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A review of the sand whiting *Sillago Sihama* (Forsskål, 1775) suitability as a diversified Brackishwater finfish species and its culture potential

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Abstract
This paper reviewed the natural resources, wild seed availability, the biology, fishery and export potential of the sand whiting, *Sillago sihama*. Also, this paper reviews the scope, cost of production, feed conversion ratio of existing diversified species, salinity tolerance, growth, survival, crude protein level requirement, food and feeding habits of Sillago fish. The paper also discusses the fish potential in capture and culture sectors; suitability for pond, pen and cage culture conditions in freshwater and saltwater systems. On reviewing the various desirable culture attributes and foreseeing the diminishing profit margins of other diversified fish species we conclude that there is a need to standardize the package of practices and technical innovations on various culture aspects of fish including nursery and grow out raising, optimum stocking density, salinity tolerance, crude protein level requirement of fish to further foster and include a new diversified species in the aqua farming basket.

Keywords: *Sillago sihama*, review, brackishwater aquaculture, sand whiting, diversification

1. Introduction

The importance of the commercial culture of marine finfish has grown up in recent years, followed by many successful trials conducted in coastal ponds and pens. Although India's vast and varied fishery resources have a rich production potential, this potential has not yet been efficiently utilized (Mishra *et al*, 2017) [50]. Marine finfish culture is believed to be an excellent investment in the country's saline water aquaculture sector (Gopakumar *et al*, 2012) [23]. With the techniques available in hand, a wide range of suitable species and the vast potential areas such as protected bays, lagoons, vast estuaries, brackishwater and backwaters areas, the scope for aquaculture of marine finfish in India on sound scientific lines is promising (Nammalwar, 2004) [54]. The finfish culture is in its infancy and is practiced only in a few pockets for species like seabass, milkfish, mullet, etc. The "sand whiting" or "sand borer", commonly known as "ladyfish" (Sillaginidae), has a high commercial value in capture and culture sectors (McKay, 1992) [49]. Among the five species listed by Fischer and Bianchi (1984) [21], only two species viz. *Sillago sihama* and *S. vincenti* are commercially important in India. *Sillago sihama* can tolerate significant fluctuations in the ecological parameters; rapid growth rate and excellent demand for tasty table fish make them preferred candidate species for culture in coastal sea waters, estuaries, and brackishwater (Bal and Rao, 1984) [9]. Looking at the ease of culture, wide salinity tolerance and preference by the local people (Bhakta *et al*, 2019) [11] and high price (Sawant *et al*, 2017) [64], the fish has considerable potential for the region. The introduction of the species will be one step boost towards diversification of aquaculture as the culture of the species is beneficial on account of its good growth, quality meat and market potential. Only few studies published the grow-out culture, brood development, food and feeding habits and artificial breeding of the fish but none have reported commercial farming of the species. Also, most of the studies don't focus on the field application. Hence, an attempt is made to review the research studies keeping in view the species potentiality as a candidate species for various brackishwater aquaculture systems and suggest future research studies to bridge the gap in their culture practices.

2. Scope of Diversification in Brackishwater Aquaculture

For the development of diversified aquaculture, cultivable carnivorous fish species like Asian seabass (*Lates calcarifer*), grouper (*Epinephelus tauvina*), snappers (*Lutjanus spp.*) are good alternatives. Among the herbivorous fish species grey mullet (*Mugil cephalus*), milkfish

(*Chanos chanos*), pearl spot (*Etroplus suratensis*), rabbitfish (*Siganus spp*.), orange chromide (*Etroplus maculatus*), cobia (*Rachycentron canadum*), silver pomfret (*Pampus argenteus*) and pampano (*Trachinotus carolinus*) are future options for the development of sustainable and eco-friendly aquaculture practice, (Biswas and Kumar, 2015) [12]. The introduction of certain fish species in aquaculture confers definite benefits like scavenging organic waste by finfishes ensures lower bacterial load in a culture system and reduces bacterial disease outbreaks (Paclibare *et al,* 2002) [55]. Viral diseases are a major threat to the shrimp aquaculture industry worldwide, and several viral outbreaks often cause catastrophic losses in shrimp farming around the globe (Lightner, 1996) [47]. To further increase the scope of brackishwater fish production, introducing newer varieties is the need of an hour. As the demand for fish rises, diversification of species in aquaculture by counting more species for increasing production levels has become essential (Alagarswami, 1981) [2]. The cost of production, survival and ease of managing carnivorous species delimits the widespread adoption of the finfish in aquaculture. The introduction of Sillago fish will be one step boost towards diversification of aquaculture as the culture of the species is beneficial on account of good growth, good quality meat, and its tolerance to a wide range of salinities (Bal and Rao, 1984) [9].

3. Distribution

The sand whiting is a vastly valued food fish occurring in the coastal and estuarine waters of the Indian and Western Pacific oceans from South Africa to northern Japan. (Jayasankar, 1989) [38]. The initial report of the family Sillaginidae in Indian waters was by Day (1876) [18]. He recorded three species of the genus Sillago: S. domina, S. sihama, and S. maculata. Devanesan and Chidambaram (1948) [19] reported the occurrence and distribution of *S. sihama* in Ganjam District, Pukkilipeta, Bimilipatnam, Uppada, Madras, Tranquebar and Sethubavachathram, Mukkur, Pamban and Tuticorin on the east coast and Hosdurg, Cannanore, Valapad, Calicut and Tannur on the west coast of India. It is distributed near coastal waters, brackishwater, and estuaries along India's east and west coasts. It is also reported from Hooghly river, Chilka lake, Visakhapatnam, Kakinada, Madras, Mandapam, Cochin, Karwar, Netravathy, and Gangoli estuaries and Goa (Sujatha, I987) [67]. The seasonal availability of *S. sihama* seeds may be similar in both the east and west coasts of India, with minor variations in the peak months in large quantities (James *et al,* 1984c) [35]. Bhakta *et al,* 2019 [11] and Sharma *et al,* 2014 have confirmed the availability of *S. sihama* fish species from the Narmada river and the Okha fish landing centre, Gujarat, during the period of January–December. At the same time, Sawant *et al,* (2017) [64] reported its presence from the coastal waters of Ratnagiri of Maharashtra.

4. Wild Seed Availability and Collection

The seasonal availability of the seeds may be equally distributed on the east and west coasts of India, with minor deviations in the peak months of abundance. The fish seeds are adequately available from the wild (Table 1) and A brief account of the seasonal availability of different life stages of *S. sihama* is described in table 2.

Sillago sihama is generally caught by gill net, drag net and cast net. It is seen almost throughout the year, most abundantly after monsoon rains in June (Radhakrishnan, 1957) [58]. The spawning of *S. sihama* in the laboratory was studied by Kuma and Nakamura (1978) [45].

5. Food and Feeding Habits

Several authors studied the food and feeding habits of *S. sihama* in Pulicat lake (Chacko *et al,* 1953) [16], Vansanthara Estuary (Chacko and Srinivasan, 1954) [17], Korapusha Estuary, Kerala (Chacko, 1949) [14], Karwar coast (Palekar and Bal, 1961) [56]. Lee *et al*. (1981) [46] recommended an appropriate feeding schedule for rearing the larvae of the fish in hatchery. The fish feeds on a wide variety of food materials supplied directly from the environment (James *et al,* 1984b) [34]. Kongkumnerd (1999) [42] conducted studies on the suitability of food, larval survival and growth of *S. sihama* larvae for 60 days. The results concluded that larvae rearing from 1-8 days old initially fed with small-sized rotifer, sieved through 80-micron mesh net, and gave the highest survival (35.98%). Larvae from 14-42 days old reared at the low density (2 fish litre-1) and fed with lipid-enriched *Artemia sp*. resulted in a survival rate of 86.62%. Krishnamurthy (1969) [43] have shown that during acclimatization from brackishwater to freshwater, fingerlings readily accepted prawn pulp and polychaetes while adults preferred polychaetes. Gowda *et al,* (1988) [26] studied the food and feeding habits of the fish from the Netravali estuary and revealed that the major food item of fish consists of crustaceans and polychaetes. Bumb (1992) [13] reported that a low rate of feeding intensity during summer and heavy feeding during monsoon did not prove a direct relationship between feeding intensity and maturation as well as spawning and the feed crude protein levels. Yousif *et al,* 2015 [71] reported better growth results when brooders were provided with a diet of squid, sardines, shrimps, and pelleted feed (52% crude protein).

6. Salinity Tolerance, Growth and Survival

Studying the salinity acceptance of eggs and larvae of the species in culture conditions, Lee *et al,* (1981) [46] inferred a superior acceptance of fertilized eggs resulting from ordinary spawning to salinity change than those from induced spawning. They also reported the salinity tolerance of larvae acclimated to lower salinities. Larvae survived longer in lower compared to higher salinities. Kongkumnerd (1999) [42] reported no significant difference in survival when reared in salinity of 20 and 30 ppt; however, the growth of larvae reared in 20 ppt was significantly higher than 30 ppt. Zhou *et al,* (2017) [73] studied the juvenile of *S. sihama* to examine the effects of salinity on the survival and growth of juvenile fish in a controlled environment. He reported that juveniles could survive at 0 ppt for 34 hr and when the salinity is 2ppt, the survival rate, total daily length growth rate, daily weight growth rate of the juvenile were 86.7%, 0.207 mm day-1 and 2.63 mg day-1, respectively. On the other hand, when the salinity was 49 ppt, the survival rate, total daily length growth rate, daily weight growth rate reduced to 66.3%, 0.064 mm day-1 and 1.13 mg day-1, respectively. The appropriate survival salinity of juvenile fishwas 1.4 - 45.1 ppt whereas, growth was evident in 1.6 - 40.2 ppt salinity and the optimal growth salinity was 2.0 - 7.0 ppt.

Lee *et al,* (1981) [46] have observed a better survival of the larvae in lower salinities. Similarly, Yousif *et al,* 2015 [71] recorded 87% survival rate during the grow-out phase but did not mention salinity. The fish has been considered suitable for freshwater and saltwater systems (James *et al,* 1976 [29]; Dhulkhed and Ramamurthy, 1977 [20]; Bal and Rao, 1984 [9];

Alagarswami, 1990) [2]. Radhakrishnan (1961) [59] recorded that selecting suitable seeds of finfishes for culture experiments in cages and ponds is very important. The growth rate of *S. sihama* was 15.6 cm (51.8 g) in 12 months at Mangalore. Yousif *et al*, (2015) [71] conducted fry rearing in a 40m3 growing tank and grown further for 32 weeks. During this period, fish were fed with 0.3-0.9 mm feed (52% crude protein) at 5% body weight per day, and fresh whole sardines were placed at the bottom of the tank. At harvest, the fish average body length was 13.6 cm (12.8 g) with an average daily body weight gain of 56.3 mg day-1 with a survival rate of 87% recorded at this phase.

7. Live Fish Transportation

James *et al*, 1976 [29] made transportation attempts of Sillago fish in oxygen-filled plastic bags and recommended 30 numbers of fish in 6 litres of water for a distance of 100 km. The salinity range was from 19.17-31.69%<), whereas Ramamurthy and Dhulkhed (1975) [60] suggested live fish transport in conventional fish cans of 35 litre capacity.

8. Crude Protein Level Requirement in the Diet

The fish readily accepts formulated pellet feed under culture conditions (James, 1984) [31]. Yousif *et al*, (2015) [71] conducted rearing of *S. sihama* with 52% crude protein and 58.4% crude protein, and 56.2% crude protein levels for 20 days old, 28-35 days old and 32-40 days old larvae and reported very low survival rates (only 1.0%). On the contrary, Huang *et al*, (2020) [28] recommended 45% dietary protein for the juveniles of *S. sihama* for the highest average final body weight gain with a low feed conversion ratio. Formulation of artificial feed for farming can be achieved at a meager cost (Huang *et al*, 2018) [27]; hence the cost of production will be comparatively low.

9. Culture Potential

The significance of the fish as food fish is perhaps underestimated because, in many areas, there are small-scale fishermen using seine net and hook-and-line in large quantities and do not necessarily enter in records of commercial catches (McKay, 1992) [49]. Scattered information is available on wide salinity tolerance (Bal and Rao, 1984 [9]; Zhou *et al*, 2017) [73] and broader feed acceptability (Krishnamurthy, 1969; Gowda *et al*, 1988) [43, 26]; Yousif *et al*, 2015) [71], but none of the reports showed the field application of the studies. Though the fish is a new species with immense culture possibilities, the main constraints behind the scaling up of *S. sihama* culture are the lack of information and studies on larval rearing, feed management, and farming systems. It becomes essential to survey the various cultural aspects of *S. sihama*, such as stocking densities and optimum salinity for growth and survival, feed & seed production, their economic feasibility etc. All these considerations will enable the technology to popularize at its new heights. The culture of *S. sihama* is only in its infant stage (Kumai and Nakamura, 1977). The species have been well documented as a potential species for culture in freshwater and marine water systems (James *et al*, 1976 [29], Dhulkhed and Ramamurthy, 1977 [20]; Alagarswami, 1990) [1]. Experimental culture of the fish has been initiated in Japan. Fry measuring 50 mm in fork length (average size) were cultured in a floating net cage and fed with minced fish meat. They grew up to an average size of 168 mm fork length, 310 mm standard length and 40.0 g in weight in a year (Kumai and Nakamura, 1978). Radhakrishnan (1961) [45, 59] suggested selecting suitable finfish seeds for culture experiments in cages and ponds is very important. He reported that being a non-predatory, the fish can be cultured in a polyculture system with other fish species.

The species can be cultured with *Chanos chanos*, *Liza macrolepis*, and *Valamugil seheli*, with a growth rate of *S. sihama*, which was 156.0 mm (51.8 g). The yield ha-1 and the survival were 26.7 kg (6.7%) in 12 months at Mandapam (James and Rengaswamy, 1984) [31]. In another polyculture trial, *Chanos chanos*, *Valamugil seheli* and *Sillago sihama* were stocked at a stocking density of 50,000 ha-1. The average monthly growth increments recorded for the above species were 22.7 mm and 10.3 g, 26.9 mm and 10.5 g and 16.8 mm and 8.1 g, respectively. (Nammalwar, 2004) [54]. At Mandapam and Tuticorin, mono and polyculture experiments in pens (size: 80 m^2) with Chanoschanos, Mugil sp. and Sillagosihama at a stocking density of 50,000 fry ha-1 yielded the production rate of 400-800 kg ha-1 (James *et al*, 1984b) [34]. The CMFRI also examined the possibility of culturing some economically important marine fishes (Rabbit fishes, groupers, and *S. sihama*) in low-cost cages erected in coastal waters at the Tuticorin coast. The average monthly growth rate for the species was 10 mm, which is encouraging (James *et al*, 1984b) [34]. At Mandapam, several experiments were designed to investigate the possibilities of culturing some economically important marine fishes in low-cost cages erected in coastal waters. Rabbit fishes, *Siganus canaliculatus*, *S. javas*, Groupers, *Epinephelus tauvina* and *E. hexagonatus* and sand whiting, *Sillago sihama* were cultured in the cages (James *et al*, 1984b, James *et al*, 1993) [34, 37]. The average monthly growth increments for *S. canaliculatus* and *S. javus* were 8.5 mm 3.1 g-1 and 6.6-6.2 mm 2.1.1 g-1, respectively. The mean monthly growth for *E. tauvina* and S. sihama were 19 mm 87.3 g-1 and 10 mm 1.6 g-1, respectively.

10. Market Potential

The fish has a ready domestic market in states like Kerala, West Bengal, and North-East India (Xavier *et al*, 2016) [70]. It commands a high price (Rs. 300-400 kg-1) in different states of India, especially in coastal Karnataka and has a vast export demand in China and Vietnam countries (Philipose, 2017) [57]. There is a huge potential to export Sillago to countries like Indonesia, Vietnam, and the Philippines. This species has a great demand in Indian metros, apart from the local market. Presently, Sillago spp. Is exported to the United Kingdom, Indonesia, Vietnam, and the Philippines. The United Kingdom is the main supplier of sillago to the international market with total quantities of 5,346 kg with $ 13,011 during 2018. (https://www.zauba.com).

11. Important Peculiarities and Future Perspectives

It is non – cannibalistic (Shamsan, 2008) [65] and compatible with other cultivable species like milkfish, grey mullets, rabbit fishes, pearl spot and prawns (Ramamurthy *et al*, 1978; James *et al*, 1984b; Nammalwar, 1997) [34, 53]. It is also used as potential live bait in the tuna industry due to its shiny and attractive appearance. (Alagarswami, 1981) [2]. The fish is suitable for pond, pen culture (James *et al*, 1984) [31] and cage culture (James *et al*, 1984b) [34]. It is also considered an appropriate and candidate species for culture in freshwater and saltwater systems (Dhulkhed and Ramamurthy, 1977 [60]; Kaliyamurthy, 1977; James *et al*, 1976, 1984, 1984c [29, 31, 35];

Alagarswami, 1990) [1]. The fish seeds are adequately availablefrom the wild (Table 1) and The fish seeds have a reasonably good survival rate compared to other brackishwater species (Nagayalanka, 2014) [52]. Apart from this, wide tolerance to salinity and temperature, better growth rate and high palatability make the fish prospects brighter for aquaculture in the coastal waters, backwaters, and estuaries (Jayasankar, 1989) [38].

Sillago can be a prime fish for species diversification in the brackishwater area. Disease prevalence is very low, and there has been no significant incidence of disease outbreaks in the Sillago farming sector until today. Due to disease outbreaks in shrimp, dumped farms and hatcheries can be utilized for Sillago fish farming and seed production.

12. Limitations

The species is not commonly farmed in the region. India has just introduced the farming of this fish. The farmers lack the package of practices for the species culture that need to be developed for better growth, survival, and economic feasibility, apart from the hatchery technique of producing the fry, which has been identified as the critical constraint to fish culture in the country. The farming is presently confined to a small-scale level. To meet the higher market demand, it is possible to scale up the production using larger net cages.

Table 1: Details of Production cost and Food Conversion Ratio for different finfish species

Sr. No.	Fish	Types of culture	FCR	Cost of production (Rs. kg^{-1})	Feed Cost (Rs. kg^{-1})	References
1	Milkfish (*Chanos chanos*)	Pond	4-5:1	90-100	30.0	Mandal *et al*, 2018 [48]
2	Tilapia (*Oreochromis mossambicus*)	Pond	1.25-1.5	142.19	28.0	Gammanpila & Singappuli, 2014 [22]
3	Seabass (*Lates calcarifer*)	Pond	1.5-1.7	175-225	55.0	Vijayan & Kailasam, 2018 [69], Gammanpila & Singappuli, 2014 [22]
4	Mullet (*Mugil cephalus)*	Pond	1.1:1		40.0	Syamadayal, 2017 [68]
5	Silver Pompano (*Trachinotus blochii*)	Cage	1.8-2.0	262.0	20-25	Aswathy *et al*, 2020 [8]
6	Cobia (*Rachycentron canadum*)	Cage	4.1:1 (Formulated-1:2)	156.0 (Formulated-90)	20-25	Aswathy *et al*, 2020 [8]
7	Groupers (*Epinephelus sp.)*	Cage	5:1	280.0	10.0	Baliao *et al*., 2000 [10]

Table 2: Seasonal availability of different stages *S. sihama*

Sr. No.	Region	Stage	Season	References
1	Palk Bay and Gulf of Mannar	Juveniles	Rainy season	Radhakrishnan, 1957 [58] and James *et al*, 1984d [36]
2	South Kanara coast	Juveniles	Rainy season	Ramamurthy and Dhulkhed, 1975 [20]
3	Gangolli estuary	Juveniles	Rainy season	James *et al*, 1976 [29]
4	Calicut	Fry	January - February, and October	Mohan, 1980 [51]
5	Pulicat lake	Larvae and juveniles	throughout the year	Ramamurthy *et al*, 1978 [61]
6	Palk Bay	Larvae and juveniles	throughout the year	James *et al*, 1984 [31]
7	UttaraKanada district	Larvae and juveniles	throughout the year	Reddy and Shanbhogue, 1990 [63]
8	Goa	-	throughout the year	Ansari *et al*, 2006 [7]
9	Palk bay	Young ones	throughout the year (abundance during January, May, and October)	James *et al*, (1982) [30]
10	Trivandrum coast	Young ones	April	Gopinath (1942) [24]
11	Trivandrum coasts	Post-larvae	end of December, with plenty in February	Gopinath, 1946 [25]
12	Karwar waters	Young juveniles	December - January	Palekar and Bal (1961) [56]
13	Gangolli estuary	Young ones	January - February	James *et al*, (1976) [29]
14		Spawning period	Beginning from November-March	Chacko (1950) [15]
15	Palk Bay and the Gulf of Mannar	Spawning period	winter months (probably October-February)	Radhakrishnan (1957 and 1961) [58, 59]
16	Karwar waters	Spawning season	August-October	Palekar and Bal, (I961) [56]
17	Pulicat lake	Fry and fingerlings	January - April	Nammalwar, 2004 [54]
	Adyar estuary		August - November	
	Chilka lake		October - June	
	South Kanara and Gangolli estuary		January – February	
	Palk Bay and Gulf of Mannar		July - September	
18	Narmada estuary in Gujarat	Adult		Bhakta *et al*, (2019) [11]

13. Conclusion

The sand whiting, Sillago sihama is a euryhaline, omnivorous and a candidate fish species for industrial culture. The introduction of Sillago fish will be beneficial because it occupies the lower level in the food chain, and thus its culture will be economical and eco-friendly. Sillago fish farming may prove advantageous on account of its easy adaptation to captive conditions, high growth rate, acceptance of low-value natural foods, higher survival,, ease of culture under higher stocking densities, low disease incidence, good taste, high market price, export potential and compatibility to various farming systems viz. pen culture, cage culture, monoculture, polyculture. Further, research focused on standardizing the protocol for the nursery raising, rearing and grow out culture will boost the acceptance of the species on a wider scale. There is a massive potential for developing feed manufacturing, feed input suppliers, brood-stock suppliers, seed production, and marketing enterprises associated with aquaculture. Ready markets are available at a national and international level to market hatchery-produced seeds and various processed Sillago based products. It can be cultured in a polyculture system along with other species. Sillago fish culture has the potential to revolutionize brackishwater farming due to low farm input costs, high profit margin and environment-friendly farming systems.

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