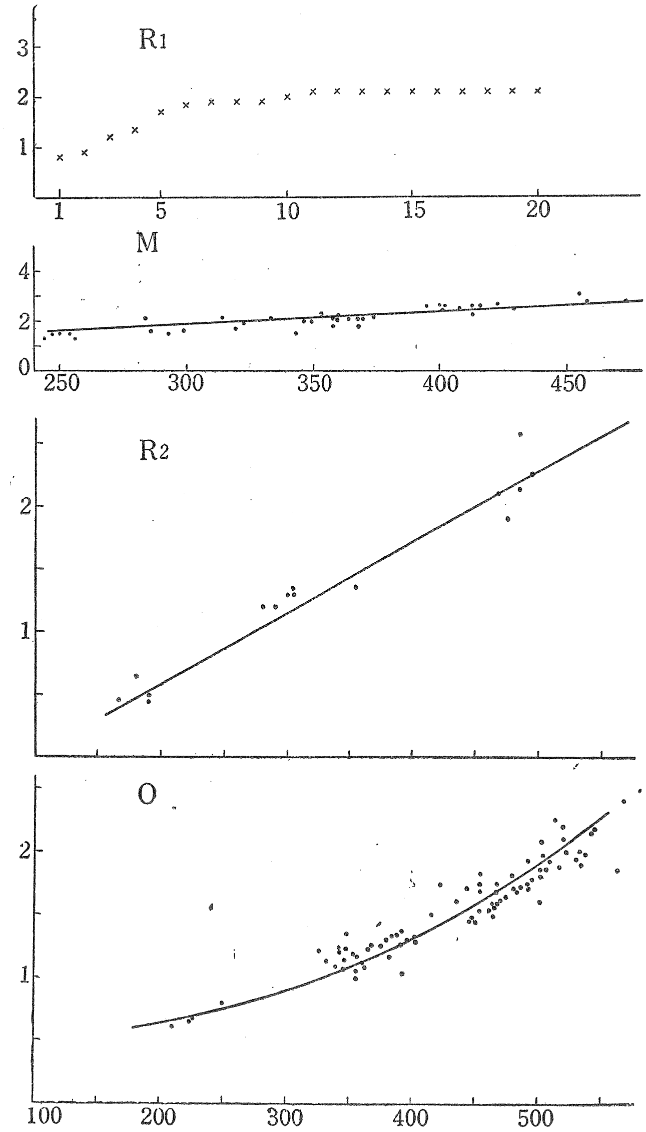

Fig. 54. Showing variation of the radius in mm of centra by positions ranging from the anteriormost to the twentieth of the vertebrae in R_1, and relations between the size of body and the radius of centrum in M, R_2 and O. Ordinate, radius of centrum (mm); abscissa, order of vertebral position from first to twentieth in R_1, and width of disc (mm) in M, but total body-length in R_2 and O. M, *Raja kenojei;* O, *R. hollandi;* R_1 and R_2, *R. fusca.*

2. **Growth of the centrum:** The present author has examined whether or not the centrum grows proportionally with the body. As shown in Fig. 55 the length of the centrum shown by the radius of the centrum (T) as in the case of teleosts seems to grow with proportional relation to that of the body, following fairly straight or curvilinear correlation (Fig. 54 **M**, **R**$_2$, **O**). From this fact, we have find that the growth of the centrum is more or less regularly related to that of the body of respective species, so that the following regression equations are given by means of the least square method in calculation for the three species;

Raja fusca, $T=0.0094\ L+0.19$ (mm),
R. hollandi, $T=0.30\ e^{0.0036\ L}$ (mm),
R. kenojei, $T=0.0061\ D+0.026$ (mm),

where e, D, L and T in the equations represent base of natural logarithm, disc-length, total body-length and radius of centrum, respectively. The equations are also conformable to those obtained from the cutting sections of the vertebral centra of the three kinds of rajids.

3. **Number of calcified concentric rings in the centrum in relation to size of body:** Longitudinal sections*) cut through the center of centrum of young rajids are seen in three different histological structures, viz., inner-, median- and outer-zone (1 in Fig. 55). The inner-zone, which is observed around the outside of the notochord, is characterized by having sparsely arranged cells. The median-zone is, however, made of minute calcified cells crowded together into a V-shaped narrow band, and is distinguished from others by thicker staining for the dye (haematoxylin) than elsewhere. The cells in the outer-zone are round or oval in shape, closely arranging to some extent.

On the other hand, the cross sections in the center of centrum take up with calcification in five different radials, forming a curious design (2 in Fig. 55). The dorsal radial among these calcified regions shows generally flat margin at the central part of the dorsal side, and moreover, the similar shape is found to continue from the center of the dorsal margin in the radial toward both extremities of the centrum. The other radials, lateral and ventral, are found irregular in outlines throughout the centrum. These facts are proved by the serial cross sections cut from the center of centrum to the intervertebral ring (i. r. in Fig. 55: 1).

Further, the median-zone in the longitudinal sections of the vertebrae taken from a specimen of the immature possesses one or more number of the bands, where the calcification becomes denser due to condensing cells than in surrounding tissue. The cells in the tissue of the outer-zone are also in a peculiar form observed as a layer, which is composed of many flat, or more or less lentiform, cells piling themselves in the middle portion of this zone. Apparently, this layer is somthing like the annual rings of plants. Moreover, this layer is observed to be connected with the denser calcified band of the median-zone curving upward from the central part to both anterior and posterior ends. These particular layer in the median- and outer-zones appear to be denser stained bands with the dye than the surrounding tissue.

In an adult rajid, the denser calcified layers found in the median- as well as in the outer-zone are calculated to be increasing in number from three to four, but three in most cases.

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* The method of cutting section was pursued by the same technique as was used in the previous reports (ISHIYAMA, 1951), i. e. the materials were embeded the celloidin and stained by the haematoxylin-eosin solution after being cut in sections.

Thus, the number of calcified bands in the centrum increases with the growth of fish. These bands are observed as concentric rings of the centrum when viewed from the concave surface, known as tectospondylous vertebrae characteristic of the backbone of batoids termed by HASSE (1855).

Such being the case, the present writer has examined whether or not the number of rings of the centra taken from the different size-groups of the common skate, *Raja kenojei*, caught in December, June and September can be regarded as the annual rings, as seen in the other two kinds of rajids (l.c.).

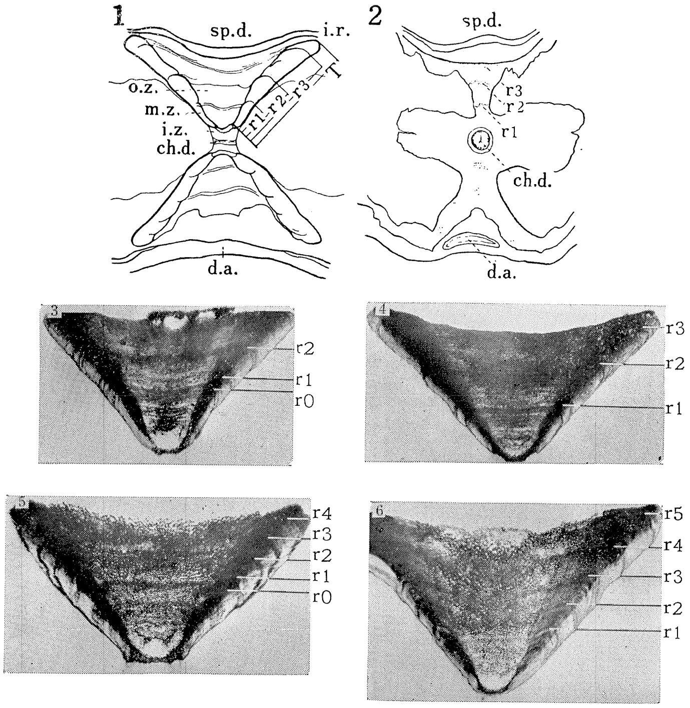

Fig. 55. Sections of the vertebral centrum of the skate, *Raja kenojei*, showing the method of measurement and terminology used in the age-determination, in 1 and 2, the former represents vertical longitudinal section along the center of the centrum, but the latter shows vertical cross section at the middle, and the photographs, 3 — 6, of the centrum representing various ages of the skate. ch. d., chorda dorsalis; d. a., dorsal aorta; i. r., intervertebral ring; i. z., m. z. and o. z., inner-, median- and outer–zone, respectively; r_0, r_1, ... r_5, rings corresponding respectively to ages; sp. d., spinal cord; T, radius of centrum.

4. **Radius of the ring in each ring class:** According to the writer's knowledge it is clear that the young skates, measuring less than 150 mm in total length, must have been hatched so lastly from the egg-capsules that the ring has not yet been found in the centrum. Then, supposing that the fish having no ring (r_o) is O-age, 1-ring (r_1) is I-age, and so on, n-ring (r_n) is n-age, the writer has measured the radius of ring in each ring class of the fish caught in different seasons. As shown

Table 17. Showing the radius of ring in each ring class of various size-groups of the skate, *Raja kenojei*, caught in three different months from the East China Sea.

Date of catch	No. of specimens	Age	Ring class, $r \pm \sigma$, mm					Total body-length, mm	
			r_1	r_2	r_3	r_4	r_5	range	average
Dec., 1952	2	I	0.93±0.02					336—372	354
	3	II	0.90±0.01	1.29±0.03				336—457	401
	5	III	0.73±0.07	1.26±0.11	1.66±0.20			444—631	514
June, '53	4	II	0,87±0.24	1.35±0.21				376—525	432
	3	III	0.83±0.04	1.16±0.17	1.50±0.22			364—510	449
	2	IV	1.05±0.03	1.37±0.02	1.69±0.03	2.06±0.02		587—596	591
	1	V	0.73	1.12	1.66	1.92	2.63		596
Sept., '53	6	II	0.95±0.10	1.42—0.14				431—547	494
	3	III	0.89±0.17	1.45—0.15	1.76±0.11			515—520	517
	4	IV	0.81±0.05	1.27—0.16	1.65±0.22	2.07±0.26		506—606	572
	(33) average, r_n		0.87±0.08	1.29±0.12	1.65—0.16	2.01±0.14	2.63		

in the following table, the distances r_n are nearly equal each other for the same number of n in average in the different size-groups. The same result was obtained in the other two kinds of skates treated previously.

Hence, we can easily assume the size of body of the skate when the radius of centrum becomes equal to that of the ring, computing from those figures and the equations mentioned above, as was done by LEA in the scales of teleosts.

Table 18. The calculated mean width of disc when the rings are formed in the centrum of the skate, *Raja kenojei*.

Age \ r_n, mm	r_1	r_2	r_3	r_4	r_5
I	157.9				
II	154.7	228.0			
III	149.8	214.9	273.6		
IV	149.8	218.2	275.2	342.0	
V	128.6	221.4	275.2	317.5	369.7

5. **Estimation on the season of ring-formation:** On the basis of the ratio between T and the difference from T to the length of lastest ring, that is T-r/T calculated in each age-class in the three different months.

It will be seen from the diagram that ring-formation lies in a period covering from January to May, when the water-temperature is relatively low in a year, and the eggs are spawned in this period. The same fact is also found to exist about the age-determination of the other rajid, *Raja fusca* (Fig. 56).

Judging from the above mentioned analysis, the concentric calcified rings of the centra of rajids that HASSE used as a basis for classification by the name of tectospondylous can be considered as a physiological character, which is regarded as the annual growth rings related closely with the water-temperature of environments where rajids live, or related with the physiological condition of the fish so far as the three rajid species are concerned, as is the case with the rings laid down in the hard tissues in many teleosts.

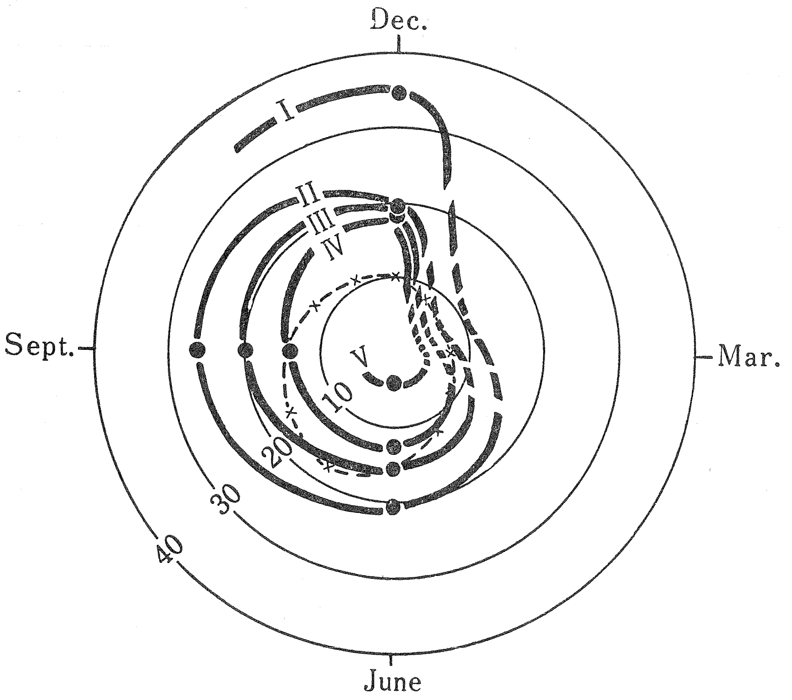

Fig. 56. Showing seasonal growth cycles of the rings in the centra of various sizes of the skate, *Raja kenojei*. Arabic numerals represent the growth percentage of the centrum, $(T\text{-}r/T)\times 100$, and also the temperature(°C) of the fishing ground; Roman numerals show the age of the fish. Brocken portion in the thickened line, which indicates successive changes of the age of the fish, covers the season of ring-formation suggested; the thin brocken line represents seasonal change of water temperature (°C).

b. Growth of the body

The term "growth" is here used to include the increase of size in the fish, and the animal body, in general. Strictly speaking, the growth means not only increase but also decrease in size of the body with chronological age of the fish, that is known as positive or negative growth. The growth includes, therefore, very complex problem, and is subject to different factors caused by both genetic and environmental conditions. Change in size and form goes on cojointly throughout the life of fishes with different rates of growth in development. Further, in the majority of animals, the various parts or organs of the body of any species have their own rate of growth, which has also been used in taxonomy as well as fishery biology.

Where the growth of fish is studied we should like to consider its close relation with age, because a comparison of sizes or parts between two forms of fishes may cease to have any validity without either chronological or physiological age, or both. When the age factor is taken into account, it becomes clear that the rate of growth is no constant, but differs with age and among species. But it is difficult to know the correct age of any particular form, still more difficult to do so about the deep-sea fishes like most rajids.

In the present scheme, therefore, the writer has intended to find out in a simple and invariable way a body dimension which grows with age throughout the life-history of the fish than any other part where the growth is revealed in complex features. If such a dimension can be defined, it will be a substitute for the age of fish. And, if it is not difficult to measure the dimension, we can use it as the standard measurement in taxonomy and fishery biology so that the trend of growth may be compared simply and easily between any bodily parts or different species.

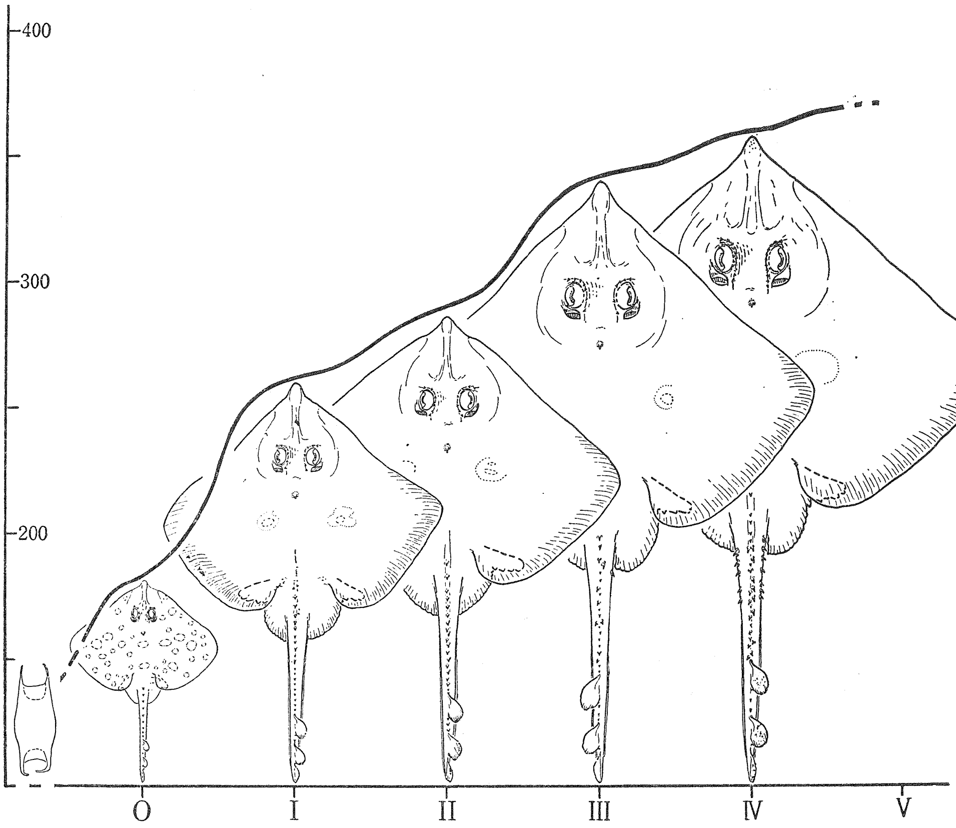

Fig. 57. Diagrammatic illustration of annual growth of the common skate, *Raja kenojei*, estimated from the rings formed in the centrums. Age, x-axis; disc-width (mm), y-axis.

Comparing the curve of Fig. 57 with that of Fig. 58, it is rather clear in the species (M) that the width of disc grows in more simple trend with age than the total length of body, which shows a complex curve in the growth. This differential growth in the respective dimension, viz., growth of the width of disc is considered to occur in direct relation with monosymmetrical increase in the pectoral fins which surves principally for locomotion; in other words, as KEARNEY (1914) in the growth of a dogfish and also by HAMAI (1940) in the carp, the parts holding a high percentage of musculature have necessarily the most intensive growth-rate on account of the massive growth of the musculature. On the contrary, the growth of total length is given rise to by various parts with differential growth-rates which change more or less during the life-history. This is the reason why the width of disc seems useful for the standard dimension, when relative growth of various bodily parts with age is compared in different species.

It should be specially mentioned herewith that, in the annual growth of the width of disc that provides an exponential curve in the species (M) and probably in other rajids, the growth curve is well fit with WALFORD's growth transformation (WALFORD, 1946), and from this straight line the ultimate width of disc or the age may be computable as about 600 mm or six ages, which are well comparable with those presumed from actual landings of the fish of this species. But, the ultimate width of disc supposed from the curve calculated is somewhat less than that derived from WALFORD's method. This difference in the two figures may be caused from the sampling method in age-determination used in the present study. In this connection, the calculation of the width of disc in relation to the age of fish has been summed up in amalgamation of the two sexes, though the female grows larger than the male even in the same age (cf. Fig. 73 and Table 16).

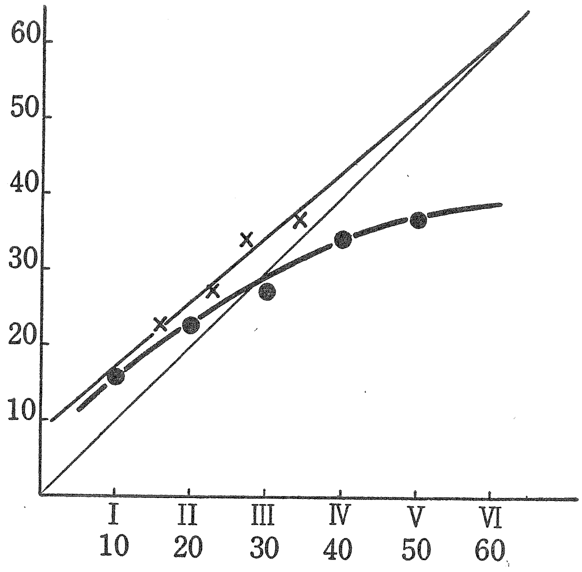

Fig. 58. Calculated age/disc-width relations of the skate, *Raja kenojei*, indicating by dotts on thickened curve, and by crosses on straight line transformed by means of WALFORD's method, where disc-width at ages 1, 2, ... , n are plotted along the x-axis against widths at ages at 2, 3,... , n−1 along the y-axis.

B. Zoogeographical remarks

In the following are briefly summarized some results obtained from geographical reconnaissance of Japanese rajids, to elucidate the faunal characteristics of this group of fishes in comparing them with those of the other representative regions in the world*).

1. Distribution of genera

As often recorded by the present writer, Japanese rajids are classified into three

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* Division of major faunal regions of the sea is referred to EKMAN (1952) and SVERDRUP et al. (1955: The Ocean).

genera, which are found in the seas covering from the South China Sea to the Sea of Okhotsk. Of the three, *Rhinoraja* seems endemic to the deep seas of the Pacific, offing of the northern and middle districts of the main island of Japan, that is, the southern regions in the east Asiatic temperate region. But the genera *Breviraja* and *Raja* are cosmopolitic, being found in the Atlantic and the Pacific faunas. In Japan, however, *Breviraja* is more or less arctic as compared with *Raja* which is more or less a representative of the southern Japan.

The genera found in the seas around Japan and its adjacent regions are less numerous than those found in the Atlantic Ocean inclusive of the western and southern regions, which contain six, though we are still uncertain of the generic composition of rajids in the tropical Indo-Australian Pacific regions. It may be said, however, that Japanese rajids have poorer generic composition than those of the Atlantic basin, where the most numerous genera with highly diversification in features are found among all the representative regions of the world.

2. Distribution of species

Through the present study it becomes evident the 21 species and 4 subspecies of rajids are represented in the seas around Japan, attaining to twice as many species as hitherto been recognized. Of these, about half the number of species (**A** to **L**) are referred to the two genera, *Breviraja* and *Rhinoraja*, the so-called northern form, and the rest (**M** to **W**) are included in the genus *Raja*, the southern form. Geographically, the species referred to the former two genera seem to be in close relation with the cold currents, as the Oyashio and the Liman current, and the latter genus seems influenced directly by the warm current, the Kuroshio current. The boundary in distribution between the two forms corresponds fairly well with that found between the representative currents mentioned above. Namely, the northern form is distribtuted in the seas from the north of Hokkaido to the middle of southern part of Japan proper (Honshû), extending to off Kôchi in the Pacific and off Shimane Prefecture in the Sea of Japan. The southern form, on the contrary, is distributed from the shallow waters off northern districts of Japan proper to the South China Sea or to the deep seas off the middle of our main island (Honshû or Hondo), passing through the Tsugaru Strait, but the two species (**T** and **U**) are excepted, which inhabit the seas around Hokkaido. Thus, the geographical distribution of the two major forms of Japanese rajids is overlapped in northern and middle regions of Japan, as is found in the two currents. These facts agree well with those given by TANAKA (1931, pp. 22-25) in geographical distribution of Japanese fishes and other marine animals.

Although genera of rajids are rather few in number in the seas around Japan as aforementioned, species are rather numerous, when compared with those in other faunal area in the world*).

3. Consideration of faunistic features characteristic of the rajids found in the seas around Japan

On the basis of distributional pattern in both genera and species of rajids dealt with here, the characteristic features may be summarized in the following line: i) from a viewpoint of generic composition rajid fishes found in the Pacific are thought to be in close relation with those found in the Atlantic, because the two basins comprise the two common genera, which seem to be the leading stocks of modern

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* As regards generic as well as specific composition of rajids hitherto found in the representative regions of the world, see the voluminous work done by BIGELOW and SCHROEDER (1953^b).

rajids. However, according to JORDAN's theory (1925), the center of dispersal of rajids may be the Atlantic, where number of genera and species of this group are more numerous than those found in the Pacific, on the whole; ii) the rajids found in the North-western Pacific may have closer affinity to those found in the North-Eastern Pacific than to those of any other part of the Pacific region, though we are still lacking in the details of systematic composition of this group from the latter region.

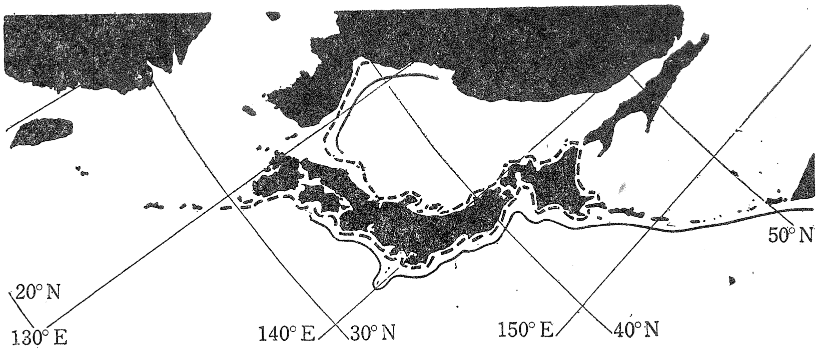

Fig. 59. Total range of rajid fishes found in the seas around Japan, showing distributional patterns of the two representative forms. Unbroken line, northern form; broken line, southern form.

For instance, the two species (G and H) of the northern form are common in the seas off northern Japan and Alaska as well as in the North American waters, although the identification of these two species is still more or less doubtful. Probably, some rajids of the northern form found in the northern Japan may also be found to inhabit the North-eastern Pacific region, which belongs to the arctic faunal region together with the North-western Pacific one. If so, it may be said that the rajids in the two different regions may have arisen from a congeneric stock, and may have been differentiated in their own evolutional pattern on the two sides of the North Pacific; and iii) it is a striking evidence that in Japanese rajids, almost all members of the northern form and the whole of the southern one are endemic, and that the two forms in the waters around Japan are well balanced in the number of species, although both forms may have arisen from the common ancestral stock in the northern waters. These facts are presumed to have been caused, powerfully influenced by the two main currents, the Kuroshio and the Oyashio.

As regards the biogeographical differentiation in minor ranks, they shall be discussed in the systematic part.

VI. Taxonomy

Family Rajidae

The diagnosis of the present family was so completely given by BIGELOW and SCHROEDER (1953^b) on world-wide basis of the study that there seems no room for the neccesity of newly adding to the description.

The Japanese rajid fishes has classified into three genera, i. e. *Raja*, *Breviraja* and *Rhinoraja*, the last of which is thought to be endemic to the waters around Japan, but other two may be cosmoplitic as already mentioned.

Although the present family should be subdivided genealogically into higher ranks above those genera heretofore erected by various authors it may be wise to reserve for future study untill more compact knowledge of the fish shall be accumulated with world-wide study.

The following key to the Japanese genera is based on both external and internal features which seem to be merit for the fundamental importance of each genera.

Key to genera of Japanese rajids

1a. Snout with hard axis in touch, bearing distinct rostral ridge. Disc always longer than tail with less number of counts of precaudal vertebrae, ranging from 36 to 61. Electric organ more or less well-developed with disc-form elements, extending from tip to near or beyond the base of tail (Fig. 30). Rostral cartilage stout, projecting from skull in a rod- or tape-like bar, inserted by rostral appendices or wings at the anterior extremity of the cartilage; posterior ends of the wings free or very close to lateral sides of rostral cartilage. Radial cartilages of pectoral fins apart far from lateral sides of the wings, leaving more or less broadly developed semicartilaginous tissue in the snout (Fig. 27). Clasper usually depressed dorso-ventrally, bearing complex structure (Types 8—13)............ *Raja*

1b. Snout very soft and flexible without clear rostral ridge. Disc usually shorter than or nearly as long as tail with some exceptions; precaudal vertebrae numerous, ranging from 63 to 91. Electric organ composed of cup-form elements, covering from tip to near middle of the tail (Fig. 30). Rostral cartilage very feeble, developed from skull in slender tape- or bar-like projection, inserted anteriorly by rostral appendices, posterior ends of which are apparently free from lateral sides of rostral cartilage. Radial cartilages of pectoral fins closely contact with the rostral appendices (Fig. 28). Clasper usually cylindrical, taking rather simple structure of glans (Types 1—7).

2a. Rostral cartilage without segment (Fig. 26 B). Tail usually almost as long as or slightly longer than disc, but when tail bears relatively large electric organ (Fig. 35 H, I) the disc more or less longer than tail even when provided with numerous precaudal vertebrae ranging from 63 to 87 .... *Breviraja*

2b. Rostral cartilage with a segment (Fig. 26 K). Tail always longer than disc, bearing small electric organ (Fig. 35 J, K, L) and numerous precaudal vertebrae with range from 74 to 91 .... *Rhinoraja*

Breviraja BIGELOW and SCHROEDER 1948, emend

Breviraja BIGELOW and SCHROEDER, Jour. Mar. Resser. 7 (3): 231. Genotype; *Breviraja colesi* BIGELOW and SCHROEDER, 1948, Atlantic species.

The diagnosis of the present genus may further be emended so as to add following characters which were already given in part by the present author (1952): Whole dorsal surface of disc and tail furnished more or less with prickles or thorns bearing stellate bases when born, thenceforth the scales become more setose or smooth with growth of the body. Snout very soft, without clear rostral ridge when touch. Tail usually slender, elongated (Round-type), nearly as long as or longer than disc. Rostral cartilage delicate, projecting foreward from skull, with a slender tape- or bar-like cartilage, which bears anteriorly a very thin rostral appendix on each side; the appendix hanging posteriorly with distal part free from lateral side of the rostral cartilage (Fig. 28). Radial cartilages of pectoral fins stand very close to the rostral appendices. Clasper usually cylindrical (Club-type), with or without pseudosiphon on posterior dorsum; structure on inside border of the glans rather simple, avoiding the development of rhipidion and shield (Figs. 3 and 4); but the cartilages show ideomorphic feature (Figs. 12 and 13). Precaudal vertebrae numerous, covering 63 to 88. Electric organ composed of cup-form elements, running from tip to midway of tail (Fig. 35). Egg-capsule usually bearing long horn on each four corner with slit located at midway or near distal tip of the horn; capsule-wall composed of two layers, having rough surface in most cases.

It is wiser to treat Japanese species referable to the present genus by subdividing into three subgenera on the basis of following points, thus; feature of spination, number of abdominal and precaudal vertebrae, structure of glans clasper, relative length of tail in relation to degree of development of the electric organ, and features of egg-capsules.

Key to subgenera of the genus *Breviraja*

1a. Tail much longer than width of disc; abdominal vertebrae relatively few, measuring below 30; characteristics of glans clasper, Type 3; electric organ very small; egg-capsule with smooth surface .... *Notoraja*, n. subg.

1b. Tail shorter than width of disc; abdominal vertebrae numerous, being above 30; characteristics of glans clasper, Types 4—7; electric organ moderately large; egg-capsule with rough or rather rough surface.

  2a. Tail greater than 70% of width of disc; dorsal surface of disc setose or almost smooth when matured; electric organ moderately developed, usually polygonal in cross view; precaudal vertebrae less than about 80; clasper is of Types 4—6; egg-capsule equipped with long, whip-like horns and roughened with pungent spines .... *Bathyraja*, n. subg.

  2b. Tail less than 60% of width of disc; dorsal surface of disc largely smooth in the adult; electric organ relatively large, roundish in cross view; precaudal vertebrae more than about 80; clasper is of Type 7; egg-capsule bearing flattened horns and rather roughened with minute ridges running lengthwisely...... *Arctoraja*, n. subg.

Notoraja, n. subg.

Body entirely covered with numerous prickles on dorsal surface, but ventral side wholly smooth; snout, soft and flexible, projecting forward with blunt tip. Tail exceedingly long, longer than half the total length of body or than width of disc; procaudal portion rather long, with distinct caudal fin prickled. Pelvic fin deeply notched with slender anterior lobe. Rostral cartilage much slender, inserted anteriorly by long rostral appendices which reach to near midway point of the rostral cartilage. Anterior fontanelle large, triangular in shape. Abdominal vertebrae quite different in number from other members of the genus *Breviraja*, measuring 24—27. Structure of glans clasper is of peculiar, Type 3. Electric organ very small in both size and number of elements. Egg-capsule with very smooth surface and long roundish horn on each corner.

Type species: *Raja tobitukai* HIYAMA, 1940

Notes: The present subgenus differs rather widely from *Bathyraja* and *Arctoraja* as given in the foregoing key, especially in having such fundamental characters as less abdominal vertebrae and specialized clasper organ, which serve in establishing this new subgenus. Only one species is referred to this subgenus, with limitted range in the habitat from the southernmost region within the seas inhabited by the northern members.

Breviraja (*Notoraja*) *tobitukai* (HIYAMA)

(Abbreviated as A; Japanese name, Tobituka-ei)

Fig. 60; Pl. I, A

Raja isotrachys MATSUBARA (non GÜNTHER), 1936, p. 23, Kumano-nada (key).

Raja tobitukai HIYAMA, 1940, p. 169, fig. 1, Kumano-nada (original description). —— KAMOHARA, 1952, p. 10, off Kôchi.

Breviraja tobitukai ISHIYAMA, 1952, p. 1, fig, 1, Kumano-nada (key). —— ISHIYAMA, 1955, p, 271, figs. 1,3,4, Kumano-nada (electric organ). ——ISHIYAMA and KUWABARA, 1955, p. 87, figs. 1-4, Kumano-nada(electric organ).——Matsubara, 1955, p. 138, Kumano-nada (key).

Materials examined: 22 specimens, 374-507 mm in total length, and 4 egg-capsules, deep sea (300-400 m in depth) off Aichi and Shizuoka Prefectures; 1940—1953.

External: Snout very soft, flexible and pointed only at the extremity, proportion of which 2.03-2.20 and 2.10-2.26 times into head in male and female, respectively. Eye very large, longer diameter greater than interorbital width and about 2 times into snout-length; iris lapet absent. Tail remarkably long, much longer than width of disc; precaudal almost equal to or trifle shorter than length of disc; procaudal rather long, about as long as preoral length in most case; lateral folds of tail distinct, run from root to tip of tail. Anterior lobe of pelvic fin slender, bearing a deep notch between it and the posterior lobe. Caudal fin distinct, about as long as eye.

Prickles uniformly developed on entire dorsal surface without noticeable enlarged thorns, no sexual differences in spination but in matured male, pelvic fins without prickle and pectoral fins armed with backler spines opposite being the case with matured female; dorsal and caudal fins all setose, but under surface of body smooth; somewhat thickened prickles set along mesial line of tail (Fig. 60 A_1).

Color on both sides uniform gray without any pattern (A in Pl. I).

Internal: Rostral cartilage very feeble and long; rostral appendices also very long and thin, reaching as far posteriorly to near middle of rostral cartilage. Anterior fontanelle of cranium long, triangular in shape; posterior one elongated with shallow constriction at the middle portion (Fig. 28 A).

Vertebrae in abdominal and precaudal portions comparatively few in number, ranging 24-27 (25.5 in average) and 63—70 (65.6 in average), respectively (Figs. 43 and 44: A).

Intestinal valves much fewer than in any other species referred to the genus, covering 5-6 (5.7 in average), (Fig. 48 A). Heart valves set in four series in three rows as in other species of this genus (Fig. 51 A).

Clasper specialized in its glans, in having knife modified from accessory terminal

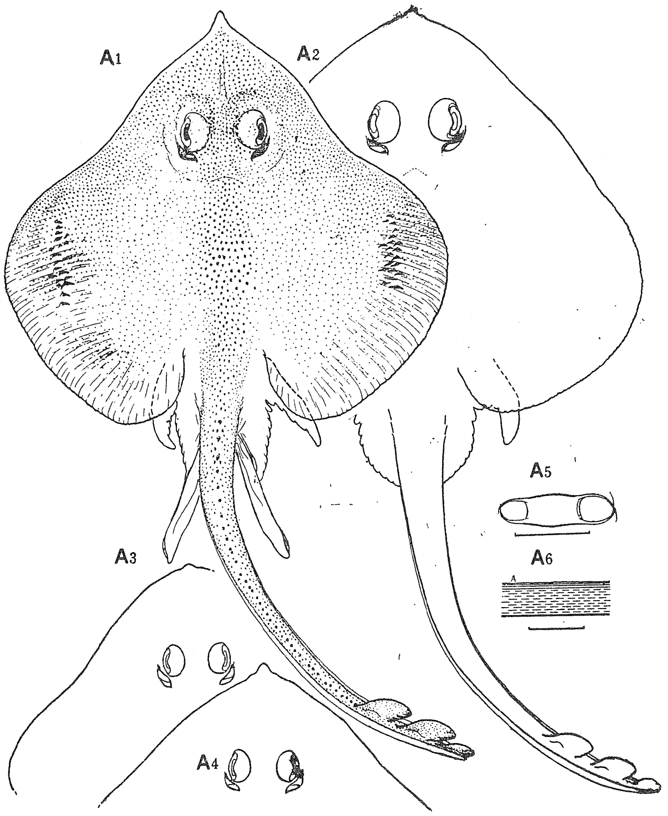

Fig. 60. *Breviraja tobitukai* (HIYAMA); A_1, adult male (473 mm); A_2, adult female (507 mm), prickles omitted; A_3, subadult male (473 mm); A_4, subadult female (412 mm); A_5, egg-capsule, scale 5 cm; A_6, section of capsule-wall, scale 0.2 mm. $A_{2,3,4}$ showing differences in outline of body or anterior portion between adult male and female or the younger fishes. All these specimens were taken from the Kumano-nada.

and having claw and pela on ventral lobe, Type 3 (Figs. 4 and 12: A).

Developmental stages: One adolescence is available in the present study, but the knowledge on the young is still scanty. It should be noted herewith that the features as well as the proportion of snout are markedly change when matured in male, but the phenomena are not so conspicuous in the female even in the adult (A_{1-4} in Fig. 60).

Egg-capsule: (Type 1); very small, translucent when fresh, characterized by having very smooth surface, long whip-like projection at each four corner and monotypic structure of the wall, all of which are considered to be generalized characters ($A_{5,6}$ in Fig. 60).

Notes: This species was first added to Japanese rajids by HIYAMA (1940) from Kumano-nada off Aichi Prefecture. But the range in distribution of the present species seems to be confined to the deep sea, offing from Kôchi to Shizuoka Prefectures (Table 1), where the animal is rarely found in the landings of the trawler, and the range mentioned above is thought to cover the southernmost part in the region where the northern form inhabits. On the basis of the characters in both external and internal as mentioned above, the present species seems to maintain rather generalized features as compared with the relatives. Thus, we may be able to agree here with a view (BRIGGS, 1955, p. 157) on geographical distribution and differentiation in the animal that the most primitive form occurs on the periphery of the area inhabited by the family.

The present species resembles species J in general appearance, especially in having long tail, numerous prickles without noticeable modification, but the two species are quite distinct from each other in the fundamental characters, such as the rostral cartilage, counts of precaudal vertebrae and structure of glans clasper.

Bathyraja, n. subg.

Dorsal side of disc entirely prickled or partly setose when matured, but ventral surface usually naked with a few exceptions; enlarged thorns usually present on nuchal and shoulder regions, and on mesial line of tail. Snout bluntly elongated in more or less extent, and soft, flexible in touch. Tail long, slender and rod-like in general outline (Round-type), about as long as 70% or more of disc-width; procaudal portion moderate in length, leaving rather distinct caudal fin. Pelvic fin notched more or less.

Rostral cartilage slender, tapers in its main portion, which shows serpentine form in some species; rostral appendices characteristically develop in various degrees (Fig. 28). Shape and location of anterior fontanelle vary specifically. Abdominal and precaudal vertebrae ranging 31-38 and 66-82, respectively. Electric organ moderately developed. Clasper is of Types 4-6, taking with ideomorphic feature. Egg-capsule roughened in greater or less degrees, bearing very long, whip-like horns (Type 4).

Type species: *Raja isotrachys* GÜNTHER, 1877

Notes: The present subgenus seems to involve some variants, but they agree well with each other in some fundamental characters, such as trend in development of prickles and enlarged thorns, and in egg-capsule, and features of rostral cartilage and its appendices, number of vertebrae in both abdominal and precaudal portions, proportional length of tail closely relating to the degree of development of electric organ, and tendency in transpecific specialization of structure of clasper. On the basis of these characteristics the present author established this new subgenus so as to make clear from other subgenera in the genus *Breviraja*. The present subgenus includes annexed six species, in which one is recorded herein as new to science.

Key to species of the subgenus *Bathyraja*

1a. Dorsal surface of disc entirely rough with numerous prickles or partly smooth even in the adult; enlarged thorns more or less well-developed on both nuchal and shoulder regions.

2a. Snout broad and elongate, about half times as long as head; dorsal surface entirely rough with numerous prickles, but smooth the ventral; nuchal spines 3-5, intermitted from those setting on tail; ventral surface without distinct black blotches. Rostral cartilage slender, rod-like in shape, about as long as or shorter than cranium.

3a. Dorsal surface of disc uniformly covered with numerous minute prickles in both males and females; nuchal and shoulder thorns usually distinct. Rostral cartilage about as long as cranium (B in Fig. 26); intestinal spiral valves 10-11 (10.6 in average). Clasper representing Type 4 (B in Figs. 4 and 12), characterized by having rudimentary pseudosiphon (Type-Ps^2) .... *isotrachys* (Fig. 61).

3b. Dorsal surface of disc entirely roughened with rather thickened prickles, which are somewhat sparse on basal portion of pectoral fins in matured male; both nuchal and shoulder thorns more or less obscure. Rostral cartilage shorter than cranium (C in Fig. 28); intestinal spiral valves 8-10 (9.0 in average). Clasper structure is of Type 5 (C in Figs. 4 and 12), distinct from that of preceding species in absence of pseudosiphon and in having much reduced dorsal terminal 1 .... *trachouros*, n. sp. (Fig. 62)

2b. Snout long, rather accumulated, more than half times as long as head; disc wholly furnished with very small prickles on both surfaces; large thorns developed on shoulder and nuchal region, to which those setting on mesial line of tail are continued in a row; ventral surface bearing some black blotches, Rostral cartilage tapers, meandering in serpentine form in most cases (G in Fig. 28). Clasper, Type 6 (G in Figs. 4 and 12), distinguished from those of relatives in having much simple structure and reduced ventral terminal .... *aleutica* (Fig. 66)

1b. Dorsal surface of disc greater or less smooth when matured, but armed with more or less well-developed prickles overall in young, enlarged thorns present or absent on nuchal, and absent on shoulder.

4a. Enlarged thorns usually absent or very few, if present, on nuchal region; dorsum of disc setose on anterior marginal, orbital and mid-belt portions, to which prickles developed on tail are continuous, covering in a band. Ventral surface wholly white with or without dark ring margined cloaca. Rostral cartilage long, about as long as cranium; rostral appendices much shorter than half the length of rostral cartilage (Fig. 28). Intestinal valves 8—11. Egg-capsule armed with numerous prickles without cover of heavy thread-like tendrils.

5a. Pelvic fin moderately notched; nuchal spine absent, but caudal ones present at places in a row. Dorsum of disc grayish brown, with irregular patterns. Precaudal vertebrae 66—70 (67.6 in average), and intestinal valves 8—9 (8.2 in average). Clasper, Type 5 (D in Figs. 4 and 12), characterized by having remarkably reduced dorsal terminal 1 without pseudosiphon .... *abasiriensis* (Fig. 63)

5b. Pelvic fin deeply notched; nuchal spines absent or a few, if present, ranging 1—3 (0.35 in average), but caudal ones usually distinct, setting regularly in a row. Dorsum of body uniformly faint rosy or dark chocolate, without any peculiar color patterns. Clasper is of Type 6 (E in Figs. 4 and 12), characterized by having rather small pseudosiphon and specialized accessory terminal 2 .... *diplotaenia* (Fig. 64)

4b. Nuchal thorns distinct, usually 3—6, well-developed. Dorsum of disc largely smooth, but small areas on anterior marginal, orbital and mid-belt regions armed with prickles, with which prickles covering on tail are continuous, running in a band. Both surfaces of body darkish purple. Clasper, Type 6 (F in Figs. 4, and 12), especially notified with large pseudosiphon and long accessory terminal 2. Egg-capsule much specialized in having heavy cover of thread-like tendrils over prickly surface .... *matsubarai* (Fig. 65)

Breviraja (*Bathyraja*) *isotrachys* (GÜNTHER)

(Abbreviated as B; Japanese name, Soko-gangi-ei)
Fig. 61

Raja isotrachys GÜNTHER, 1877, p. 434, southern Japan (original description). —— 1887, p. 7, Pl. 3, lat. 34° 7' N, long. 38° E. —— JORDAN and

SNYDER, 1901, p. 42, (reference). —— JORDAN and FOWLER, 1903, p. 649 (compiled). —— TANAKA, 1927, p. 670, fig. 430, Hokkaido to northern Japan. —— JORDAN and HUBBS, 1925, p. 93, northern Japan (key). —— FOWLER, 1930, p. 354 (reference). —— MATSUBARA, 1935, p. 44, (in Japanese) (key). —— 1936, p. 22, (in Japanese) fig. 13 (compiled). —— OKADA and MATSUBARA, 1938, p. 23 (in Japanese) (key). —— FOWLER, 1941, p. 379 (reference). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2, Sea of Japan and coast of Hokkaido (egg-capsule); 1950—1951.

Raia isotrachys GARMAN, 1913, p. 354 (compiled).

Breviraja isotrachys ISHIYAMA, 1952, p. 9, fig. 2, Sea of Japan and northern Japan (key). —— HONMA, 1954, p. 2, Sea of Japan (listed). ——, 1955, p. 218, Sea of Japan (listed). —— ISHIYAMA, 1955, p. 271, figs. 2—4, northern Japan (electric organ). —— MATSUBARA, 1955, p. 139, northern Japan (key).

Materials examined: 34 specimens (209—930 mm in total length) and 4 egg-capsules; deep seas off middle of Japan and coast of Hokkaido; 1940—1950.

External: Snout broadly elongated with rather straight lateral margins, nearly half as long as head, being trifle greater in the ratio in male than in female (B in Fig. 24). Eye moderately large, the diameter on longer axis a little smaller than interorbital width, which is 3.2 to 3.8 times as long as snout. Tail rod-like in general form (Round-type), almost as long as disc, but shorter than the disc-width, being 1.2—1.8 times in the latter (B in Fig. 31). Pelvic fin moderately notched; two dorsals subequal, the longest dimension about one-fifth the length of head; caudal fin usually distinct as a small flap.

Doral surface of body wholly armed with numerous minute prickles without noticeable reduction even in the adult; 2—6 and 1 thorns developed respectively on nuchal and shoulder regions, in most cases, and a row of 18—28 enlarged thorns also along mesial line of tail; dorsals, caudal and pelvic fins prickled. Ventral surface of body entirely smooth.

Prior to preservation dorsum golden drab, but it becomes grayish brown after preservation, without any particular color pattern; ventral side of body white, excepting tail, where a few dusky bands are found in some cases. (Fig. 61 $B_{1,2}$).

Internal: Rostral cartilage long, elongated anteriorly, about as long as cranium; rostral appendices extending as far posteriorly to about one-third the way to base of rostral cartilage. Anterior fontanelle large, elliptical in shape, followed anteriorly by a small slit in some specimens; posterior fontanelle long, strongly constricted medially (B in Fig. 26).

Vertebrae as many as 34—40 + 73—82. Intestinal spiral valves 10—11 (10.6 in average). Heart valves mainly 4 in a row (B in Fig. 51).

Electric organ medium in size, pertaining fundamental structure in the electric elements of northern form (B in Fig. 35).

Clasper is of Type 4, especially peculiar in possessions of half vestiged pseudosiphon and large dorsal terminal 1 (B in Figs. 3, 4 and 17).

Developmental stages: Proportional length of snout in young almost the same as in the adult (B in Table 6), but that of tail more or less different between the two stages, being the tail about as long as disc-width in the young (B in Table 7).

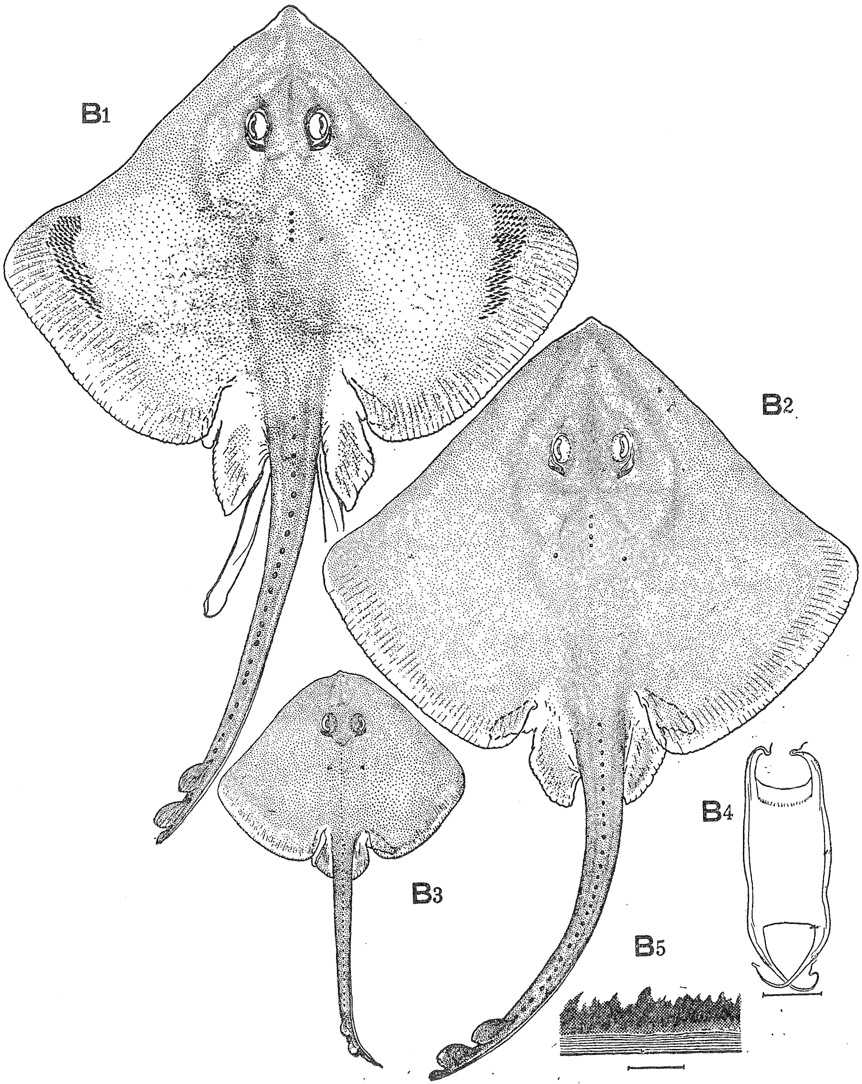

Fig. 61. *Breviraja isotrachys* (GÜNTHER); B_1, adult male (930 mm); B_2, adult female (875 mm); B_3, young male (209 mm); B_4, egg-cupsule, scale 5 cm; B_5, section of capsule-wall, scale 1 mm. All these specimens were taken from the Okhotsk Sea, off Monbetsu and Wakkanai, Hokkaido.

Egg-capsule: Capsule is of Type 4, large, characterized by having long horns and rough surface with numerous minute prickles ($B_{4,5}$ in Fig. 61).

Notes: So far as is known to the writer the present species seems to inhabit the northern waters around Japan, covering the main island northward of middle region, i.e. from off Shimane Prefecture (the Sea of Japan) and Chiba Prefecture (the Pacific) to north of Hokkaido (the Sea of Okhotsk). In the southern area within this region, the depth of habitat usually exceeds 200 meters, but it becomes shallower, about 100 meters or shallower in the north.

Since GÜNTHER (1877) has recorded first this species from south of Japan very few confusions in its identification were encountered with some ichthyologists on account of being very common in the northern waters, and having rather conspicuous features in the first sight. However, the present author found an another one which closely resembles the present species, and the comparison between the two will be given in detail with annexed species.

Breviraja (*Bathyraja*) *trachouros*, n. sp.
(Abbreviated as C; New Japanese name, Zara-kasube)
Fig. 62

Materials described: Holotype, 900 mm, off Erimo Peninsula, Hokkaido, May 19, 1951; paratypes, 30 specimens (230—1023 mm in total length) and 5 egg-capsules, off Kushiro and Muroran in Hokkaido, and off Same and Shiogama in northern Hondo; 1950—1951.

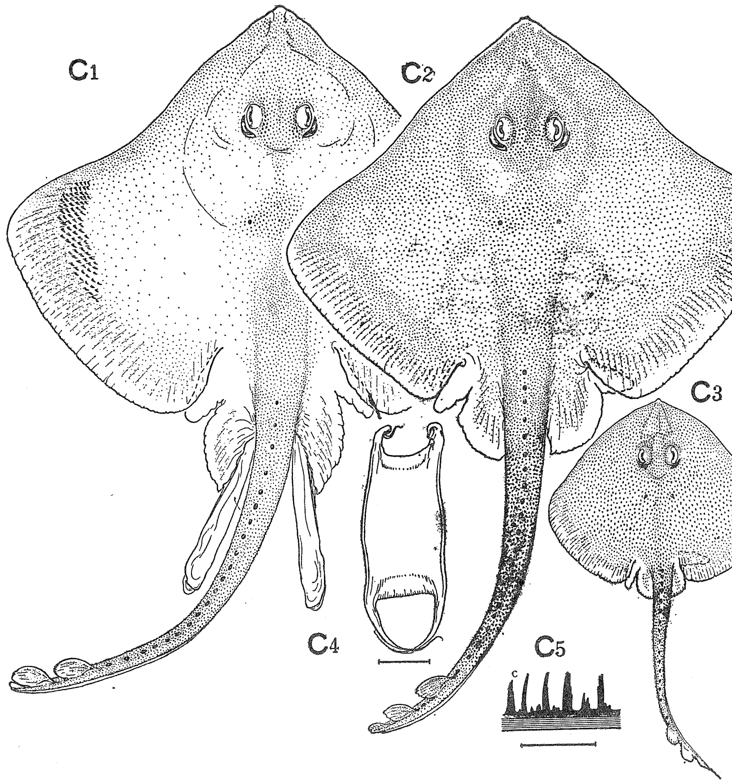

Fig. 62. *Breviraja trachouros*, n. sp.; C_1, holotype, adult male(900 mm); C_2, adult female (835 mm); C_3, young female (230 mm); C_4, egg-capsule, scale 5 mm; C_5, section of capsule-wall, scale 1 mm. All these specimens were gathered at Same fish market, being taken from off the Erimo Peninsula.

External: Disc-length 2.05, width 1.58, tail 1.83 in total length; head 1.95, snout 4.18, precaudal 1.13, preoral 1.53 in disc-length. Snout 2.15, 1st and 2nd dorsal 4.15 and 4.56, respectively, and caudal fin 10.70 in head. Interorbital width 3.51, diameter of eye 4.08 in snout.

Body is more rugged in general appearance than in the preceding species. Anterior oblique margins weakly undulated from opposite of gill chamber to tip of snout, which is broadly elongated to the blunt tip. Tail stiffened, rod-like in shape (Round-type), 0.90 and 1.15 times in disc-length and disc-width, respectively. Interorbital space rather flat, the width 1.19 times as broad as the longer diameter of eye. Pelvic fin moderately notched with anterior lobe broadened. Clasper large, stiffened with blunt glans, reaching to middle of tail, whereby dermal fold originates and becomes broader rearward on both sides. Two dorsals moderately large, ensuing small caudal fin.

Entire dorsal surface setose with rather thickened prickles, which become denser toward anterior oblique marginal region, orbital margins, mid-belt of disc from nucha to tail, but become sparse toward basal portion of pectoral fins. Posterior lobe of pelvic fin and two dorsals also prickled. Nuchal thorns illegible, but shoulder one rather distinct on both sides. Backlar spines broadly developed, one to seven in a transverse series. Enlarged thorns 20, setting in a longitudinal row along mesial line of tail. (C_1 in Fig. 62).

Color of dorsum in fresh condition uniformly golden drab, which changes from brown to grayish after preservation; ventral surface white as a whole, with exceptions of tail and margin of cloaca, both of which are pigmented with dusky color.

Internal: Rostral cartilage rather feeble, anteriorly elongated into slender rod-like projection, which is shorter than cranium (C in Fig. 28). Rostral appendices moderately developed, reaching posteriorly one-third the way to the base of rostral cartilage. Anterior fontanelle tumbler-like in shape, and posterior one elongated, much constricted at midway point.

Electric organ feebly developed and electric elements not so numerous, locating on posterior portion of tail (C in Fig. 35). Vertebral counts in two portions, 32—36 + 71—76. Intestinal spiral valves 8—10, and 9.0 in average. Heart valves 3 in a row in most cases.

Clasper is of Type 5, much specialized, particularly annotated with broadly expansible glans without pseudosiphon, and much reduced dorsal terminal 1 (C in Figs. 3,4 and 12).

The external features mentioned above was derived from the holotype, but the internal features as well as the followings were taken from paratypes.

Egg-capsule: Egg-capsule of this species closely resembles in general appearance those of species B, E and F, in having long horns and rough surface. But, having examined in detail the characters, the capsule-wall of the present species was referred to Type 4 together with that of species B and E, in having numerous prickles running lengthwisely over the surface ($C_{4,5}$ in Fig. 62).

Developmental stages: Snout becomes relatively longer with growth of the fish, covering the ratio in head-length from 1.89 to 2.07 times (C in Table 6). As shown in the accompanying Figs. the snout is blunter in the young than the adult ($C_{1—3}$ in Fig. 62). Proportional measurement of eye-diameter to snout-length and to interorbital width are remarkably changed with growth of the body, viz., the eye-diameter is greater than one-third times as long as snout, and it is longer than interorbital width in the young. Tail about as long as disc-width in young, but the former becomes shorter than the latter with the growth of the fish (C in Table 7).

Spination of dorsum almost the same throughout life, except for the adult male, in which the prickles setting on basal portions of pectoral fins much fewer than those of the adult female. Nuchal thorns one to four, if present, usually inconspicuous; a pair of shoulder thorns conspicuous in most cases; a row of 18 to 30 tail thorns obviously developed, interrupted by intervention of 1st dorsal fin.

Color on both sides of body rather same throughout life as explained in the holotype. The present species is apparently deep-sea dweller off northern part of the main island of Japan, from Chiba to Aomori Prefectures, where the present fish is captured rather numerous by means of deep-sea trawler operating in the depth of about 200 to 300 fathoms.

Remarks: The present species very closely resembles the foregoing species B, in general appearance, but the two are clearly distinguishable from each other by, i) clasper structure as explained elsewhere, ii) degree of development of spination, iii) proportional length of the eye-diameter to the snout-length (Table 19), iv) length of the rostral cartilage relative to cranium, and v) number of vertebrae and intestinal valves as has analyzed in foregoing description (Tables 9 and 10). Of these, proportional ratio of eye-diameter in snout-length varies from 2.10 to 5.30 times (3.45 in average) in the present species as compared with 2.26 to 4.45 times (3.26 times in average) in the foregoing species. A biometric comparison of the two species in some dimensions was tested by means of t-method as follows:

Table 19. Results of t-test for some dimensions of the two species, B (Y) and C (X); number of specimens of these fishes being respectively 34 and 24, and the degree of freedom for the test is 33 and 23, respectively. For other abbreviations, see p. 7.

Items	Mean, $\bar{X}/\bar{Y}$	S	t	t_0 ($\alpha = 0.05$)
Ratio of snout in head	2.01/2.08	0.12	0.89	2.00
——— head in disc-l.	1.91/1.89	0.04	2.05	—
——— tail in disc-w.	1.12/1.14	0.09	1.02	—
——— —— in total l.	1.76/1.80	0.07	1.68	—
——— eye-dia. in snout	3.65/3.26	0.71	2.04	—

On the basis of above figures, it may be said that the small differences between the two species are found in their proportional ratios of head in disc-length and of eye-diameter in snout.

Breviraja (*Bathyraja*) *abasiriensis* ISHIYAMA

(Abbreviated as D; Japanese name, Kitano-kasube)

Fig. 63

Breviraja abasiriensis ISHIYAMA, 1952, p. 19, fig. 9, Pl. 3, Okhotsk Sea (original description). —— 1955, p. 276, figs. 2—4, Okhotsk Sea (electric organ). —— MATSUBARA, 1955, p. 138, Okhotsk Sea (key).

Materials examined: 10 specimens (622—715 mm) including holotype, offing of Abashiri to Monbetsu, Okhotsk Sea; Oct. 1948 and May to June, 1951.

As regards this species the present author has given details in previous report (1952). Therefore, the diagnostic characters heretofore being uncertain will be mentioned below.

Internal: The clasper is of Type 5 (D in Figs. 3, 4 and 12), characterized by having broadly expansible glans without pseudosiphon accompanied by much reduced dorsal terminal 1. Heart valves mostly 4 in a row. Electric organ moderately developed and the elements forming the organ moderate in number. Abdominal and precaudal vertebrae 31—33 and 64—70, respectively (D in Figs. 43 and 44, and Table 9).

Egg-capsule: Unknown.

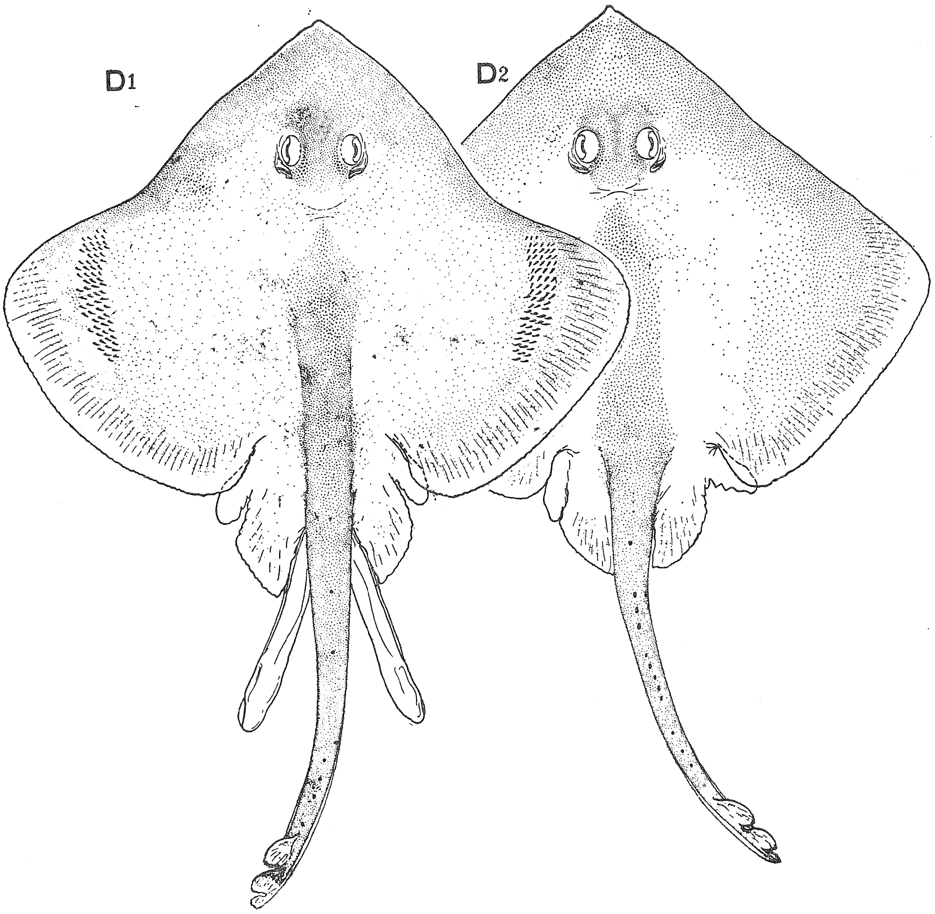

Fig. 63. *Breviraja abasiriensis* ISHIYAMA; D_1, holotype, adult male (715 mm); D_2, adult female (710 mm), from Okhotsk Sea, off Abasiri, Hokkaido.

Notes: The present species is distinct from any other relatives in the first appearance of its peculiar color patterns of the dorsum as has recorded in the previous paper (l.c.). On the basis of internal features, especially of the clasper, however, the systematic position of this species within the subgenus may be suggested to be in close relation with species **C**, through which the phyletic stem including these two species may be linked with other forms, such as species **B**.

The present species appears rather rare in the catch by the motor trawler operated in the Sea of Okhotsk and the neighbouring region.

Breviraja (*Bathyraja*) *diplotaenia* Ishiyama

(Abbreviated as **E**; Japanese name, Ribbon-kasube)

Fig. 64

Raja diplotaenia Ishiyama, 1950, p. 30, figs. 1 and 2 (egg-capsule).
Breviraja diplotaenia Ishiyama, 1952, p. 15, fig. 5, Pl. 2 (original description).
—— Ishiyama, 1955, p. 271, figs. 2—4, northern Japan (electric organ).
—— Matsubara, 1955, p. 138 (key).

Materials examined: 31 specimens (407—850 mm in total length) including holotype, and 5 egg-capsules, offing of Chôsi to Kushiro, the Pacific coast; Oct., 1948 and May to June, 1951.

A detail description of the present species was given in the previous article (ISHIYAMA, 1952), so that only the characteristics of internal features are given here so as to meet with keen diagnosis responsible for discrimination of the species and for interpretation of the characteristics useful for phyletic consideration within the genus.

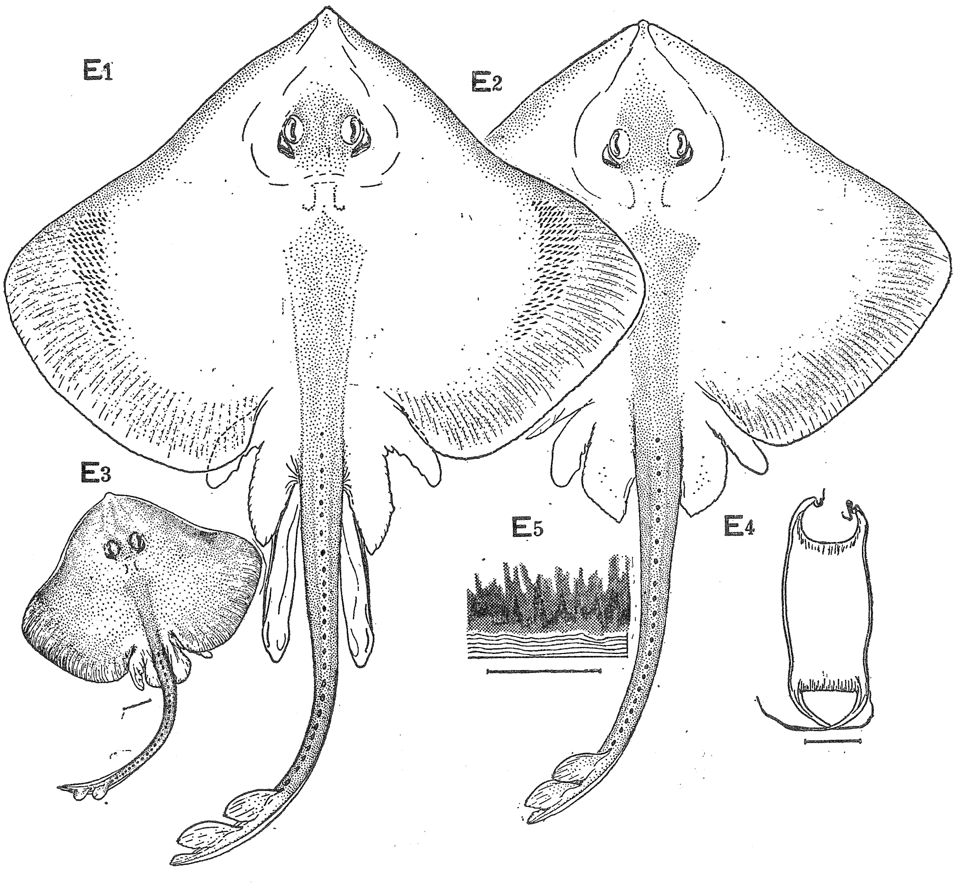

Fig. 64. *Breviraja diplotaenia* ISHIYAMA; E_1, holotype, adult male (850 mm); D_2, adult female (797 mm); D_3, young male (409 mm); D_4, egg-capsule, scale 5 cm; D_5, section of capsule-wall, scale 1 mm; off Erimo Peninsula, Hokkaido.

The clasper structure is of Type 6, which particularly attracts our attension to the possession of small pseudosiphon and broad dorsal terminal 1 (E in Figs. 3, 4 and 12). Abdominal and precaudal vertebrae, 31—37 and 70—74, respectively (E in Figs. 43 and 44). Heart valves 6 in a row in most cases (E in Table 11). Electric organ well-developed, rather large (E in Fig. 35).

Notes: This species is thought without doubt to be corgeneric descendant with the species F and G, in having some fundamentally important features closely related with each other, such as number of vertebrae and clasper structure. Moreover, it may be sure to believe that the present species might be nearest representative to their suppositional common ancestor which may be closely related to species **B** in various features as aforementioned.

Breviraja (*Bathyraja*) *matsubarai* ISHIYAMA
(Abbreviated as **F**; Japanese name, Matsubara-ei)
Fig. 65

Breviraja matsubarai ISHIYAMA, 1952, p. 10, figs. 3 and 4, Pl. 1, northern Japan (original description). —— ISHIYAMA, 1955, p. 271; figs. 2—4, northern Japan (electric organ). —— MATSUBARA, 1955, p. 138, northern Japan (key).

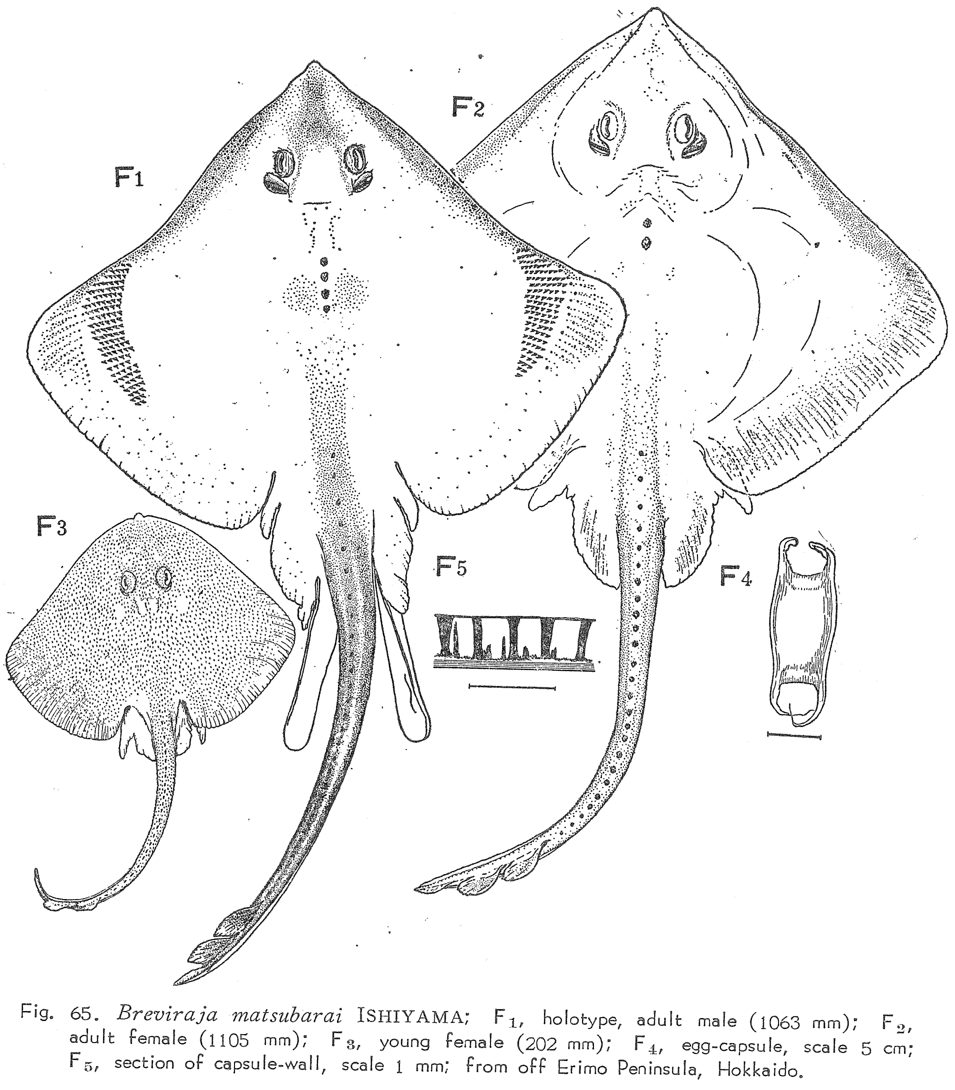

Fig. 65. *Breviraja matsubarai* ISHIYAMA; F_1, holotype, adult male (1063 mm); F_2, adult female (1105 mm); F_3, young female (202 mm); F_4, egg-capsule, scale 5 cm; F_5, section of capsule-wall, scale 1 mm; from off Erimo Peninsula, Hokkaido.

Materials examined: 18 specimens (176—1165 mm in total length) including holotype, and 2 egg-capsules, caught in the deep sea off Kushiro to Same, the Pacific coast of northern Japan; May to June, 1951.

As regards the present species the writer has given the description in detail (l.c.), so that merely some characteristics are herein appended so as to make clear the diagnosis for the basis in seeking a derivation of the species.

Structural characteristics of the clasper, Type 6, which is distinguishable from those of any other species, in having specially the distinct pseudosiphon and the partly reduced dorsal terminal 1 (F in Figs. 3,4 and 12), numerous precaudal vertebrae ranging from 71 to 73 (F in Fig. 44), and much specialized egg-capsule ($F_{4,5}$ in Fig. 65).

Notes: From above noteworthy features together with some other external and internal ones, there may be no doubt that the present species is the most specialized form resulted from its life in the great depth (cf. Table 1). The present species is found below 800 meters off the Pacific coast of the northern Honsyu.

Breviraja (*Bathyraja*) *aleutica* (GILBERT)

(Abbreviated as G; Japanese name, Alaska-kasube)
Fig. 66

Raja aleutica GILBERT, 1895, p. 397, Pl. 21, Aleutian waters (original description). —— JORDAN and EVERMANN, 1896, p. 75 (reference). —— JORDAN and GILBERT, 1899, p. 435 (reference). —— EVERMANN and GOLDSBOROUGH, 1907, p. 230, Alaska. —— SOLDATOV and LINDBERG, 1930, p. 22 (reference). —— ANDRIASHEV, 1939, p. 1 (reference). —— FOWLER, 1941, p. 393 (reference).

Raia aleutica GARMAN, 1913, p. 343 (reference).

Breviraja aleutica ISHIYAMA, 1952, p. 9, northern Japan (key). —— ISHIYAMA, 1955, p. 271, figs. 2—4, northern Japan (electric organ). —— MATSUBARA, 1955, p. 139, northern Japan (key).

Materials examined: 17 specimens, (412—1510 mm in total length), and 17 egg-capsules; deep seas off northern Honshû on the Pacific and coastal waters of Okhotsk Sea off Hokkaido; Oct., 1948 and June, 1951.

External: Disc-length 1.71—1.98 (1.90 in average), disc-width 1.49—1.71 (1.62), tail 1.75—2.20 (1.91) times into total length, respectively. Snout 1.60—2.05 (1.84) times into head, which is 1.72—1.87 (1.78) times into disc-length. Eye 4.16—8.44 (5.74), interorbital width 3.20—4.48 (3.89), 1st dorsal fin 4.70—6.97 (5.61), the second 4.83—6.61 (5.16) times into snout, respectively.

Precaudal length 1.86—2.82 (2.26) and caudal fin 5.50—11.61 (8.57) times into head, respectively.

Body largest among members of the northern form. Snout very long and flexible in touching, anterior margins of the disc almost straight even in the adult. Tail rather long and thick, almost as long as disc, but shorter than disc-width. Cutaneous fold on lateral sides of tail distinct, covering from middle to tip of tail. Pelvic fin moderately notched; two dorsals rather large, separated by a space, varying from 9.4 to 14.5 times into head-length; caudal fin well-developed, ensued from posterior end of base of 2nd dorsal fin. Clasper long, slender and stiff when matured.

Spination on dorsal surface is characteristic, viz., enlarged thorns, 34—40 (36.9 in average) in number, set in a row, running continuous from the nuchal to 2nd dorsal fin, but interrupted by an intervention of the 1st dorsal; the one to two thorns also set on each shoulder; minute prickles covering entire dorsal surface in the young, but in the matured male the spination on the pectoral fins becomes largely sparser and the surface of the pelvic fins entirely smooth; the prickles covering sides of tail somewhat thickened; two dorsal and caudal fins also armed with prickles; backlar thorns of alar spines distinct in 24 to 25 transverse rows with 1 to 6 in one series; ventral surface of head and distal part of tail roughened with minute prickles (G_1—G_3 in Fig. 66).

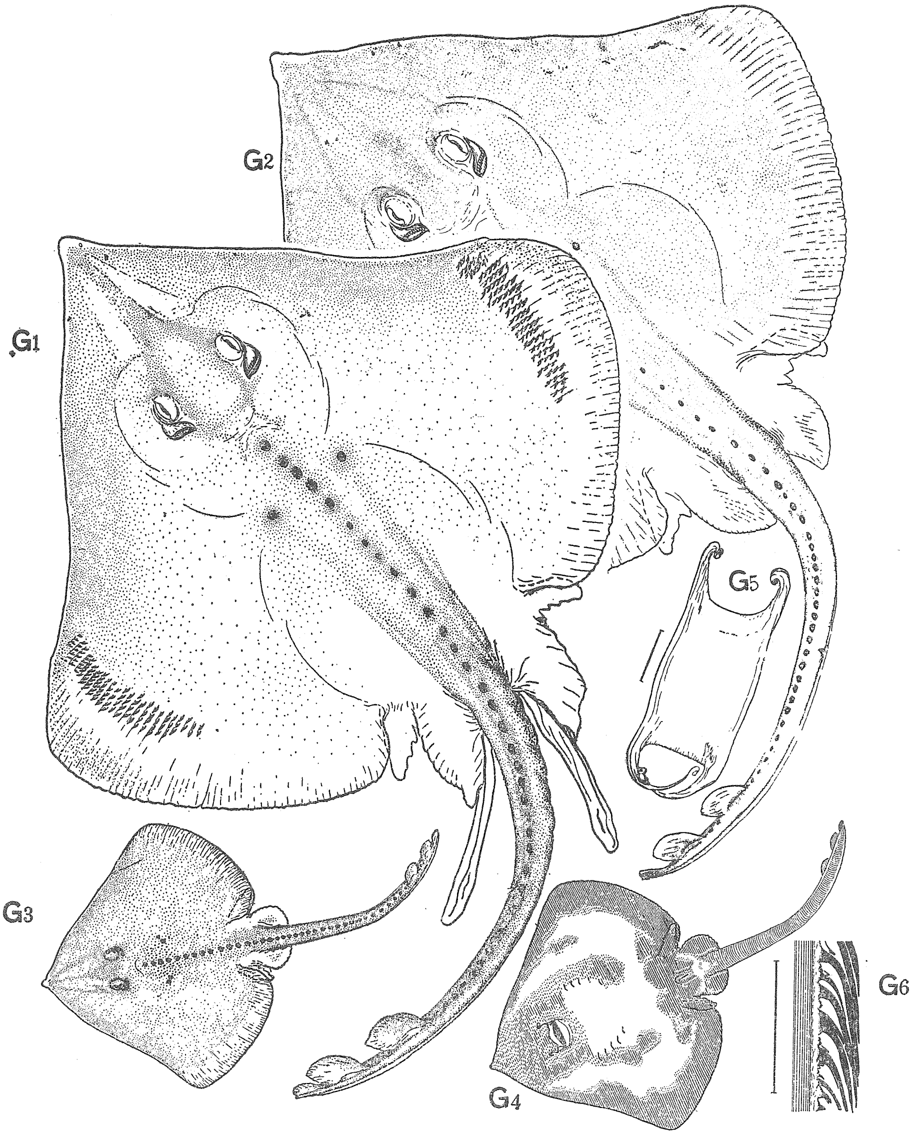

Fig. 66. *Breviraja aleutica* (GILBERT); G_1, adult male (1500 mm); G_2, adult female (1500 mm); $G_{3,4}$, young female (230 mm), showing color patterns on ventral side in G_4; G_5, egg-capsule, scale 5 mm; G_6, section of capsule-wall, scale 1 mm; from off Erimo Peninsula, Hokkaido.

Color of dorsum golden drab when fresh, but gray in preservation; ventral surface pigmented with dark blotches on such portion as; marginal portion of disc, entire surface of pelvic fins and tail, anterior half of head, and on outer side of a series of gill openings (G_4 in Fig. 66).

Internal: Rostral cartilage very long and tapers in its main portion, meandering in serpentine form, which is described elsewhere; rostral appendices rather long and distinct. Anterior fontanelle broadly opened, and the posterior one long and constricted at the middle portion (G in Fig. 28).

Vertebrae 35—38 (36.0 in average) + 69—74 (70.5) (G in Figs. 43 and 44). Electric organ moderately large runs rearward from middle to distal tip of the tail (G in Fig. 35). Intestinal valves 8—9 (8.8) (Table 10), and heart valves 4—5 in a row (G in Table 11). Clasper, Type 6, characterized especially by having pseudosiphon (Type-Ps1) and much reduced ventral terminal (G in Fig. 3, 4 and 12).

Egg-capsule: Very large in size, measuring from 120 mm to 136 mm long exclusive of horns; entire surface of capsule roughened with minute prickles, bending anteriorly (Type 4), ($G_{5.6}$ in Fig. 66).

Notes: Scince occurrence of the present species has been first described and figured by GILBERT (1895) from the Sannak Pass, Aleutian Island, and redescribed by JORDAN and EVERMANN (1896), using the same specimen, immature male of 835 mm in total length, no one has given any information on this species, except for the present author (1952, '55, '57). By careful comparison of external features in the original description with that of the Japanese specimens here dealt with, the present author has found that they agree rather well each other, especially in the general spination and coloration, in number and arrangement of the enlarged thorns setting along the mesial line of dorsum and tail, and in the relative lengths of both snout and tail. Nevertheless, there are some doubts for the identification of the present specimens inasmuch as these external features mentioned above reveal rather extensive variations in our specimens in accordance with growth of the fish. Such uncertainty in the identification of our specimens on the basis of the external features may be ascribed to the incompleteness of the examination of the internal features of the holotype.

Until we have more accurate knowledge of the such features which seem to be important for the classification of the rajids, it appears to me appropriate, for the present, to assign the Japanese species to the Aleutians *aleutica* with which they are in agreement in some external features as mentioned above.

The geographical distribution of the present species appears rather great, if the view mentioned above is correct, covering the deep sea from off northern Japan to the Aleutians through the Sea of Okhotsk (Fig. 1). If this opinion is justifiable on the habitat range, it is an interesting fact to note here that the Japanese rajids have close affinity to those inhabiting the Aleutian and Alaskan waters through the so-called northern members like the present species.

Arctoraja, n. subg.

Dorsum almost smooth, with exceptions of anterior marginal portion, orbital region, mid-belt and tail regions, where the body is furnished more or less extent with broad stellate prickles. Ventral side entirely smooth. Snout moderately elongated with blunt tip, the anterior portion easily be bent. Tail rather short, flattened dorso-ventrally (Depressed-type), much shorter than width of disc, measuring as long as

70% or more shorter than width. Both dorsal and pelvic fins moderately large; caudal fin much reduced in size.

Rostral cartilage slender, rather flat, more or less meandered in most cases when dissected the preserved specimens; rostral appendices small, reduced into less than one-third length of rostral cartilage. Anterior fontanelle large, but posterior one elongated with a constriction at the midway portion.

Vertebrae more numerous than in any other subgenera of the present genus, covering respectively 35—40 in abdominal and 82—88 in precaudal portions. Intestinal spiral valve also numerous, varying from 11 to 13.

Clasper is of Type 7, especially being noticed in the absence of pseudosiphon and in having specialized axial cartilage and dorsal terminal 1. Electric organ developed in large size with numerous electric elements.

Egg-capsule peculiar in shape and configuration of the surface (Type 2).

Type species: *Raja smirnovi* SOLDATOV et PAVLENKO

Notes: The present subgenus is distinguishable from all other relatives among the genus, in having much shorter tail armed with large electric organ, numerous counts of both precaudal vertebrae and intestinal valves, and also peculiar egg-capsule which are thought to be credible for erection of the present new subgenus. The present subgenus is referred to one species and two subspecies, the latter of which are newly established herein.

Key to species and subspecies of the subgenus ***Arctoraja***

1a. Enlarged thorns setting continuous in a row running along mesial line from the nuchal to dorsal fins; a pair of the thorns developed on each shoulder. Width of disc less than 1.5 times of tail. Rostral appendices longer than one-third the length of rostral cartilage. (H in Fig. 28). Precaudal vertebrae 82. Ridge and funnel of glans clasper well-developed; dorsal lobe of the glans without prickles. Tubercles on surface of egg-capsule densely developed with ridged apexes .... *parmifera* (Fig. 67)

1b. Two to four enlarged thorns setting in a row on the nuchal, isolated from those of caudal ones; one large thorn developed on each shoulder. Width of disc greater than 1.5 times the length of tail, except for the young. Rostral appendices shorter than one-third the length of rostral cartilage (Fig. 28: I, I′). Precaudal vertebrae 83 to 91. Ridge and funnel of glans clasper obscure or absent; dorsal lobe of the glans furnished with prickles. Tubercles growing on egg-capsule sparsely developed with domed apexes.

2a. Tail 1.1 to 1.2 times as long as disc-width, and 1.4 to 1.7 times the length of head, in most cases. Caudal fin usually more distinct, and electric organ less developed than 2b (I in Figs. 35 and 38) .... *smirnovi smirnovi* (Fig. 68)

2b. Tail 1.2 to 1.3 times as long as disc-width, and 1.3 to 1.5 times the length of head, in most cases. Caudal fin usually reduced to very small flap, and electric organ well-developed (I′ in Fig. 38) .... *smirnovi ankasube*, n. subsp. (Fig. 69)

Breviraja (*Arctoraja*) *parmifera* (BEAN)

(Abbreviated as H; Japanese name, Tsuno-kasube)

Fig. 67

Raia parmifera BEAN, 1882, p. 150, Iliuliuk, Unalaska (original description). —— JORDAN and GILBERT, 1883, p. 378 (copied). —— GARMAN, 1913, p. 345 (compiled).

Raja parmifera GILBERT, 1895, p. 395, Bristol Bay, Alaska. —— JORDAN and EVERMANN, 1896, p. 74 (copied). —— JORDAN and GILBERT, 1899, p. 434, Bering Sea. —— EVERMANN and GOLDSBOROUGH, 1907, p. 230, Alaska. —— SOLDATOV and LINDBERG, 1930, p. 21 (reference). —— TARANETZ, 1935, p. 90 (reference). —— FOWLER, 1941, p. 394 (reference). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2, Hokkaido (egg-capsule).

Breviraja parmifera ISHIYAMA, 1952, p. 1, Hokkaido (key). —— 1955, p. 16, fig. 4 (electric organ). —— MATSUBARA, 1955, p. 138 (key). —— ? KOBAYASHI and UENO, 1956, p. 240, fig. 2, Bristol Bay.

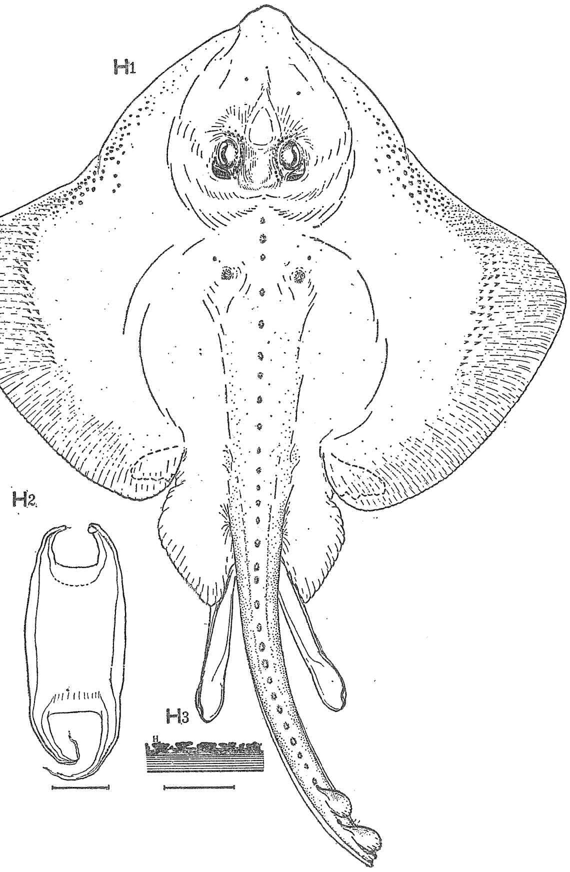

Fig. 67. *Breviraja parmifera* (BEAN); H_1, adult male (941 mm); H_2, egg-capsule, scale 5 mm; H_3, section of capsule-wall, scale 1 mm; from off Muroran, Hokkaido.

Material examined: 1 specimen, adult male of 941 mm in total length, and 2 egg-capsules, collected by Dr. MATSUBARA from off Muroran, Hokkaido, in 1938.

External: Disc-length 1.79, disc-width 1.45 and tail 2.14 in total length; head 1.86, snout 3.79 and precaudal 1.33 in disc-length; interorbital width 3.51, eye-diameter 5.27, 1st and 2nd dorsal fins 2.85 in snout.

Anterior oblique margin of disc undulated, bearing a shallow notch at the middle way, which may seems to have caused by an accident. Snout very soft and broadly elongated with blunt tip. Eye moderately large, slightly less than interorbital width, which is shallowly concave. Tail rather short, depressed dorso-ventrally, about two thirds times as long as disc-width, and 1.61 times as long as head; precaudal portion longer than three times the length of procaudal one. Pelvic fin normally notched; clasper long and thickened posteriorly, extends beyond middle of tail; two dorsals rather small, subequal in size, separated by a space equal to about half the basal length of dorsal fin; caudal fin very small but distinct, reduced into small flap about half times as long as dorsal fin.

Body largely smooth on dorsal surface, but marginal and central portions of disc, supraorbital and tail are armed more or less with prickles or thorns as: a few prickles scattering on snout, rather thickened ones covering anterior marginal portion; very small ones on posterior oblique margins of disc; somewhat thickened scales on supraorbital ridge; very large thorns, numbering 30, in a continuous row from nucha to dorsals; a pair of the thorns on each shoulder; mid-belt rearward from the center of disc furnished with numerous prickles, which are connected with those developed on tail. Two dorsals also setose but pelvic fin and under surface of body entirely smooth.

In preserved specimen dorsal side uniformly brown, under surface white, with exception of marginal portion of cloaca, where the skin is pigmented with dusky (Fig. 67).

Internal: Rostral cartilage very feeble, elongated, and rod-like in shape as in case of other members of this genus; rostral appendices rather long (H in Fig. 28). Vertebrae 39 + 82. Intestinal valves 12 (Table 10); heart valves 4 to 5 in a row (H in Table 11).

Clasper, Type 7, characterized by having incomplete pseudosiphon developed on inside border of the glans, ridge and funnel as external elements and broad dorsal terminal 1 and accessory terminal as internal elements (H in Figs. 3, 4 and 13).

Egg-capsule: A pair of the egg-capsules was examined that are distinguished from those of other members in the following points; i) surface rather rough, furnished with minute tubercles running lengthwise series with ridged appexes, ii) horn rather long and flattened, continuous with rather broad keel on each lateral side ($H_{2,3}$ in Fig. 67).

Notes: Descriptions given above were based on a matured male, so the variations of both external and internal features are uncertain. But the feature of male organ, vertebral counts, and configuration of the egg-capsule suggest that this species is referable to the present subgenus.

Since BEAN has first recorded the present species in 1882 from the Alaskan water several authorities have reported the same species from the same region. The single Japanese specimen here dealt with agree rather well with the holotype in figure and description in various features except for having blunt snout and an unreliable incision on antero-lateral margins of disc. Quite recently, KOBAYASHI and UENO (1656) gave a detailed description and a fine figure under the name of this species based on some specimens taken from the Bristol Bay, Alaska. These specimens also agree rather well with the holotype in description, but differs from our present specimen at least in having pointed snout and in lacking an incision on antero-lateral margins of the disc. But, because of lacking of the precise description on the holotype the present author can not be sure at present whether or not the present Japanese specimen is identical with the present species, and again whether or not the identification given by KOBAYASHI and UENO is correct*). At any rate, it may be meaningful for zoogeography that the northern North Pacific is inhabited by rajid fishes which are closely related to those found in the waters off Hokkaido.

Breviraja (*Arctoraja*) *smirnovi smirnovi* (SOLDATOV et PAVLENKO)
(Abbreviated as I; Japanse name, Dobu-kasube)
Fig. 68

Raja smirnovi SOLDATOV et PAVLENKO, 1915, p. 162, Pl. 5, Peter the Great Bay (original description). —— SOLDATOV et LINDBERG, 1930, p. 21, Pl. 1, Peter the Great Bay; —— TARANETZ, 1935, p. 90 (note). —— FOWLER, 1941, p. 369 (reference). —— SCHMIDT, 1950, p. 33, Okhotsk Sea.

Raja binoculata SCHMIDT, 1904, p. 291, Okhotsk Sea. —— FOWLER, 1930, p. 502 (reference).

Breviraja smirnovi ISHIYAMA, 1952, p. 8, Sea of Japan; Okhotsk Sea (key). —— 1955, p. 271, Okhotsk Sea (electric organ). —— MATSUBARA, 1955, p. 138 (key).

Materials examined: 21 specimens, 354—1160 mm in total length, and 4 egg-capsules; Okhotsk Sea, off Wakkanai and Monbetsu, Hokkaido; Oct., 1948 and June, 1951.

External: Disc-length 1.69—1.83, disc-width 1.25—1.43 and tail 2.03—2.38 in total length; head 1.83—1.97 and snout 2.92—4.44 in disc-length; interorbital width 2.80—4.01 and eye-diameter 1.42—1.72 in snout, respectively.

Body very swollen with flexible snout and pectoral fins when fresh. Disc broad, much wider than long, the length is measured from 70 to 80% of the width. Tail relatively short, depressed dorso-ventrally, about half times as long as total length (Table 7); precaudal length about half the width of disc, ranging from 1.86 to 2.32 times in the latter, and the procaudal reduced to about one-third length of precaudal; integumentary folds along sides of tail distinct posteriorly, originating at the middle between the root and tip of tail. Interorbital space flat, apparently wider than eye-diameter in the adult, but equal to the latter in the young specimen measuring about 400 mm in total length. Pelvic fins notched in moderate degree with rather broad anterior lobe; two dorsals rather small, subequal in size, about twice as long as eye-diameter; caudal fin reduced into about half length of the 1st dorsal measured in oblique. Clasper very large, stiffened when matured, the posterior extremity blunt, reaching beyond middle of tail.

Dorsum of disc almost smooth in adult, except for marginal, supraorbital and central regions, where either prickles or enlarged thorns or both of them are developed with more or less stellate bases. While, in young the dorsal entirely setose, although sparsely prickled on central portion of disc and on interorbital space as in the case of other northern members. Two to four enlarged thorns setting on the nuchal, and one on each shoulder; tail densely covered with prickles, which extend anteriorly to the center of disc, forming a distinct mid-belt although the prickles gradually decreasing anteriorly; tail also armed with a row of 20 to 34 thorns ar-

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* A comparison of the rajids between the two sides of the northern North Pacific will make clear this question.

ranged regularly along mesial line, but interrupted by an intervention of first dorsal fin. Two dorsals sparsely prickled, but the pelvic and caudal fins naked.

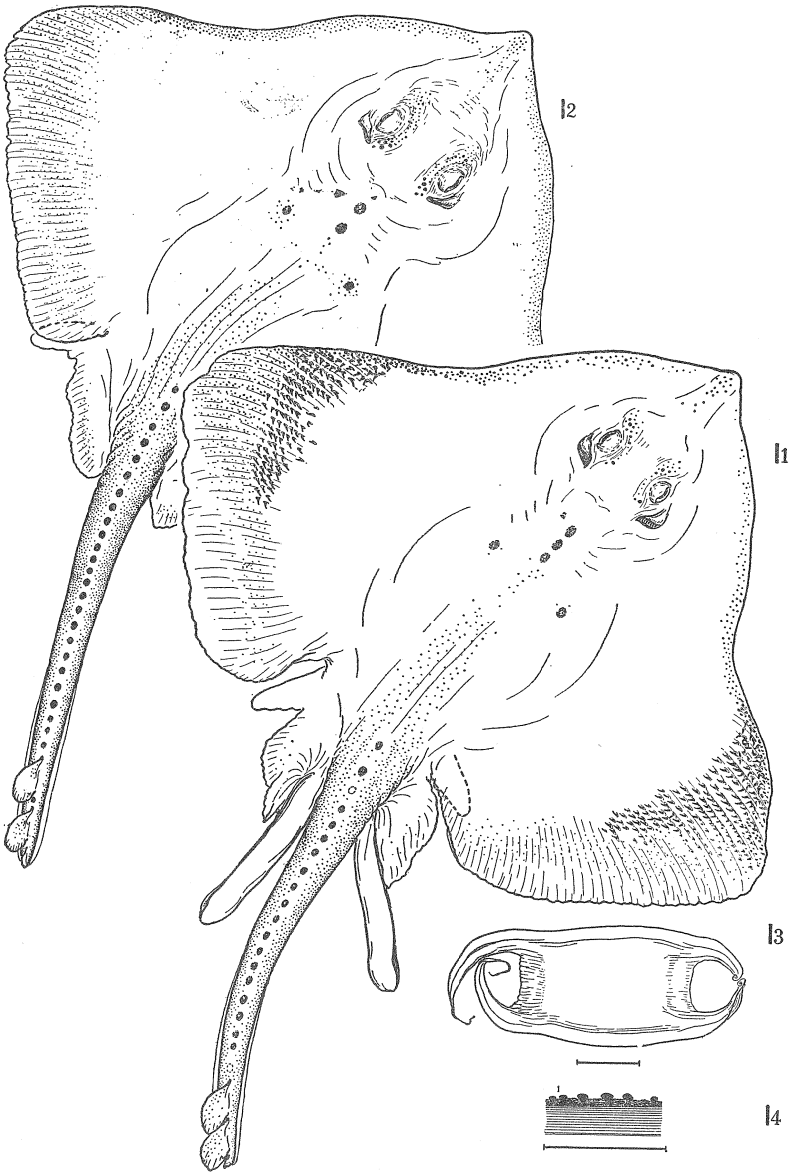

Fig. 68. *Breviraja smirnovi smirnovi* (SOLDATOV et PAVLENKO); I$_1$, adult male (970 mm); I$_2$, adult female (1052 mm); I$_3$, egg-capsule, scale 5 cm; I$_4$, section of capsule-wall, scale 1 mm; from the Okhotsk Sea, off Monbetsu, Hokkaido.

Mature male remarkably armed with 26 to 27 transverse series of alar spines, each series represented by 1 to 7 spines. It should be remembered herewith that the outer margin of dorsal lobe of the glans clasper furnished sparsely with minute prickles as has mentioned elsewhere. The ventral surface of body entirely smooth.

Prior to preservation in formalin, the dorsum golden drab without any pattern, but it changes brownish gray after preservation; the ventral surface whitish except for marginal portion of cloaca and whole of the tail, both of which more or less pigmented with dusky extent. (Fig. 69 $I_{1,2}$).

Internal: Rostral cartilage very feeble; rostral appendices very small, shorter than one-third the length of the cranium; anterior fontanelle broad, shifted towards the center of cranium; posterior fontanelle long, constricted at the central portion (I in Fig. 28).

Vertebrae more numerous than in any of the present genus in the northern members, ranging from 35 to 40 and from 83 to 88 in abdominal and precaudal portions, respectively (I in Figs. 43 and 44). Intestinal valves also numerous, covering from 11 to 13, (Table 10); heart valves 4 to 5 in a row, in most cases (I in Fig. 51; Table 11).

Electric organ larger than in any of the northern members, excepting the following subspecies, (I in Fig. 35). Clasper, Type 7, characterized by having prickles, much reduced pseudosiphon (Type-Ps^3) shifted to inside boader of the glans, distally truncated axial cartilage and broad dorsal terminal 1 (I in Figs. 4, 5 and 13).

Egg-capsule: In general shape the capsule closely resembles that of the preceding species (H), in having flattened horns with slender tips, broad lateral keels and rather rough surface. But it is distinguishable from the latter in minute structure developed over the surface, viz., very small tubercles setting lengthwisely are furnished sparsely with domed appexes ($I_{3,4}$ in Fig. 68).

Notes: *Raja smirnovi* recorded by JORDAN and HUBBS (1925), and by FANG and WANG (1932) undoubtedly referable to *Raja pulchra*. The former apparently differs from the latter in having at least such external features as; i) pectoral ocellus is absent (present in *pulchra*), ii) dorsum of the disc is largely smooth except for anterior margin where the disc is roughened with prickles even in the young (entirely smooth in the young of *pulchra*), iii) spines set on orbital rim are numerous in the young (three distinct spines are set on definite positions in the young of *pulchra*), iv) 20 to 34 enlarged thorns set in a single series are present on the tail (7 to 9 in the young of *pulchra*, but five rows in adult female), and v) integumentary fold on each lateral side of the tail falls at a position far from the base of tail (extends to the base of tail in *pulchra*), (cf. Figs. 83 and 84: U). An examination of the specimens of *Raja smirnovi* of SATO and KOBAYASHI (1956), taken from the Volcano Bay, south of Hokkaido near Hakodate has been proved that they are apparently identical with *Raja pulchra*. A comparison of their internal features, such as rostral cartilage, structures of the glans clasper and of the electric organ, and counts of the vertebrae, shows us that the two species should be referred each other to different genus as mentioned elsewhere.

Breviraja (*Arctoraja*) *smirnovi ankasube*, n. subsp.

(abbreviated as I′; new Japanese name, An-kasube)

Fig. 69

Breviraja smirnovi ISHIYAMA, 1952, p. 8 (pars), Sea of Japan (key). —— ISHIYAMA, 1955, p. 271 (pars), Wakasa Bay, Kyoto Prefecture (electric organ). —— HONMA, 1955^a, p. 45, off Sado Island, Niigata Prefecture. —— HONMA, 1955^b, p. 223, off Sado Island.

Materials described: Holotype, 930 mm, Wakasa Bay, off Maizuru, Kyoto

Prefecture; Oct. 13, 1953; paratypes, 24 specimens, 223—983 mm, Akita; Sado Island, Niigata Prefecture; Maizuru; Oki Island, Shimane Prefecture.

External: Disc-length 1.73, disc-width 1.29 and tail 2.31 in total length; head 1.78, snout 4.12, precaudal 1.70 and procaudal 6.14 in disc-length, respectively. Eye diameter 2.95 and interorbital width 4.04 in snout. Lengths of 1st and 2nd dorsal fins 5.12 and 5.35, and caudal fin 21.43 in head, respectively.

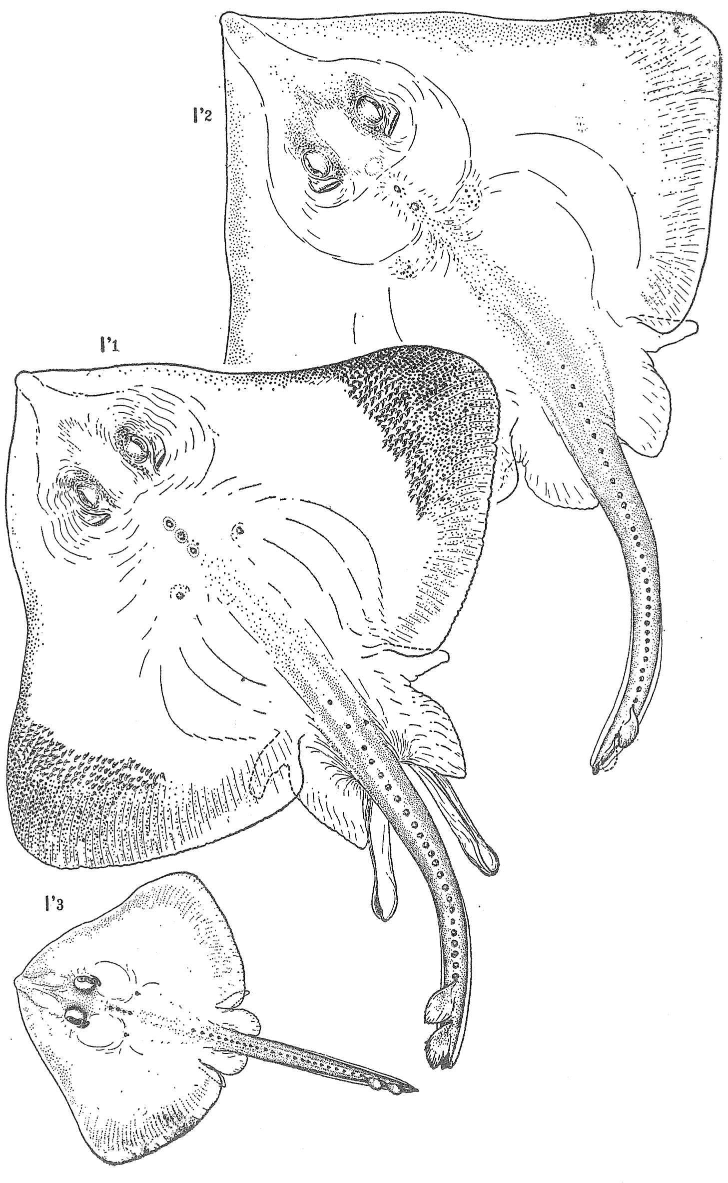

Fig. 69. *Breviraja smirnovi ankasube*, n. subsp.; I'_1, adult male, holotype (930 mm); I'_2, adult female (983 mm); I'_3, young male (223 mm); from off Maizuru, the Japan Sea.

General physiognomy of the present subspecies is quite similar to that of the preceding, but the two are distinguishable from each other in some external features, such as proportional lengths of the tail and of the snout, which will be mentioned in detail later on.

Internal: Of what seems to be annotated in the internal features examined in this subspecies, the characteristics revealed in the male organ and in the degree of development of the electric organ are specially noticed to show the distinction of the present subspecies from the preceding one, i. e. both the ventral and accessory terminals of the clasper of the present form is slenderer than those of the preceding (I′ in Figs. 3, 4 and 13), and the degree of the development of electric organ is more advanced in this subspecies than in the other (I′ in Fig. 38).

Egg-capsule: Uncertain.

Trend of intrasubspecific variation in the proportional ratios of both snout and tail is much similar to that of the preceding one.

Geographical distribution of the present subspecies seems to be limited to the Sea of Japan, covering from off Oki Island, Shimane Prefecture to the northern region of the sea probablly near Teuri Island, south of Wakkanai, Hokkaido, but no example was found to exist on the Pacific shelf of Japan.

Remarks: The present subspecies much resembles the foregoing one in general appearance, but the two are discriminable from each other with their internal characters as mentioned above and also with the following external ones treated biometrically.

Table 20. Result of t-test for some dimensional characters of the two subspecies, I(X) and I′(Y) number of specimens of these animals being respectively 21 and 24, and the dgree of freedom for the test, therefore, is 20 and 23, respectively. For other abbreviations, see p. 196.

Items	Mean, $\overline{X}$ / $\overline{Y}$	S	t	t_0 (α =0.01)
Ratio of snout in disc-l.	3.82 / 3.64	2.14	9.29	2.69
________ tail in disc-w.	1.58 / 1.64	0.09	8.99	—
________ ____ in total l.	2.13 / 2.15	0.10	0.66	—
________ ____ in disc-l.	1.21 / 1.25	0.07	1.86	—
________ head in tail	1.56 / 1.45	0.36	0.01	—
________ snout in head	2.05 / 2.01	0.12	1.09	—

As a result, it may be safely said from the above table that the differences between the two subspecies are significant in their proportional ratios of snout and tail. Namely, the proportions of the two bodily parts of the present subspecies are relatively smaller in regard to width or length of the disc than those of the relative.

Though there are some intricate problems concerning the nomenclatorial consideration on subspecies, and though there is no definite lower limit to subspecies category at present, as has recently been discussed by WILSON and BROWN (1953), the present writer has established the two subspecies on the basis of the facts as aforementioned.

Rhinoraja ISHIYAMA, 1952, emend

Rhinoraja ISHIYAMA, Jour. Shimonoseki Coll., Fish.,
2 (1), p. 24. Genotype: *Raja kujiensis* TANAKA, 1916, off
Kuji, Ibaragi Prefecture.

The diagnosis of this genus was given by the present author in his previous work

(1952), where the present genus was established. In addition to the diagnosis already given some features, which seem to be worthy for the criterion of the genus, are here newly attended by the following: Entire dorsal surface more or less studded with prickles even in the adult without remarkable reduction of the spination. Snout very soft, flexible in touching. Tail very long, slender, longer than disc. Rostral cartilage very feeble, projecting foreward with slender rod-like bar, which bears a segment on the basal portion; rostral appendices inserted before the rostral cartilage as is the case with the preceding genus. Clasper cylindrical in general shape, characterized by having a distinct pseudosiphon along dorsal border of the glans; pseudosiphon intimately lined internally with well-developed dorsal terminal 1 (Figs. 2 and 3). Abdominal and precaudal vertebrae numerous, ranging respectively 30—38 and 74—91. Turns of intestinal valves 8—10. Electric organ very small or inconspicuous, composed of cup-formed elements characteristic to the northern form. Egg-capsule with rather smooth or thorny surface, provided with slender horn at each corner.

Notes: In comparing above diagnosis with those given in the genus *Breviraja*, the present genus is distinguishable from the latter in the following points: i) relatively longer tail with more numerous precaudal vertebrae, ii) presence of rostral segment, and iii) clasper with seemingly generalized structure bearing distinct pseudosiphon.

Although it may be sure to believe that the present genus might be an offshoot sprung from an ancestor not very unlike the genus *Breviraja* as has been discussed by the author (1952), some of the characteristics given above to discriminate the present genus appear to be more specialized than the corresponding features found in the preceding genus.

Three distinct species are referable to the present genus, and they are all endemic to the deep sea along the Pacific coast of Japan from middle part to northern region of our main island.

Key to species of the genus *Rhinoraja*

1a. Dorsal surface entirely covered with more or less distinct numerous prickles without enlarged thorn on shoulder region; nuchal spines absent or present, not continuous, if present, with those on tail. Ventral side white, without any distinct color pattern. Tail almost as long as or longer than width of disc in adult. Clasper is of Type 2.

2a. Both nuchal and shoulder spines absent. Dorsal side yellowish brown in ground color, furnished with numerous dark brown spots and a pair of pectoral ocelli margined with white. Precaudal as long as or trifle shorter than, disc. Precaudal vertebrae 85—91. Ventral terminal of clasper is of Type Vt^2 .... *odai*, n. sp. (Fig. 70; Pl. I, J)

2b. 1 to 4 nuchal spines present. Dorsal side purplish gray or dark gray in basic color, furnished with darkish brown patterns or spots, but bearing no pectoral ocellus. Precaudal always longer than disc. Precaudal vertebrae 74—80. Ventral terminal of clasper is of Type Vt^4 .... *longicauda* (Fig. 72)

1b. Dorsal surface entirely covered with numerous minute prickles accompanying enlarged thorns on shoulder and nucha; nuchal thorns continuous with those developed on tail, running in a row. Ventral side scattered with some indefinite black blotches. Tail shorter than width of disc in adult. Clasper is of Type 1, characterized by having unique features of dorsal terminal 1 and ventral terminal without knife .... *kujiensis* (Fig. 71)

Rhinoraja odai, n. sp.
(Abbreviated as J; Japanese name, Oda-ei)
Fig. 70; Pl. I, J

Materials described: Holotype, 514 mm, off Izu Peninsula, Shizuoka Prefecture, March, 8, 1956; Paratypes, 16 specimens, 267—520 mm; 2 egg-capsules, Miya fish market, Aichi Prefecture, March—May, 1956.

External: Disc-length 2.14, disc-width and tail 1.74 in total length; head 2.42, snout 6.16; precaudal and procaudal lengths 1.19 and 6.42, in disc-width, respectively. Diameter of eye 2.18, interorbital space 2.82 in snout. Longer axes of 1st and 2nd dorsal fins 4.88 and caudal fin 11.11 in head.

Body trumped with conspicuous hue and well-armed spination. Anterior oblique margins run to blunt tip with gentle curve. Snout very short, thin and flexible in fresh, about a fifth times as long as disc-length. Eye very large, the longer axis always longer than interorbital width. Tail stout, more or less depressed in anterior portion, just as long as disc-width. Precaudal trifle longer than disc or than twice the length of head, but the procaudal is rather short, about as long as snout. Ventral fin moderately notched with rather broad anterior lobe. Two dorsals closed together without interspace between them, followed by a small flap of caudal fin. Clasper slender, quite masculinized with hard axis.

Body entirely furnished with numerous prickles without enlarged thorn on both nuchal and shoulder regions, but somewhat thickened ones covering supraorbital ridge and mid-belt of disc. Tail densely crowed with prickles accompanying a row of slightly enlarged grayish colored thorns along mesial line. Posterior lobe of pelvic fin, two dorsals and caudal fins more or less prickled. Ventral side wholly smooth, without scales.

Dorsum with yellowish to brown hue, scattered with numerous deep brown spots as large as pupil and marked with a pair of pectoral white ocelli on each side. Ventral side colorless, except for tail which bearing dusky striae of faint gray (Fig. 70 and Pl. I, J).

Internal: Rostral cartilage very slender, about as long as cranium, with a basal segment. Rostral appendices very thin, about a third as long as rostral cartilage. Anterior fontanelle broadly opened with anterior tip pointed; posterior one long, constricted at the midway point (Eig. 28 J). Abdominal vertebrae 33 to 36, the precaudal one more numerous, covering 85 to 91 (88.4 in average). Intestinal valves 8 to 10, and heart valves 4 or 5. Clasper peculiar in structure in having knife and pseudosiphon in addition to more or less well-developed dorsal and ventral terminals, based on these characteristics the organ is referred to Type 2 together with that of species **L**. (J in Figs. 3, 4 and 13). Electric organ moderately large, composed of cup-formed elements as is the case with other northern members (J in Fig. 35).

The description given above was based on external features of the holotype and on internal ones of the paratypes as well. The followings are prepared so as to give more details on external as well as internal and other characters worthy for distinguishing the present species from other relatives.

Egg-capsule: A pair of the capsule was extruded from a female measuring 502 mm in total length, captured offing of Izu Peninsula, where the depth was measured from 330 to 350 meters. The capsule closely resembles that of species L, in having slender horns with long slits, and in having rather smooth surface (J_3, J_4 in Fig. 70). But the two are distinguishable from each other on; i) width of the capsule of the present species measuring 33 mm instead of being 43 to 44 mm in the species L, although the length exclusive of both anterior and posterior horns is subequal in the two, and ii) minute prickles covering the surface of the capsule in this species are somewhat sparser and shorter than those in species L (vide, Figs. 70 J_4 and 71 L_4).

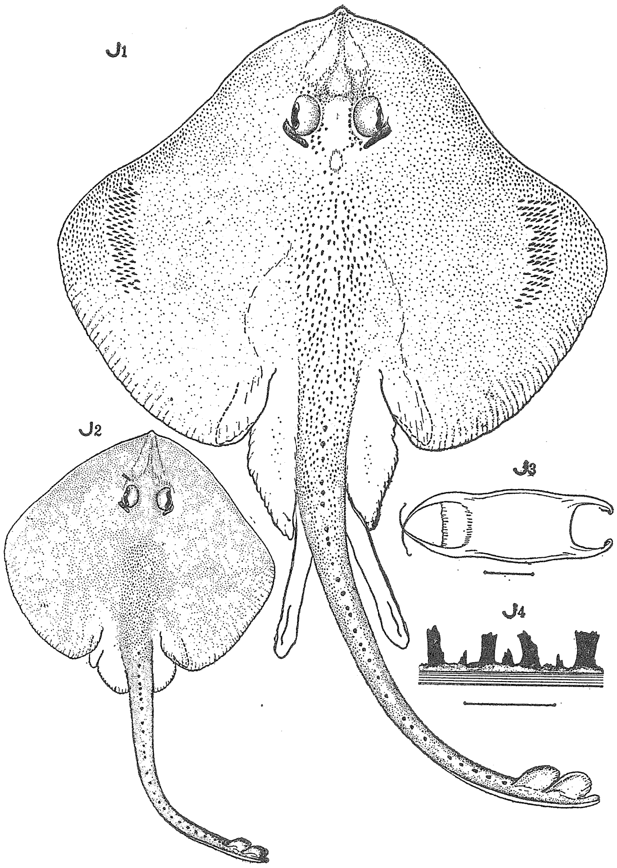

Fig. 70. *Rhinoraja odai*, n. sp.; J_1, holotype, adult male (514 mm), color patterns c. f. Pl. I; J_2, subadult female (267 mm); J_3, egg-capsule, scale 5 cm; J_4, section of capsule-wall, scale 1 mm; from near Mikomoto Island, off Izu Peninsula.

The proportional length of snout in this fish advanced than the adolescent, shorter in male than that in female, being the ratio against the head-length is 2.23 to 2.61 times in male and 2.10 to 2.20 times in female (J in Fig. 24 and Table 6). But the length of tail runs almot proportionally with equimultiple trend in both sexes (J in Fig. 31 and Table 7).

Variation in number of thorns along mesial line of tail very large, measuring 8 to 21, the reduction is thought to be due to retrogression accompanied by the development of electric organ (cf. Fig. 35 J). Although the specimens of very young stage are not available in this study the feature of spination throughout the developmental stage may not be so much different from that found in the holotype and paratypes. But, the color and pattern of dorsum reveal intraspecific variation to some extent even in the specimens older than that of adolescent stage. Some have much distinct pectoral ocellus and brownish spots, which are more or less obsolete in others.

Remarks: The present species resembles externally *Rhinoraja longicauda* on one hand, and *Breviraja tobitukai* on the other, in having the following features; i) relatively short snout, ii) extraordinarily long tail, iii) very large eye, iv) uniformly developed prickles without noticeable specialization, and v) medium size even in the adult. But, the internal features, such as rostral cartilage, vertebral counts and clasper structure, give clear criterion for generic as well as specific significance. Namely, on the basis of both the rostral cartilage and vertebral counts, it is clear that there exist no room for doubt in separating species A from J and L, and that the features should be used in determining objective standard for the separation of genus. Furthermore, the present species is distinct from species L as shown in following lines:

Characteristics	*longicauda*	*odai*
1. Nuchal spines	present (1—4)	absent
2. Color pattern on dorsum	absent or obscure, if present	distinctly present
3. Precaudal length	as long as or shorter than disc-length	longer than disc-length
4. Precaudal vertebrae	74—80	85—91
5. Ventral terminal of clasper	Type Vt^4	Type Vt^2
6. Width of egg-capsule	43—44 mm	33 mm

It must be recorded herewith that the both the present species and species A were found to exist in the same region offing of Izu Peninsula, as mentioned above, although they are distinctly distinguished from each other in some fundamental features.

It is interesting to note further that the present species shows externally close resemblance to *Breviraja colesi* recorded as the type of the genus *Breviraja* taken from off the north and south coasts of Cuba by BIGELOW and SCHROEDER. In fact the two species have in common with many external features, such as short snout, large eye, relatively long tail and numerous prickles, in addition to the numerous color patterns of irregular spots and blotches of darker brown. The present writer, however, has stressed only in these internal features which are credible for the critical separation of the pressent genus from the genus *Breviraja*, and moreover, these external features mentioned above which are closely relating within the two forms are thought to be used as specific ones rather than generic. As a matter of fact, the establishment of the genus *Breviraja* has been given by the original authors being used roentogenogram of the rostrum without confirmination by dissection of the specimens*). Such being the case, as the present author has stated (1952, p. 2), there seems to meet with some doubt to confirm with either view, as a matter of stand, whether *colesi* has the rostral segment and numerous number of the precaudal vertebrae as in the present species or not. In either case, the present species is distinguished from *colesi* as shown in the following comparison:

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* Personal communication from the original authors.

Characteristic features	*colesi*	*odai*
1. Disc, width in % of total length	48.0; 49.3%	53.5—60.0%
2. Tail, length in % of total length	61.6; 68.6%	53.6—58.4%
3. Precaudal, length in % of total length	50.0; 51.0%	42.3—49.6%
4. Procaudal, length in % of total length	5.86; 6.19%	6.7—10.40%
5. Enlarged thorns on nucha	present	absent

Rhinoraja kujiensis (TANAKA)
(Abbreviated as K; Japanese name, Kuji-kasube)
Fig. 71

Raja kujiensis TANAKA, 1916, p. 173—174 (original description in Japanese). ——, 1916, p. 438.—— JORDAN and HUBBS, 1925, p. 93.—— MATSUBARA, 1935, p. 44 (key). —— 1936, p. 24.—— OKADA and MATSUBARA, 1938, p. 24 (key). —— FOWLER, 1941, p. 381.—— KURONUMA, 1943, p. 102, Kurile Is'l (in Japanese).

Raja tobae (not *tobae*, 1916) TANAKA, 1927, p. 673, figs. 434 and 435.

Raja karagea TANAKA, 1927, p. 784 (n. name for *tobae* TANAKA, 1927). —— MATSUBARA, 1935, p. 44 (key). —— MATSUBARA, 1936, p. 23, fig. 14. —— OKADA and MATSUBARA, 1938, p. 23 (key).

Rhinoraja kujiensis ISHIYAMA, 1952, p. 24, fig. 1.—— ISHIYAMA, 1956 ('55), pp. 271—277, fig. 4 (electric organ).—— MATSUBARA, 1956, p. 139 (key).

Materials examined: 39 specimens (1043—218 mm in total length); 6 egg-capsules; deep sea from off Chôshi to Kushiro (600—800 meters in depth); Oct., 1948 and May to June, 1951.

External: Disc-length 2.0—2.3 (2.21 in average), disc-width 1.5—1.9 (1.73) and tail 1.6—1.9 (1.75) in total length; head 1.9—2.0 (1.97), snout 4.0—4.9 (4.53) and tail 0.6—0.9 (0.86) in disc-length; precaudal length 0.9—1.2 (1.05) in disc-width; diameter of eye 2.3—4.5 (3.45) and interorbital space 2.5—3.6 (3.16) in snout; longer axis of 1st dorsal fin 4.3—5.3 (5.07) and that of 2nd dorsal 4.1—5.2 (5.03) in head.

Body with clumsy appearance by having numerous prickles on entire dorsal surface. Disc much shorter than width, which is measured in short excess of tail in the adult, but less than the latter in the young as explained in Fig. 31 K and Table 7 K. Snout very short, flexible and slightly pointed at the tip, as long as 2.1 to 2.3 times in head. Eye moderately large, the horizontal diameter much less than interorbital space when matured, being reversal in the young. Ventral fin with notch in usual degree; two dorsals and caudal fin rather small and prickled; lateral folds in two sides of tail distinct, covering only posterior half of the tail where the electric organ lying internally.

Features of spination is characteristic, being developed with numerous prickles and enlarged thorns on dorsal surface, as has been best figured by TANAKA (1927, fig. 435), i.e. entire dorsal surface studded with numerous prickles with stellate bases, and a row of enlarged thorns developed, running continuously from nucha to dorsal fins, and a pair of the same also occurred on each shoulder. Those prickles covering basal portion of pectoral fin become sparse to some extent when matured, and these phenomena are predominant in the male. Ventral side of the body smooth without scale.

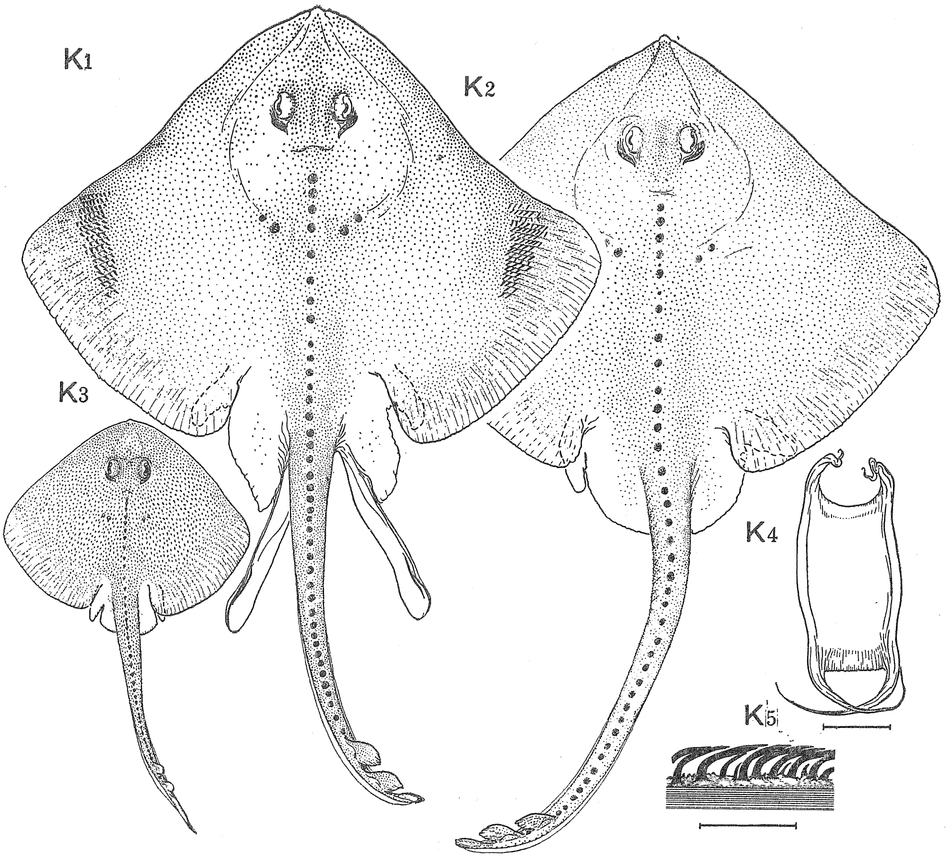

Fig. 71. *Rhinoraja kujiensis* (TANAKA); K_1, adult male (910 mm); K_2, adult female (980 mm); K_3, young female (233 mm); K_4, egg-capsule, scale, 5 cm; K_5, section of capsule-wall, scale 1 mm; from off Same, Aomori Prefecture.

Color of dorsal surface golden drab when fresh, but it changes to brownish gray in the preservation. Ventral boader white as a whole, but several dusky blotches locating branchial region or tail.

Internal: Rostral cartilage rather stout, much shorter than cranium, bearing rostral segment. Rostral appendices distinct, extending posteriorly halfway point of the rostral cartilage (Fig. 26 K).

Precaudal vertebrae numerous, varying from 76 to 83 (79.3 in average), but that of abdominal ones is not so numerous, being from 33 to 38 (K in Figs. 43, 44 and Table 9). Turns of intestinal valves 9—10, and heart valves 4—5 in a row.

Feature of clasper is much worthy for notice in both external and internal structure, viz., pseudosiphon broadly developed on dorsal boader of the glans, of which inside structure is much simple, dorsal terminal 1 is broad, resembling that of the guitarfish, and both ventral and accessory terminals are also characteristic, being in category Types Vt^1 and At^1, respectively. On the basis of features found in the clasper, the present species seems to show the most primitive phase within the organs of Japanes rajids so far as examined in this study (K in Figs. 2, 4, 7~12 and 21).

In this connection, the present writer should like to emphasize that a form which might have firstly differentiated from the genus *Breviraja* may have had the organ similar to that found in the present species, though there found some characters which are thought to show more or less well differentiation than those in the allied ones in the present genus. In fact, the feature of egg-capsule of the present species shows highly specialization as compared with those of the relatives, (Fig. 71 $\mathrm{K}_{4,5}$), but the electric organ is not so well-developed (Fig. 35 K).

Notes: This species somewhat resembles Indian rajids, such as *Raja mamillidens* ALCOCH and *R. reversa* LYLOID, in having long tail and many prickles on dorsal surface. But it is suggested that the present species and the other two Japanese forms referred to the genus *Rhinoraja* seem to belonging to different stock from that of the Indians though we are still lacking internal features of the latters.

This species inhabits the deep sea along the Pacific off northern Japan (Fig. 1), where the present species is confound with other northern forms in the landing.

Rhinoraja longicauda ISHIYAMA

(Abbreviated as L; Japanese name, Onaga-kasube)

Fig. 72

Rhinoraja longicauda ISHIYAMA 1952 p. 25, fig. 7, Pl. 4. (original description). ——, 1956 ('55), p. 271 (electric organ), fig. 4. —— MATSUBARA 1955, (key), p. 139.

Materials examined: 26 specimens (305–688 mm in total length) including holotype,

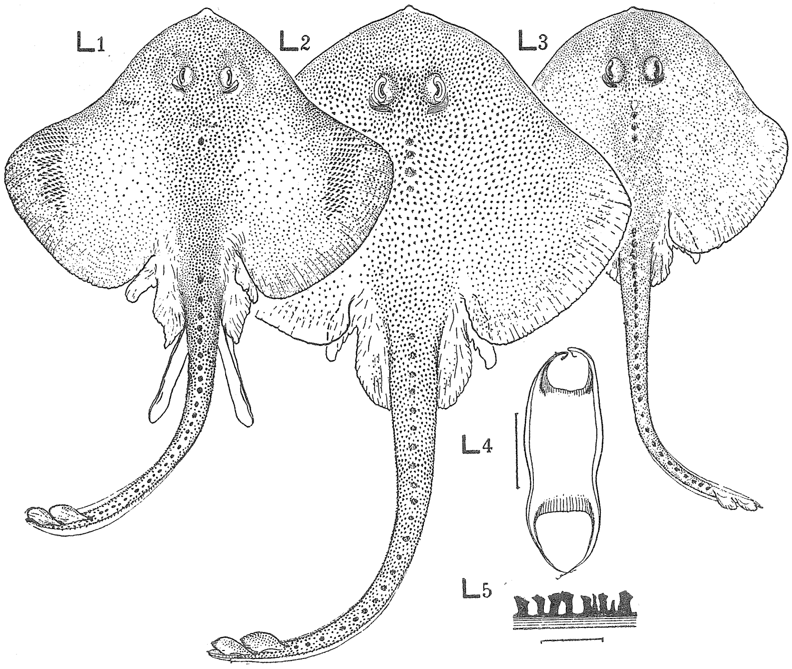

Fig. 72. *Rhinoraja longicauda* ISHIYAMA; L_1, holotype, adult male (665 mm); L_2, adult female (620 mm); L_3, subadult female (305 mm); L_4, egg-capsule, scale 5 cm; L_5, section of capsule-wall, scale 1 mm; from off Hachinohe, Aomori Prefecture.

taken from off Chôshi to Kushiro; Oct., 1948 to June, 1951.

The detail of the present species can be understood in the foregoing paper giving by ISHIYAMA, 1952. The following are given in order to supplement imperfectly known internal features which are credible for the finding not only the systematic significance but also the linealogical verification.

Internal: The clasper structure is of Type 2 (**L** in Figs. 3, 4 and 12), marked from other allied forms by having distinct pseudosiphon accompanied by somewhat reduced dorsal terminal 1 and well-specialized ventral and accessory terminals. Heart valves usually 4 in a row; electric organ very small, the cup-form elements very small in its number (**L** in Fig. 35). Abdominal and precaudal vertebrae, 30—32 and 74—80 (**L** in Figs. 43, 44 and Table 9). Egg-capsule belonging to Type Eg^2 (Fig. 73 **L**$_{4,5}$).

Notes: It may be conceivable that the present species seems to stand near the species **K** because of finding close relation in their external as well as internal characters, such as long tail with small electric organ, numerous counts of precaudal vertebrae, peculiar feature in rostral cartilage and clasper structure. Further it may be said that the present species may be intermediate between species **J** and **K** in respect to the features as aforementioned. It may be sure from these facts that these three species might have sprung off from an ancestor not very unlike these three species.

Raja LINNAEUS 1758, emend

Raja LINNAEUS syst. Nat., I, 1758, p, 231. Genotype *Raja clavata* LINNAEUS, 1758, European species.

As regards the generic synonyms as well as the generic characters and others of this genus compact description has been given by BIGELOW and SCHROEDER (1953, pp. 138—147) that only brief notes that should call attentions for the designation of the generic significance are given below.

Scales usually sharply pointed without broad stellate bases, much fewer in embryo emarged from the egg-case than in the adult, excepting one species W, possessing three spines on orbital rim, one on the nuchal and one row on dorsal mid-line of tail (Fig. 53), but they become more setose with growth of the fish, resulting remarkable sexual difference in spination of the tail, in most cases (Type Scs). Teeth densely crowded in quincunx order, with round tips in female and young instead of being cuspidate in matured male, and set in such numerous series as 35 to 50 in average (Table 14). Electric organ composed of the disc-form elements even in the young. Clasper relatively large, developed posteriorly with pointed distal tip (Spatula-type) when matured (Fig. 2 **M**). Glans clasper is of Types 8—13, much more complex than that of other genera. Egg-capsule is of Types 5—8, rectangular in general form with either smooth or rather rough surface, with or without short tubular horn at each four corner, and the wall consists of three layers in most cases.

Remarks: The rajids in the Pacific in the northern hemisphere seem to be divided into two groups on the basis of, (1) the structure of snout, (2) the relative length of snout and tail, (3) the mode of development of the prickles and thorns, especially of the tail, (4) the structure of the clasper, (5) the structure and degree of development of the electric organ, (6) the number of abdominal and precaudal vertebrae, and (7) the features of egg-capsule. Two major groups of Japanese rajids are sharply opposed with each other in these characteristics, although such relation is uncertain in two rajid groups of the northern hemisphere other than those inhabiting in the waters around Japan caused by the absence of the adequate study on whole fauna in the hemisphere. In the present work, however, the writer has dared to subdivide the Japanese rajids of the genus *Raja* into two subgenera on the basis of aforementioned categories,

Key to subgenera of the genus *Raja*

1a. Snout relatively short or moderate in length, the ratio into head-length nearly equal to or slightly less or greater than two times; tail relatively long, the ratio into disc-width in adult about 1.2—1.5; nuchal spine more than one in most cases, and tail spines three rows in both sexes except for male of species M, or more numerous in female; electric organ less or moderately developed; glans clasper is of Types 8-10; abdominal vertebrae relatively few, less than 30; intestinal spiral valves 5 to 8; body moderately large or small in parallel with size of egg-capsule .... *Okamejei*, n. subg.

1b. Snout relatively long and stout, the ratio into head-length never exceeds two times; tail relatively short, the ratio into disc-width about 1.5—1.8; nuchal spine mostly 1, and tail spines set in one row in male and three to five in female when matured; electric organ moderate or markedly developed; glans clasper is of Types 11—13; abdominal vertebrae rather numerous, varying from 30 to 34; intestinal valves 9 to 15; body and egg-capsule usually large .... *Tengujei*, n. subg.

*Okamejei**), n. subg.

The establishment of the present subgenus is contrasted to the forthcoming one, basing the following characteristics which are thought to be different genetically from those in the relative as mentioned in the foregoing key.

The features diagnostic to the present subgenus are the relatively shorter snout, numerous rows of spines developed on the tail of male except species M, less developed electric organ, much more specialized structure revealed in the clasper, and relatively fewer number of the abdominal vertebrae. These characteristics are revealed in such seven species as M, N, O, P, Q, (Q′), R and S, all of which are the dwellers in either the shallower or more southerly waters than the species referred to the forthcoming subgenus.

Type species: *Raja fusca* GARMAN, 1885

Key to species and subspecies of the subgenus *Okamejei*

1a. Tail armed with one row of enlarged spines along mesial line in matured males instead of being three rows in the adult females though they have merely one row in young ones; venter uniform gray instead of being very variable with numerous brown patterns and having a distinct ocellus on each base of the pectoral fin; membranous folds along both sides of tail ill-defined especially in the adult. Clasper is of Type 8 .... *kenojei* (Fig. 73; Pl. II, M)

1b. Tail armed with three or more numerous rows of enlarged spines in adult of both sexes though the young commonly having only one row of the spines; venter mostly white except marginal portion; dorsum mottled with various patterns with or without pectoral ocellus; membranous folds of tail distinct even in the adult. Clasper is of types 9 or 10.

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* Modeled after *Okame* in Japanese tradition, meaning a female with low-nose, and *jei* is a skate and ray in Japanese, i. e. low-nosed skate.

2a. Snout rather long, pointed at distal tip, longer than 2.5 times the width of interorbital space; rostral cartilage in adult relatively long, as long as or longer than cranium. Clasper is of Type 9.

3a. Procaudal portion relatively long, subequal to or greater than one-third the length of tail; pectoral ocellus absent in the young. Electric organ small, not reaching to the base of the tail. Clasper is of Type 10, characterized by having much specialized sentinel.

4a. Eye smaller than interorbital width; in the adult, 1—3 nuchal spines running in a row; tail armed with three rows of spines in male instead of being numeous rows in female; dorsum of disc and pelvic fins dressed in various color patterns with many brown spots; abdominal vertebrae ranging from 28 to 29 (28.4 in average). Clasper characterized by having a distinct sentinel and rhipidion monolobed .... *hollandi* (Fig. 75)

4b. Eye longer than interorbital width; in the adult, 2—3 nuchal spines setting in triangular pattern in most cases; tail spines very sharp, and sparse, arranging in three rows in male instead of being five in female; dorsum of disc and pelvic fins mottled with numerous brown patterns, but without brown spots; abdominal vertebrae 25 to 26 (25.4 in average). Clasper specialized in having remarkably long spike and rhipidion bilobed ...... *macrophthalma*, n. sp. (Fig. 76)

3b. Procaudal portion of tail relatively short, reduced to below one-third the length of tail; pectoral ocellus usually present in the young. Electric organ moderatly developed, reaching anteriorly to the basal portion of tail. Clasper is of Type 9, marked with bulgy developed sentinel.

5a. Nuchal spines varying from 1 to 3, but mostly 1 even in the adult; tail spines growing in three rows in adult male, but numerous rows setting irregularly in female; ventral surface colorless without black blotch. Clasper characterized by having monolobed rhipidion and broad dorsal terminal 1 .... *acutispina*, n. sp. (Fig. 74; Pl. II, N)

5b. Nuchal spines numerous, covering 2—16 in adult; tail spines growing three rows in adult male, but five regular rows in female; ventral surface dressed with dusky blotches in many cases. Clasper characterized by having bilobed rhipidion and much narrow dorsal terminal 1.

6a. Snout relatively short; tail longer than that of 6b as explained later on. Accessory terminal 1 of clasper elongated posteriorly and as long as the accessory terminal 2 (Q in Figs. 5 and 18) .... *porosa meerdervoorti* (Figs. 77, 78 and Pl. II, Q)

6b. Snout relatively long; tail shorter than that of 6a. Accessory terminal 1 elongated posteriorly, reaching beyond tip of accessory terminal 2 (Q′ in Figs. 5 and 18) .... *porosa tobae* (Figs. 77 and 79)

2b. Snout very short, pointed at the tip, less than 2.5 times the width of interorbital space; rostral cartilage shorter than cranium in the adult. Clasper is of Type 9.

7a. Ground color of dorsum of disc deep brown, furnished with numerous blackish spots and distinct pectoral ocellus; nuchal spines 3—5 in the adult; tail spines developed in three distinct rows in both sexes; precaudal vertebrae 39—43 (41.0 in average). Clasper marked with the rhipidion bilobed .... *fusca* (Fig. 80)

7b. Ground color of dorsum of disc brownish yellow, scattering numerous brown spots and having distinct pectoral ocellus; in the adult, nuchal spines 1—3, but mostly 1; tail spines set in three rows in male, instead of being numerous irregular rows in female; precaudal vertebrae 42—45 (43.4 in average). Clasper defined with the rhipidion monolobed .... *schmidti*, n. sp. (Fig. 81; Pl. III, S)

Raja (*Okamejei*) *kenojei* MÜLLER et HENLE

(Abbreviated as **M**; Japanese name, Gangi-ei)

Figs. 57, 73; Pl. II, M

Raja kenojei (BÜRGER) MÜLLER et HENLE, 1841, p. 149, pl. 47, Nagasaki, southern Japan (original description). —— RICHARDSON, 1846, p. 197, Seas of China and Japan. —— SCHLEGEL, 1850, p. 308, Nagasaki. —— BLEEKER, 1853, p. 22, Nagasaki; China. —— DUMÉRIL, 1865, p. 556 (compiled). —— GÜNTHER, 1870, p. 461, Japan. —— NYSTRÖM, 1887, p. 51, Nagasaki. —— JORDAN and SNYDER, 1901, p. 41 (reference). —— SCHMIDT, 1904, p. 289 (noted). —— JORDAN and STARKS, 1906, p. 515, Port Arther (listed). —— JORDAN and METZ, 1913, p. 5, Port Arther. —— JORDAN and THOMPSON, 1914, p. 208, Misaki (listed) —— JORDAN and HUBBS, 1925, p. 113 (pars), Japan, from Tokyo to Nagasaki. —— UI, 1929, p. 21, Wakayama. —— FOWLER, 1930, p. 501, Japan. —— SOLDATOV and LINDBERG, 1930, p. 19, Far East Sea (reference). —— TANAKA, 1931, p. 15, Japan (listed). —— SCHMIDT, 1931, p. 11, Japan; Korea. —— WANG, 1933, p. 105, fig. 7, Chusan. —— MORI and UCHIDA, 1934, p. 3, Korea (listed). —— MATSUBARA, 1935, p. 45 (key). —— TARANETZ, 1935, p. 89 (reference). —— MATSUBARA, 1935, p. 45 (key in Japanese). —— OKADA, UCHIDA and MATSUBARA, 1935, p. 59, pl. 10. —— MATSUBARA, 1936, p. 29 (key in Japanese). —— OKADA and MATSUBARA, 1938, p. 25, Japan (key in Japanese). —— KAMOHARA, 1938, p. 6. Kôchi (listed). —— FOWLER, 1941, p. 374, (reference). —— BOESEMAN, 1947, p. 224 (pars). —— CHEN, 1948, p. 5. —— HIKITA, 1950, p. 112, Japan Sea (listed). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2. Japan Sea (egg-capsule). —— HERRE, 1953, p. 39 (listed). —— ISHIYAMA, 1955, p. 271, figs. 2—4, Japan (electric organ). —— MATSUBARA, 1955, p. 137, Japan (key). —— HONMA, 1955, p. 50, Sado, Japan Sea (listed). —— KAMOHARA, 1955, p. 4, pl. 4.

Raja meerdervoortii BLEEKER, 1860, p. 66, Nagasaki. —— PIETSCHMANN, 1908, p. 642, Japan. —— IIZUKA and MATSUURA, 1920, p. 187, Asamushi.

Raja japonica NYSTRÖM, 1887, p. 52, Nagasaki.

Materials examined: 102 specimens (97-662 mm in total length), 2 embryos and 10 egg-capsules; shallow waters from off Aomori Prefecture to moderate depth off southern Japan; 1947—1954.

External: Snout moderate in length, the ratio into head of adult greater in male than in female (M in Table 6). Tail stiffened, rod-like in shape, longer in male than in female when matured (M in Table 7). Membranous fold of tail scarcely visible in the adult, but apparent in the young. Dorsum of body smooth excepting tip of snout, orbital rim, nuchal region and tail; the spines on nuchal and tail are characteristic in this species, thus: nuchal region armed usually with only one spine, but occasionally with 2 to 3 ones; tail armed with one row of enlarged spines along mesial line in matured male, but three rows in the female (M in Figs. 36 and 57), as is the case with species T and V. Ventral side entirely smooth with exception of tip of snout.

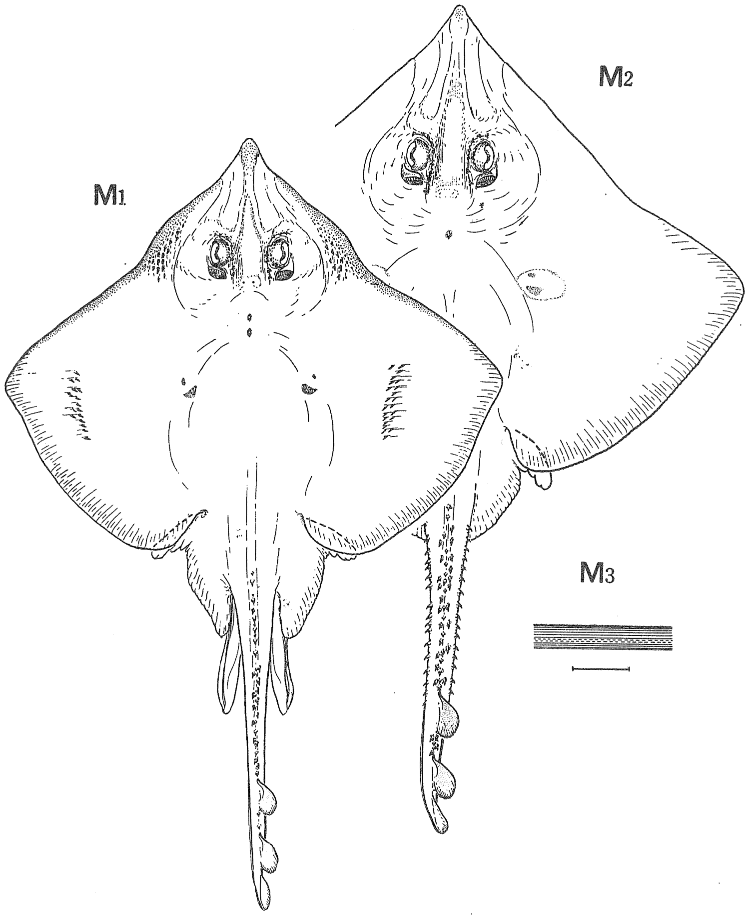

Fig. 73. *Raja kenojei* MÜLLER et Henle; M_1, adult male (820 mm); M_2, adult female (880 mm); section of egg-capsule, scale 1 mm; from the East China Sea.

Color of dorsum brown, mottled with lighter or darker patterns, and always with pectoral ocellus, which is larger than eye, furnished with a white or pale center and marked with 2 dark rings with one inside the other (Pl. II, M). Ventral side uniform gray, giving remarkable specific hue.

Internal: Rostral cartilage rather stout, thickened at the basal portion, and almost as long as cranium; rostral appendices moderately developed; both anterior and posterior fontanella broadly opened with a boat-like foramen, and the posterior one not constricted at the midway portion (Fig. 27 M).

Abdominal and precaudal vertebrae covering respectively 27—28 (28.3 in average) and 44—47 (44.8 in average) (M in Figs. 43, 44 and Table 9). Intestinal valves 7—8 (7.6 in average), and heart valves in a row 4—5, but mostly 4 (Table 11). Electric organ medium in both number of the elements and size (M in Figs. 36, 39 and Table 8). Clasper is of Type 8 (M in Figs. 2, 5 and 17).

Developmental stages: Snout relative to head length reveals in much complex change with growth of body, contradistinguishing between two sexes as shown in Fig. 25. Tail relative to disc-width also changes in no small extent with growth of the fish (Fig. 32). Thus, it may be difficult to show exactly those constant values in relative lengths of the snout and tail.

Color and pattern of the dorsum as well as that of ventral side are discernible characteristic in the present species inasmsch as the similar hue is found to occur in common without exception throughout the life of the fish.

Spination of the tail increasingly changes with growth of the fish from the young to the adult. In the newly hatched fish, 9 to 12 spines are found to develope in one row in both sexes, interrupted posteriorly by an intervention of 1st dorsal fin, and afterward the spination becomes three rows in female as the fish attains to maturation with total length of about 450 mm, although it is one row in male even in the adult, but the adult male has both the alar and malar spines (M in Figs. 36, 57 and 73).

Egg-capsule: Moderate in size, representing Type 6, characterized by having smooth surface with thicker silky hairs and also by having the wall composed of three layers of the tissue (Fig. 73 M_3).

Distribution: The present species is an endemic form, ranging from the northern extremity of the main island of Japan to the East China Sea throughout the coastal waters on both sides of the island, where the range of vertical distribution covers from about 20—30 meters (northern district) to 70—80 meters or deeper (southern district). It may be interest to note that the Tsugaru Strait might be a barrier to the present species because no specimen has been obtained in the waters off Hokkaido.

Notes: There were found much many instances confusing the identification of the present species among the Japanese rajids since the original description has been given by MÜLLER and HENLE (1841) having used badly preserved immature specimen of a male. By detailed examination of the original description compared with many specimens gathered from various localities the present writer has attained to have a compact knowledge of the identification of the present species without any space for doubt, as mentioned above. Further, it may be sure to believe that the present species has more or less close relation to species T in such noteworthy characters as the clasper structure, number of precaudal vertebrae, spination of tail in the adult and the construction of egg-capsule.

As regards the age and growth of the present species the present writer has given the details elsewhere in this account (p. 119).

Raja (Okamejei) acutispina, n. sp.

(Abbreviated as N; New Japanese name, Moyô-kasube)
Fig. 74; Pl. II, N

Materials described: Holotype, 413 mm, off Shimane Prefecture, Sea of Japan, Dec. 3, 1952; paratypes, 67 specimens (123—435 mm in total length) and 6 egg-capsules, from off Kanaiwa, Ishikawa Prefecture, to the Tsushima Strait; 1952—'55.

External: Disc-length 1.72, width 1.49, tail 2.09 in total length; head 1.79, snout 4.00, precaudal 1.84, procaudal 3.58, in disc-length. Snout 2.23, 1st and 2nd dorsal fins 4.78 and 4.96, respectively, and caudal fin 8.33 in head. Interorbital width 3.62, eye-diameter 3.52 in snout length.

Body has more gentle appearance than species M. Anterior edge of disc slightly undulated, elongated anteriorly into a sharp end. Tail rather stout but depressed

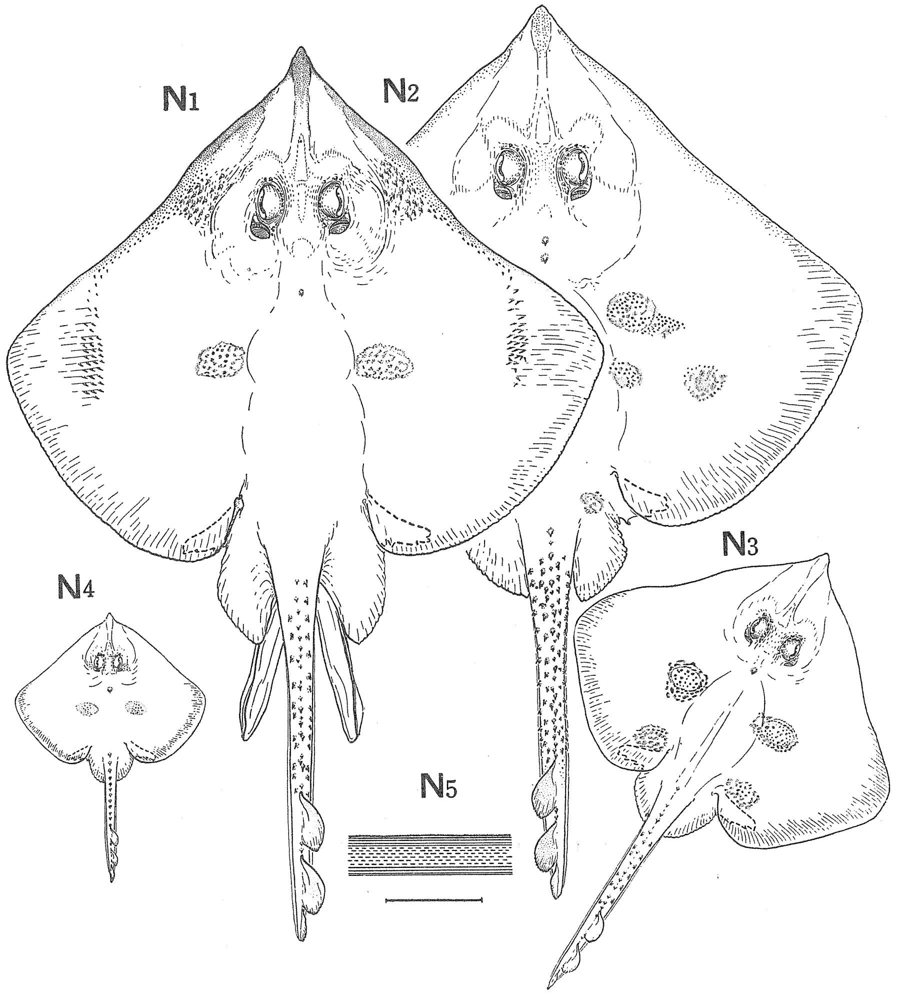

Fig. 74. *Raja acutispina*, n. sp., N_1, holotype, adult male (413 mm); N_2, adult female (405 mm); N_3, subadult female (235 mm); N_4, young male (112 mm); N_5, section of egg-capsule, scale 0.5 mm; $N_{1,2}$, off Shimane Prefecture, the Japan Sea; $N_{3,4}$, off Maizuru, the Japan Sea.

dorso-ventrally (Depressed-type), 1.21 and 1.39 times in disc-length and disc-width, respectively. Interorbital space shallowly concave, the width trifle smaller than diameter of eye. Pelvic fin commonly notched with broad anterior lobe. Clasper is of Spatula-type, stiffened with pointed posterior tip, which extends to the halfway point of tail; dermal fold distinct, growing from base to the extremity of tail. Two dorsal fins moderately large; the 1st one begins at the posterior one-third point of tail; caudal fin distinct, just as long as interorbital width.

Dorsal surface of disc wholly smooth except for anterior oblique margins, orbital rim and nuchal center, where the disc more or less armed with spines and prickles, i. e. a band of minute prickles on anterior oblique margin on each side and on rostral axis, five enlarged spines on orbital rim, only one large spine on nucha, and patches of alar and malar spines on both sides. Three rows of spines run on tail; minute prickles covering dorsal fins, but the caudal fin naked (Fig. 75 N_1).

Color of dorsum of disc mottled with various color patterns, bearing distinct pectoral ocellus on each side (Group 5); venter of body colorless as a whole, excepting marginal portion with faint orange yellow. Entire body surface extremely slimy when fresh (Pl. II, N).

Internal: Rostral cartilage rather long, longer than the cranium; rostral appendix distinct, a little shorter than half the length of rostral cartilage; anterior fontanelle triangular in shape with round corners, and the posterior one boat-like in general appearance (Fig. 27 N).

Electric organ rather small, scarcely reaching anteriorly the center of posterior ends of pelvic fins (Fig. 36 N). Vertebral counts 26−29 + 40−42 (N in Figs. 43, 44 and Table 9). Intestinal valves 5−8 (6.8 in average). Heart valves 5 in a row, in most cases (Table 11).

Clasper is of Type 8, remarkable in having bilobed rhipidion, small spike and broad dorsal terminal 1 (N in Figs. 5 and 17).

Egg-capsule: Egg-capsule of the present species has close resemblance with that of species M, O and S, in having three layers in the capsule-wall, but the capsule of the present species is distinct from that of the relatives by having much chickened pulpy layer with 60% of total thickness of the wall and having thick cover of the silky fibres over the surface (Fig. 74 N_5).

As shown in the Fig. 74 the snout is more acute in the adult male than in the female. The relative ratios of snout and tail change with growth of the fish as is the case with other species (Fig. 25 and Table 6). Namely, the change of proportional ratio of snout in length of head is more remarkable in the male than in the female, but reverse is the case in the change of ratio of the tail in width of disc.

Nuchal spines vary from 1 to 3, in most case 1; increase of tail spines from one to three rows occur at a total length of about 250 mm (Fig. 75 $N_{3,4}$); spines on orbital rim are developed with variation covering from 5 to 8, but in most cases 6 or 7 (N_3 in Fig. 74); minute prickles are crowded on anterior oblique margins of the disc in adult male, but they are developed only on distal portion of the rostral axis in the adult female. The individual variation of color and pattern on dorsum is great in the present species, and in the accompanying photograph (Pl. II) is shown that of the most common case; the pectoral ocellus is always present on two sides.

The present species inhabits only the coastal waters in the Sea of Japan, ranging from Noto Peninsula, Ishikawa Prefecture, to probably the Tsushima Strait, where the fish is usually caught by the motor trawler or the long-line.

Remarks: From external features the present species is liable to confuse with the species Q(Q′), especially in their young stages and frequently in their color and patterns. But, the two species are distinguishable externally from each other, thus; i) snout of the present species is more acutely pointed than that of the relative, and marginal portion of ventral side of disc of the present species is orange yellow, though it is grayish orange in the relative, in the young, ii) interorbital width of the present species is trifle greater than diameter of eye, but it is apparently greater than the diameter in the other, iii) nuchasl pines are fewer in the present species than in the other as explained later on, in the adult, and iv) tail spines in the adult female are set in numerous irregular rows in the present species, but they are in five regular rows in the other (c.f. Figs. 74 and 77—79).

On the basis of internal features, the present species shows more close affinity with species **M** than with other species in the southern members, especially in the male organs. It may be considered that the present species may have been specialized from an ancestor not very unlike the species **M**, as the present species have been adapted in the shallower water than the species **M** inhabits.

Raja (*Okamejei*) *hollandi* JORDAN et RICHARDSON
(Abbreviated as O; Japanese name, Isago-gangi-ei)
Fig. 75

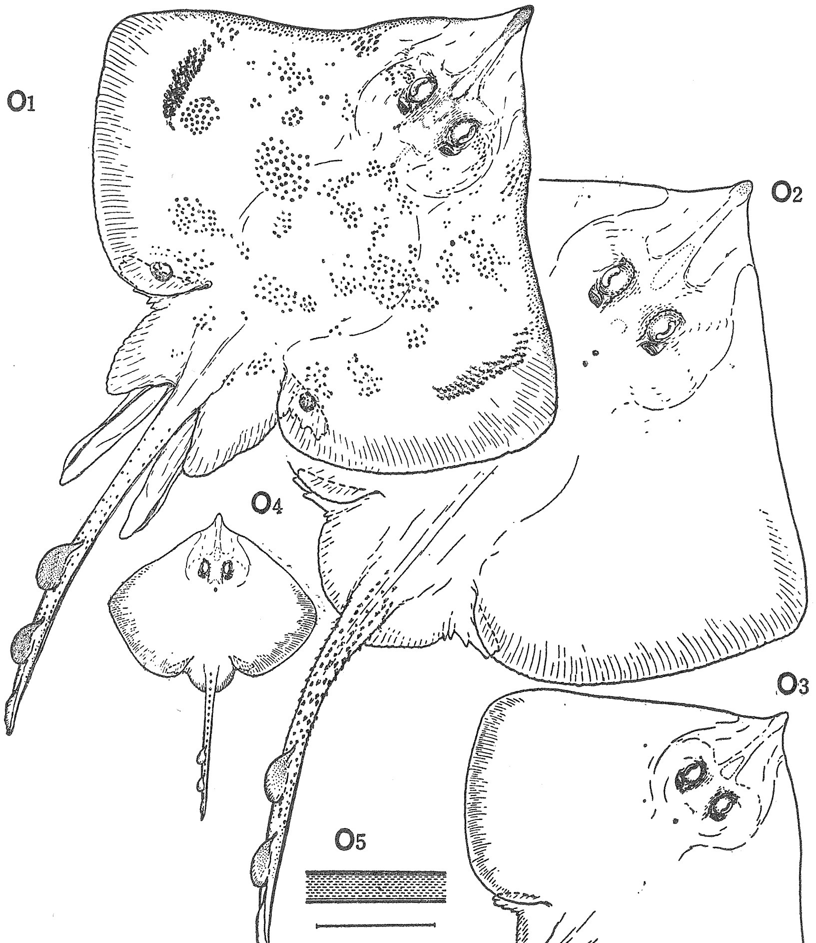

Fig. 75. *Raja hollandi* JORDAN et RICHARDSON; O$_1$, adult male (480 mm, 3—4 ages); O$_2$, adult female (500 mm, 3—4 ages); O$_3$, subadult male (320 mm, 2 ages); O$_4$, young male (160 mm, 1 age); O$_5$, section of egg-capsule, scale 1 mm; from the East China Sea.

Raja hollandi JORDAN et RICHARDSON, 1909, p. 163, Pl. 64 (original description), Takao, Formosa.—— FOWLER, 1929, p. 501 (reference).—— MATSUBARA, 1935, p. 44 (key).—— MATSUBARA, 1936, p. 25, fig. 16.—— KAMOHARA, 1938, p. 6, Kôchi. —— OKADA and MATSUBARA, 1938, p. 24 (key). —— ISHIYAMA, 1950, p. 30, figs. 1, 2, off Shimane Prefecture (egg-capsule). —— ISHIYAMA, 1951, p. 636, figs. 1—4, East China Sea (age-determination).—— ISHIYAMA, 1955, p. 271, fig. 4 (electric organ).—— ISHIYAMA, 1956, p. 99, fig. 2 (age-determination). —— MATSUBARA, 1955, p. 137 (key).

Raia hollandi, GARMAN, 1913, p. 351 (compiled).

Raja porosa (non GÜNTHER) TORTONESE, 1936, p. 36, fig. 4, Hong Kong. —— CHEN, 1948, p. 5, Formosa.

Materials examined: 59 specimens (190—540 mm in total length), off Kôchi (the Pacific shelf) and Shimane (the Japan Sea shelf) to the South China Sea; 1950—1954.

External: Snout rather long, pointed at the tip, the length relative to head-length in the adult shorter in male than in female, the ratio being 1.95—2.15 and 1.80-1.95 times, respectively (○ in Fig. 25 and Table 6). Tail slender, roundish in cross section of the main portion, the relative length also different between two sexes in the adult as in case of the snout, the ratio in width of disc 1.25 and 1.44 times in average of male and female, respectively (○ in Fig. 32 and Table 7). Interorbital space shallowly concave, the width greater than or nearly as long as diameter of eye. Procaudal portion rather long, retaining rather long caudal fin, which is about twice as long as interorbital width. Both dorsum and ventral side of the body naked with exception of tip of snout, orbital rim, nuchal and tail portions as is the case with other southern forms. Nuchal spines 1 to 2, but mostly 1; tail armed with three rows of spines in matured male, but five irregular ones in the female (Fig. 75).

Dorsum brown, densely covered with small black spots with the size of coffee grains, which show various patterns on pectoral fins. Underside of disc pale gray or whitish except for marginal portion.

Internal: Rostral cartilage nearly as long as cranium, which is twice as long as rostral appendices (Fig. 27 ○).

Abdominal vertebrae 28—29 (28.4 in average); precaudal vertebrae 38—42 (40.8 in average) (○ in Figs. 43, 44 and Table 9). Intestinal valves 6—7 (6.8 in average) (Table 10); heart valves mostly 4 in a row (Table 11). Electic organ small, extending from tip of tail to the portion behind the base of the same (Fig. 36 ○). Structure of clasper discriminated from the relatives, being referred to Type 10 of the organ (○ in Figs. 5 and 17).

Developmental stages: Proportion of snout-length into head-length rather constant in female larger than 100 mm in disc-width, but the ratio markedly changes in male larger than 250 mm in disc-width. By the change of relative length of the tail with growth of the fish the two sexes are also distinguished (○ in Fig. 32 and Table 7). Development of accessory spines on tail becomes evident when the fish attains about 300 mm in total length (Fig. 76 ○$_3$).

Color and pattern of dorsum appear to be invariable throughout from the young to the adult, and the pattern formed by numerous black spots is attractive character in fresh condition, but the pectoral ocellus is always absent in the youg.

Egg-capsule: The egg-capsule of the present species is quite similar to that of species M or N at first sight, but they are distinguishable histologically from each other on basis of degree of development of the pulpy layer (c. f. p. 47), although they are all referred to Type 6 in the character of this organ.

Distribution: This species is known to cover southern regions from offing Kôchi in the Pacific and Shimane in the Japan Sea to the South China Sea, where rather large amounts of the fish are caught by the motor-trawler.

Notes: JORDAN and RICHARDSON's original description of this species was based on an immature male, so that the proportions of some dimensional parts of the body differ in some extent from those of the adult. This species can be distinguished externally from others, at least in having blackish brown spots on the dorsum and relatively long caudal fin even in the adult. The present species is closely related to the species P in some fundamental characters, such as the structure of clasper, number of vertebrae and features of egg-capsule. Probably, the two species may be offshoots sprung from a common ancestor.

Previously, the present writer has examined rather large amount of specimens of this species caught from the East China Sea in order to determine the age-composition of the fish (ISHIYAMA, 1951). As a result, it becomes evident that the age of the fish can be determined by the examination of vertebral centrum as aforementioned, and the fishes representing various ages are now shown in this account.

Raja (*Okamejei*) *macrophthalma*, n. sp.

(Abbreviated as P); Japanese name, Medama-kasube)

Fig. 76

Raja macrophthalma ISHIYAMA, 1950, p. 30, fig. 1, 2, off Hamada, Shimane Prefecture (egg-capsule). —— ISHIYAMA, 1955, p. 271, figs. 1—4, off Shimane Prefecture (electric organ).

Materials described: Holotype, 347 mm, Miya fish market, Aichi Prefecture, March 13, 1950; paratypes, 71 specimens (94—369 mm in total length) and 2 egg-capsules, off Shimane Prefecture and Shimonoseki fish market (the Japan Sea), and off Aichi and Shizuoka Prefectures, Kumano-nada, and Yawatahama, Ehime Prefecture (the Pacific); 1950—1954.

External: Disc-width 1.57, disc-length 1.92, tail 1.89, head 3.58 in total length; head 2.26, snout 5.00, precaudal length 1.92, procaudal length 3.21 in disc-width; interorbital width 4.19, eye-diameter 3.52, longer axis of both dorsal and caudal fins 2.09, and ventral incision 2.0 in snout.

Snout rather long and pointed; anterior oblique margins of disc strongly undulated. Interorbital space concave, smaller than eye, which is relatively large*). Tail stiff, slender and rather depressed; precaudal elongated, 2.67 times in length of tail. Dorsals separated by a distance equal to base length of the fin. Lateral fold of tail inconspicuous, extending anteriorly beyond distal tip of the pelvic fin. Clasper stout and elongated, extending as far beyond midway point of tail posteriorly.

Spination of dorsum rather similar to that of the preceding species O, i. e., tip of snout, anterior oblique margin of disc, orbital rim, nuchal and tail portions are all setose in some extent, of which the spination on last three regions is characteristic of the present species. Namely, 5 spines on orbital rim, 2 spines on nucha and three rows on tail; two dorsal and caudal fins and both sides of tail rearward of the 1st dorsal are also prickly. Ventral side of body smooth, without any scale (Fig. 76 P_1).

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* The specific name was derived from this characteristic.

Dorsum brown, furnished with numerous dark brown spots, which crowd to make roundish patterns scattered at places on main portion of disc. Ventral white with numerous sensory pores of dark gray.

Internal: Rostral cartilage slender, much longer than cranium, with exceedingly projecting median process; rostral appendix rather long, more than half the length of cranium. Both anterior and posterior fontanella broadly opened, but their anterior and posterior extremities pointed (P in Fig. 27). Electric organ less developed, scarcely reaching anteriorly to posterior extremity of the pelvic fin (P in Fig. 36). Abdominal vertebrae 25—26 (25.4 in average); precaudal vertebrae, 38—43 (40.4 in average)(P in Figs. 43,44 and Table 9). Intestinal valves 5—7; heart valves mostly 4 in a row. Clasper is of Type 10, marked with specialized sentinel and accessory terminal 2 (P in Figs. 5 and 17).

The above external characters are derived from the holotype of full-matured male measuring 347 mm in total length, but the internal characters as well as following external ones are given by paratypes.

Ratio of snout-length into head-length 1.9—2.1, but it is trifle greater in male than in female in adult (Fig. 25 and Table 6). Ratio of tail-length into disc-width is also not so different between two sexes in stages older than adolescent, but the trend reversals as compared with the case of snout (P in Table 7).

The newly born young (Fig. 76 P_3) is equipped with a common tract of spines, viz., 3 supraorbital, 1 nuchal and one row of tail ones, which are increased by addition of accessory ones as the fish attains about 200 mm in total length. The difference in the spination is rather distinct between the sexes when matured, viz., in the female, anterior oblique margin of disc quite smooth with exception of the tip of snout (Fig. 76 P_2), while in the male the portion densely armed with numerous prickles and malar spines (Fig. 76 P_1); number of spines on orbital rim mostly 6 in female but 5 in male; nuchal spine ranges 2—3, setting usually in triangular pattern in female instead of being 1—2 in a row in male; 5 rows of spines on tail in female, while 3 in male without exception.

In color pattern on dorsum, there is no difference between young and adult in most cases, but sometimes it happens to occur some dusky blotches on the dorsal as well as on ventral side in the adult.

Egg-capsule: The egg-capsule is of Type 6, the smallest one so fas as known to us measures 39 to 42 mm in length exclusive of the horns (Fig. 76 P_4).

The present species is found to occur in the coastal waters ranging from the middle regions offing of Shizuoka and Shimane Prefectures to the south of our main island, but probably is found around Kyusu.

The present species is often captured together with such three related forms as **N**, **Q′** and **S**, which are found to inhabit the southern waters, but they are distinguishable externally from each other in relative length of both snout and procaudal portion, relative size of eye-diameter, mode of arrangement of spines, especially on nuchal and tail portions, and presence or absence of pectoral ocellus in addition to the size of body when matured.

Remarks: This species closely related to species **O** in their fundamental characters, such as structure of clasper, configuration of rostral cartilage and cranium, vertebral counts, and degree of development of electric organ. In this connection, the two species may be congeneric descendants, which might have been sprung into different but neighbouring waters.

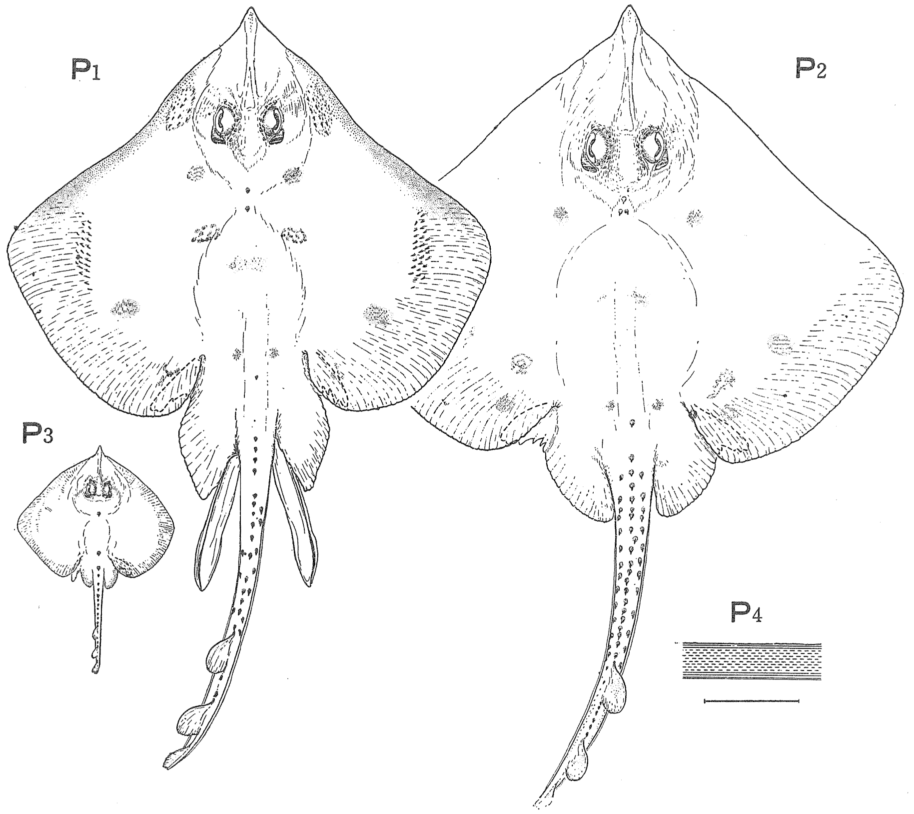

Fig. 76. *Raja macrophthalma*, n. sp.; P_1, holotype, adult male (347 mm); P_2, adult female (369 mm); P_3, young female (120 mm); P_4, cross section of egg-capsule, scale 0.5 mm; $P_{1,3}$ from off Aichi Prefecture; $P_{2,4}$ from off Shimane Prefecture, the Sea of Japan.

Raja (Okamejei) porosa meerdervoorti Günther
(Abbreviated as Q; Japanese name, Komon-kasube)
Figs. 77 and 78; Pl. II, Q

?*Raja chinensis* Basilewsky, 1855, p. 215, Pepin, China.—— Garman, 1913, p. 356 (compiled).

Raja porosa Günther, 1874, p. 154, Chefoo, China (original description).—— ?Mori, 1928, p. 3, Mokpo, Korea (listed).—— Fowler, 1929, p. 501 (reference).—— Fang and Wang, 1932, p. 264, Chefoo, China.—— ?Mori and Uchida, 1934, p. 26, Mokpo, Korea (listed).—— Liu, 1932, p. 161, Tsingtao, China.—— Okada and Matsubara, 1938, p. 25(key). ——? Kamohara, 1952, p. 11, Kôchi.—— (pars) Matsubara, 1955, p. 137 (key).

Raia porosa Garman, 1913, p. 154, China.

Raja meerdervoorti (*pars; non* Bleeker) Jordan and Fowler, 19303, p. 605, fig. 7, Tokyo; Nagasaki; Kôbe; Wakanoura; Hakodate.—— ?Jordan and Metz, 1913, Fusan, Korea (listed).

Raja meerdervoortii (*pars; non* Bleeker) Jordan, Tanaka and Snyder, 1913,

p. 26, fig. 13, Japan (listed). —— ?MORI, 1928, p. 3, Fusan, Korea (listed). —— HONMA, 1955, p. 212, Sado Is'l, Niigata Prefecture (listed).

Raja meerdervoortii meerdervoortii ISHIYAMA, 1950, p. 30, figs. 1, 2 (in Japanese), off Akita, Sea of Japan (egg-capsule).

Raja katsukii TANAKA, 1927, p. 662, figs. 426—428, Niigata and Aomori, Sea of Japan. —— MATSUBARA, 1935, p. 45, (key). —— MATSUBARA, 1936, p. 26, fig. 17 (reference). —— OKADA and MATSUBARA, 1938, p. 24 (key). —— FOWLER, 1930, p. 501 (compiled). —— FOWLER, 1941, p. 371 (compiled).

Materials examined: 13 specimens, 243—365 mm. in total length and 2 egg-capsules; coastal waters of the Sea of Japan, offing of Kasumi, Tsuiyama, Niigata, and Funakawa; 1948—1954.

External: Snout very short, pointed at distal tip, the length into head length 2.07 times on average with range from 1.97 to 2.31, discriminating between sexes (Fig. 25 Q): tail short, depressed dorso-ventrally becomes somewhat slenderer posteriorly, the length into disc-width 1.38 times in average with range from 1.28 to 1.53, varying between sexes (Fig. 32 Q); interorbital space shallowly concave, the width apparently broader than eye-diameter, being 3.47 to 4.08 times as broad as eye diameter with 3.39 times in average; the width into snout-length varies 2.74 to 3.39 times with 3.05 times on average.

Anterior marginal portion of disc including mesial plane on rostral cartilage studded with prickles, which are denser in male than in female; posterior and mesial portions of disc furnished with prickles in female, but smooth in male; a row of 2 to 5 spines on nuchal; orbital spines present; spines on tail setting in 3 regular rows in male, but in 5 similar rows in female; two dorsal and caudal fins usually smooth except for original portions of dorsals; ventral surface entirely smooth except for tip of snout which is armed with a few scales (Fig. 77 $Q_{1,2}$).

Variation of color pattern on dorsal side of disc remarkable, being mottled with various hue, but the pectoral ocellus usually distinct; ventral side of disc generally white, bearing blotted dapples on central portion in some cases.

Internal: Rostral cartilage short, about as long as cranium-length; rostral appendices small, but distinct as in other members of this subgenus; anterior and posterior fontanella long, the posterior one not constricted at the middle portion (Fig. 27 Q).

Abdominal and precaudal vertebrae 27.3 and 41.1 in average, respectively (Q, Q' in Figs. 43, 44 and Table 9). Intestinal valves 7.6 in average (Q, Q' in Fig. 48 and Table 10). Heart valves larger in number than in any Japanese rajids, ranging 4 to 6 in a row (Q, Q' in Table 11). Electric organ rather small and the elements of the organ rather few, occupying both sides of whole tail (Fig. 36 Q).

Clasper is of Type 9, characterized by having large sentinel and rhipidion in external, and in having symmetrically elongated accessory terminal 1 and shorter accessory terminal 2, as has mentioned elsewhere (Q in Figs. 5 and 18).

Developmental stages: Snout shorter and more pointed in the young than in the adult, the length into head-length varies with growth of the body (Q in Table 6). Tail relatively long, depressed even in the young, the length into disc-width change with growth of the fish as in case of other members of this genus (Q in Table 7). Increase of spines on tail from one to three or five rows starts at a total length of about 200 mm (Fig. 78 Q). The variation of color and patterns in the developmental stages also remarkable, giving various hue of the skin—olive to dark sepia with or without pale

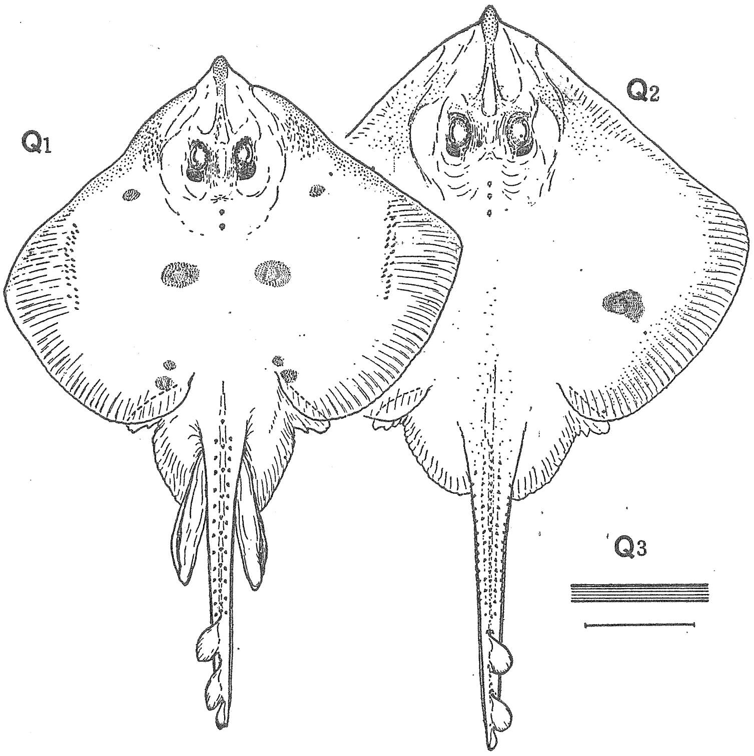

Fig. 77. *Raja porosa meerdervoorti* GÜNTHER; Q_1, adult male (335 mm); Q_2, adult female (393 mm); Q_3, section of egg-capsule, scale 1 mm; from off Kasumi, Hyogo Prefecture, the Sea of Japan.

spots, which are sometimes few and many, and sometimes numerous and small as is the case with the adult, but pectoral ocellus always present even in very young fish, and marked with dark brown ring on both sides of disc.

Egg-capsule: The capsule belonging Type 5, distinguishable from others in its small size (43 to 59 mm long exclusive horns) and in having very thin capsule-wall (0.15 mm thick), which is composed of two layers without pulpy layer (Figs. 22 Q, and 77 Q_3).

Notes: The present subspecies is found to inhabit the coastal waters of the Sea of Japan, covering from off Akita to Yamaguchi Prefectures, where the next form is confound with this form. But, it should be noticd herewith that the present subspecies could not be collected in the waters along the Pacific, including the Inland Sea of Japan, central region of the East China Sea, and the Tsugaru Strait.

The fishes of this group are very variable, especially in the color and pattern, the spination and other external features, so many ichthyologists have confused them or separated them under various names. If many specimens gathered from various localities are compared externally, everybody may agree to separate the several forms, although sometimes various interconnecting forms within them are found. As the result of my careful study on many specimens, I came to conclusion that the present much ambiguous group of fishes must be separated into two subspecies based on the following external as well as internal features, thus; i) proportional length of snout; ii) interorbital width relative to snout or eye-diameter; iii) structure of glans clasper; and iv) geographical distribution. Of these, the latter two items were explained elsewhere (c. f. pp. 36, 180), where the present writer has emphasized that the characteristics of the male organ seem to show the most reliable basis for distinguishing the present subspecies from the related one. The differences in other two items mentioned above, however, are not so distinct as to warrant clear-cut demarcation of these two related forms, especially in their youngs. The following is a result of a biometric comparison of some bodily parts of same sex of the two subspecies by using both adult and subadult specimens:

Table 21. Result of t-test for comparison of proportional ratios of snout, eye-diameter and interorbital width in the two subspecies, Q ($\bar{X}$) and Q′ ($\bar{Y}$). Number of specimens used are 7 males and 11 females in Q, and 11 males and 10 females in Q′. For other abbreviations, see p. 7.

Items	Mean $\bar{X}$ / $\bar{Y}$	S	t	t_0 ($\alpha = 0.01$)
Snout-length into head-length, male	2.13 / 2.31	0.16	0.13	2.92
……………………………, female	1.84 / 2.01	0.10	2.97	2.97
Eye-diameter into snout-length, male	3.64 / 3.71	0.24	0.60	2.92
……………………………, female	4.02 / 3.75	0.51	2.97	2.97
Interorbital width into snout-length, male	3.02 / 3.28	0.26	1.24	2.92
……………………………, female	3.47 / 3.28	0.28	2.97	2.97

From Table 21 it may be said that the differences between these two subspecies are significant only in those bodily parts of the female. Conclusively, subspecific demarcations of the two forms in question are found to exist in the structure of male organ, proportional ratios of snout, eye-diameter and interorbital width in female, and difference of their geographical distribution.

Raja (*Okamejei*) *porosa tobae* TANAKA

(Abbreviated as Q′; Japanese, Toba-kasube)
Figs. 78 Q′ and 79

Raja tobae (*non tobae* TANAKA, 1927) TANAKA, 1917, p. 313 (in Japanese), Toba, Mie Prefecture. —— TANAKA, 1917, p. 453, figs. 353—356, Toba, Mie Prefecture (original description). —— (pars) JORDAN and HUBBS, 1925, p. 111, off Fukui, Sea of Japan; Otaru, Hokkaido. —— FOWLER, 1930, p. 501 (reference). —— MATSUBARA, 1935, p. 45 (key). —— KAMOHARA, 1938, p. 5 , Kôchi. —— FOWLER, 1941, p. 379 (reference). —— ISHIYAMA, 1955, p. 271, figs. 2—4, off Yamaguchi, Inland Sea (electric organ).

Raja porosa ? FANG and WANG, 1932, p. 266, Chefoo, China. —— (pars) MATSUBARA, 1955, p. 137 (key).

Raja meerdervoortii UI, 1932, p. 22, Wakayama, Inland Sea.

Materials examined: 60 specimens (97—495 mm in total length) and 16 egg-capsules from coastal waters of the Pacific and the Sea of Japan; offings of Totoro; Shimonoseki; Senzaki; Yawatahama; Kôchi; Onomichi; Kasumi; Maizuru; Kanaiwa; Chôshi and Funakawa; 1948—1955.

Since the present subspecies closely resembles the foregoing one in both external

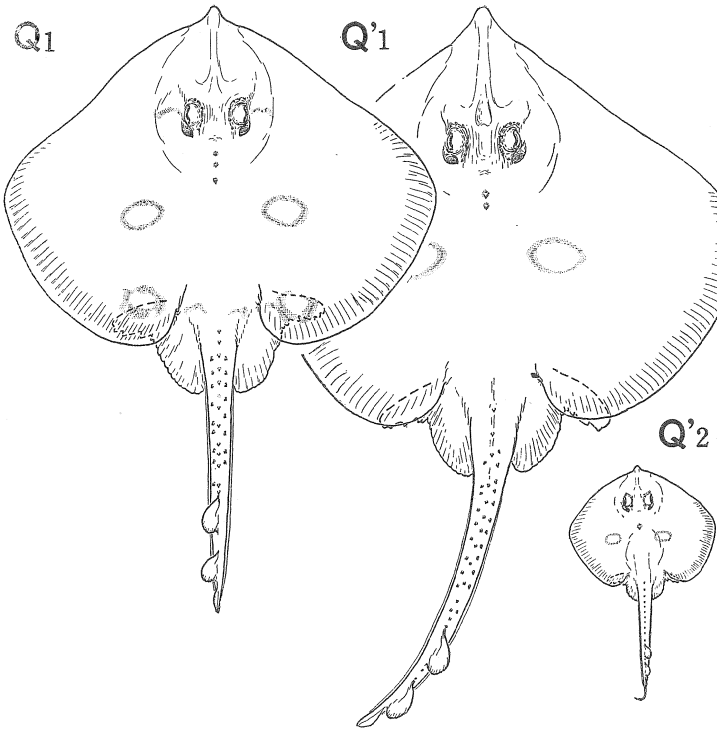

Fig. 78. Comparison of the two subspecies in adolescent and postlarval stages; Q_1, subadult female of *R. porosa meerdervoorti*, (271 mm), from off Kasumi, Hyogo Prefecture; $Q'_{1,2}$, subadult female, (310 mm) and postlarval young of *R. porosa tobae*, (100 mm), from off Yamaguchi Prefecture, the Inland Sea, respectively.

and internal features, and in geographical distribution, the characteristics which will enable us to manifest the present form from the relative may be given here.

External: Snout relatively short, the length relative to head-length different between sexes, being the ratio 2.08 times on average with range from 1.91 to 2.26 (Q′ in Fig. 25); tail short, markedly depressed dorso-ventrally from the root to distal tip, the proportional length to disc-width different between two sexes, being the ratio 1.38 times on average with range from 1.12 to 1.48 (Q′ in Table 7); interorbital space concave, the width apparently greater than eye diameter; interorbital width into snout-length varies from 3.22 to 4.33 times with 3.85 times on average; eye rather small, the diameter into snout length varies from 2.79 to 4.08 times and 3.24 times on average.

Prickles along marginal portion of disc studded in a band, which is somewhat denser than that of the foregoing subspecies when matured, but those setting on nuchal and tail are more or less noteworthy in this subspecies, thus; nuchal spines vary from 2 to 5 and from 7 to 15 in male and female, respectively, and spines on tail not so conspicuously developed in three (male) or five (female) rows, which follow anteriorly a band of minute prickles mesially; two dorsals furnished sparsely with prickles, but pelvic and caudal fins all smooth; ventral side smooth except for a few prickles developed on tip of snout (Fig. 78 $Q'_{1,2}$ and Fig. 79).

Color of dorsal side mottled with various patterns as in case of the relative, and the pectoral ocellus distinct in adult as well as in young stage although it becomes obscure after preservation in formalin; ventral side usually white, excepting some indistinct grayish blotches scattered on central portion of disc and on tail.

Internal: Rostral cartilage rather long, as long as or slightly longer than cranium-length; degree of development of rostral appendices and general form of both anterior and posterior fontanella much the same as in those of the foregoing fish (Fig. 27 Q′). Counts of abdominal and precaudal vertebrae, and of intestinal valves vary in the same extent as in those of the former fish so far as the present investigations go (Q, Q′ in Figs. 43, 44, 48 and Tables 9 and 10); heart valve also numerous, varying from 4 to 6 in a row (Q′ in Fig. 51); electric organ moderate in size as illustrated in Fig. 36 Q′.

Clasper is of Type 9, distinguished from the foregoing subspecies by having relatively longer spike on account of elongated accessory terminal 2 as compared to that in the relative (Q′ in Fig. 5 and 18).

Developmental stages: Increase of thorns on tail begins at a total length of about 300 mm (Fig. Q′ 78), and proportional ratios of snout and tail change with growth of the fish (Q′ in Tables 6 and 7).

Egg-capsule: The capsule somewhat larger than that of the foregoing fish, but capsule-wall having the same structure being composed of two layers without pulpy layer.

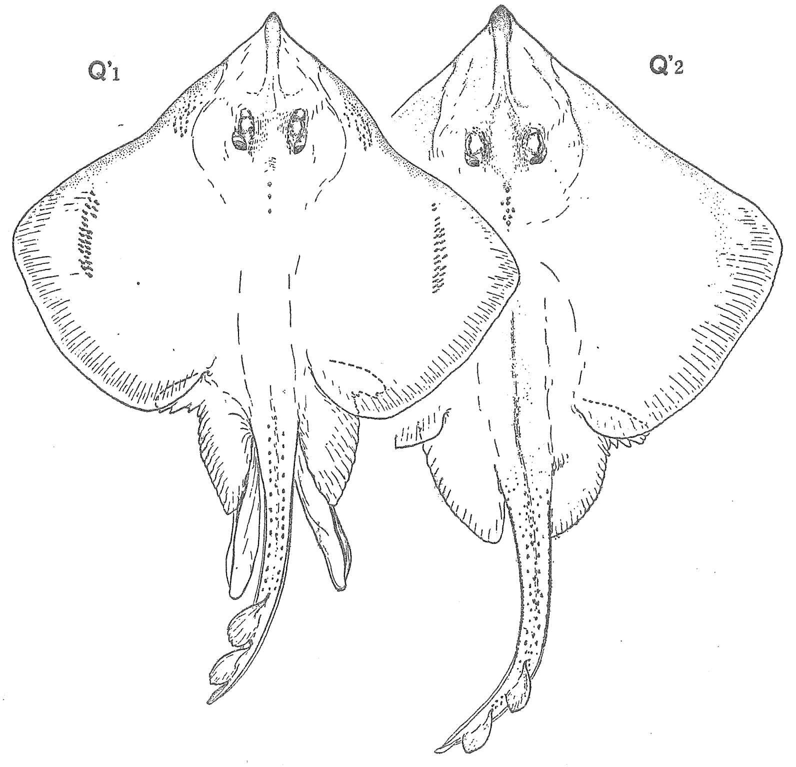

Fig. 79. *Raja porosa tobae* TANAKA; Q′₁, adult male (450 mm); Q′₂, adult female (495 mm); from off Yamaguchi Prefecture, the Inland Sea.

Notes: Any workers have met with difficulty in determing whether or not any fish belonging to this group is to be identical with GÜNTHER's *porosa* or JORDAN and FOWLER's *meerdervoorti*, or TANAKA's *tobae*. Thus, the present subspecies and the foregoing one have much the similarity in many respects as has explained repeatedly. But my own examination of a series of specimens involving both the younger and the older fishes taken from various localities listed has succeeded in showing some consistent differences in both external and internal features and in geographical distribution aforementioned. The two subspecies, however, are partly sympatric in their habitat areas along the coastal waters of the Sea of Japan.

Raja (Okamejei) fusca GARMAN

(Abbreviated as R; Japanese name, Kuro-kasube)
Fig. 80

Raja fusca GARMAN, 1885, p. 42, Japan (original description).—— JORDAN and SNYDER, 1900, p. 337, Tokyo (listed).—— JORDAN and FOWLER, 1903, p. 649 (copied). —— PIETSCHMANN, 1908, p. 645, Japan.—— (pars?) JORDAN and HUBBS, 1925, p. 110, Misaki, near Yokohama.—— FOWLER, 1930, p. 501 (reference). —— MATSUBARA, 1935, p. 44, Tokyo (key). MATSUBARA, 1936, p. 24, fig. 15, Tokyo.—— OKADA and MATSUBARA, 1938, p. 24 (key).—— ISHIYAMA, 1950, p. 30, figs. 1 and 2, Chôshi (egg-capsule). —— ISHIYAMA, 1951, p. 629, Chôshi (age-determination). —— ISHIYAMA, 1952, p. 1, fig. 1, Chôshi.—— ISHIYAMA, 1955, p. 271, fig. 4, Chôshi (electric organ).—— MATSUBARA, 1955. p. 137, fig. 21 (key).

Raia fusca (pars) GARMAN, 1913, p. 349, Pl. XX, figs. 4 and 5. Tokyo Bay (holotype).

Raja kenojei (not of MÜLLER and HENLE in part) JORDAN and SNYDER, 1903, p. 652, —— Misaki.—— (pars) JORDAN and FOWLER, 1903, p. 652, Misaki. —— ? PIETSCHMANN, 1908, p. 646, Japan.—— JORDAN and THOMPSON, 1914, p. 208, Misaki. —— (pars) JORDAN and HUBBS, 1925, p. 110, Misaki; Yokohama.

Materials examined: 67 specimens (108—518 mm in total length) and 4 egg-capsules; coastal waters (20—50 m in depth), from off Hachinohe, Aomori Prefecture, to Chôsi, Chiba Prefecture; 1948—1952.

External: Snout very short and blunt, the proportionate length against head not so different between sexes even in adult stage, being 2.2 and 2.1 times on average in male and female, respectively (R in Fig. 25 and Table 6). Tail markedly flattened throughout its entire length, the length relative to disc-width also rather same between sexes, measuring 1.4 and 1.5 times on average in the adult of male and female, respectively (R in Fig. 32 and Table 7). Membranous folds of tail broad without pigment (Fig. 36 R). Interorbital space shallowly concave, the width 2.5—3.0 times in snout-length, and about 1.5 times the diameter of eye, which is rather small. Scales present on dorsum, crowded on anterior portion over rostral axis, anterior-posterior oblique margins of disc, orbital rim, nuchal region, and tail. Of these, those studded orbital rim, nuchal and tail portions are characteristic to the present species, and those growing on anterior marginal region of disc and nuchal portions are different between sexes when matured. Namely, number of orbital spines being respectively 7—9 and 9—13 in male and female; nuchal spines ranging 4—6 in male and 5—9 in female, followed posteriorly by a broad belt of small prickles continued with three rows of tail spines, which develop in the same manner in the two sexes when matured; in male, anterior marginal portion of the disc opposite the branchial region thickly covered with prickles and malar spines followed posteriorly by a band of alar spines, but in female only the posterior marginal region of disc and distal portion of rostral axis are sparsely furnished with spinous prickles. Two dorsals naked in both sexes even in the adult (Fig. 80 $\mathbf{R}_{1,2}$). Ventral surface smooth other than distal portion of snout.

Dorsum deep brown other than snout, scattered with many small black spots, which disapear in preservation. Ventral side white, as a whole, except for distal portion of tail, which is provided with some brown streaks, but in some specimens small brown spots are occasioned.

Internal: Rostral cartilage very short, apparently shorter than cranium; rostral appendix having usual shape as in other species within this genus, the length measuring one-third times the length of rostral bar. Anterior fontanelle triangular in shape, with round corners; the posterior one broadly opened, but with a shallow constriction at the middle portion (**R** in Fig. 27).

Vertebral counts in the two portions respectively 28—29 (28.8 on average) and 39—43 (41.0 on average) (R in Figs. 43, 44 and Table 9). Intestinal valves 7—8, 7.8 on average; valves of conus arteriosus mostly 4—5 (Table 10). Structure of clasper, Type 9, characterized by having elongated spike and rather tapered dorsal terminal 1 (**R** in Figs. 5 and 18).

Developmental stages: Snout-length relative to head-length not so markedly changes with growth of body, especially in female, but in both cases the ratio in head-length becomes greater with age (Fig. 25 **R**). Change of relative length of tail in disc-width with growth of the fish also undiscernible between sexes as explained in Fig. 32. Increase of spines on orbital rim, nuchal and tail regions occur at a total length of about 230 mm (Fig. 80 $\mathbf{R}_3$). It should be noticed that two nuchal spines are found even in the early stage, in most cases (Fig. 80 $\mathbf{R}_4$).

Dorsum darker in adult than in young which having yellowish to brown color and furnished with distinct pectoral ocellus (Fig. 80 $\mathbf{R}_{4,5}$).

Egg-capsule: The egg-capsule is of Type 5, moderately large, but the wall is composed of two layers ($\mathbf{R}_7$ in Fig. 80).

Distribution: The present species is found in the waters shallower than 50 meters in depth, ranging from Aomori Prefecture to Tokyo Bay.

Notes: The present species was first recorded by GARMAN (1885) by a very young specimen, 4 $^{3}/_{8}$ inches in the original description, but 4 $^{3}/_{4}$ inches in his subsequent record (1913), drawn out from an egg-capsule. PIETSCHMANN (1908) also described based upon a very young female specimen measuring 140 mm in total length. Since all the species referable to the subgenus *Okamejei* closely resemble with each other in the young stage, the identification of this species is by no means easy task based upon the brief description given previously. Having examined many such small specimens taken from near the type locality as those described by GARMAN and PIETSCHMANN, the present author arrived at a conclusion that the present specimens are all referable to the present species on the basis of following facts: i) although four such species as **M**, **P**, **Q′** and **S** are closely related to the present specimens, and although they are found to inhabiting the waters of the type locality of the GARMAN's species and its neighbourings, the two species **M** and **P** are distinguishable from the present

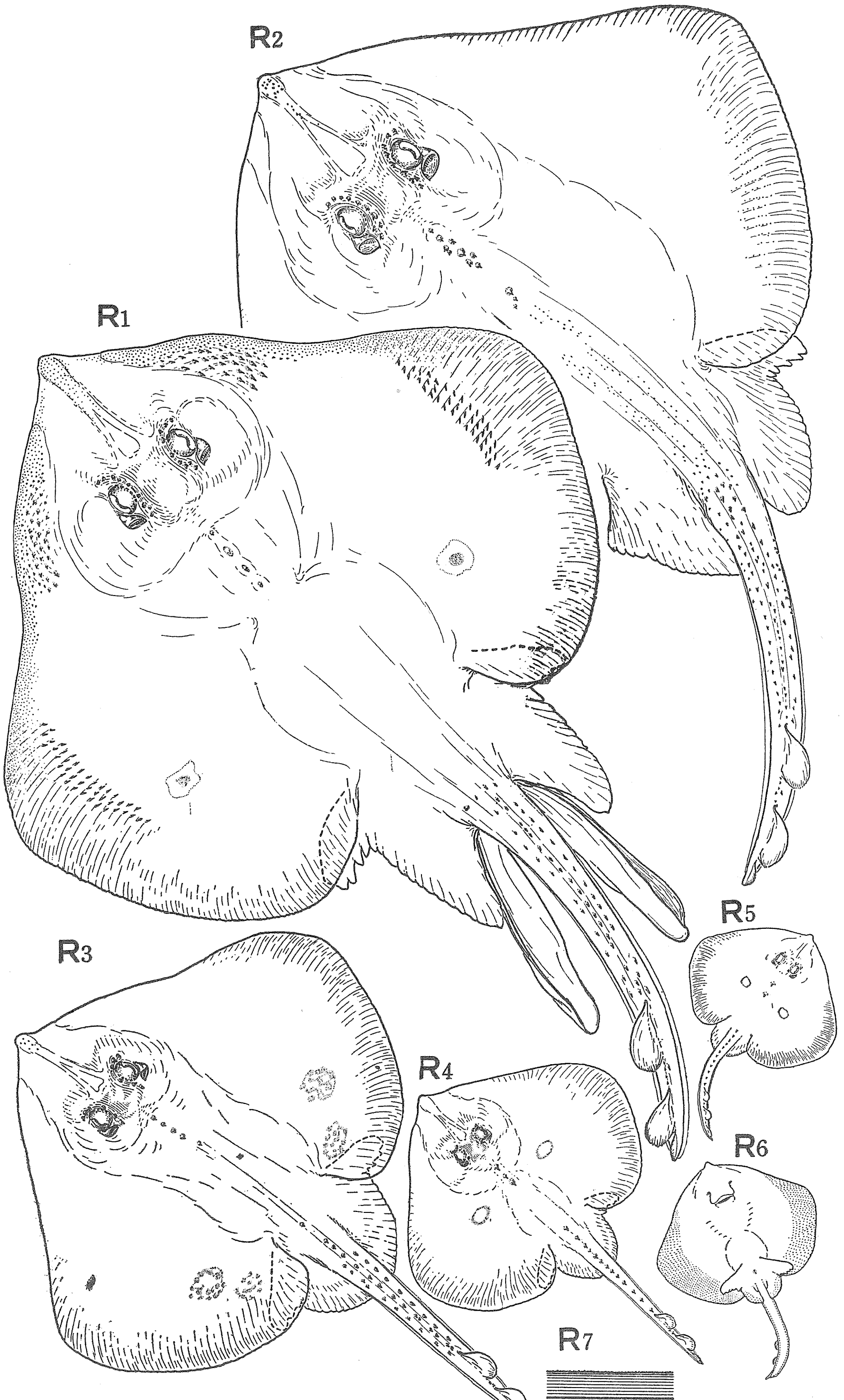

Fig. 80. *Raja fusca* GARMAN R$_1$, adult male (517 mm, 2—3 ages); R$_2$, adult female (518 mm, 2—3 ages); R$_3$, subadult female (325 mm, 1—2 ages); R$_4$, young female (191 mm, 0—1 age); R$_{5,6}$, dorsal and ventral aspects of postlarval young male (118 mm, 0—1 age); R$_7$, section of egg-capsule, scale 1 mm; from off Chôshi, Chiba Prefecture.

specimens in having unique color pattern or in lacking pectoral ocellus even in the early stage; ii) in comparison of the present specimens with those of Q′ and S as well as the present specimens in description with this species given by GARMAN, it was found that the present specimens are more closely fitted with GARMAN′s species than either Q′ or S.

The present author agrees with the opinion given by JORDAN and HUBBS (1925) that "the form identified by recent workers as *R. kenojei* is the adult of *Raja fusca*, ...", but their identification of the fish taken from the Toyama Bay, being referred to the present species, is doubtful inasmuch there is no reliable record of the occurrence of the present species from the Japan Sea so far as the present author is aware.

SCHMIDT′s (1931) description of this species will be discussed with annexed species.

The present author has given an account (1951), where he has dealt with the method of age-determination of the present species, and made clear the annual growth of the fish (cf. p. 120 in this article and Fig 80).

Raja (*Okamejei*) *schmidti*, n. sp.

(Abbreviated as S; Japanese name, Tsumari-kasube)

Fig. 81; Pl. III, S

Raia kenojei (non MÜLLER and HENLE, 1841) GARMAN, 1913, p. 349, pl. XXIV, figs. 1 and 2. Izu Sea, Shizuoka Prefecture.

Raja kenojei (pars) FOWLER, 1940, p. 372 (reference).——(pars) HERRE, 1953, p. 39 (listed).

Raja fusca (non GARMAN, 1885) SCHMIDT, 1931, p. 11, figs. 2 and 3, Tokyo Bay.

Materials described: Holotype, 507 mm, off Ehime Prefecture, Bungo Strait, March 20, 1950; paratypes, 39 specimens (162—523 mm in total length) and 4 egg-capsules, from off Totoro, Miyazaki Prefecture; Yawatahama, Ehime Prefecture; Miya, Aichi Prefecture; 1948—1953.

External: Disc-width 1.58, disc-length 1.91, tail 1.88, head 3.72 in total length; head 2.35, snout 5.71, precaudal 1.74 and procaudal 3.76 in disc-width; interobital width 2.73, eye-diameter 2.94, longer axis of two dorsal fins 1.33, and caudal 2.94 in snout, respectively.

Snout very short, pointed anteriorly; anterior margins on two sides of disc strongly undulated. Interorbital space concave, 1.05 times as wide as eye-diameter, which is rather large. Tail rather flattened, as long as disc. Two dorsals large, the longer axis much longer than interorbital width; caudal fin small; ventral incision moderately deep. Clasper stout, extending posteriorly as far as the midway point of tail.

Body almost naked with exceptions of anterior marginal region, orbital rim, nuchal and tail regions as usually found in the relatives, viz., minute prickles covering both surfaces of distal part of snout and anterior oblique region of dorsum of disc, which is also furnished with patches of malar and alar spines; 9 enlarged spines setting on each orbital rim; only one spine present on nuchal region; an irregular row of spines running along mesial line of tail, which is strengthened by a row of spines on left side and two rows of similar ones on rim; very small prickles covering dorsals (Fig. 81 S_1).

Color yellowish brown with many dark-brown spots, which are densely crowded on middle belt, but large and sparsely set on head. Pectoral ocellus present in fresh condition, but disappeared after preservation. Ventral side faint gray in main portion of disc excepting marginal band with pale purplish brown; ventral side of tail and pelvic fin whitish (Pl. III, S).

Internal: Rostral cartilage very short, much shorter than cranium; rostral appendix shorter than half the length of rostral cartilage; both anterior and posterior fontanella broadly opened, the anterior one pointed at anterior tip (Fig. 27 S). Electric organ less developed, but reaching ateriorly as far beyond posterior extremity of pelvic fin (Fig. 37 S). Precaudal vertebrae 27—29 (28.0 on average); procaudal vertebrae 42—45 (43.4 in average) (S in Figs. 43, 44 and Table 9).

Intestinal valves, mostly 7; valves of conus arteriosus 4 in many cases, (S in Tables 10 and 11).

Structure of clasper is of Type 9, distinguished from that of relatives in having lesser produced spike and broadly developed dorsal terminal 1 (S in Figs. 5 and 18).

Of descriptions mentioned above, those on external features were given from the holotype, but those on internals were derived from paratypes, based on which the followings are supplemented.

Length of snout relative to head-length gradually reduced with growth of the fish, being the ratio into head-length increases from about 2.0 times or more large

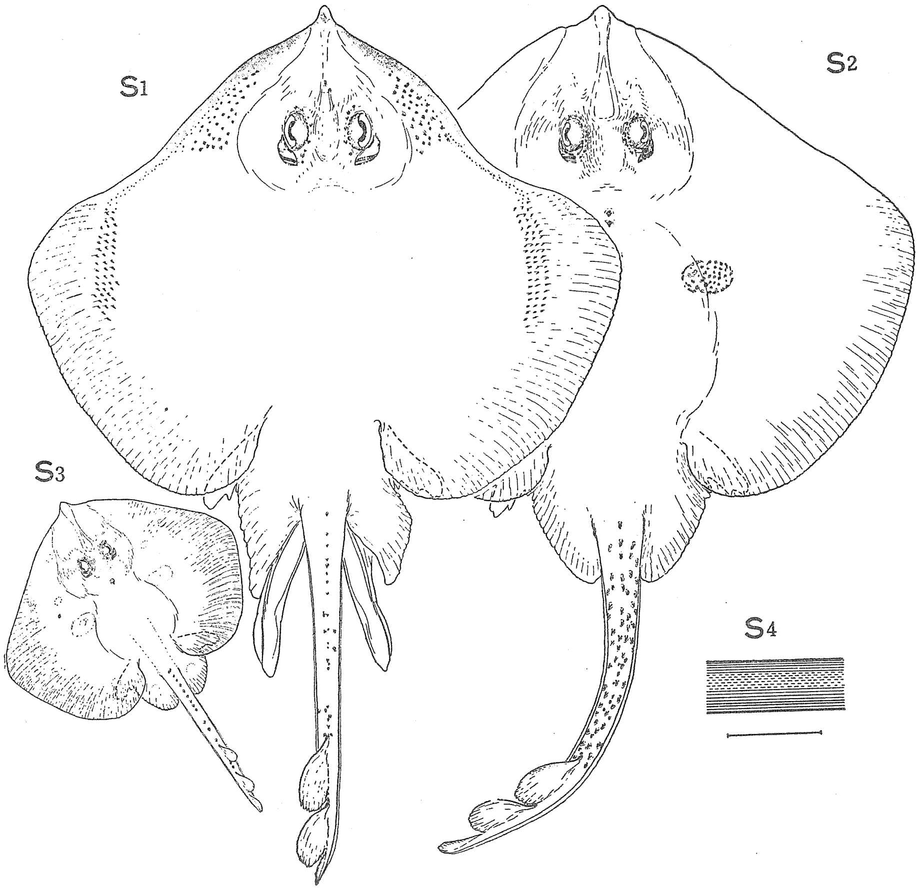

Fig. 81. *Raja schmidti*, n. sp.; S_1, holotype, adult male (507 mm); S_2, adult female (521 mm); S_3, young male (198 mm); S_4, section of egg-capsule, scale 0.5 mm; from off Ehime Prefecture, Bungo Strait.

up to about 2.2 (female) or 2.4 (male) times (**S** in Fig. 25 and Table 6). Conversely, relative length of tail against disc-width decreased in small extent with the growth of the fish, discriminating between two sexes (**S** in Fig. 32 and Table 7).

Developmental stages: Spination in the young is revealed with the same tract as in many of the southern forms, viz., three spines on orbital rim, one on nuchal, and a row with 12—14 spines on tail. These downy prickles begin to increase when the fish attains to total length of about 250 mm. In the adult, supraorbital and nuchal spines cover from 4 to 13, mostly 6 and from 1 to 3, mostly 1, respectively, and tail of the female is marked by having irregular rows of spines (**S** in Fig. 37).

Color of dorsum in the young orange brown and furnished with distinct dark brown pectoral ocellus which enclosing some 4—6 brown spots, but the ocellus disappears or becomes obscure in the adolescent, in most cases, in turn for the development of deep brown spots on the surface. The ventral side in the young with similar hue as in the adult.

Egg-capsule: Egg-capsule is moderate in size with similar appearance to that of species **R**, but the two are distinguished from each other by having different structure of the capsule-wall. The wall composed of three layers inserting a pulpy layer in the present species (Fig. 81 $\mathbf{S}_4$), but two layers in the other (cf. Fig. 80 $\mathbf{R}_7$).

The present species is confined to the coastal waters shallower than 50 meters in depth, ranging from the Tokyo Bay to southern extreme of Kyusyu except for the regions facing the Japan Sea and the Inland Sea (Fig. 1).

Remarks: The present species was first described by GARMAN (1913) erroneously as *Raja kenojei* from a specimen taken by Alan OWSTON from the Izu Sea, offing Sizuoka Prefecture. SCHMIDT (1931) also erroneously referred the specimens corresponding to the present species to *R. fusca*, with a view to supplement the original description that has been given briefly based upon a young specimen. The present species is sharply defined from an allied species, *R. fusca*, in the following points:

	fusca	*schmidti*
1. Interorbital width	much greater than eye-diameter.	almost as great as eye-diameter.
2. Snout, from upper lip	much longer than width of mouth.	slightly longer than width of mouth.
3. Longer axis of 1st D.	triffle longer than interorbital width.	much longer than interorbital width.
4. Two dorsals	naked.	prikled.
5. Nuchal spine	4—6 in adult male	1—2 in adult male.
6. Ground color of dorsum	deep brown.	yellowish borwn.

The present species may be a derivative sprung off from a specialized form like form not very unlike the species **R**, since the present species has more advance features in such parts as snout and clasper than the latter, and the two species are found to inhabit with a boundary near Tokyo Bay, viz., the present species is found southern region from the boundary to the extreme south of Kyusyu, but the latter ranges northern waters from the boundary to the extreme north of the main island of Japan, on the Pacific coast.

*Tengujei**), n. subg.

The characteristics of the present subgenus are in relatively long snout, tail furnished with spines (one row in male and three or five rows in female) and electric organ developed in greater or moderate degree, numerous counts of precaudal vertebrae and clasper established in related features with much specialized or rather simple structure. In Japanese rajids, the following four species are referable to the present subgenus, and are all large in size of the body and the egg-capsule.

Type species: *Raja tengu* Jordan et Fowler, 1903.

It is of much interest to note that a considerable number of species having such similar features in general appearance as to the Japanese species are found to exist in both the Pacific and the Atlantic and its neighbourings, such as *Raja rhina*, *R. binoculata* in the north western Pacific, and *R. batis* and *R. oxyrhynchus* in the Atlantic. In this connection, although assumtive it may be, the present subgenus appears to have a congeneric origin with those which may be found in the north western Pacific and the Atlantic.

Key to species of the subgenus *Tengujei*

1a. Precaudal vertebrae fewer than 50, varying from 38 to 50; glans clasper is of Type 11 or 12, rather simple or much specialized; electric organ moderately developed even in adult.

  2a. Precaudal vertebrae 46—50, 47.6 on average; spiral valves of intestine 9—11, 10.1 on average; glans clasper is of Type 11; snout narrowly elongated; tail relatively long, slender and rod-like form in its main portion, having one row of spines in male, but three rows in female when matured; color uniformly grayish brown on dorsum without pectoral ocellus .... *tengu* (Figs. 82 and 84 T)

  2b. Precaudal vertebrae 38—42, 39.1 on average; intestinal valves 14—15, 14.5 on average; glans clasper is of Type 12, much specialized in structure; snout broadly elongated; tail relatively short and depressed, armed with a row of spines in male, but five rows in female when matured; dark brown blotches numerous on dorsum with distinct pectoral ocellus .... *pulchra* (Figs. 83, 84 U and pl. III, U)

1b. Precaudal vertebrae more than 50, varying from 53 to 61; glans clasper is of Type 13, characterized by having rather complex structure; electric organ highly developed.

  3a. Precaudal vertebrae 53—59, 55.3 on average; ventral incision rather shallow; dorsal surface smooth in young, excepting those spines on orbital rim and tail; thorns on tail of adult female poorly developed; both surfaces of body lead-gray without pectoral ocellus .... *macrocauda* (Figs. 84 V and 85)

  3b. Precaudal vertebrae 59—61, 60.0 on average; ventral incision remarkably deep; dorsal surface entirely setose with minute prickles in addition to tracts of spines developed in the young; thorns on tail of adult female much thickened, running in three rows; both surfaces of body blackish gray without pectoral ocellus .... *gigas*, n. sp. (Figs. 84 W and 86).

Raja (*Tengujei*) *tengu* JORDAN et FOWLER

(Abbreviated as T; Japanese name, Tengu-kasube)
Figs. 82, 84 T

Raja tengu JORDAN et FOWLER, 1903, p. 654, fig. 8, Matsushima Bay, Miyagi

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* Named from *Tengu* in Japanese mythology, a long-nosed goblin, and from *jei*, meaning a skate and ray in Japanese, i. e. long-nosed skate.

Prefecture; Aomori; Hakodate (original description). —— JORDAN and STARKS, 1904, p. 578, Matsushima Bay (listed). —— JORDAN and HUBBS, 1925, p. 110 (key). —— FOWLER, 1929, p. 501 (reference). ——? SOLDATOV and LINDBERG, 1930, p. 20, Pl. 1. —— MATSUBARA, 1935, p. 30 (key). —— OKADA, UCHIDA and MATSUBARA, p. 59, pl. 10. —— MATSUBARA, 1935, p. 45, fig. 20. —— TARANETZ, 1935, p. 89 (reference). —— OKADA and MATSUBARA, 1938, p. 25 (key). —— FOWLER, 1941, p. 361, northern Japan. —— ISHIYAMA, 1955, p. 271, figs. 2—4, off Kasumi, Japan Sea (electric organ). —— MATSUBARA, 1955, p. 137 (key). —— TANAKA and ABE, 1955, p. 27, fig. 61.

Raia tengu GARMAN, 1913, p. 355 (compiled).

Materials examined: 51 specimens (185—1130 mm in total length) and 2 egg-capsules; moderate depth off from Otaru, Hokkaido to Totoro, Miyazaki Prefecture; 1947—1955.

External: Snout very long and acuminated, being concave with more or less undulation on both sides, and relatively shorter in male than in female, covering 1.7 times in head-length in male, but 1.6 times in female in the adult (T in Fig. 25 and Table 6). Tail reltaively long, stiffened with roled appearance in its main portion, relatively somewhat longer in male than in female, being about 1.6 times in disc-width in male and 1.7 times in female in the adult (T in Fig. 32 and Table 7). Interorbital space broad and flat, the ratio of width in snout-length variable even in the adult, ranging from 4.3 to 5.3 times. Eye very small relative to broad interorbital space, the ratio being 1.0—1.8 times in the latter.

Anterior marginal portion of the dorsum and entire ventral surface of head of the adult are studded with prickles; somewhat enlarged thorns placed irregularly along orbital rim; usually only one, but occasionally two to four, large nuchal spines present; a row of about 20 to 40 spines runs along mesial line of tail in adult male, intermitted by an intervention of lst dorsal fin, but the spines are running in three rows inclusive of those on sides of tail in matured female, (Type-Sc^{SA}); two dorsal fins prickled more or less in both sexes; alar and malar spines also distinct when the fish attains to its maturation, as is the case with other species, (Figs. 82 and 84 T).

Color of dorsal surface uniformly brown in usual case, but it is somewhat lighter in ventral side, and occasionally very obscure patterns of dark color are develoved on both sides when fresh.

Internal: Rostral cartilage very long and stout, about 1.5 times as long as cranium-length; rostral appendix also long and distinct, covering about the half length along the side of rostral cartilage; anterior fontanelle very long, posterior one constricted at the middle portion (Fig. 27 T).

Abdominal and precaudal vertebrae 31—32 and 46—50, respectively (T in Figs. 43, 44 and Table 9). Intestinal valves 9—11 (Table 10). Heart valves 4—5 in a row. Electric organ moderately developed occupying of whole length of tail on both sides (Fig. 37 T).

Clasper is of Type 11, characterized by having rather simple structure as compared with those of the relatives (T in Figs. 6 and 19).

Developmental stages: Snout long and narrowly elongated even in very young stage (Fig. 84 T), and the length relative to head is unchanged with growth in male instead of becoming somewhat longer in female (Fig. 25 T). Tail relatively longer in young than in adult, being gradually increased with growth of the fish its ratio to

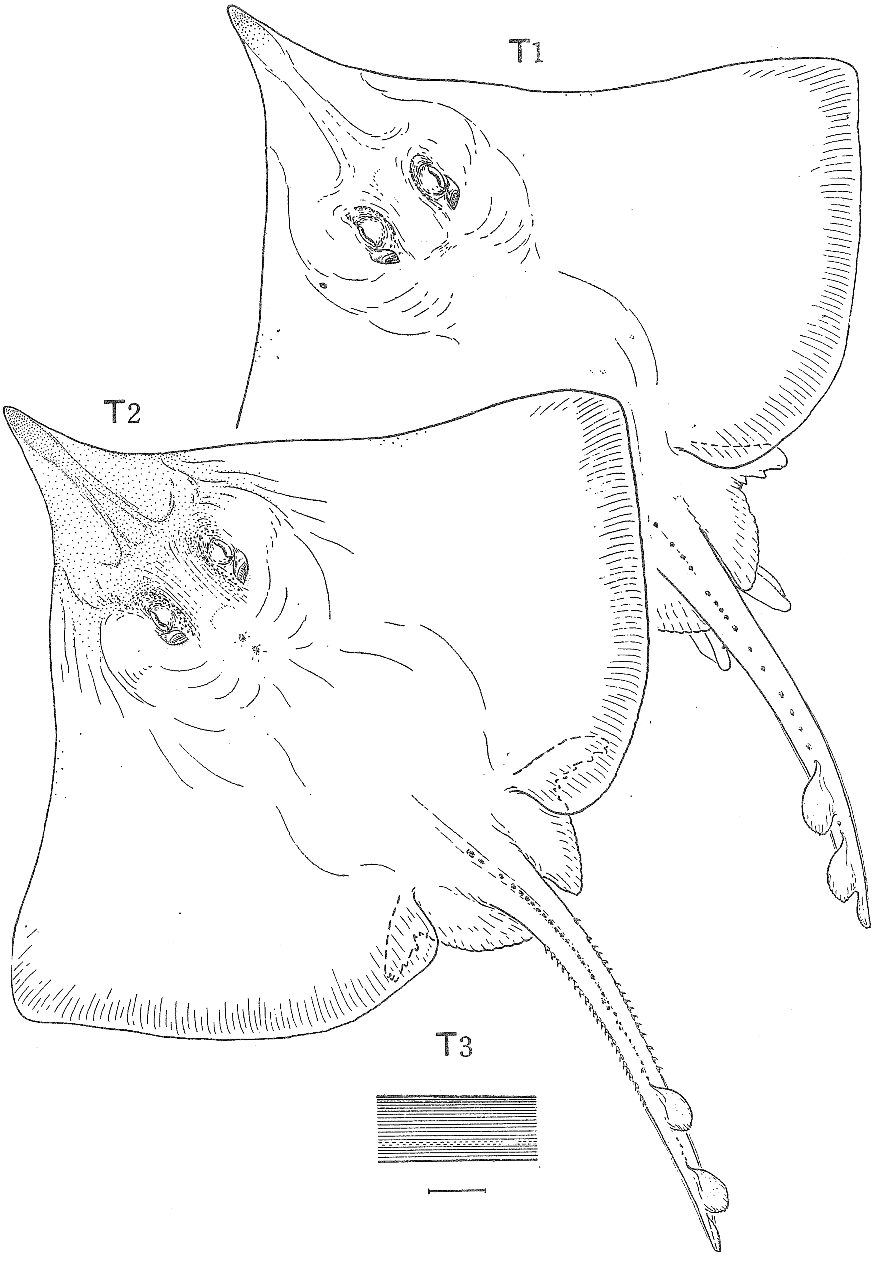

Fig. 82. *Raja tengu* JORDAN et FOWLER; T_1, adult male (728 mm) T_2, adult female (920 mm); T_3, section of egg-capsule, scale 1 mm; T_1, from off Totoro, Miyazaki Prefecture; $T_{2,3}$, from off Aichi Prefecture.

disc-width in both sexes (Fig. 32 T). Relative length of both snout and tail thus change in adolescent stage, attaining from about 200 to 400 mm of disc-width. Newly hatched young armed with a series of 13 to 15 spines on tail and one on nucha and three on orbital rim as in case of other members of the southern form.

Color on both sides of body yellowish brown without any color patterns in young stage.

Egg-capsule: Rather large, about 100 mm in length exclusive of horns; the horn is short and tube-like form; surface very smooth; capsule-wall composed of three layers, being inserted very thin pulpy layer. On the basis of these characteristics the capsule of this species is referred to Type 6 as explained elsewhere, (Fig. 82 T_3).

Notes: The present species is found from northern region of the Japanese waters to the East China Sea, throughout the waters on both sides of the shelf around Japan except for the Sea of Okhotsk. It lives in the moderate depth, covering from about 60 meters (in northern regions) to 100 meters or more below (in southern waters).

This species is by no means confused with other relatives of Japanese rajids, by having much longer, slenderer snout and having unique features of the spination especially in the adult. A comparison of the young with those of the relatives in Japanese rajids will be dealt with the following species, which resemble more or less the present species in general faces. In these characteristics the present species is closely related to the European species, *R. oxyrynchus*. But the present species can be distinguished from it in having relatively shorter snout when compared the same sized fishes of the two. Namely, the snout is contained 2.9 times into disc-width and the former 5 to 6 times as long as or a little longer than interorbital width in European species (disc-width, 778—994 mm), but the ratios are 3.2 to 3.7 times and 4.3 to 5.7 times, respectively, in the present species of similar size.

Raja (Tengujei) pulchra Liu
(Abbreviated as **U**; Japanese name, Megane-kasube)
Figs. 83, 84 **U**; Pl. III, **U**

Raja smirnovi Jordan and Hubbs (non Soldatov and Pavlenko), 1925, p. 111, off Fukui and Otaru.—— Fang and Wang, 1932, p. 262, fig. 21, Chefoo, China.—— Matsubara, 1935, p. 45 (key).—— Matsubara, 1936, p. 27, fig. 18 (reference).—— Okada and Matsubara, 1938, p. 24 (key).—— Lin, 1955, p. 30, fig. 22. North China.—— Satô and Kobayashi, 1955, p. 1, Volcano Bay, Hokkaido.

Raja tengu Fowler, 1941, p. 361 (reference).

Raja pulchra Liu, 1932, p. 162, fig. 10, Tsingtao (original description).—— Ishiyama, 1950, p. 30, figs. 1 and 2, Wakkanai, Hokkaido (egg-capsule). —— Ishiyama, 1954, p. 75, figs. 1—3, Hokkaido (electric organ).—— Ishiyama, 1955, p. 43.—— Ishiyama, 1955, p. 271, fig. 4 (electric organ). Matsubara, 1955, p. 136 (key).

Materials examined: 89 specimens (150—1119 mm in total length), 20 embryos, and 25 egg-capsules; from shallow waters off Hokkaido to moderate depth of the East China Sea; 1947—1954.

External: Snout broadly elongated, different between two sexes in relative length, being the ratio into head length 1.95 times on average in adult male as compared with 1.72 times on average in adult female (**U** in Fig. 25 and Table 6). Tail relatively short, Depressed-type, being the average ratio into disc-width 1.57 times in adult male

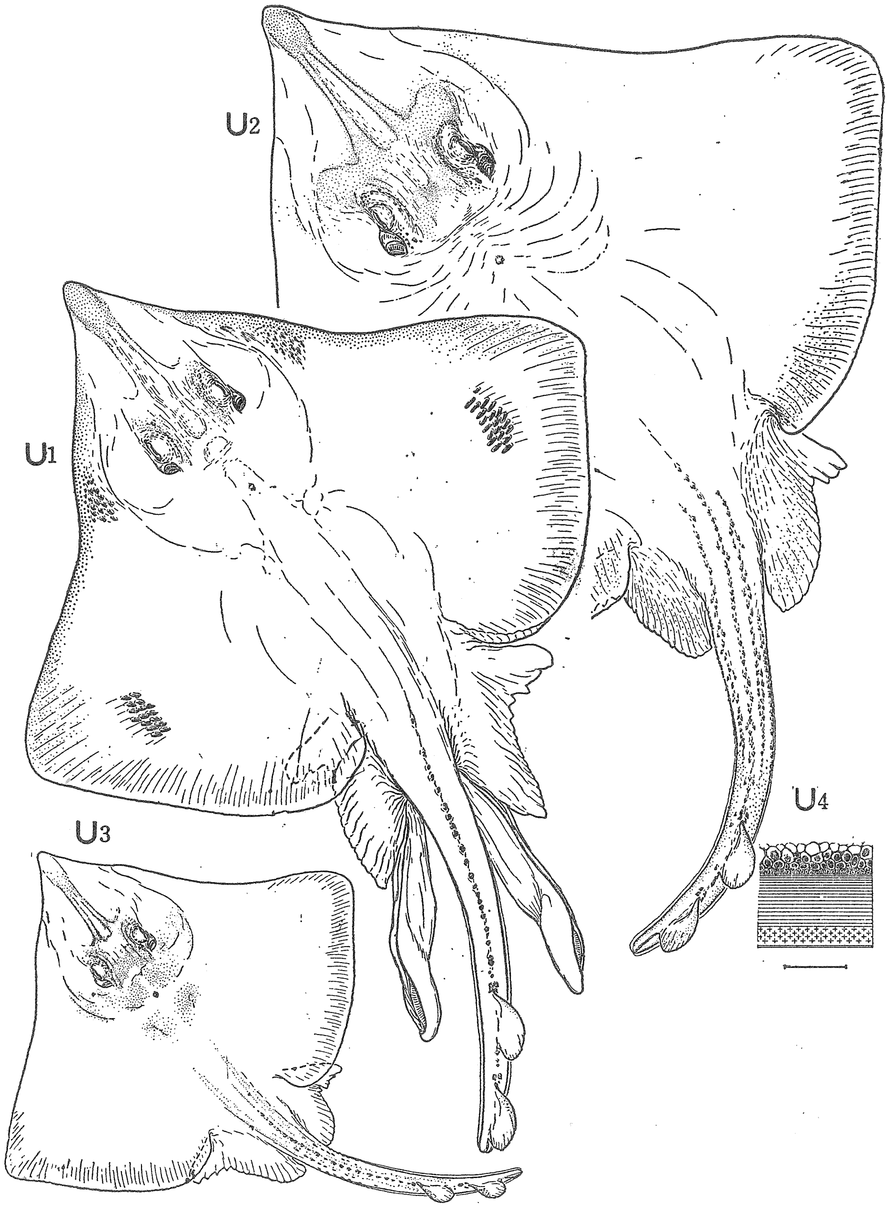

Fig. 83. *Raja pulchra* LIU; U_1, adult male (1052 mm); U_2, adult female (1119 mm); U_3, subadult female (606 mm); U_4, section of egg-capsule, scale 0.5 mm; $U_{1,2,3}$, off Wakkanai, Hokkaido; U_3, off Monbetsu, Hokkaido, the Okhotsk Sea.

and 1.71 times in adult female (U in Figs. 30, 32 and Table 7). Interorbital space broad, flat, and the width relative to length of snout about 3.3 and 3.6 times respectively in male and female when matured. Eye rather small, the average ratio into snout-length about 5.6 and 8.5 times, respectively, in adult of male and female. Caudal fin very small or eventually reduced into rudimentary.

Prickles develop in adult fish on anterior marginal portion of head as in the species T, but absent on ventral surface except for distal and mesial portions of the snout; a series of enlarged spines closely covering each orbital rim; a large nuchal spine present without exception; a row of large spines setting along mesial line of tail in adult male, but five rows in the female (Type-Sc^{SB}); two dorsals sparsely prickled in both sexes (Fig. 83).

Color of dorsum mottled with dark brown irregular patterns, and the pectoral ocellus more or less well-developed, but occasionally obscure in the adult; ventral surface of disc usually white without any color patterns, but on the tail a few brown streaks present in some cases (Pl. III, U).

Internal: Rostral cartilage long and stiffened especially in its basal portion, and the length into cranium-length about 1.5 times; rostral appendices small, reduced into one-fourth the length of rostral cartilage or shorter; anterior fontanelle distinct, elongated anteriorly with shallow furrow, posterior one divided into two hollow by an intervention of a narrow cartilaginous bridge (Fig. 27 U).

Abdominal and precaudal vertebrae 30—32 and 38—42, respectively (U in Figs. 43, 44 and Table 9). Intestinal valve thickened, more numerous than in any of the relatives, varying from 14 to 15 (U in Figs. 47, 48 and Table 10). Heart valves mostly 8 in a row (U in Fig. 51 and Table 11).

Electric organ relatively small, lying from distal tip to base of pelvic fins (U in Figs. 30 and 37).

Clasper very large (Fig. 83), and much specialized in both external and internal features, being marked as the organ of Type 12 (U in Figs. 6 and 19).

Developmental stages: Snout relatively short and somewhat flexible in young fish (Fig. 84 U) immediately after emerged from the egg-capsule, but it becomes longer and stouter when the fish attains to above 100 mm or more in width of disc and discernible the difference of relative growth between two sexes (Fig. 25 U). Length of tail relative to width of disc markedly changes with growth of the body, discriminating between sexes when matured, being relatively longer in female than in male as in case of the preceding species T, (Fig. 32 U). Caudal fin gradually reduced its relative size with age, though it is distinct in the young (U in Figs. 30 and 34). Newly hatched larva armed only with a series of 9—12 spines on tail, 3 spines on orbital rim, and one large spine on nucha (Fig. 84 U), but the spines on tail become to increase when the fish attains to about 100 mm in width of disc (Fig. 83 U_3).

Color and pattern of dorsum in developmental stages are similar to as in the adult, as a whole, but the pectoral ocellus very distinct in the young; ventral surface white as in the case of the adult.

Egg-capsule: The egg-capsule is peculiar (Type 8), in having rectangular outline with deep notches on middle portion of lateral sides, and having short flattened horns on anterior and posterior corners, and remarkable capsule-wall belonging Type-Eg^7 (Fig. 83 U_4). The capsule is usually enclosing more than one egg, varying from one to five.

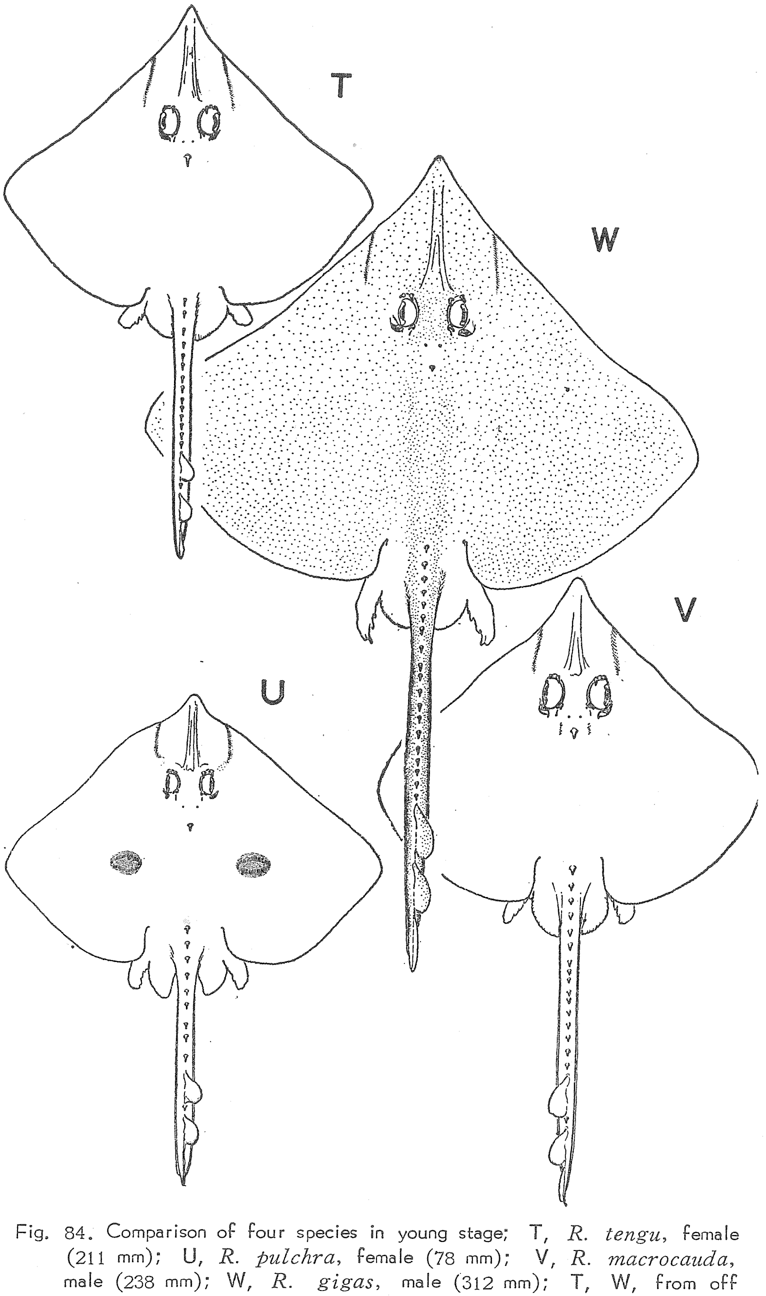

Fig. 84. Comparison of four species in young stage; T, *R. tengu*, female (211 mm); U, *R. pulchra*, female (78 mm); V, *R. macrocauda*, male (238 mm); W, *R. gigas*, male (312 mm); T, W, from off Totoro, Miyazaki Prefecture; U, off Monbetsu, Hokkaido; V, off Miya, Aichi Prefecture. All these fishes are in the same stage in life history.

Notes: The present species ranges from the Sea of Okhotsk to the East China Sea, throughout the shelf of both the Pacific and the Sea of Japan, especially abundant in the coastal waters around Hokkaido, where the present fish is important commercially as its "dried fish" is sold in considerable quantities, the so-called as "Hoshi-kasube" in Japanese. It is usually caught in the coastal waters covering from about 30 meters (the Sea of Okhotsk) to 80 meters (offing from middle region of the main island of Japan to the East China Sea) in depth.

Since JORDAN and HUBBS (1925) and FANG and WANG (1932) misidentified this species taken from the Sea of Japan and the China Sea as *Raja simirnovi* SOLDATOV et PAVLENKO Japanese ichthyologists has followed this identification without any criticism. But the present author (1950) has confirmed that *Raja smirnovi* of JORDAN and HUBBS and of FANG and WANG is quite different from that of SOLDATOV and PAVLENKO (1915), and that in fact it is identical with *Raja pulchra* given by LIU in 1932.

The present species resembles the species T and V, in having some important characters, such as longer snout, spination in adult male, number of vertebrae and structure of clasper. On the basis of these characteristics, the present species is supposed to be a shallow-water representative that may have specialized from an ancestor like the species T. Several species have been known from both the Atlantic and the north western Pacific which somewhat resemble the present species in general appearance, in having broadly elongated snout and largely smooth dorsal surface with mottled color pattern as in such species as *Raja batis* found in the Atlantic, *R. rhina* and *R. binoculata* from the north Pacific, and *R. flavirostris* from the South American waters of the Atlantic. But the present species is endemic in the waters around Japan though these relatives seem to be congeneric descendants.

Raja (Tengujei) macrocauda ISHIYAMA
(Abbreviated as V; Japanese name, Kitsune-kasube)
Figs. 84 V, 85

Raja oxyrinchus MATSUBARA (non Linnè), 1936, p. 30, fig. 22, Kôchi fish market.—— OKADA and MATSUBARA, 1938, p. 25 (key).—— KAMOHARA, 1938, p. 10, Kôchi.—— KURODA, 1952, p. 7, SURUGA Bay.

Raja macrocauda ISHIYAMA, 1955, p. 43, figs. 1 and 2, off Aichi Prefecture, Kumano-nada (original description).—— ISHIYAMA, 1955, p. 273, figs. 2—4 (electric organ).—— MATSUBARA, 1955, p. 136, off Aichi Prefecture (key).

Materials examined: 37 specimens (189—1250 mm in total length) including holotype, deep seas offing from Totoro, Miyazaki Prefecture to Chôsi, Chiba Prefecture; 1950—1955.

On this species, a detailed description has been given in the previous report (ISHIYAMA, 1955), where both the external and internal features of the present species as well as relationship in the relative forms were given. In this account, therefore, only the characteristics other than those given in the previous report will be mentioned.

Clasper is of Type 13, characterized by having specialized accessory terminal 2 (V in Figs. 6 and 19). It may be sure to consider that the present species is intermediate between species T and W, and that the species W is nearer than T to the present species. Comparison between the present species and related ones will be shown precisely later on.

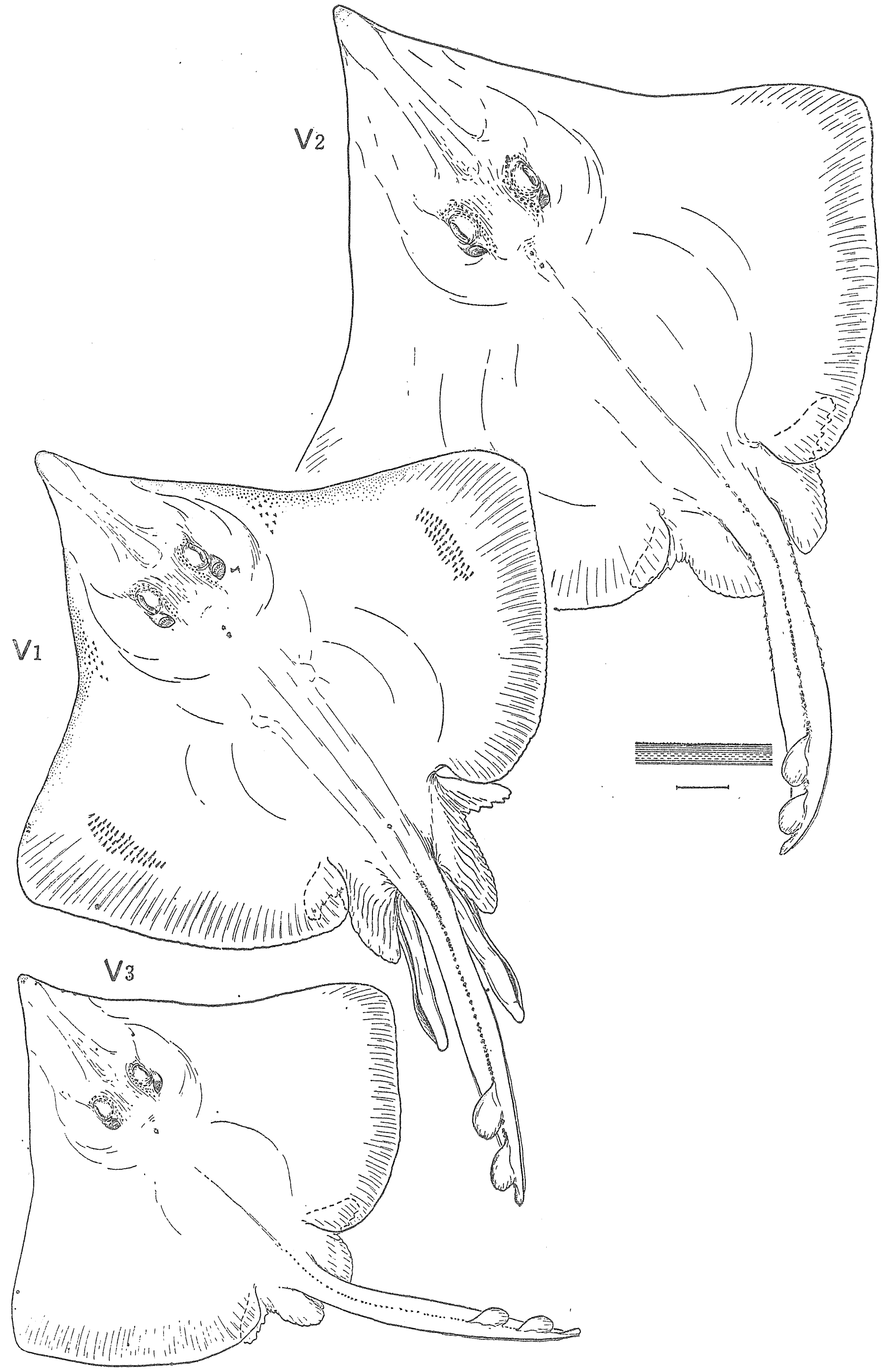

Fig. 85. *Raja macrocauda* ISHIYAMA; V_1, holotype, adult male (997 mm); V_2, adult female (1088 mm); V_3, subadult male (745 mm); V_4, section of egg-capsule, scale 1 mm; from off Miya, Aichi Prefecture.

Raja (*Tengujei*) *gigas*, n. sp.

(Abbreviated as W; New Japanese name, Zô-kasube)

Figs. 84 W, 86

Materials described: Holotype, 1345 mm, off Aichi Prefecture, Kumano-nada, March 27, 1955; paratypes, 20 specimens (313—1860 mm in total length) and 2 egg-capsules, off Totoro, Miyazaki Prefecture; Miya, Aichi Prefecture; Maisaka, Shizuoka Prefecture: 1954—1955.

External: Disc-width 1.34, disc-length 1.72, tail 2.11 in total length; head 2.24, snout 4.16, precaudal 1.10 and procaudal 4.87 in disc-width; interorbital width 3.58, diameter of eye 6.66, lengths of both dorsal fins 3.03, and that of caudal 3.22, ventral incision 2.52 in snout.

Snout long, broadly elongated anteriorly, having a stout rostral axis, with anterior oblique margins strongly undulated. Interorbital space broad and flat, the width much greater than eye-diameter, which is 1.86 times into the width. Anterior lobe of pelvic fin markedly elongated, inserting very deep notch between it and the posterior lobe. Clasper very large and stout, reaching midway point of tail. Membranous fold along the sides of tail distinct, extending from the basal portion to the tip.

Body almost smooth on both surfaces excepting the annexed portions, which are furnished with thorns and spinules, thus; anterior and posterior oblique marginal portions of dorsal side of disc covered with either minute or enlarged prickles, or the both of them, and mesial portion of rostral axis on ventral side also prickly; a number of thorns scattered on orbital rim of each eye; nuchal spine obscure due to worn out being in mature; a patch of the alar spines robustly developed; a row of large spines setting along mesial line of tail, some of which are distinct but others more or less illegible owing to worn out as is the case with the nuchal spines (Fig. 86).

Color of dorsum uniformly gray or blackish gray without pectoral ocellus; the ventral side of the body blackish gray.

Internal: Rostral cartilage very long and stout, inserted anteriorly by a pair of rostral appendices fused throughout their whole lateral edges with the sides of rostral bar, as in the relatives; the bar is about 1.5 and 1.3 times as long as cranium-length and cranium-width, respectively, and is about 2.4 times the length of rostral appendices. Anterior fontanelle distinct, leaf-like in shape, followed anteriorly by excavated portion; posterior one also large, ellipsoid in outline (Fig. 26 W).

The electric organ well-developed, bluntly pointed anteriorly and gradually becomes slenderer posteriorly, extending from the basal portion to the tip of tail (W in Figs. 37 and 40).

Abdominal and precaudal vertebrae more numerous than in any of the southern members, varying from 30 to 34 and from 59 to 61, respectively (W in Figs. 43, 44 and Table 9). Intestinal valves 10 or 11; heart valves 4 in a row (W in Tables 10 and 11).

Clasper is of Type 13, characterized by having much specialized accessory terminals 1 and 2 (W in Figs. 6 and 19).

The above description on external features was derived from the holotype (matured male) measuring 1345 mm in total length, but those on internal ones were taken from the paratypes. The followings are supplemented in making clear diagnosis of the present species, based on many specimens involving younger and also older fishes, and

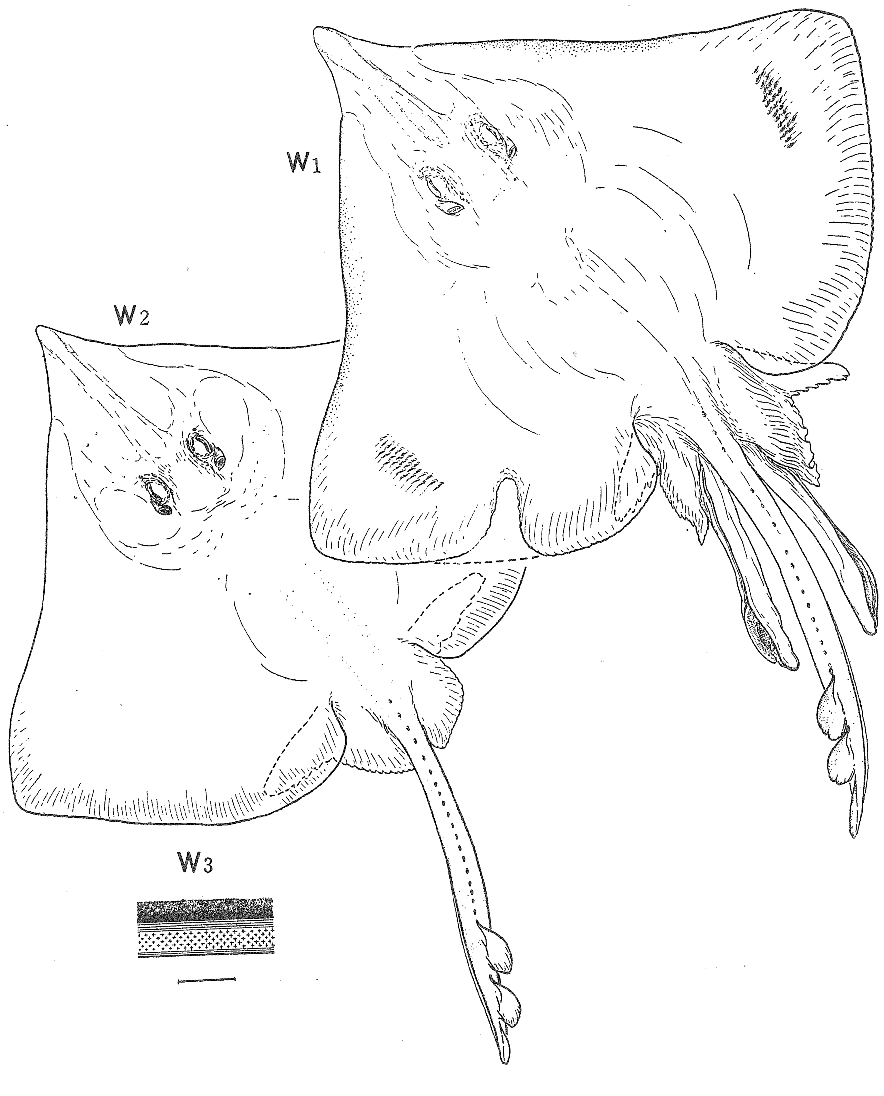

Fig. 86. *Raja gigas*, n. sp.; W_1, holotype, adult male (1345 mm); W_2, subadult female (945 mm); W_3, section of egg-capsule, scale 1 mm; W_1, off Miya, Aichi Prefecture; $W_{2,3}$, off Totoro, Miyazaki Prefecture.

on egg-capsules.

The relative length of snout against head varies in rather large extent with growth of the body in the male, but the change is not so remarkable in the female (W in Fig. 25 and Table 6). On the contrary, the change of relative growth of the tail is predominant in the female rather than in the male (W in Fig. 32 and Table 7). The anterior lobe of pelvic fin very long even in the young, elongated posteriorly beyond the tip of posterior lobe when bent down posteriorly (Fig. 84 W).

The spination in the young measuring up to about 500 mm in total length much conspicuous as annotated elsewhere (p. 191), viz., minute prickles developed sparsely on whole dorsal surface of body, especially they well-developed on the tail in addition to large spines that commonly developed in the orbital rim and tail of the species referable to the genus *Raja*, (Fig. 84 W). Another characteristics in the spination is revealed as the fish attains to the adult, giving remarkable difference in the tail as shown in Fig. 35 W.

Egg-capsule: The capsule is greatest in size as compared with that of other species. It is rectangular in outline, without horns, and the capsule-wall is composed of three layers as is the case of species **U**, being marked as Type 8 of the capsule (Figs. 22 W and 86 W_3).

It lives in the deep seas along the Pacific coast, offing from central to southern regions of the main island of Japan (Fig. 1). The present fish is captured together with the preceding species, **V**, in many cases.

Remarks: The present species closely resembles the preceding species, **V**, in general physiognomy, but the two species are distinguishable externally from each other at least in the condition of the spination and the degree of notch of the pelvic fin, and further, they are sharply discriminated each other in the following points, such as the rostral cartilage, number of precaudal vertebrae, degree of development of the electric organ, structure of the clasper, and features of the egg-capsule.

It is interesting to note that the two species of rajids, *Raja rhina* and *R. binoculata*, are closely resembling in their external appearances, and are found together in the north western Pacific region, and such relation in features and similar tendency in habitat as revealed by the two species are also seen between the present species and the species V. At any mean, the present species seems to stand nearer *Raja binoculata* than *R. rhina*, and the comparison of the four related species can be summarized in the following.

Table 22. Comparison of external features of the body and egg-capsules in the four related species inhabiting the north Pacific.

Species Characters	*R. gigas*	*R. macrocauda*	*R. rhina*	*R. binoculata*
Pectoral ocellus	absent	absent	present	obscure
Ventral incision	deep	shallow	deep	shallow
Number of rows of thorns of tail in adult	reduced, one in male, three in femle	one in male, three in female, distinct	one in male, three in female, distinct	reduced, one in male, three in female
Nuchal spine	1	1	1—3	1
Total body-length, mm	1800—1900	1100—1200	800—900	ca. 2000
Horns of egg-capsule	absent	present	present	absent

It is likely to consider that the two pairs of rajids inhabiting separately the two sides of the north Pacific may suggest that they may be descendants from a common ancestor, from which they might have been evolved in parallel.

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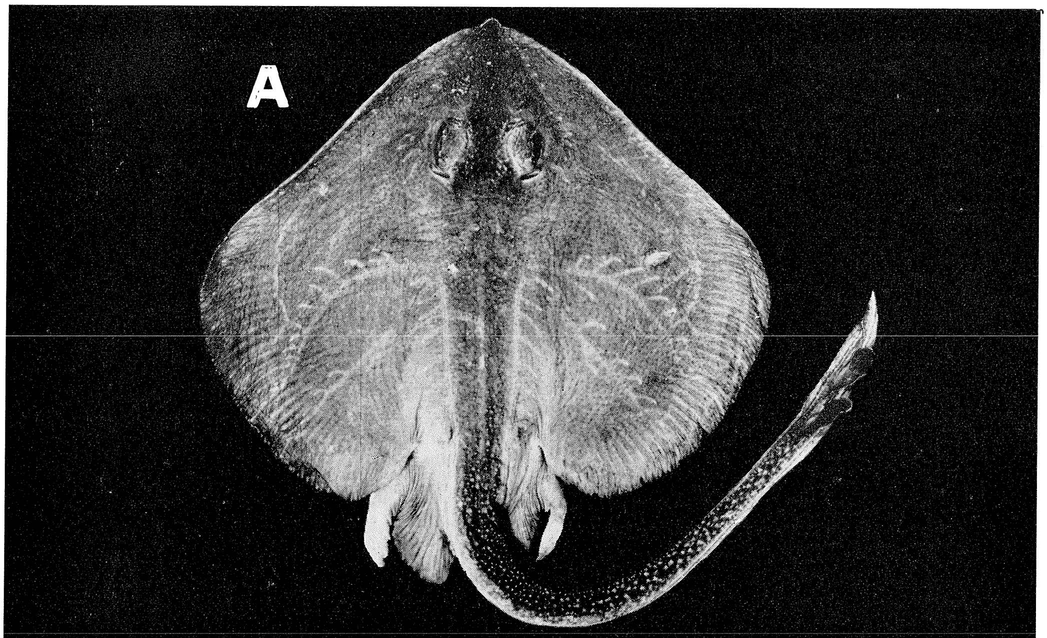
PLATES

PLATE I

Fig. A. *Breviraja tobitukai* (HIYAMA), adult female, 500 mm long; from off Aich Prefecture, Kumanonada.

Fig. J. *Rhinoraja odai*, n. sp., subadult male, 406 mm long, showing color pattern; from off Shizuoka Prefecture.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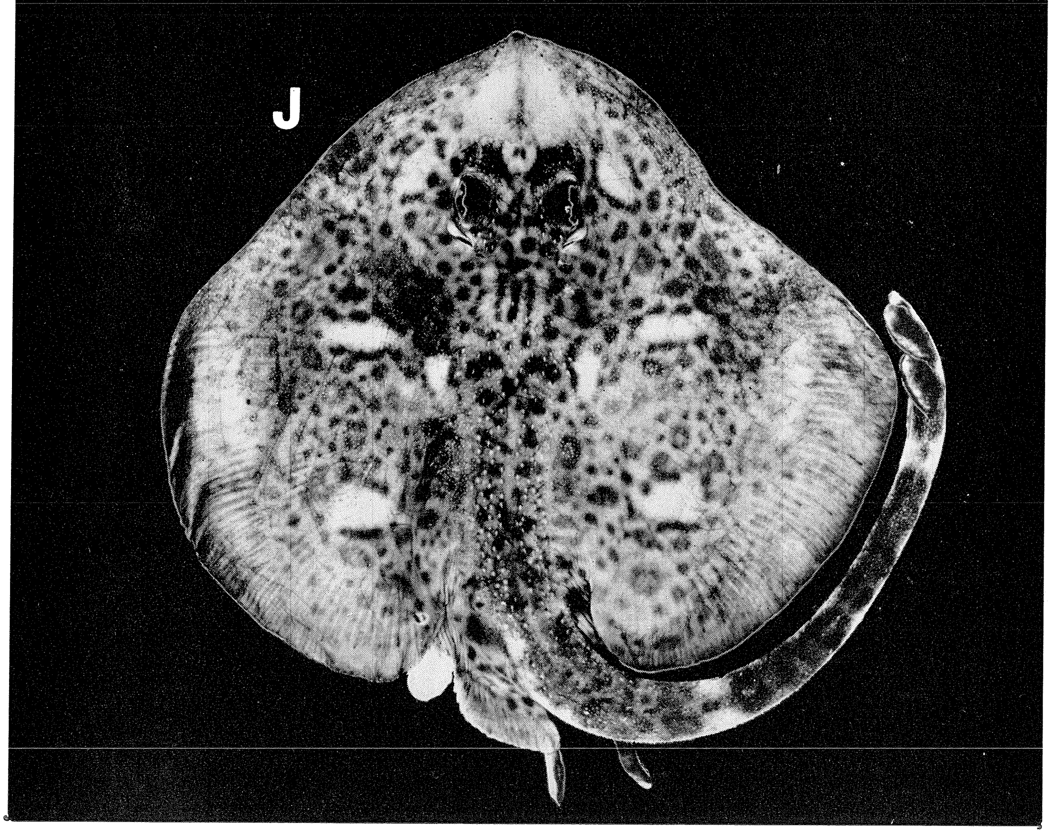
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PLATE II

Fig. M. *Raja kenojei* MÜLLER et HENLE, subadult male, 485 mm long, showing color pattern; from off Nagasaki Prefecture.

Fig. N. *Raja acutispina*, n. sp., adult female, 407 mm long, showing color pattern; from off Yamaguchi Prefecture, the Sea of Japan.

Fig. Q. *Raja porosa meerdervoorti* GÜNTHER, adult female, 380 mm long, showing color pattern; from off Tsuiyama, the Sea of Japan.

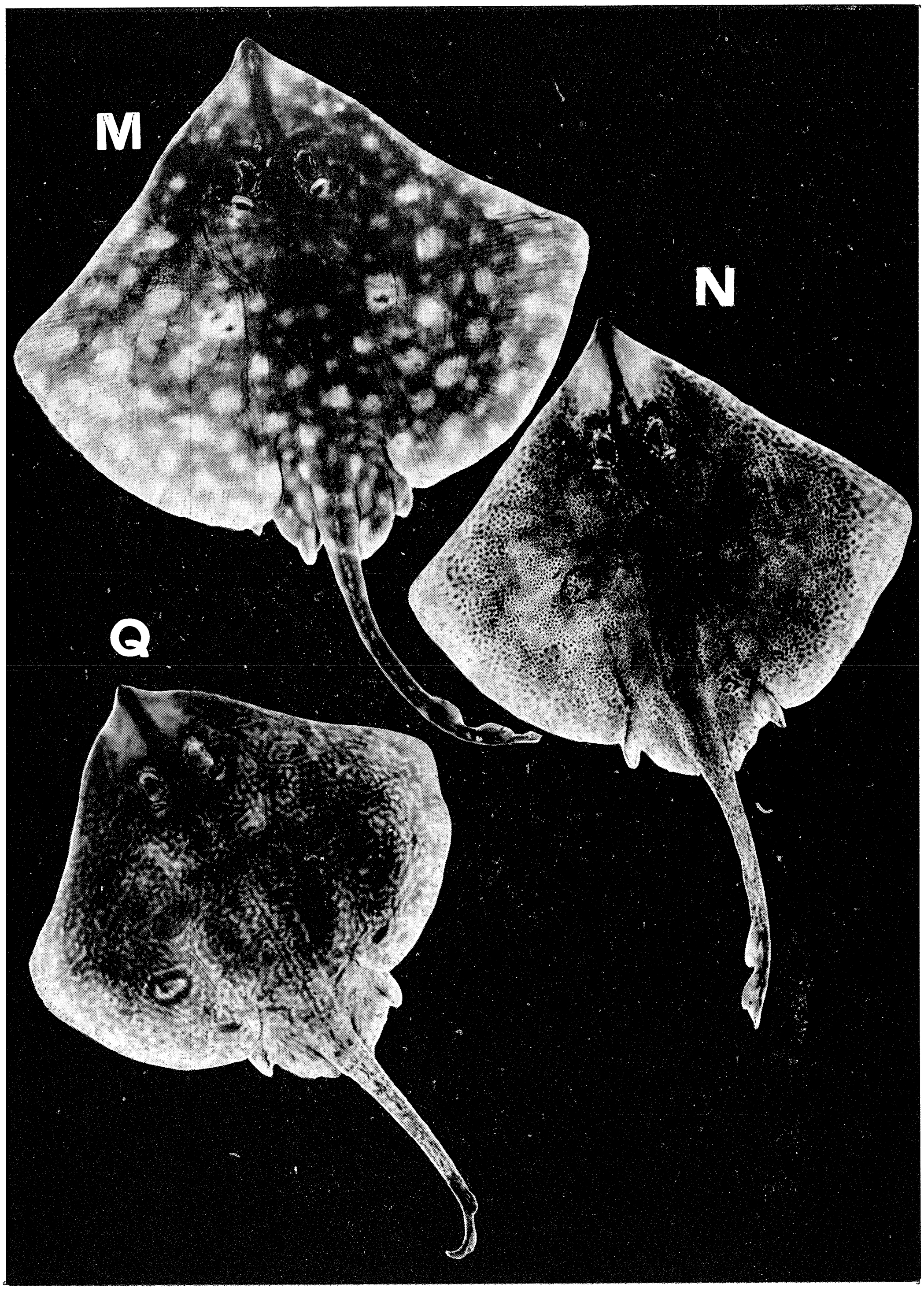
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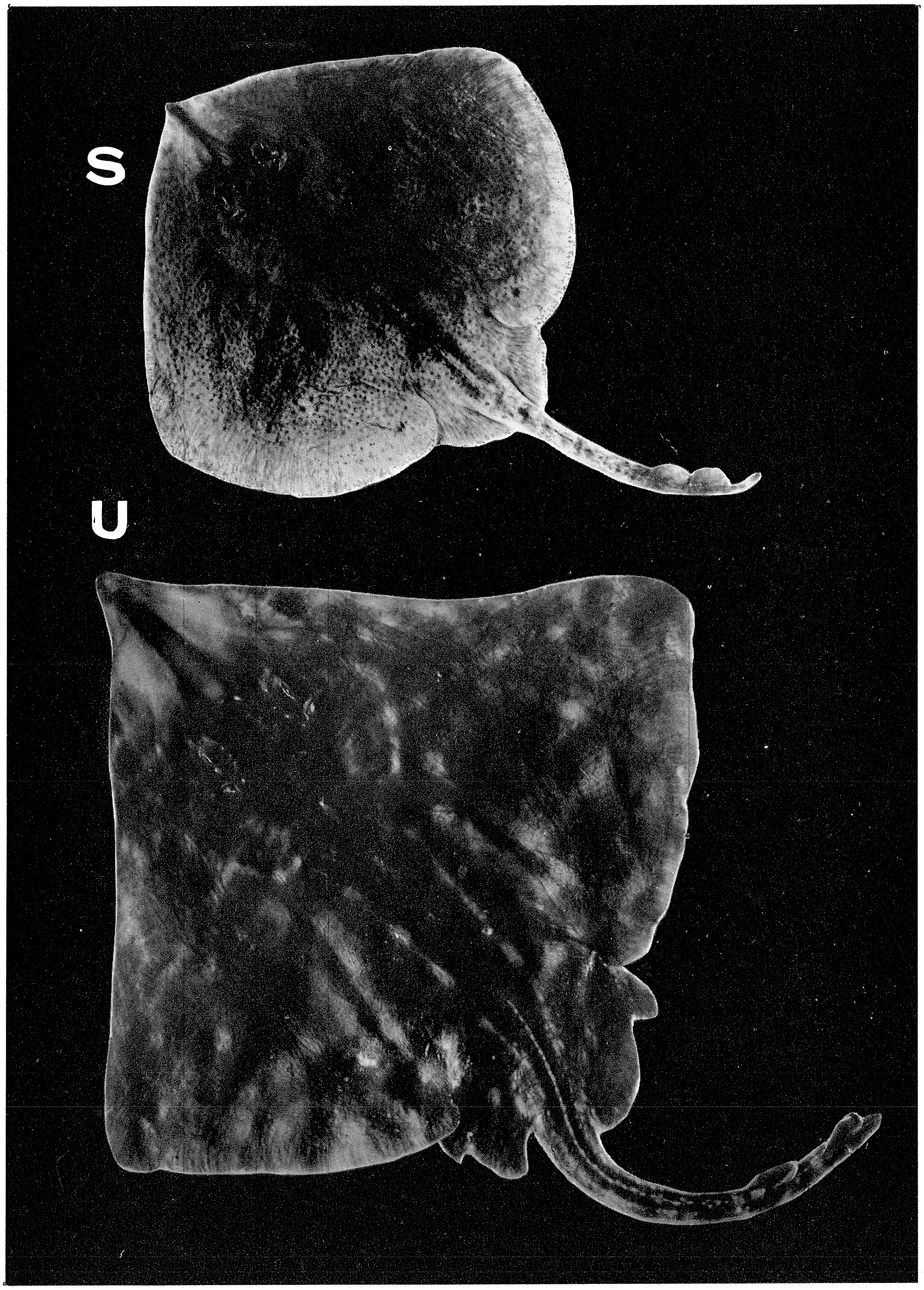
PLATE III

Fig. S. *Raja schmidti*, n. sp., adult female, 400 mm long, showing color pattern; from off Miyazaki Prefecture.

Fig. U. *Raja pulchra* LIU, adult female, 1119 mm long, showing color pattern; from off Hokkaido, the Sea of Okhotsk.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