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Unique Behaviour-Driven Fishing Strategy of Freshwater Mullet, *Rhinomugil Corsula* (Hamilton, 1822) in Lower and Estuarine Stretch of River Ganga

Ranjan Kumar Manna*, Dibakar Bhakta, Sangeetha M. Nair, Srikanta Samanta and Basanta Kumar Das

ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal - 700 120

Abstract

The freshwater grey mullet, *Rhinomugil corsula*, exhibits distinctive behaviors in its habitat. Based on these behaiour patterns, eight novel capture strategies have been noticed for catching this species in the lower and estuary zones of the Ganges River. Fishers take advantage of the attraction to light by this species by using traditional gear such as 'Set barrier' and 'Cast net', along with light traps at night. The tendency of the fish to leap when escaping has inspired the use of an aerial trap called *'Chali tana'* in Nabadwip. Their habit of schooling and swimming at the surface is exploited with various modified lift nets – '*Chhita*' or *'Chowki jal'* in Buxar and Patna, Bihar, and '*Khancha*' in Roychak, West Bengal. The small mesh gill net, known as *'Corsula jaal'*, is effective when water is disturbed with a boat's oar, forcing the mullet to dive and become caught in the net. Other behaviors, like gathering in whirlpools or near drainage outlets, aid in using the scoop net, *'Thopa jal'*, in Tribeni. Juveniles of *R. corsula* are also collected alive near shorelines or drains using push nets and seine nets, for subsequent cultivation in ponds. This study sheds light on specific fishing techniques informed by the mullet's behavior, enhancing management of this valuable species in the wild and for aquaculture purposes.

Keywords: Fish behaviour, mullet fishing, light as fish trap, set barrier trap, aerial trap, lift net, gill net, scoop net, seine net

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**E-mail: rkmanna@yahoo.com*

Introduction

The freshwater mullet, *Rhinomugil corsula* (Hamilton, 1822) is a fish species under the family Mugilidae (Fig. 1). Considered as a single species of the monospecific genus *Rhinomugil*, the species is available in rivers and estuaries of Southeast Asia - reported from India, Nepal, Bangladesh, Myanmar (Talwar & Jhingran, 1991). Owing to its rich taste and demand, the freshwater mullet is a favoured food fish amongst the large section of the fish-eating community. This fish is a prized commodity inthe Indian subcontinent, where the market price varies from Rs. 250 to Rs. 500 per kilogram in lower Gangetic region (Sultana et al., 2013). Different aspects of biology of this fish has been studied like morphometrics (Hossain et al., 2015a; Hasan et al., 2020; Mukherjee & Chanda, 2020; Ara et al., 2021), breeding (Akter et al., 2012), food and feeding habit (Bhuiyan et al., 1994; Khan & Fatima, 1994) and population characteristics (Kumar et al., 2014; Ara et al., 2019) including its conservation status and overall fishery (Hasan et al., 2020; Hossain et al., 2015b). The fish has the unique habit of uninterrupted swimming along water edge with eyes remaining above the surface like many other mullets (Hora, 1938). Different biological aspects related to its swimming behaviour have drawn attention of researchers. The oxygen consumption, nitrogen excretion, and glycogen utilisation of the fish were investigated with particular relevance to swimming (Sukumaran & Kutty, 1969; Sukumaran & Kutty, 1986; Mohamed & Kutty, 1980). The fish is considered vulnerable in India, even though the IUCN Red List (2020) places it in the 'least concern' category (Dahanukar, 2004; Hossain et al., 2015b). Over-exploitation, habitat modification, indiscriminate destruction of juveniles are noticeable threats to sustainability of its fishery in open waters

(Hossain et al., 2015b). In river Ganga, *R. corsula* is distributed both in the rivers as well as in estuaries (Das et al., 2020). Thorough knowledge of the various fishing techniques used in the Ganga is necessary to comprehend its exploitation patterns and management requirements. The habit of leaping out of the water may not only be to avoid predation, but other factors like aid to respiration or adaptation to feed on floating matter as observed in many other mullets, e.g. *Mugil cephalus* (Holder, 1903; Hora, 1938; Hoese, 1985; Luther, 1973). Corsula are predominantly surface dwellers and move in shoals. They are very swift in nature, as they respond very quickly to escape by jumping over the water, as opposed to swimming away or submerging themselves against any slight disturbance (Luther, 1973). Hence, they are rarely caught in conventional fishing gears like gill net, cast net, bag net, etc. A large number of studies have documented fishing methods in river Ganga (Hornell, 1924; Mitra et al., 1987; Saxena, 1966; Srivastava, 1985; Remesan et al., 2009). Gear targeting mullets in estuaries and coastal waters have been reported by Luther (1973). However, no report is available on specific fishing strategy targeting *R. corsula* from inland waters of India. Our recent survey in lower and estuarine stretch of river Ganga revealed at least eight different unique methods for catching adult and juveniles of *Rhinomugil corsula* from river Ganga. Most of the methods are highly unconventional, designed based on the unique behavioural pattern of the fish. The conventional gears are also suitably improvised based on their behavioural pattern. The present paper describes these highly selective targeted fishing methods. Though fishing of this species is subsistence in nature, the strategies developed and adopted by the fishers revealed its unique behaviour, unlike other fishes. The present paper aims at documenting the highly targeted fishing methods to catch *Rhinomugil corsula* from open waters using unique fishing gears and knowledge associated with the specific behavioural pattern of the fish.

Materials & Methods

Primary information on the fish behavior vis-à-vis fishing methods was collected by observing the operation of various fishing gears in the selected stations of Ganga river (Fig. 1) as well as measuring the dimensions of the gear, mesh size, CPUE, etc. The secondary information related to the particular fishing method was documented through interaction with the respective fishers. The classification of the recorded fishing methods has been done following Brandt (1972) and FAO (1968 and 1987).

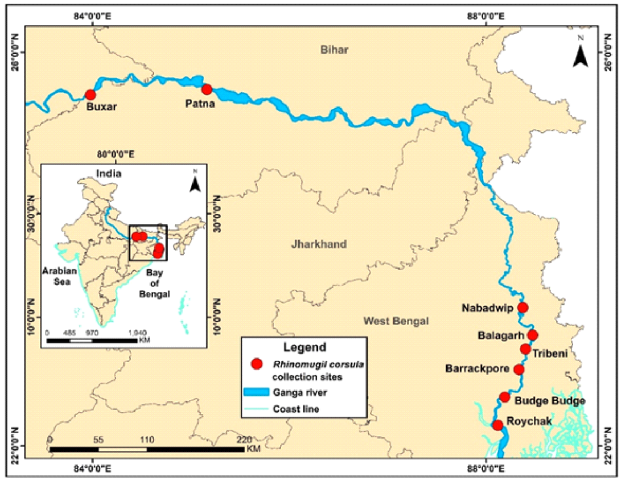

Fig. 1. Sampling stations at lower and estuarine stretches of River Ganga

Results and Discussion

Exclusive swimming behaviour of the fish was observed to have influenced the designing of different fishing gears targeting *R. corsula*. Unlike other fishes, *R. corsula* mostly swimson the water surface near the river edge in a shoal (Fig. 2) like many other mullets (Bhimachar, 1945). Catching the fish is a difficult since the bulging eye remains above the water surface during its movement (Hora, 1938) and therefore it responds very rapidly against any possible threat by leaping out of water and plunging at a certain distance (Luther, 1973). Most of the fishing methods targeting *R. corsula* are unconventional; fishing gears were fabricated keeping in mind the unique swimming behaviour of the fish. Moreover, the fish being phototactic, several conventional fishing gears like cast net, set barrier, etc are operated using light as fish trapping device during night hours. The fish is also observed to congregate near eddies or whirlpools and also at the mouth of drains. Some of the fishing strategies has also been conceived keeping this behaviour in mind.

The fishing gears targeting adult *R. corsula* recorded from lower and estuarine stretches of river Ganga can be categorised under six different heads. These are mostly set barrier trap, aerial trap, gill net, cast net, lift net and scoop net (Table 2). Two more methods (push net and shore seine) are adopted to collect the seeds of *R. corsula* from the river.

Fig. 2. Exclusive surface swimming behaviour of fresh-water mullet *R. corsula* (Inset: b *R. corsula*)

Set barrier (Chaurpata) with light trap: Set barrier is a fine / small mesh (10 mm) net screen used to trap the fishes approaching near the shore line in tidal stretch of the river. It is locally called as *Chaurpata* as '*Chaur*' means shoreline and '*pata*' means screen. Fishers take the advantage of wide fluctuation of water level between high and low tide in estuarine zone to catch *R. corsula*. A suitable stretch of the river with gentle slope is selected for operation of this fishing gear. During low tide, water recedes to make the muddy shoreline exposed. One side of a long net is inserted in the soft mud along the exposed shoreline. Bamboo or wooden poles are driven just beside the net with sufficient gaps in between in such a way that during high tide upper portion of the pole remains above the water surface. The net remains in rolled condition on the sediment surface

Table 2. Fishing methods in relation to fish behaviour for catching *Rhinomugil corsula* in river Ganga

Sl.	Type of fishing gear	Local name & place of record (within bracket)	Location	Fish behaviour manipulated for designing of fishing method	Name of the response / behaviour
		Fishing methods for catching the adults			
1	Set barrier with light trap	Chaurpata jal (Barrackpore)	22°462 22.73 N 88°202 063 E	Aggregating behaviour in presence of light	Phototaxis
2	Aerial trap	Chali tana (Nabadwip)	23°252 42.43 N 88°222 16.63 E	Jumping above water for escaping	Predator avoidance and aerial respiration
3	Gill net with manual disturbance	Arduyar jalla (Buxar);	25°342 53.83 N 83°582 42.23 E	Dipping inside water for escaping and coming to water surface after certain distance	Predator avoidance and aerial respiration
		Kharsula jal (Balagarh)	23°072 41.33 N 88°272 55.33 E		
4	Cast net with light trap	Khepla jal (Tribeni)	22°592 09.23 N 88°242 09.73 E	Aggregating behaviour in presence of light	Phototaxis
5	Lift net	a Chhita (Buxar);	25°342 53.83 N 83°582 42.23 E	Schooling and surface swimming nature	Feeding / respiratory adaptation / Shoaling behaviour
		Chowki jal (Patna)	25°372 16.53 N 85°112 00.13 E		
		b Khancha (Gajipur, Roychak)	22°142 52.83 N 88°052 15.53 E	Schooling and surface swimming nature	Feeding / respiratory adaptation / Shoaling behaviour
6	Scoop net	Thopa jal (Tribeni)	22°592 09.23 N 88°242 09.73 E	Aggregation in eddy or whirlpool	Destabilization of postures and trajectories
		Fishing methods for collection of juveniles			
1	Push net	Thela jal (Charial Khaal, Budge Budge)	22°282 44.53 N 88°102 12.63 E	Swimming in schools by juveniles linenear shore	Shoaling behaviour
2	Shore seine	Ber jal (Tribeni)	22°592 09.23 N 88°242 09.73 E	Higher abundance of juveniles near drain outlet	Upstream migration

with the upper side of the net tied with the top portion of the pole by a rope. During high tide, water level rises to submerge the net. For catching the *R. corsula*, the operation of the gear is performed during night hours (time varies with tidal cycle) using an illuminating device (mostly lantern) which is placed on the river bank during high tide (Fig. 3). During the process, shoal of targeted fish gets attracted and assembles around the light, the net screen is then lifted with the help of the rope tied with the poles. Fishes are thus cornered by the net screen along the river bank. Once the level of water again recedes during low tide, fishes are trapped within the net which are further handpicked. The height of the set barrier net remains 1.5-2.0 ft above water surface to avoid escape of *R. corsula* by jumping. More catch of the fish is reported during spring tides. Being a barrier type trap, this gear was observed to catch all sizes of the fish, from adult to juvenile (56-166 mm; 1.8-38.9 g).

Light fishing is commonly manipulated in many active gears especially in marine waters (Ben-Yami, 1976; Marchesan et al., 2005; Okpala et al., 2017). Manna et al. (2011) earlier reported use of a falling gear using light as Fish trapping device from lower stretch of river Krishna, a peninsular river in India.

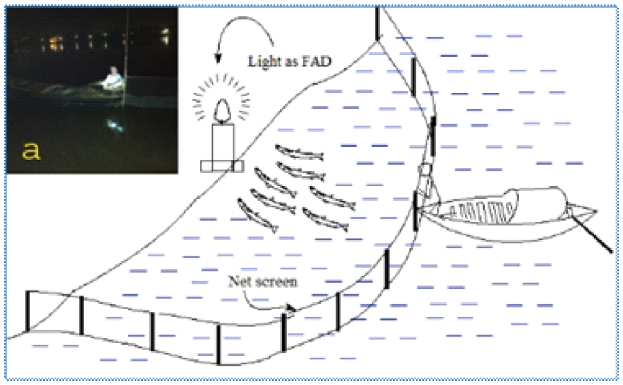

Fig. 3. Setting of 'set barrier' using light for catching *R. corsula* (Inset: Set barrier operation in night)

Aerial trap (Chali tana): Utilizing the leaping behaviour of *R. corsula*, an aerial trap was observed to be in use to catch the fishes from the river at Nabadwip, West Bengal. A rectangular sheet, locally known as 'Chali' (about 2.5 m long, 1.5 m wide) is prepared using the jute sticks tied by bamboo strips (Fig. 4a). Subsequently, banana stem leaf sheaths (Fig. 4b) are tied at both sides of the sheet in such a way that the concave side of the sheath remains inside. Three such sheets are tied together to form a long chain (Fig. 4). They are tied on one side in such a way that they can easily be configured into a 'U' shaped structure. The whole structure floats on the water during operation. One side of the sheet is tied near river bank and other side is held by a fisher sitting on a boat in the middle of the river. The fishes are trapped when *Rhinomugil* come near the floating gear. The fishers quickly drive the boat towards the river bank to surround the fish shoal. On being obstructed by banana stem, the fishes jump out of the water and plunge on top of the jute stick sheet to get captured. The gear is mostly operated during the months of October- November at night hours from 8-10 pm. In some parts of the river, for preparing the sheet, reed grass stem is used in place of jute stick. The gear caught mostly targeted adult fishes (125-168 mm; 17.3-41.9 g), however sub-adults are also caught in some cases.

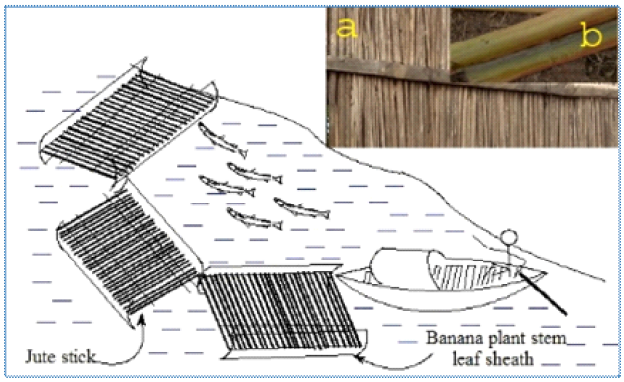

Fig. 4. Aerial trap to catch jumping and leaping *R. corsula* (Inset: a: Jute stick made sheet; b. Banana stem leaf sheath)

Gill net (Fansh jaal): Though *R. corsula* is also caught using the most popular fishing gear in the river i.e. gill net, the surface swimming behaviour helps the fishes to swim over the net and also escape the net by jumping. The fishes being cylindrical in shape, are difficult to catch using gill net. However, based on the target size group, 15-18 mm drift gill net is used to catch the fishes (Fig. 5). During drift gill net operation, to avoid the fishes from escaping by jumping, the fishers strikes hard on the water using the oars, to elicit diving behaviour in fishes, thereby reducing escape. Operation during evening hours with coloured float increases efficiency of the gear. Being highly specific gear with a fixed mesh size, only adult fishes with limited size range (151 – 168 mm; 29.6-41.9 g) are caught.

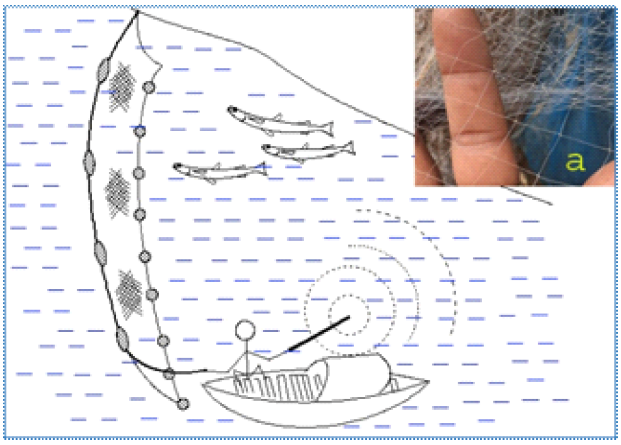

Fig. 5. Gill net operation involving disturbance in water to catch *R. corsula* (Inset: gill net, 18 mm mesh)

Cast net (Khepla jal) with light trap: Cast net is a circular falling gear where it is thrown on the water over the fishes. While trying to escape from the net, the fishes enter the pockets present at the periphery of the gear and get caught. Due to the fact of surface swimming nature, capturing *R. corsula* by cast nets is difficult. Therefore, during night hours, fishers keep a kerosene lantern (light trap) near the river banks allowing the fishes to aggregate near the light when fishers go silently and cast their net (10 mm mesh) to capture the fishes (Fig. 6). Fishing with light is a well-studied area in fisheries research, however the same was not reported for catching freshwater mullet *R. corsula*. The gear was observed to have Corsula catch consisting of both adult and sub-adults (98-151 mm; 6.9-29.6 g).

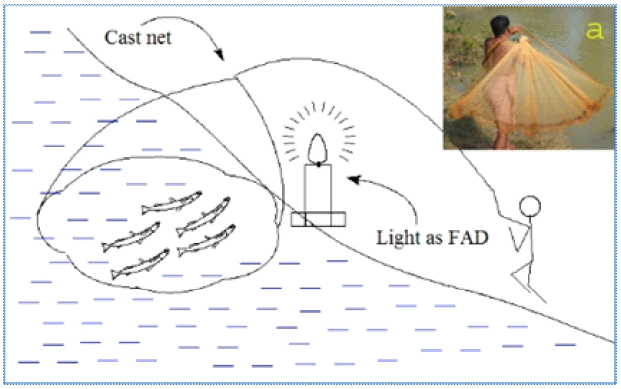

Fig. 6. Fishing of *R. corsula* using cast net with light trap (Inset a: the fishing gear)

Lift net: Two types of lift nets targeting *R. corsula* were recorded from lower and estuarine stretch of river Ganga. However, the fish being surface-swimmer promptly escapes usual lift net operation. Hence, suitably modified conventional type lift nets are operated. A square shaped lift net (*Chhita* / Chowki jaal) was documented from Buxar – Patna stretch of river Ganga, whereas trapezoidal shaped lift net (Khancha) was recorded from Gajipur, Roychak in estuarine stretch of the river.

Chhita / Chowki jaal: A square shaped net (2.0 m x 2.0 m approx.; 10 mm mesh) lined with rope is used for preparation of the gear (Fig. 7). Four corners of the net are tied with two bamboo strips where each strip is tied with diagonally opposite corners and forms a dome-shaped structure. A rope is tied at the crossing point of two bamboo strips to operate the gear. The gear is placed inside water near the shoreline with the attached rope reaching up to certain distance in river bank. Sitting at a distant place, fisher keeps eye on the movement of the fish while holding the rope. The whole gear is rapidly lifted from water by sudden pull (jerk) of the gear with the help of the rope when it is observed that the target freshwater mullet, *R. corsula* swimming above the net. Size range of the catch consisted of adult fishes (140-154 mm; 20.6-33.8 g).

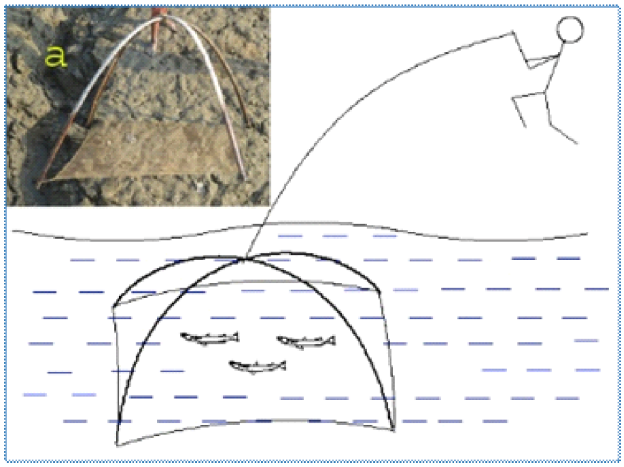

Fig. 7. Sudden jerky lift to catch *R. corsula* in river Ganga (Inset a: Chhita/ Chowki jal)

Khancha: An isosceles trapezoidal shaped net (9 ft x 10.5 ft x 4.5 ft x 10.5 ft) is used to prepare the modified lift net locally called as 'Khancha' (Fig. 8). The net (10 mm mesh) is lined with a rope along the periphery. Small metallic sinkers are attached with the two equal-sized side ropes so that during operation, net does not float. Smallest side (4.5 ft) of the net remains towards the fisher sitting at a distance on the river bank. Two thick ropes are tied at the two farthest corners. Those two corners are

also attached with two iron rods of about 1.5 m length each. At other end, those corners are tied with wooden nails, which are inserted inside the sediment to fix the gear at a selected place. The iron rods are fixed at the bottom and, the net structure is also fixed with ropes tied at four corners and wooden nails. Fisher hold both the thicker ropes by sitting at a distance from the river bank so as to not alert the fish. As soon as fishes come above the net, fisher drag to lift the net above water along with the fishes. During the survey, about 500 g of fish was observed to be caught in 2 hrs during low tide. Mostly adult fishes (135-147 mm; 18.6-27.8 g) constituted the catch (Fig. 8).

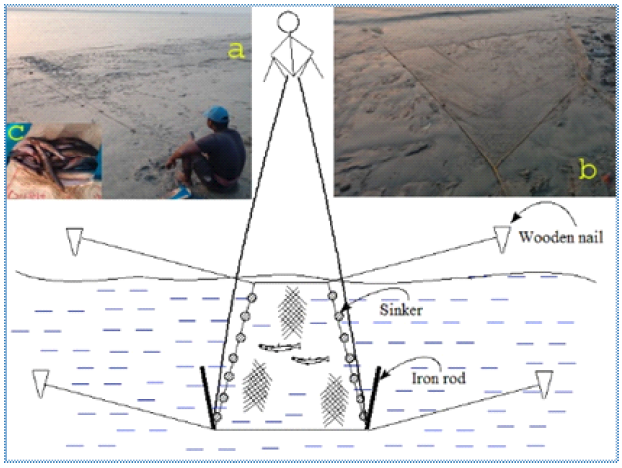

Fig. 8. Sudden jerky lifting of gear to catch *R. corsula* (Inset a: Fisher operating the gear; b: the gear)

Scoop net (Thopa jal): Tidal zone of estuarine stretch of river Ganga experiences many eddy or small whirlpool during high tide where mullets prevail in shoals due to higher availability of natural fish foods. There are circular movement of water around the eddy, hence fishes are unable to recognize any other source of small disturbance. Fishers take this opportunity to go inside water with a scoop net (10 mm mesh) with long handle (locally known as *Thopa jal*) and scoops out the swimming fishes present inside the eddy (Fig. 9). Eddies are already known to have similar strong influence on fish swimming abilities (Tritico & Cotel, 2010). Higher abundance of adults was also noted at the point of discharge of municipal wastes. Such aggregation is observed to be manipulated by the fishers using same gear. The diameter of the frame in which the net is attached is approximately 0.6-0.7 m whereas length of the bamboo-made handle is 1.25 -1.5 m. Adult and sub-adult fishes (115-144 mm; 12.5-24.3 g) both were caught by this method.

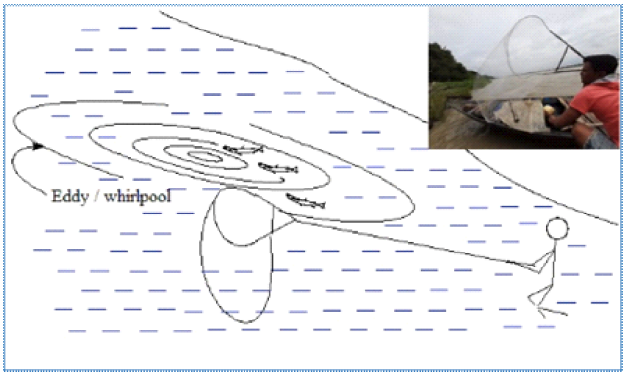

Fig. 9. Congregation of *R. corsula* in eddy is manipulated by Thopa jaal, a scoop net (Inset: the gear)

Fishing methods targeting juveniles: In recent times, demand for Corsula juveniles as input for aquaculture is noticed in different parts of West Bengal. Since standard breeding and rearing protocol is yet to be established, *R. corsula* seeds are collected from river. During monsoon, fish seed is collected by push net or shore seine (made of fine mesh mosquito net) and kept live in water for marketing which fetches high price. The fish juvenile (mostly spawn) are marketed @ Rs 1.00-2.00 per piece. Higher abundance of both adult and juvenile fishes was noted near the mouth of the sewer discharging municipal wastes. The fish is reported to feed on plant derivates, along with small fish, insects, etc. (Bhuiyan et al., 1994) and hence organic detritus coming to the river through municipal drain can be devoured by the fish.

Push net: Push net or skimming net is afine mesh net fitted to a triangular frame made of bamboo. The gear is placed in waste-dip water and pushed to a certain distance before lifting (Fig. 10). Juveniles of fishes, prawn are mostly targeted using the gear. The gear was observed to be in use at Chariyal Khal (Budge Budge) to collect juvenile stages of *R. corsula* from the river. Collected seed is transported live and kept in a plastic sheet made pool for marketing. However, the process is highly destructive, as it destroys many non-targeted fish and prawn spawns / juveniles.

Seine net: A rectangular piece of fine mesh net with size approx. 1.5 m x 4.0 m is employed as a shore seine which is operated by two persons by surrounding an area with higher abundance of mullet juveniles (Fig. 11). Discharge points of municipal waste water are mostly selected as preferred site for operation. Captured fish seeds are

Fig. 10. Habit of swimming in shoal near shoreline guides the operation of push net to collect juveniles of *R. corsula* (a: Operation of gear; b: Live condition preservation)

immediately transferred in live condition to a container for marketing. Similar to push net as described above, the gear destroys spawn of many non-targeted fish and prawns in open waters and hence should be discouraged.

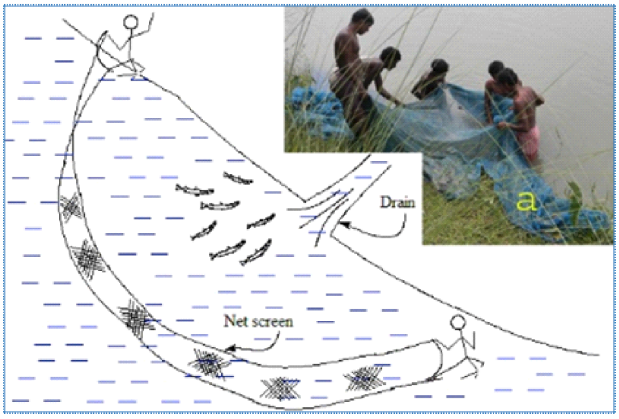

Fig. 11. Aggregation near drain mouth guides Seine net operation to collect *R. corsula* juveniles (Inset: Zero mesh net)

R. corsula is a fish with high demand and hence offered better price than most of the other fishes collected from river Ganga. Most of the fishing gears targeting mullet harvest the fishes in live condition without much injury. The fish also remains live for long time when compared to other riverine fishes. Natural collection of juveniles generally affects sustainability not only to the targeted fish seed, but also other fishes. Reported breeding period of the fish is April to July (Bhuiyan et al., 1994). But, as observed the fishes are mostly targeted during breeding season, which is also highly detrimental to sustainable fishery. Breeding technique of the fish requires to be developed and protocol needs to be standardized to protect its natural stock. The species *R. corsula* can offer a potential candidate fish species for aquaculture in terms of species diversification (Radheyshyam et al., 2011; Jahan et al., 2021). Knowledge about the effective fishing methods can help in getting suitable brood fishes in live condition from natural waters.

Conclusion

Like many riverine fish species, the stock of *R. corsula* is rapidly declining in numerous rivers and estuaries due to a variety of anthropogenic factors. Over the years, there is a loss of traditional fishing gear and unique techniques, partly attributed to reduced catches and changing social dynamics. These traditional fishing methods, which have been evolved over time and are largely based on the behaviour of the species, are crucial for gear-based conservation efforts and, as such, must be preserved and this manuscript is an attempt towards.

Furthermore, while the fishing techniques and methods detailed herein are mainly for subsistence purposes, our study has found that they are inadvertently capturing a significant number of juveniles, thereby posing a risk to sustainability. Therefore, it is essential that regulations be applied to even small-scale gears to safeguard the long-term sustainability of this fishery.

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