J. mar. biol. Ass. India, 1982, **24** (1 & 2) : 80 –91

ON THE SYSTEMATICS OF RAINBOW SARDINES *DUSSUMIERIA* SPP. (FAMILY: DUSSUMIERIIDAE, PISCES) FROM INDIAN WATERS

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ABSTRACT

The systematics of the rainbow sardines of the Genus *Dussumieria* Valenciennes has been studied in detail. The existence of two species namely *Dussumieria acuta* Valenciennes and *D. hasseltii* Bleeker in Indian waters has been re-established as against the view of Whitehead (1963) who synonymised these two species to one namely *D. acuta* Val. In this study specimens collected from east and west coasts of India were analysed morphometrically and meristically and the characters compared statistically. Clear differences in many of the characters, sufficient enough to substantiate the existence of two different species, were noticed. The two species are redescribed and photographs presented in the text.

INTRODUCTION

THE RAINBOW SARDINES of the genus *Dussumieria*, belonging to the family Dussumieriidae, are small clupeoid fishes widely distributed in tropical and temperate seas, mainly in the Indo-Pacific region. The Dussumieriidae differs from the clupeidae by the absence of abdominal scutes, thus having somewhat rounded rather than keeled bellies. Earlier workers like Jordan and Gilbert (1883), Günther (1868) and Weber and de Beaufort (1913) considered the round herrings (Dussumieridae) as a subfamily of the Clupeidae, but since Jordan (1925) they are usually given family status. Whitehead (1963) considered that presence or absence of scutes is of such fundamental importance that the round herrings should be separated from the clupeids at family level.

The systematics of the species of the genus *Dussumieria* Valenciennes had been a confusing problem to many of the earlier and recent workers, especially regarding the identity of the two widely accepted species namely *Dussumieria acuta* Val. and *D. hasseltii* Blkr. Fowler (1941) made it clear when he included *D. elopsoides* Bleeker under the synonymy of *D. acuta* and *D. elopsoides* Günther under *D. hasseltii* and not considering *D. productissima* Chabanaud as a valid species. In the final analysis he recognized only two species *viz. D. acuta* and *D. hasseltii* under the genus *Dussumieria* Val. But Whitehead (1963) brought all these species under the synonymy of *D. acuta* believing that any variation in the characters can be correlated with geographical distribution.

All the earlier Indian workers on this group have recognised two distinct species from this area. In the landing centres also these can be easily distinguished by their body shape, which indicates the side-by-side occurrence of these two species in the same geographical area. During the course of his study on the biology of *D. acuta* of Mandapam area, on the southeast coast of India, the author observed that the two species of *Dussumieria* are distinct in this area and they differ each other in many of the morphometric and in a few meristic characters. The fish with a short and broad body was identified as *D. acuta* and the other with a longer and more cylindrical body as *D. hasseltii*. These two species occur in the same areas, either in mixed schools or separately and are even caught in the same net during fishing.

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According to Bleeker (1872) the main characteristics of the two species of *Dussumieria* are as follows:

1. *Dussumieria acuta* Valenciennes

Length of body without caudal 4 times the head; this length 4 - 4½ times the height of body; length of head 3-3½ times the diameter of the eye. About 40 to 42 scales on a longitudinal row; opposite ventrals at the middle of dorsal.

2. *Dussumieria hasseltii* Bleeker

Length of body without caudal 3-3⅜ times the head; this length 5 times the height of body. Length of head 4 times the diameter of eye, about 52 scales on a longitudinal row; opposite ventrals at the posterial middle of dorsal.

From the above description it is clear that *D. acuta* has a shorter head and a broader body than *D. hasseltii* which, according to Bleeker (1872) have more elongated and cylindrical body with a greater head size. From the differences in scale number it may also be assumed that *D. acuta* have a shorter body length than that of *D. hasseltii*.

The scales of *Dussumieria* are highly deciduous and it is very difficult to get a correct count of the lateral line scales. Whitehead (1963) also have felt that the scale counts are unreliable for separating the species.

The author is grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute for kind encouragements and to Dr. R. V. Nair for suggesting this problem for studies. Thanks are also due to Shri M. Kumaran and Shri C. Mukundan for critically going through the manuscript and suggesting improvements. The author is also thankful to Shri K. V. Narayanan Rao for his valuable suggestions and final scrutiny of the paper.

Material and Methods

Material for the study was collected from fish landing centres along the Palk Bay and the Gulf of Mannar at Cuddalore, Panaikulam, Rameswaram Road, Kundugal Point, Mandapam, Kilakkarai, Tuticorin and Kanyakumari on the southeast coast and from Vizhinjam and Calicut on the west coast of India. 25 specimens of *D. acuta* ranging in size from 115 to 157 mm total length and 25 specimens of *D. hasseltii* ranging in size from 111 to 189 mm total length, preserved in 5% formaldehide were selected from among the number of collections and examined for taxonomic studies. The materials include both the sexes and their measurements and meristic counts were recorded carefully. The measurements were taken using a devider. The number of gill rakers on the upper and lower limbs of the left outer arch was counted. The number of pyloric caecae were counted carefully after removing the gut out of the body cavity. The vertbrae were counted by removing the flesh all along the length of the body making the vertebral column visible clearly. The exposed side of the vertebral column was further cleaned using 5% potassium hydroxide solution and the number of vertebrae were then counted with the help of a magnifying glass and needle. The stomach of all the fish examined were totally empty and shrunken with thick walls and internal folds.

Results

The range, mean, standard deviation and standard error of 16 morphometric body proportions of *D. acuta* and *D. hasseltii* were studied. The characters are: fork length, standard length, head length, snout length, maxillary length, eye diameter, pre-dorsal length, pre-pectoral length, pre-pelvic length, pre-anal length, depth of head, depth of body, depth of caudal peduncle, length of caudal fin, length of stomach and length of stomach

caecum. Of these, two characters (fork length & standard length) were analysed in percentage of total length and the rest in percentage of standard length. Four measurements *viz.* snout length, maxillary length, eye diameter and depth of head were further studied in percentage of head length. In addition to these, 6 meristic characters, *viz.* number of dorsal fin rays, number of pectoral fin rays, number of anal fin rays, number of gill rakers, number of pyloric caecae and number of vertebrae were also examined of which the last three characters were analysed in the above line. The details are given in Fig. 1. The percentage occurrence of each species within the overlapping ratio of body proportions are given in Table 1. It could be seen that there is no overlapping between species in the proportions of fork length, standard length (both in percentage of total length), caudal fin length, depth of head, depth of body, depth of caudal peduncle, stomach length and stomach caecum length (all in percentage of standard length). The depth of head in percentage of head length also did not show any overlapping. Regarding the pre-dorsal length, the percentage of overlapping was considerably less, since only 16% of *D. acuta* and 12% of *D. hasseltii* came under the overlapping range.

Out of the meristic characters, numbers of pyloric caecae and vertebrae showed clear variation without any degree of overlapping between the two species. The other meristic characters did not show any variation.

Further the actual values of different morphometric characters of the two species were plotted in scatter diagrams in Fig. 2 and Fig. 3 and the regressions were fitted using the least square method. The fork length and the standard lengths were plotted against the total length and the rest of the characters against the standard length. Snout length, maxillary length, eye diameter and depth of head were further plotted against the head length (Fig. 3)

Inorder to study the significance of variation in the regressions, analysis of co-variance was employed for each character of the two species. The 'B' values and the results of significance test of the slopes and the elevations of regressions of the two species are given in Table 2. It may be noticed from the Table that the differences in slope of regressions between the species was significant in regard to total length - standard length, standard length-depth of head, standard length-depth of body, standard length-depth of caudal peduncle, standard length-stomach length, standard length-stomach caecum length and head length–maxillary length. The elevations of regressions showed significant differences in all the characters excluding standard length - maxillary length, standard length - pre-pectoral length, standard length - pre-anal length and head length - maxillary length. The results of these analyses further showed that the differences, both in the slope and the elevation of regressions of these two species, were non-significant only in respect of three characters namely maxillary length, pre-anal length and pre-pectoral length (all against standard length). In all other characters, either slope or the elevation of regressions showed significant differences. All these show that these two species are clearly distinct from each other and cannot be grouped together as one species.

The frequency distribution of four meristic characters such as dorsal fin rays, pectoral fin rays, anal fin rays and the gill rakers (total number) of the two species were analysed statistically to test the equality of proportions, forthwith to determine whether there is any significant variation between the two or not. The numbers of pyloric caecae and the vertebrae which didnot show any degree of overlapping, were not subjected to this analysis. The formula employed was that given by Fisher (1950, p.87) which is as follows:

$$\chi^2 = \frac{1}{\bar{p}\ \bar{q}} (a_1 p) - n_1 \bar{p}$$

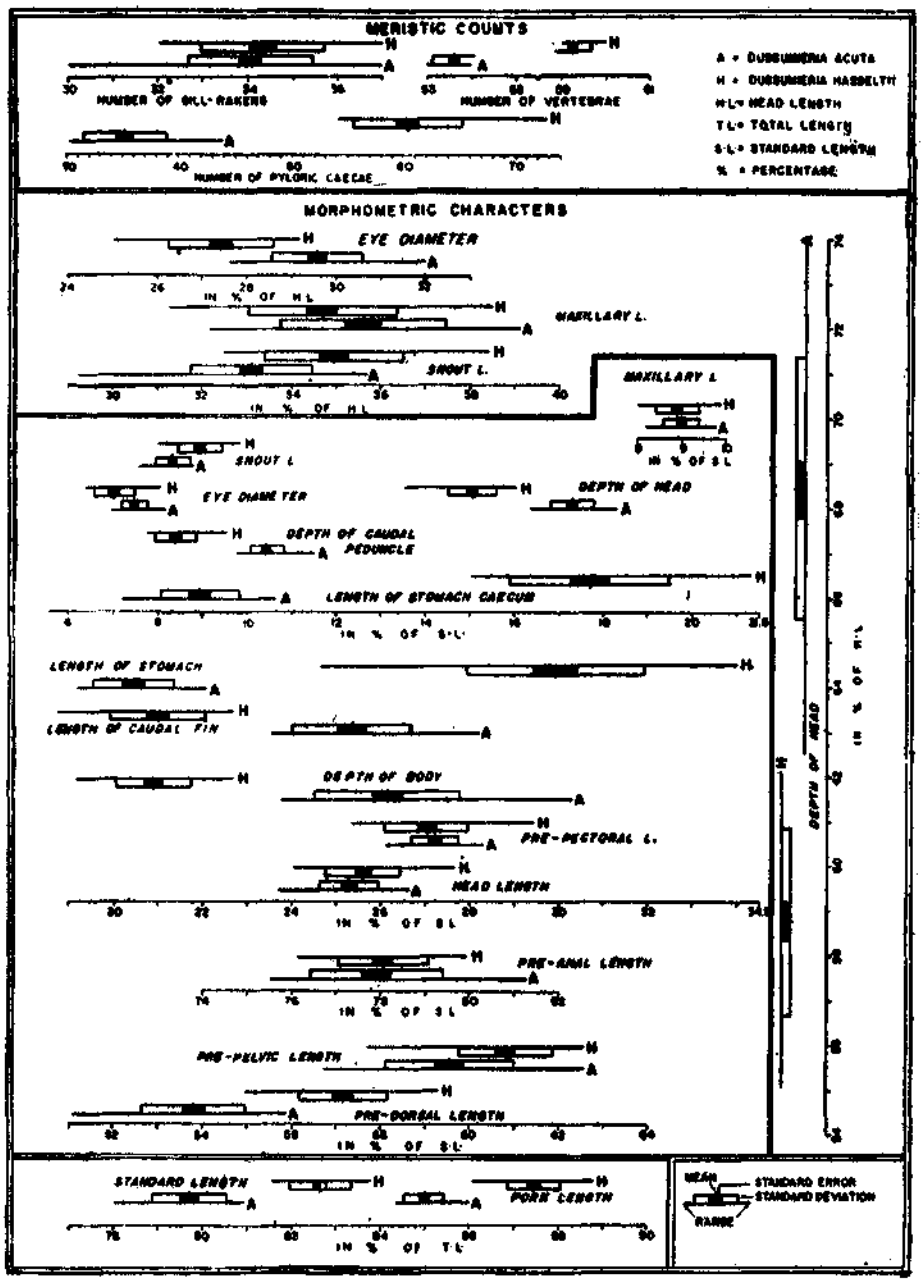

Fig. 1. Range, mean standard deviation and standard error of morphometric and meristic characters of *Dussumieria acuta* and *D. hasseltii*.

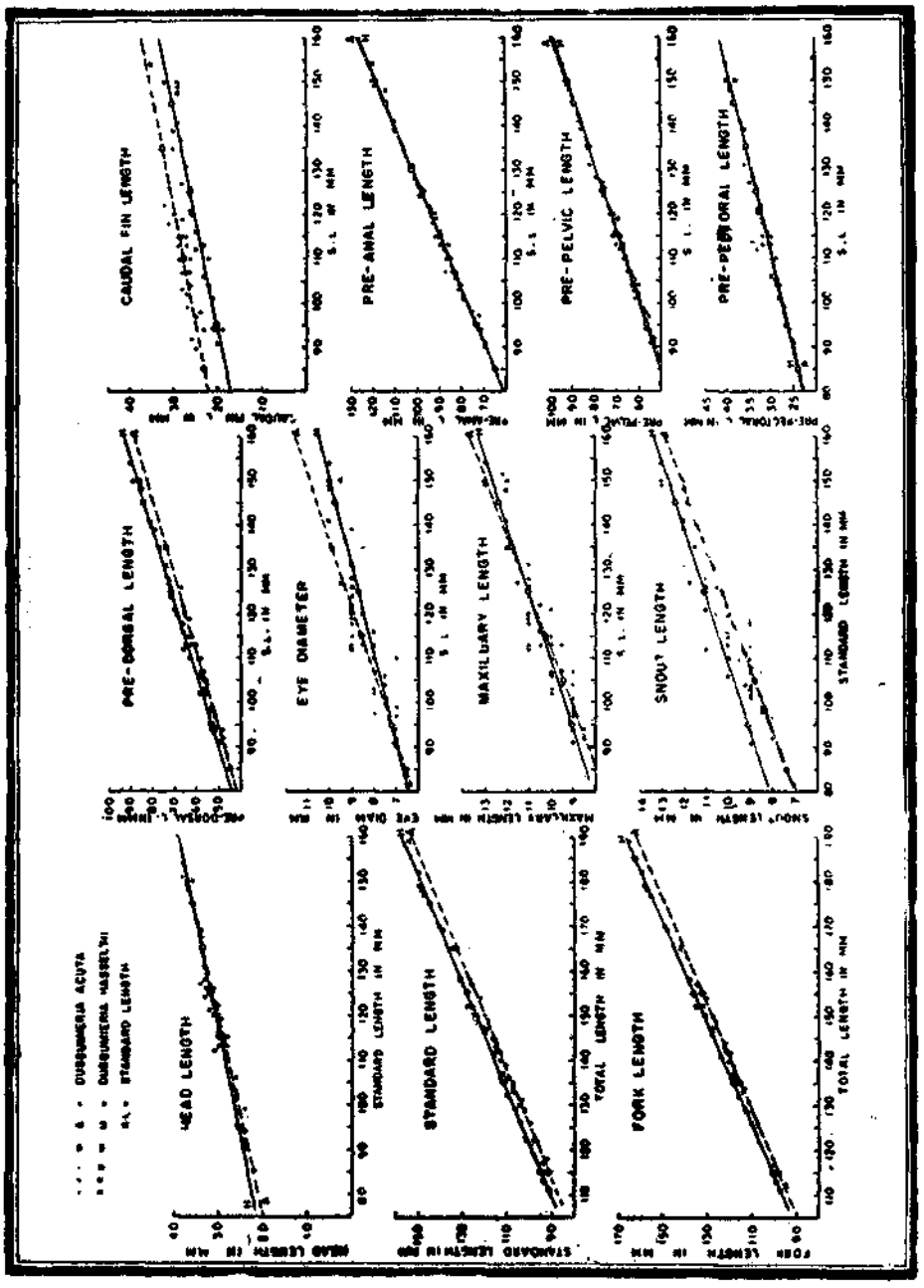

Fig. 2. Scatter diagram, fitted with regressions of morphometric characters of *Dussumieria acuta* and *D. hasseltii*.

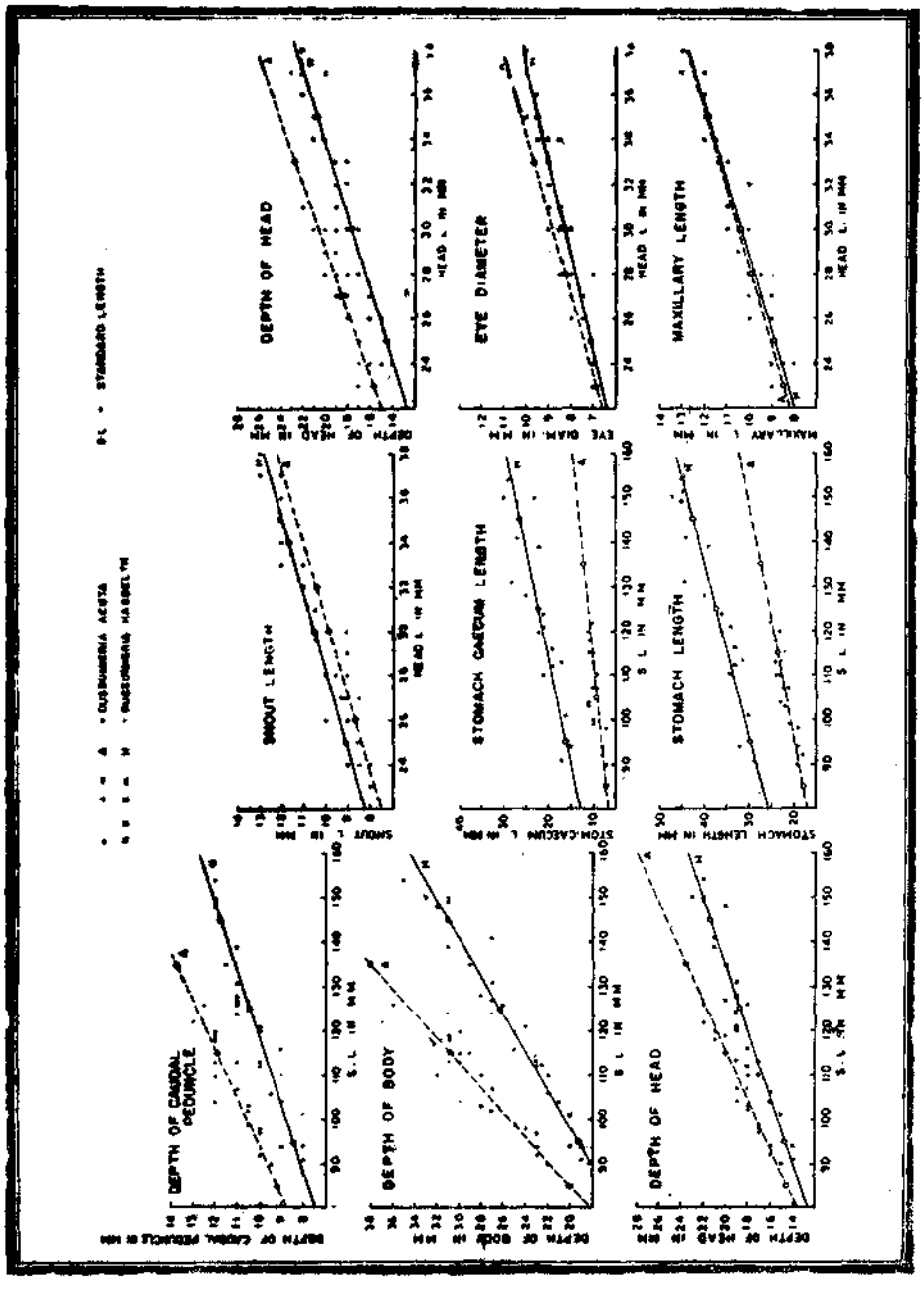

Fig. 3. Scatter diagram, filled with regressions of morphometric characters of *D. acuta* and *D. hasseltii*.

TABLE 1. *Range of overlapping in the morphometric and meristic characters of* D. acuta *and* D. hasseltii *and the percentage occurrence of fish within the overlapping range.*

Characters	Range of overlapping	*D. acuta*		*D. hasseltii*	
		N	%	N	%
In percentage of total length:					
Fork length	Nil	25	—	25	—
Standard length	Nil	25	—	25	—
In percentage of standard length:					
Head length	24.00–26.67	25	96	25	92
Snout length	8.00– 8.85	25	76	25	52
Maxillary length	8.18– 9.80	25	100	25	84
Eye diameter	6.96– 8.04	25	96	25	60
Pre-dorsal length	54.95–55.93	25	16	25	12
Pre-pectoral length	26.09–28.32	25	100	25	84
Pre-pelvic length	57.69–62.60	25	88	25	100
Pre-anal length	76.11–80.00	25	92	25	100
Caudal fin length	Nil	25	—	25	—
Depth of head	Nil	25	—	25	—
Depth of body	Nil	25	—	25	—
Depth of caudal peduncle	Nil	25	—	25	—
Stomach length	Nil	18	—	18	—
Stomach caecum length	Nil	18	—	18	—
In percentage of head length:					
Snout length	32.43–35.71	25	72	25	76
Maxillary length	31.14–38.46	25	96	25	96
Eye diameter	27.59–29.17	25	40	25	40
Depth of head	Nil	25	—	25	—
Meristic characters:					
Number of gill rakers	32–37	25	96	25	100
Number of pyloric caecae	Nil	25	—	25	—
Number of vertebrae	Nil	25	—	25	—

TABLE 2. *Analysis of covariance test on the morphometric characters of* D. acuta *and* D. hasseltii

Characters	'B' values		Results of covariance test			
	D. acuta	*D. hasseltii*	Difference in slopes	At the level of	Difference in elevations	At the level of
Against total length:						
Fork length	0.8443	0.8791	S	5%	S	1%
Standard length	0.8325	0.8339	NS		S	1%
Against standard length:						
Head length	0.2324	0.2090	NS		S	5%
Snout length	0.0733	0.0653	NS		S	1%
Maxillary length	0.0761	0.0657	NS		NS	
Eye diameter	0.0670	0.0510	NS		S	5%
Pre-dorsal length	0.5810	0.6099	NS		S	1%
Pre-pectoral length	0.2378	0.2302	NS		NS	
Pre-pelvic length	0.6717	0.6409	NS		S	5%
Pre-anal length	0.8317	0.8136	NS		NS	
Caudal fin length	0.1878	0.1944	NS		S	1%
Depth of head	0.1803	0.1334	S	1%	S	1%
Depth of body	0.3578	0.2335	S	1%	S	1%
Depth of caudal peduncle	0.0900	0.0661	S	5%	S	1%
Stomach length	0.1875	0.2584	S	1%	S	1%
Stomach caecum length	0.0994	0.2073	S	5%	S	1%
Against head length:						
Snout length	0.2971	0.2896	NS		S	5%
Maxillary length	0.2912	0.2885	S	5%	NS	
Eye diameter	0 2794	0.2334	NS		S	1%
Depth of head	0.6941	0.5828	NS		S	1%

S = Significant; NS = Non significant.

The chi-square values and their associated degree of freedom (D.F.) and the corresponding probability limits are tabulated in Table 3.

The chi-square value was calculated at 1.22 to which 'P' value is between 0.2 and 0.3 and hence the variations are non-significant.

TABLE 3. *Chi-square values for 4 meristic characters of* D. acuta *and* D. hasseltii *and the levels of their probability*

Characters	Chi-square value	Degree of freedom	Value of 'P'
Dorsal fin rays	5.04	2	Between 0.05 & 0.10 (NS)
Pectoral fin rays	1.22	1	Between 0.2 & 0.3 (NS)
Anal fin rays	0.44	2	Between 0.8 & 0.9 (NS)
Gill rakers (total)	1.62	5	Between 0.8 & 0.9 (NS)

NS = Non significant.

Dorsal fin rays: In both the species 4 unbranched and 14 to 16 branched rays are present, the total range of all the rays being 18 to 20. The frequency of occurrence of the latter is given below:

Species	Dorsal fin counts			No. fish examined
	18	19	20	
D. acuta	1	16	8	25
D. hasseltii	3	20	2	25
Total	4	36	10	50

The calculated chi-square value was 5.04 to which the value of 'P' is between 0.05 and 0.10 (Table 3). This shows that the variations are nonsignificant and cannot be considered as a specific character for differentiating the two species.

Pectoral fin rays: In both the species, one unbranched ray and in *D. acuta* 11-12 and in *D. hasseltii* 11-13 branched rays are present. The range of total rays being 12-14. The frequency is given below:

Species	Pectoral fin rays			No. fish examined
	12	13	14	
D. acuta	6	19	—	25
D. hasseltii	3	20	2	25
Total	9	39	2	50

Anal fin rays: In both the species 3 unbranched rays and 12-14 branched rays are present, the total range being 15-17 numbers. The frequency of occurrence is given below:

The chi-square value was found to be 0.44 to which the 'P' was 0.8 to 0.9. The variations were found to be nonsignificant.

Species	Anal fin rays			No. fish examined
	15	16	17	
D. acuta	13	9	3	25
D. hasseltii	12	11	2	25
Total	25	20	5	50

Gill rakers: The number on gill rakers on the upper and the lower limbs of the left outermost arch was counted. The observed frequency for both the species is given below:

Species	Number of gill rakers								No. fish examined
	30	31	32	33	34	35	36	37	
D. acuta	1	—	1	5	10	5	2	1	25
D. hasseltii	—	—	2	5	8	4	5	1	25
Total	1	—	3	10	18	9	7	2	50

The chi-square value was found to be 1.62 to which the 'P' is 0.8 - 0.9 and hence the variations were nonsignificant.

This reveals that the above mentioned meristic characters did not show any significant variation between these two species.

COMPARISON OF SPECIES

Comparison of *D. acuta* and *D. hasseltii*, based on the relationship of their body proportions and two important meristic counts, is given below.

Dussumieria acuta	*Dussumieria hasseltii*
The maxillary length more than the snout length. The maxilla clearly reaching the front margin of eye.	The length of maxilla equal to or less than the snout length.
The origin of dorsal fin $\frac{1}{2}$ of its eye diameter behind the middle of body.	Origin of dorsal fin clearly an eye diameter behind middle of body.
Ventral fin origin more than $\frac{3}{4}$ diameter of eye behind a vertical from dorsal origin.	Ventral fin origin $\frac{1}{2}$ eye diameter behind a vertical from dorsal origin.
Depth of head more than double the snout length.	Depth of head less than double the snout length.
Depth of body slightly more than head length.	Depth of body much less than head length.
Depth of caudal peduncle always more than maxillary length.	Depth of caudal peduncle less than, rarely equal to, maxillary length.
Length of stomach far less than half the predorsal length.	Length of stomach more than half the predorsal length.
Length of stomach caecum equal to maxillary length.	Length of stomach caecum nearly double the maxillary length.
Length of caudal fin almost equal its head length and always more than thrice eye diameter.	Length of caudal fin always less than head length, and nearly thrice its eye diameter.
Pre-pectoral length more than thrice that of snout length and equal to thrice the maxillary length.	Pre-pectoral length thrice that of snout length.
Pre-anal length slightly less than three times body depth.	Pre-anal length nearly $3\frac{3}{4}$ times body depth.
Number of pyloric caecae 30-44.	Number of pyloric caecae 54-73.
Number of vertebrae 53-54.	Number of vertebrae 59-60.

Description of Species

Dussumieria acuta Valenciennes 1847 (Pl. I A)

The complete synonymy is given by Fowler (1941). D. iv 14-16; A. iii 12-14; P.i 11-13; v.i 7; G.R. 30-37; Vertebrae 53-54; Pyloric caecae 30-44.

In percentage of total length: fork length 84.33-86.03 and standard length 77.97-80.99.

In percentage of standard length: head length 23.71-26.67; snout 7.56-8.85; maxillary 8.18-9.80; eye 6.96-8.16; pre-dorsal 51.06-55.93; pre-anal 75.53-81.31; pre-pectoral 26.09-28.32; pre-pelvic 56.70-62.61; depth of head 16.36-18.27; depth of body 23.71-30.33; depth of caudal peduncle 9.73-11.54; caudal fin 23.53-28.26; length of stomach 19.13-22.12; length of stomach caecum 7.14-10.68.

In percentage of head length: snout 29.17-35.71; maxillary 32.14-39.13; eye diameter 27.59-32.00 and depth of head 62.50-73.91.

The maxillary length more than the snout length, maxilla clearly reaching the front margin of eye. Origin of dorsal fin ½ eye diameter behind the middle of body. Ventral fin origin more than ¾ diameter of eye behind a vertical from dorsal origin. Depth of head more than double the snout length. Body depth slightly more than head length. Depth of caudal peduncle always more than maxillary length. Length of stomach far less than half the pre-dorsal length and the caecum equal to maxillary length. Length of caudal fin almost equal its head length and always more than thrice its eye diameter. Pre-pectoral length more than thrice its snout and equal to thrice the maxillary length. Pre-anal slightly less than three times its body depth. Maximum size 167mm total length.

Colour: Bluish grey dorsally and silvery white below. A narrow lateral band of silvery grey with a golden tinch extends from opercle to caudal base. Ventral and anal white, other fins pale with dusky margin on caudal edge. First rays of dorsal and pectoral dusky. Snout pigmented. Eye white.

Distribution: East coast of mediterranean, Red sea, Gulf of Aden, East coast of Africa, Madagasker, Gulf of Iran, India (east and west coasts), Ceylon, Malay Peninsula, Singapore, Pinang, East Indies, Philippines, China up to Foochow. Inhabits coastal waters.

Dussumieria hasseltii Bleeker 1850 (Pl. I B)

Complete synonymy is given by Fowler (1941). D.iv 14-16; A.iii 12-14; P.i 11-13; V.i 7; G.R. 32-37; Vertebrae 59-60; Pyloric caecae 54-73.

In percentage of total length: fork length 86.06-88.82; standard length 81.48-83.80.

In percentage of standard length: head 24.00-27.68; snout 8.00-9.89; maxilla 8.00-9.89; eye 6.30-8.04; pre-dorsal 54.95-59.33; pre-pectoral 25.33-29.46; pre-pelvic 57.69-62.60; pre-anal 76.11-80.00; depth of head 13.51-16.07; depth of body 19.15-22.73; depth of caudal peduncle 7.76-9.57; caudal fin length 18.75-22.73; stomach length 24.67-34.04 and stomach caecum length 15.04-21.37.

In percentage of head length: snout 32.43-38.46; maxilla 31.25-38.46; eye diameter 25.00-29.17 and depth of head 54.05-62.16.

The maxillary length equal to, or less than snout length, origin of dorsal fin clearly an eye diameter behind middle of body, ventral fin origin ½ eye diameter behind a vertical from dorsal origin, depth of head less than double the snout length, depth of body much less than head length, depth of caudal peduncle less than (rarely equal to) maxillary length, length of stomach caecum nearly double the maxillary length, length of caudal fin always less than head length and nearly thrice its eye diameter, pre-pectoral length thrice that of snout length

and pre-anal length nearly 3¼ times body depth. Maximum size 205 mm total length.

Colour: Upper half dark greenish blue with a narrow lateral band of silvery grey with a golden tinch extending from upper operculum to caudal base. Silvery white on sides and belly. Forkal edge of caudal black. Dorsal and pectoral fins pale but the first ray dusky. Ventral and anal fins white. Upper surface of eye and head emerald green. Snout stongly pigmented. Eye white.

Distribution: East and west coasts of India, Ceylon, Burma, Malay peninsula, Singapore, East Indies, Philippines, Formosa (Taiwan), China, Queensland and North east coast of Australia. Inhabits coastal waters.

Discussion

Whitehead (1963), in his notes on synonymy of *Dussumieria* spp., studied mainly four characters namely (a) body depth, (b) snout length, (c) gill rakers and (d) dorsal rays. From the scatter diagram on the body depths of specimens measured by him it could be seen that the percentage of body depth in standard length had a wide range from 18 to 30. The present observation showed that height of body is a differentiating character of the two species and the range is 23.71 to 30.33% in *D. acuta* and 19.15 to 22.73% in *D. hasseltii*. Based on this if a demarcating line is drawn at 23% in Whitehead's diagram, a clear differentiation could be observed below and above this line. The specimens plotted above this line form a homogeneous group with a limited range of variation which may agree with *D. acuta*. Similarly, the homogeneous group below the line also show a limited range which is in full agreement with that of *D. hasseltii*.

Regarding the snout length, Whitehead (1963) came to the conclusion that this cannot serve as a basis for distinguishing the species. Even then a close study of the histogramms of snout length given by him reveals that those specimens which have differential homogenity in body height show homogenity in snout length also. In the present work it is observed that the snout length of *D. acuta* is 7.56 to 8.85% and of *D. hasseltii* is 8.00 to 9.89% of standard length with an overlapping range between 8.00 and 8.85%. 76% of *D. acuta* and 52% of *D. hasseltii* came within this range. This shows that there is only slight difference in snout length of these species, but not to the extent to depend on as a specific character. Whitehead (1963) observed slight difference in gill raker counts of a few specimens, but this could not be noticed in the present study. The dorsal fin counts also did not show any variation as has been observed by him. In the present study several other characters were considered which show specific distinction between the two species which helped to justify the re-establishment of *D. hasseltii* Bleeker. Thus two species, *viz. D. acuta* and *D. hasseltii* under the genus *Dussumieria* are recognised in the present study. Delsman (1925) tried to identify the two species of *Dussumieria*. According to him the scales are extremely deciduous in *Dussumieria* and it is rare to find at the fish market a sample with any scale at all on the lateral line. He also commented that, in general, there is a certain correspondence between the number of scales along the lateral line and the number of myotomes with fishes so it might be expected that in *D. acuta* the number of myotomes and vertebrae would be considerably smaller than in *D. hasseltii*. But the x-ray photographs of the specimens of *D. acuta* and *D. hasseltii* kept in the Zoological Museum of Amsterdam, sent to him by Dr. de Beaufort, had confused him. Finally he admitted that he had been unable to distinguish the two species among the materials of the fish market. This may be either due to the absence of one of the species in the commercial catches of Java sea or Delsman would have unfortunately missed to notice its rare occurrence in the single species dominant

fishery. In the present study it was noticed that at Mandapam, in the rainbow sardine fishery, *D. acuta* dominated in the catch while *D. hasseltii* was represented only in very few numbers which normally remains unnoticed. But it is to be admitted that, in the absence of specimens of both the species, it is very difficult to fix up the species of *Dussumieria* since many of the differentiating characters are of relative value only.

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