STOLEPHORUS RESOURCES IN THE SOUTH CHINA SEA

by

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ABSTRACT

The position with regard to the taxonomy of this important group of fish in South-east Asia as a result of the recent study carried out by Ronquillo (1967) and Whitehead (1967) is reviewed. The geographical and quantitative distribution of *Stolephorus* spp. in the South China Sea is discussed. The more common fishing methods for this group are mentioned and the general biology and ecology of certain members of this group are summarised from the available data.

1. INTRODUCTION

This short paper on the Stolephorus resources in the South China Sea has been prepared at the request of the IPFC Working Party on Coastal and High Seas Pelagic Resources for the Symposium on Coastal and High Seas Pelagic Resources at the IPFC 15th Session to be held on 18-20 October 1972 at Wellington, New Zealand. It is based on what little published data are available on this subject and on the notes made by the author who had an interest in the genus Stolephorus in Singapore waters since 1934. It deals with, as far as is possible, the present position of the taxonomy of the species of this genus, the distribution of the various species, the main fishing methods used in Singapore and Malaysian waters, and the general biology and ecology of the most common species found in Singapore waters. Whilst members of this genus are at present only caught in large quantities along the coastal areas of countries surrounding the South China Sea, a consideration of certain aspects of its biology would lead one to believe that they might form a high seas pelagic resource in the future.

2. TAXONOMY

Hardenberg (1934) described nine species from Indonesian waters and, according to him, many of these species were also found in the seas off many South-east Asian countries as well as other parts of the world. These species are listed in Table I, except for Stolephorus celebicus Hardenberg, which was only found by him at Menado which is outside the South China Sea area. This species was also not mentioned by Ronquillo (1965) in his extensive study on the members of the genus Stolephorus. As a result of this review, Ronquillo has revised many of the specific names of members of this genus and these revised names are also given in Table I. According to Whitehead (1967), Hardenberg's types cannot now be traced and were probably destroyed during the last war.

Most fisheries workers in this region have been accustomed to using the specific names given in Hardenberg's (1934) paper, but the revised names given by Ronquillo (1965) and Whitehead (1967) will, however, have to be used in the future, although there will initially be some confusion. They are used in this paper. For example, the species "Stolephorus pseudoheterolobus" of Hardenberg is now referred to as "Stolephorus heterolobus", whilst the "Stolephorus heterolobus" of Hardenberg is now referred to as "Stolephorus species A". The "Stolephorus zollingeri" of Hardenberg is now referred to as "Stolephorus buccaneeri", whilst the "Stolephorus insularis" of Hardenberg is now referred to as "Stolephorus bataviensis". Similarly the "Stolephorus baganensis" of Hardenberg is now referred to as "Stolephorus macrops". The specific names of three species, viz. Stolephorus tri, Stolephorus indicus, and Stolephorus commersonii have been retained.

In addition to these species, Ronquillo (1965) mentioned four other species for the South China Sea. Stolephorus andhraensis, which was first described by Babu Rao (1966) from the east coast of India, is reported by Ronquillo (1965) to be "known" from Thailand and Singapore. Stolephorus chinensis, first reported from Hong Kong, is reported by Ronquillo (1965) to have been found by him in collections from Thailand and Singapore. Stolephorus species B and Stolephorus species C are new species found by Ronquillo (1965) who intends to describe them fully in a forthcoming publication.

The key of Ronquillo (1965), though it may be plausible from the point of view of the taxonomist, is not easy for the field ecologist. It is hoped that the confusion, which developed in the case of Rastrelliger kanagurta and Rastrelliger neglectus previously, will not develop in the case of Stolephorus species, particularly in the case of S. heterolobus and S. species A in which some of the characters overlap and Ronquillo (1965) suggested the possibility of inter-breeding. In the case of S. buccaneeri and S. purpureus in Hawaiian waters, Nakamura (1970) is of the opinion that the existence of intermediate forms of these two species suggested inter-breeding of these two species and raised doubts regarding the designation of S. buccaneeri as a distinct species. The S. species B of Ronquillo (1965) is also closely related to S. purpureus and it might prove to be one of the intermediate forms mentioned by Nakamura (1970). Similarly S. species C is closely related to S. macrops, whilst S. andhraensis is also closely related to S. bataviensis.

TABLE I List of species of Stolephorus recorded in the South China Sea

No.	Author: Hardenberg (1934)	Ronquillo (1965)
1	Stolephorus tri (Blkr.)	Stolephorus tri (Blkr.)
2	Stolephorus indicus (v. Hass.)	+Stolephorus indicus (v. Hass.)
3	Stolephorus commersonii Lac.	+Stolephorus commersonii Lac.
4	Stolephorus baganensis Hardenberg	+Stolephorus macrops Hardenberg
5	Stolephorus insularis Hardenberg	+Stolephorus bataviensis Hardenberg
6	Stolephorus pseudoheterolobus Hardenberg	Stolephorus heterolobus Rupp.
7	Stolephorus heterolobus Rupp.	+Stolephorus species A.
8	Stolephorus zollingeri (Blkr.)	+Stolephorus buccaneeri Strasburg
9		Stolephorus andhraensis Babu Rao
10		Stolephorus chinensis (Gunther)
11		Stolephorus species B
12		+Stolephorus species C

+ Recorded by Whitehead (1967) in the Indian Ocean

3. DISTRIBUTION

The geographical distribution of members of this genus found in the South China Sea is given in Table II. It will be noted that many of them are found also in the Indian Ocean and East China Sea whilst a few species have been reported from the Central and South Pacific. Generally speaking, they may be divided into four groups. The first group consists of four species, viz. S. commersonii, S. indicus, S. buccaneeri, and S. heterolobus, which have been recorded from the South China Sea, East China Sea, Indian Ocean and Central and South Pacific. The second group consists of S. species A, S. macrops, and S. bataviensis, which have been recorded in the East China Sea, South China Sea, and Indian Ocean. The third group consists of S. species C, S. tri, and S. andhraensis, which have been recorded in the South China Sea and Indian Ocean only. The fourth group consists of S. chinensis and S. species B, which have been recorded in the South China Sea and East China Sea only.

With regard to the first group, I am inclined to include S. species A because of its close affinity to S. heterolobus and further study may prove that they are two races of the same species. According to Hardenberg (1934), S. indicus and S. commersonii are solitary species when found along the coasts and prefer high salinity although sometimes they do enter estuaries of lower salinity. According to Ronquillo (1965) S. buccaneeri, which was first described from Hawaii, is a commercially important species in Taiwan and even in southern Japan and at times in Hong Kong, Thailand, and Indonesia but is extremely rare in Indian waters. Hardenberg (1934) reported that he had obtained specimens of this species only from Ambon, Menado, and Puger along the south coast of Java. Presumably this species also prefers high salinity. All the species in the first group are wide ranging. Whilst S. indicus and S. commersonii are solitary species along the coasts, S. buccaneeri and S. heterolobus form the basis of lucrative fisheries in certain areas, the former in Taiwan, southern Japan, Hong Kong, Thailand and Indonesia, whilst in Indonesia, Singapore, Malaysia and perhaps other areas also, S. heterolobus forms the bulk of the anchovy fishery. Looking at the existing pattern of distribution of this group, it appears possible that S. commersonii, S. indicus, and S. heterolobus might have been transported from South-east Asian waters to the east coast of Africa by the north equatorial current across the Indian Ocean. This speculation is supported by the fact that in the straits of Malacca the current direction is nearly always north-west which means it is most improbable that they have come from South Asia or the east coast of Africa. It is also probable that S. buccaneeri was transported from the Hawaiian Islands by the north equatorial current across the Pacific Ocean to the South China Sea and thence across the Indian Ocean to the east coast of Africa. Whitehead's (1967) remark that S. buccaneeri was absent from the Arabian Sea and Bay of Bengal and extremely rare in Indian waters is significant.

With regard to the second group consisting of S. macrops and S. bataviensis, both recorded in the East China Sea, South China Sea, and Indian Ocean, I am inclined to include S. species C which is closely related to S. macrops and perhaps also S. andhraensis which is closely related to S. bataviensis. The third group will then consist only of S. tri recorded in the Indian Ocean and South China Sea. The fourth group will then also consist of one species S. chinensis, recorded in the East China Sea and South China Sea.

The picture with regard to the quantitative distribution of each species is most unsatisfactory because statistics of catches of individual members of this genus are extremely scanty and usually they are all included as one group. Certain species such as S. heterolobus is, of course, known to dominate the catch of anchovies in Malaysia, Philippines and Singapore. This is perhaps also true of certain areas of Indonesia and perhaps also in Vietnam and Thailand, but for most countries there are no available statistics. There is therefore no alternative but to deal with all the species as a group.

At the 11th Session of the IPFC held at Kuala Lumpur in Malaysia the following statistics of rough total annual landings of members of the genus Stolephorus were gathered:

Hong Kong	1,200 metric tons
Indonesia	no information
Malaysia	10,000 metric tons
Philippines	11,200 metric tons
Thailand	5,000 metric tons
Vietnam	40,000 metric tons

Of these countries, data for the rough specific composition of the Stolephorus catch are available only in respect of the Philippines. According to Tiews et al. (1970), the Philippines catch of Stolephorus was 5,000 metric tons in 1956 (being 12% of the total commercial fish catch) and rose to 11,500 metric tons in 1966. Analysing the 1957-58 catch, they found that between 42 and 96% of the catch were S. heterolobus-like anchovies, between 1 and 22% were S. buccaneeri anchovies, and between 4 and 32% were S. commersonii/bataviensis anchovies. In Singapore and the east coast of West Malaysia, about 90% of the total Stolephorus catch consisted of S. heterolobus-like anchovies with S. bataviensis next in abundance and S. indicus being least abundant. In the case of Malaysia and Singapore, data for total landings of Stolephorus spp. as well as total landings of all fish are only available for the period 1931-38 for the States of Malaya and Singapore. The total Stolephorus catch for this period amounted to between 3 and 14% of the total fish landings. In terms of weight the quantities varied from 3,200 metric tons to 9,652 metric tons per year.

In Malaysia and Singapore, the Stolephorus catch is made in the coastal zone, the outer limit of which is no more than a few miles from the shore. It is believed that the same is true for the other countries bordering the South China Sea. Little is known of the offshore distribution of Stolephorus spp. in the South China Sea. It has, however, been reported by fishermen that shoals of Stolephorus spp. have been sighted off the Anabas and Natuna Archipelago in the south central portion of the South China Sea. It has also been observed that along the east coast of West Malaysia shoals of Stolephorus are caught at different points of the coast during different months of the year and they were rare during other months of the year. These observations indicate the possibility that the offshore area of the South China Sea may have large shoals of Stolephorus spp., particularly species such as S. indicus, mature specimens of which have not been observed in the inshore waters of either Malaysia or the Philippines.

TABLE II

Geographical Distribution of Stolephorus Species as summarised by Ronquillo (1965)

	S. commersonii	S indicus	S buccaneeri	S heterolobus	S species A	S macrops	S bataviensis	S tri	S andhraensis	S species C	S species B	S chinensis
I. East China Sea												
Japan		x	x									
China coast												x
Hong Kong		x	x		x	x	x					x
Taiwan	x	x	x	x	x	x	x				x	
II. South China Sea												
Philippines	x	x	x	x	x		x			x	x	
Indonesia	x	x	x	x	x	x	x	x				
Singapore	x	x	x	x	x	x	x	x	x			x
Malaysia						x						
Thailand	x	x	x	x	x	x	x	x	x	x		x
Vietnam												
III. Central & South Pacific												
Hawaii			x									
Caroline Is.				x								
New Guinea	x	x										
New Zealand		x										
IV. Indian Ocean												
North-western Australia				x								
Burma												
India	x	x	x	x	x	x	x	x	x	x		
Ceylon					x							
Gulf of Aden					x							
Red Sea		x	x	x								
East coast of Africa	x	x	x	x								
Zanzibar	x		x									
Madagascar	x									x		
Durban	x	x	x									
Mauritius	x											

It has been observed by Hardenberg (1934) for Indonesian waters, Tham (1953) for Singapore waters and Tiews et al. (1970) for Philippines waters that many species of Stolephorus may be caught together indicating the existence of mixed shoals but that certain species such as S. heterolobus-like species may be dominant in the catch whilst others such as S. indicus and S. commersonii are only sparsely represented in the catch. This is probably due to the fact that large specimens of these latter two species feed mainly on larger zooplankton (vide Tham 1950) which are found further offshore. It was also observed that certain species may be dominant in certain areas or at certain times of the year whilst other species are dominant in other areas at other times of the year. Tiews et al. (1970) made many observations on the question of association of different species of Stolephorus and came to the conclusion that different species had different distribution centres in Philippines waters and that the special hydrographic conditions in Manila attracted more species than in the case of Batangas Bay.

Tham (1970) found that in Singapore Straits the eggs and various growth stages of S. heterolobus have a differential distribution in Singapore Straits. Whilst very few eggs and larvae were observed in Singapore Straits, the juveniles and more advanced stages up to mature individuals are caught in large quantities there. He attributed this phenomenon to the spawning of this species in the South China Sea or Java Sea and was of the opinion that the stages found in Singapore Straits formed a feeding aggregation because they were found to be feeding fairly heavily on the plankton of Singapore Straits (vide Tham 1950).

According to Hardenberg (1934), the various species of Stolephorus in the South China Sea may be divided roughly into three groups, viz: (1) species such as S. indicus and S. commersonii which are normally found further out along the coast and which normally prefer high salinity but may sometimes enter rivers; (2) species such as S. tri and S. macrops which are abundant near the mouths of large rivers, although the latter species may go further into brackish water than the former and spawns in water with a salinity of $28^{o}/oo$ or more; and (3) S. bataviensis and S. heterolobus which are normally found along the coast and around islands. This particular pattern of distribution may be the result of the particular preferences of the various species for different physical and chemical environmental conditions as well as the availability of different types of food. For example, Tham (1950, 1953) showed that whilst S. indicus and S. bataviensis preferred zooplankton organisms, particularly the larger ones, for food, S. heterolobus fed on both zooplankton and phytoplankton. It was also shown that the quantity of Stolephorus spp. caught in Singapore Straits was positively correlated with the quantity of plankton in the water. Tham (1955) observed that high wind force under certain circumstances favoured the aggregation of Stolephorus spp. in Singapore Straits. Hardenberg (1934) observed S. heterolobus migrating from Bangka to the Lingga Archipelago and then further north to the Rhiouw Archipelago during the West Monsoon in the Java Sea. This indicates that wind force may play a part in the movement of this species. Although all species of Stolephorus have a fairly wide range of salinity tolerance, e.g., $17^{o}/oo$ to $32^{o}/oo$ or even a little higher, observations seem to indicate that salinity forms part of a complex of environmental factors which determine the distribution pattern of different species.

4. FISHING METHODS

In Singapore waters and also the south-east coast of West Malaysia, the main fishing gear used for catching Stolephorus spp. is the palisade trap, known locally as the kelong, which uses lights to attract the fish into the catching enclosure and then uses a lift net to capture the fish. The beach seine is another gear which is important in other parts of Malaysia. It is fairly important in Singapore and other countries bordering the South China Sea. In East Malaysia and along the west coast of West Malaysia as well as in Indonesia, two gears with filter devices are also important in the capture of this genus. One is the filter bag net known locally as the ambai, and the other is a palisade trap using a filter net and known locally as the jermal. In West Malaysia, the fish may also be aggregated by bright lights submerged in the water and the aggregated fish then captured by means of a purse seine. In the Philippines the fish is aggregated by means of lights and captured by means of a lift net. This gear is known as the basingan (vide Tiews et al. 1970). It is probable that any or a few of these different gears or their modifications are also used in the countries bordering the South China Sea.

5. GENERAL BIOLOGY

The members of the genus Stolephorus have pelagic habits and their eggs are planktonic. They are found in small shoals along the coasts and near islands. In the Java Sea, S. indicus and S. commersonii, however, appear in shoals only during July/August and during the rest of the year they are more or less solitary.

Mature specimens of S. indicus and S. commersonii are rarely caught, but for most of the other species mature specimens are fairly common.

For S. heterolobus the number of mature eggs in a single female varies from about 1 000 in a fish of standard length 55 mm to about 2,500 in a fish of standard length 62 mm (vide Tan, 1968). Tiews et al. (1970) found that in S. buccaneeri the number of eggs varied from 7,000 to 11,000 per fish, in S. commersonii and S. bataviensis from 5,000 to 10,000 per fish, and in S. indicus from 9,000 to 14,000 per fish.

There does not appear to be any published work on the distribution of Stolephorus eggs in the South China Sea. Delsman (1931) classified the eggs into the following two groups:

(a) Eggs with a knob at one pole and without an oil globule:

(1) S. indicus
(2) S. commersonii
(3) S. bataviensis

(b) Eggs without a knob

(i) and without an oil globule -
S. heterolobus

(ii) and with an oil globule
(1) S. sp. A. (with a very tiny oil globule)
(2) S. tri (with a colourless or slightly yellowish oil globule)
(3) S. macrops (with a slightly brownish oil globule)

In the Java Sea all these eggs were found along the coast and only a few eggs of S. heterolobus were found in the central area. Eggs without an oil globule were found further from the coast and those with an oil globule were found near to the coast. Eggs of S. bataviensis and S. heterolobus were found throughout the year, showing that they spawn continually.

According to Delsman (1931) the incubation period is less than 24 hours and spawning usually occurs at night before midnight. It is believed that the growth of the larval stages is fairly rapid. Tester (1951) estimated that, in the case of S. purpureus in Hawaiian waters, the absolute growth rate is 1.5 mm per day between hatching and 12 mm standard length, whilst Yamashita (1951) estimated that the time from hatching to metamorphosis (ca. 30 mm long) was about 6 or 7 weeks. Tham (1967) estimated the age of S. heterolobus, S. bataviensis and S. indicus at 30 mm standard length to be 56 days, 34 days, and 42 days respectively. S. heterolobus attains first maturity at a standard length of about 50 mm (estimated age about 125 days). Nakamura (1970) quotes Bachman (1963) as being of the opinion that few S. purpureus reach maturity well before the age of one year. On the other hand, Tiews et al. (1970) estimated that S. heterolobus, in Philippines waters, attained a length of 30 mm at the end of the first year of life and 60 mm at the end of the second year, and did not live much older than three years.

All the stolephorids feed on plankton. Tham (1950), in his study of the food of the stolephorids in Singapore waters over a period of one year, came to the conclusion that the main food of S. heterolobus consisted of calanid and harpacticid copepods, ostracods, Leptochela, brachyuran zoea, other decapod larvae, polychaete larvae, and phytoplankton. S. bataviensis was found feeding mainly on Leptochela and S. indicus was feeding mainly on calanid copepods, mysids, Leptochela, brachyuran megalopa, squilla larvae, and even on fish larvae. The other elements of the plankton of Singapore Straits formed the subsidiary food. Hiatt (1951) found that the food of S. purpureus consisted mainly of planktonic crustacea, e.g., copepods, Lucifer, and brachyuran megalopa. Subsidiary foods consisted of cirripede larvae, brachyuran zoea, mysids, and sometimes diatoms, gastropod larvae, and fish larvae.

6. POPULATION STRUCTURE

According to Tham (1966), who studied the population structure of S. heterolobus in Singapore Straits from November 1948 to November 1949 at short intervals of about two weeks to about a month, the population structure of S. heterolobus changed from month to month. Throughout the year one could find fish of any length between 35 mm and 60 mm standard length. There could be one or more modes, with a maximum of four modes in any one sample. These modes shifted from month to month. During the period from December to May the following year, a large number of juveniles ranging from 20 mm to 35 mm in length were caught together with larger fish. From August to November, fish of less than 35 mm standard length were seldom found in the catch. Maturing fish were found in the commercial catches throughout the year.

The population of Stolephorus spp. in Singapore Straits consists of a mixture of at least four species, viz, S. heterolobus, S. species A, S. bataviensis, and S. indicus, with S. heterolobus predominating throughout the year. In Philippines waters Tiews et al. (1970) presented data which indicate that, whilst S. heterolobus-like species dominated the catches throughout the year, the other species increased in abundance only during certain periods of the year. For example, S. buccaneeri was more abundant during June, July, November, and January, whilst the S. commersonii/bataviensis group was more abundant during February, August, September, October, November, and December. S. indicus was the least abundant throughout the greater part of the year.

7. ECOLOGY

S. heterolobus were observed to aggregate in large shoals in Singapore Straits and also along the east coast of West Malaysia. Nakamura (1970) stated that S. purpureus was found in schools in Hawaiian waters. As stated earlier, Hardenberg (1934) concluded from his studies in Indonesian waters that S. heterolobus migrated from Bangka to the Lingga Archipelago and then further north to the Rhiouw Archipelago from February to October each year, but he was not sure whether there was a reverse migration.

S. heterolobus is known to be definitely positively-phototrophic, since both the Singapore palisade fish trap (known as the kelong) and the lighted purse seine use a light to attract the stolephorids before capturing them. According to Nakamura (1970), S. purpureus is not only phototrophic but is also frightened by low frequency sounds, since in catching this species the fishermen often slap the surface of the water between the ends of the net with bamboo poles to deter the school from escaping through the opening.

Tham (1953) noted that in Singapore Straits, aggregations of S. heterolobus appeared to move out of the coastal areas during periods of heavy and continued rainfall when the salinity in the coastal areas decreased. Tiews et al. (1970) also observed that stolephorids of less than one to one-and-a-half years old left Manila Bay during the rainy season when the salinity was below $29^{o}/oo$. As stated earlier, Tham (1955) observed that, in Singapore Straits, under certain circumstances high wind force favoured the aggregation of S. heterolobus.

Tham (1953), in a quantitative study of the relationship between the environmental factors such as wind force, rainfall, water temperature, salinity, phytoplankton, copepods and the weight of fish catch in Singapore Straits during 1948 and 1949, found, inter alia, that there was a statistically significant partial correlation between the number of copepods, in the water and the weight of the total fish catch of which stolephorids formed a large proportion. There was also a statistically significant partial correlation between the quantity of phytoplankton expressed as pigment content in Harvey units and the weight of stolephorids caught in Singapore Straits. There appears therefore to be a statistically significant relationship between the stolephorids and their food, which is made up of both phytoplankton and zooplankton. It was therefore concluded that the stolephorids aggregated in Singapore Straits to feed on the plankton there. In this study it was also shown that there was a positive statistically significant partial correlation between the amount of precipitation (rainfall) and the soluble inorganic phosphate content of the sea water, indicating that most of the phosphate in the coastal areas was derived from precipitation. There were also indications of a very close inverse relationship between pigment content and the phosphate content of the sea water which conforms with the view that, as the multiplication of phytoplankton cells increases the nutrients, as represented by the phosphate content, decrease. It was also found that many of the peaks in phytoplankton abundance coincided with peaks in copepod numbers.

Tham (1950) in a study carried out on the food of the more common species of fish found in Singapore Straits found that many species predate on the stolephorids. Among the more important predators are Scomberomorus guttatus, Scomberomorus lineolatus, Scomberomorus commersoni, Chirocentrus dorab, Engraulis spp., Saurida gracilis, Sphyraena spp., carangids, Trichiurus spp., Gazza minuta, sciaenids, and Therapon spp.

Tham (1953) found a positive statistically significant partial correlation between the weight of stolephorids and that of scomberomorids caught in Singapore Straits during 1948 and 1949. Fishermen along the east coast of West Malaysia also use the abundance of stolephorids as an indication of the presence of scomberomorids, i.e., whenever there is an abundance of stolephorids drift nets are set to catch the scomberomorids.

There appears to be a close relationship between the precipitation, salinity, phosphate content, phytoplankton and zooplankton abundance, stolephorid abundance, and scomberomorid abundance in Singapore Straits. Excessive precipitation will lower the salinity of the coastal area and render the environment less optimal for the stolephorids. On the other hand, it contributes to the nutrient content of the water. With the increase in the nutrient content, phytoplankton blooms will occur and the zooplankton may be expected to increase in numbers. With the increased numbers of plankton organisms, the stolephorids may be expected to aggregate in Singapore Straits to feed. When this happens, the scomberomorids and other species which predate on stolephorids will also aggregate there to feed on the stolephorids.

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