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Review Article

Reviews on the biology and culture of Silver Pomfret, *Pampus argenteus* (Euphrasen, 1788)

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Abstract: Silver pomfret, *Pampus argenteus* (Euphrasen, 1788) is one of the most valuable and desired table fishes of the world. It has high economic value and has been reported to contribute significantly in the commercial fishery in its native ranges. Considering its high economic value, it is really necessary to have scientific knowledge on its biology and culture so as to continue its fishery in long run. Substantial research has so far been conducted to gather information on its biology and culture, but till date no such consolidated report is available on these aspects. The present work has been focused to gather the already documented information on its biology and culture, and to point out the scope of further research to support its fishery and trade. Considering the information summed up in the present report, it is evident that ample information is available on its feeding and reproductive biology, but information on its culture methodologies is scanty. Hence, further study is needed to gather more information on its culture and rearing methodologies to support its fishery and trade in coming days.

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Introduction

Silver pomfret (*Pampus argenteus*) belongs to the family stromateidae under the order Scombriformes. It is one of the most valuable and desired food fishes found worldwide due to its soft and tender flesh, lesser number of bones and good taste, high protein and fat content (Masuda et al., 1975; Solanki et al., 1976; Fei et al., 2011; Hossain et al., 2011a, b, c, 2012a, b, 2016; Peng et al., 2012a, b). It is an important fisheries resource due to its high economic value and export market; and for a long time, has been reported to significantly contribute to the commercial fishery of its native countries (Pati, 1980; Khan, 1982; Dwiponggo, 1984; White, 1984; Kim and Lee, 1992; Mohamed and Ali, 1992; Luo et al., 1993; Al-Qattan, 1998; Ali et al., 2000; Al-Husaini, 2003; Almatar and James, 2007; Mohamed et al., 2008; Shi et al., 2009a, b; Liu et al., 2014a, b; Din et al., 2015). Its utilization in preparation of Chinese medicine has also been reported (Tang, 1987). Considering the high economic value of silver pomfret, it is really necessary to gather scientific knowledge on its biology and culture, so as to continue its fishery and trade in a sustainable manner. Earlier, considerable researches have been conducted on its biology and culture; however consolidated report on these aspects is unavailable till date. This report has been focused to summarize the already available information on its biology and culture and to explore the field of further research by specifying the information lacunae to support its fishery and trade in the coming days.

Morphological characters: The body is strongly compressed and oval in shape. The dorsal and ventral profile, both are almost equally convex. Caudal peduncle is short, deep and strongly compressed; scute-like scales or fleshy keels are absent. The mouth is small, sub-terminal, slit-like and curved downward posteriorly. Upper jaw is covered with skin and unmovable. Single row of villiform teeth are present on both the pre-maxillary and dentary bones. The teeth on the pre-maxillary bone are mostly uni-cuspid in nature, conical in shape and blunt, and are interspersed with a few tri-cuspids, while those on the dentary are mostly tri-cuspid in nature, narrow, sharp, and are

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interspersed with a few uni-cuspid teeth. The snout is blunt, projected over the mouth; the maxilla is reaching below the first third of the orbit. Eyes small, central and are with feeble adipose lids. Gill membranes are joined to belly; gill slit short; total gill rakers on first gill arch ranges from 10-13.

Fin: The dorsal and anal spines are in a truncated form above the skin. Anterior portion of the soft dorsal fin is elevated, but not that much extent as that for the anterior part of the anal fin which in the immature forms reaches to below the middle of the caudal fin; but as age advances it gradually becomes shortened. Dorsal fin with 37-43 fin-rays while anal fin with 34-43 fin-rays. The pelvic fins are absent. The pectoral fins are elongated and pointed with 24-27 fin-rays. The caudal fin is deeply forked; the lower lobe is much longer in the immature, sometimes being twice as long as the upper lobe. Scales are small, cycloid and deciduous in shape; extend to the base of all the fins; slightly enlarged near the caudal peduncle. Vertebrae 34-37 in number.

Colour: Upper surface of the head and back as low as the lateral line is neutral gray with purplish shine; sides of the head and body is silvery gray that is fading to white on the abdomen. A dark spot is present on the upper portion of the opercle. Dorsal and anal fins are minutely dotted with black; the outer half being the darker. Caudal and pectoral fins are yellowish-white, also are minutely dotted with black, the outer half being the darker. The iris is silvery. The young are much darker; the vertical fins are being nearly black (Day, 1878; Talwar and Jhingran, 1991; Al-Qattan et al., 2000).

Distribution: *Pampus argenteus* is widely distributed throughout the Indo-Western Pacific region, the eastern part of China, the western and south-western Korean Peninsula and the western Asia including the Persian Gulf (Day, 1878; Pati, 1982; Haedrich, 1984; Davis and Wheeler, 1985; Kagwade, 1988; Cho et al., 1989; Kim and Lee, 1992; Al- Hussaini, 2003; Azad et al., 2007; Almatar and James, 2007; Shi et al., 2009a,b; Zhao et al., 2011; Siyal et al., 2013; Egderi et al., 2019).

Habitat: *Pampus argenteus* is an inshore species; used to inhabit mainly brackish waters and estuaries and occurs in shoals over the muddy bottoms (Abdurahiman et al., 2006). It is used to live at a depth range up to 110 m (Haedrich, 1984; Khan, 2000; Shafi and Quddus, 2003; Mohamed et al., 2008).

Feeding biology

Food and feeding habit: To analyze the food and feeding habit of *P. argenteus*, so far plenty of research has been done in countries of its native range (Suyehiro, 1942; Rege, 1958; Kulkarni, 1958; Chopra, 1960; Kuthalingam, 1963; Nath, 1966; Rao, 1967; Pati, 1980; Mohamed and Ali, 1994; Dadzie et al., 2000a; Khan, 2000; Sivakami et al., 2003; Abdurahiman, 2006; Peng et al., 2011; Thangavelu et al., 2012).

Suyehiro (1942) has documented the presence of some gelatinous substances and medusae in the gut content of silver pomfret in his study in Japan. Similar kind of observations has been made further by Kulkarni (1958) and Chopra (1960). High percentage of tunicates, copepods, isopods, medusae and fishes has been noted by Kulkarni (1958) while Chopra (1960) has reported the presence of tunicates, jelly fish and medusae in the gut content of *P. argenteus*. Rege (1958) has recorded gelatinous material in the diet of silver pomfret from Bombay waters in addition to the occurrence of salps, hydromedusae, amphipods, copepods, shrimps and other small fish groups. He further has reported zooplankton and phytoplankton as the most favourite diet for this fish species.

Kuthalingam (1963) has reported crustaceans to form the main bulk of silver pomfret diet. Larger crustaceans like *Penaeus* spp., *Acetes* spp., *Squilla* spp. and anomurans have been reported to form the main bulk of adults' diet. Other components of the diet include copepods (*Oithona* spp., *Euterpina* spp. and *Eucalanus* spp.), copepod nauplii, ostracods, amphipods, *Lucifer*, zoea larvae, larval crustaceans, polychaetes, *Sagitta* sp., larval bivalves, fish scales, vertebrae, flat fish, foraminifera, algal filaments and diatoms with good quantity of mucous. High percentage of copepods and cypris along with amphipods, ostracods, cladoceran, decapod larvae,

crustacean remains, gastropod larvae, calcareous remains, fish eggs, fish scales, polychaete remains has been documented by Rao (1967) in the gut content of *P. argenteus* in his study from Andhra-Orissa coast.

Pati (1980) has documented copepod as the main food item for *P. argenteus*. *Acrocalanus* spp., *Centropages* spp., *Euterpina* spp., *Nannocalanus* spp., *Oithona* spp., *Temora* spp. and *Acartia* spp. have been documented as the mostly preferred copepods while *Paracalanus* spp., *Eucalanus* spp., *Corycius* spp. and *Pseudodiaptomus* spp. are the less preferred copepods. Apart from copepod, presence of ctenophores and medusa, diatoms, polychaete larvae, polychaete remains, copepod eggs, copepod nauplii and fish scale have been documented in the stomach content almost throughout the season and formed a fair percentage in the diet. Decapod remains, ostracod, amphipod, decapod larvae, cladoceran, bivalve larvae, gastropod larvae, fish eggs, fish larva and algal filaments have been reported as occasional food items while rare occurrence of *Acetes* spp., *Lucifer* spp., marine insect and *Sagitta* spp. in the diet has been documented. Unidentified content in the form of semi-digested pulpy mass has been reported to form the maximum part of the diet.

Nath (1966) in his study at Kerala coast has considered silver pomfret as a macro-plankton feeder; feeds mainly on crustaceans and polychaetes while Mohamed and Ali (1994) have documented silver pomfret to feed mainly on crustaceans with copepods as the dominant group. Other components which have been reported in its diet are tunicates, medusa, jellyfish, fish larvae, eggs and scales.

Dadzie et al. (2000a) in their study from Kuwait waters have reported total 19 types of crustacean items, three genera of bacillariophyceae (*Coscinodiscus* sp., *Rhizosolenia* sp. and *Hemidiscus* sp.), one species of *Sagitta* and one species of *Noctiluca* in the gut content of silver pomfret along with lamellibranch veliger larvae, polychaete larvae, fish larvae, eggs of fish and invertebrates, fish scales and filamentous algae. White pulpy masses have also been documented in the gut contents. Copepods and their eggs have been reported as the major food component followed by bacillariophyceae, other crustaceans, mollusc and fish scales. Fish eggs and larvae have been recorded as the least common items.

Khan (2000) has reported the presence of mostly digested material and gelatinous substance in the stomach content of *P. argenteus*. Copepods and amphipods have been documented in few occasions while young ones of some fish species like *Apogon* spp.; *Myctophum* spp.; *Nematopalaemon tenuipes* and fish scales have been rarely documented.

Sivakami et al. (2003) have reported crustaceans such as copepods (*Oithona* spp., *Euterpina* spp., and *Eucalanus* spp.), copepod nauplii, ostracods, amphipods, *Lucifer* sp. and zoea larvae along with larger crustaceans (*Penaeus* spp., *Acetes* spp., *Squilla* sp. and anomurans) in the diet of adult *P. argenteus*. Other food items encountered are polychaetes, larval decapods, foraminiferans, *Sagitta* spp. and sand particles.

Abdurahiman (2006) have reported crustaceans and detritus as the major diet components of *P. argenteus*. Among crustaceans, copepods have been documented as the most important food item followed by amphipods and nauplii larvae. Presence of fish items (cycloid and ctenoid scales, fish eggs and fish remains), diatoms (*Nitzschia* spp. and *Coscinodiscus* spp.) and worms has also been reported with decreasing order of importance in the diet.

Peng et al. (2011) have documented *Sagitta* sp. as the most important food item along with shrimps, jellyfish, cephalopods, fish larva and zooplanktons for silver pomfret. Thangavelu et al. (2012) have reported detritus and copepods to share the maximum part of the diet in silver pomfret. Penaeid prawns, *Acetes* sp. and fish larvae have also been recorded as other food items in the gut content.

Seasonal and depth wise variation in feeding: Investigating the seasonal variation in the diet of silver pomfret in Indian water, Kuthalingam (1963) has reported that crustaceans used to form the bulk of the diet throughout the year, with highest percentage contribution in the month of February. The reduction in the occurrence of the crustaceans in the diet during March has been reported to become compensated with

an increase in uptake of teleosts, polychaetes, molluscs and miscellaneous items. Availability of various food items in the particular habitat has been concluded as the main factor behind this kind of fluctuation in diet. Depth wise variation in diet of silver pomfret has also been reported by Kuthalingam (1963); fishes captured from the range of 5-15 fathoms had maximum percentage of crustacean items while those captured from the range of 15-40 fathoms had polychaetes and foraminifera as the dominant items of the diet.

Dadzie et al. (2000a) in their study observed seasonal variation in percentage frequency of occurrence of different food items in the stomachs of *P. argenteus*. More variety (22 items with frequent occurrence) of food items have been documented in summer than in winter (11 items with frequent occurrence) and this variation has been reported to be due to the variation in availability of the prey organisms in the environment.

Abdurahiman (2006) has reported seasonal variation in feeding mainly in respect to pre-monsoon and post-monsoon season. Detritus followed by copepods, diatoms and fish items have been reported as the mostly preferred food items in pre-monsoon while in post-monsoon season, detritus, copepods and fish items have been documented as the mostly preferred food.

Ontogenetic shift in food preference: Pati (1980) has reported a striking change in the diet from post-larval stage to the adult. He has reported that the post-larvae are dominantly phytoplankton feeders, feeding on diatoms like *Coscinodiscus centralis*, *Thallasiothrix frauenfeldii* and *Pleurosigma normanii*. With gradual growth, the juveniles have been reported to change their preference over copepods, copepod eggs and nauplii, and smaller crustaceans. Polychaete remains have been documented first in the size group of 8-9 cm and has been reported from rest of the successive size groups. With further growth, increasing number of items in the diet has been documented with proportional decrease in the amount of copepod and diatom elements, but this has been reported to become compensated by other crustacean elements, jelly fishes, polychaete larvae and chaetognaths.

Kuthalingam (1963) has reported high percentage of large crustaceans like *Penaeus* spp., *Acetes* spp., *Squilla* spp. and anomurans in the diet of adult silver pomfret while juveniles have been reported to feed mainly on copepods and other small crustaceans. Dadzie et al. (2000a) have reported that in the size groups 145-164 to 205-224 mm, copepods and other crustaceans have high preference over other food items while size group 225-244 mm has maximum preference for bacillariophyceae. In size group 245-264 mm, again high preference for copepods and other crustaceans has been reported while size group 265-284 mm prefers only copepods and other crustaceans. Sivakami et al. (2003) have reported size specific difference in food preference; small sized fishes within size range of 18-26 mm has been reported to prefer copepods (*Paracalanus parvus*, *Oithona* spp., *Euterpina* spp., *Macrosetella* spp., *Temora* spp., *Acartia* spp., Harpacticoid copepods), ostracods, amphipods, larval stages of *Squilla* sp. and *Lucifer* sp. while adults prefer small crustaceans along with larger crustaceans.

Ontogenetic shift in food preference has also been reported by Abdurahiman (2006). Detritus and copepods have been reported to be highly preferred in almost all the size groups. The size group of 91-120 mm length has been reported to prefer detritus and copepods followed by *Nitzschia* sp. and mysids. In size group of 121-150 mm length, detritus, *Oratosquillanepa*, copepods and fish eggs have been documented as preferred food items. Fishes in size group 151-180 mm length have maximum preference for detritus followed by copepods and *Nitzschia* sp. In the size group of 181-210 mm length, detritus, copepods, cycloid fish scales and *Coscinodiscus* spp. have been documented as preferred food items. The size group of 211-240 mm length has been reported to prefer detritus and copepods followed by mysids and *Nitzschia* sp. In the size group of 241-270 mm length, detritus, copepods, *Coscinodiscus* spp. and amphipods have been documented as preferred food items while for size group of 271-300 mm length, copepods, detritus, fish remains and amphipods have been

reported for the same. In size groups above 180 mm, preference for copepods has been reported to increase simultaneously with relative decrease in preference for detritus in the diet. Thangavelu et al. (2012) have also reported an ontogenetic shift in diet with increased consumption of copepods in large length groups with decreasing proportion of detritus matter.

Change in feeding intensity: Reduced feeding intensity during the breeding season has been reported for mature specimens of *P. argenteus* by Kuthalingam (1963), Pati (1980), Dadzie et al. (1998, 2000a) and Hossain et al. (2011a). Pati (1980) further has documented that increasing surface water temperature has inhibitory effect on feeding intensity of immature silver pomfrets.

Reproductive biology

Sex ratio: Most of the earlier researchers (Mohamed and Ali, 1993; Al-Abdul-Elah et al., 2002; Almatar et al., 2004; Narges et al., 2007; Nasir, 2016) have reported male dominance in the natural populations of silver pomfret except Oda and Namba (1982), Dadzie et al., (2000b) and Ghosh et al. (2009) who have reported female dominance in their studied populations. Sivakami et al. (2003) and Shi et al. (2006) have reported equal proportion of male and female in their studied populations.

Length at first maturity: All the earlier researchers have documented early maturation of male than the female in silver pomfret. Gopalan (1967) has reported 22 and 26 cm as lengths at first maturity for male and female of silver pomfret from Arabian Sea while Pati (1982) in his study at Bay of Bengal, reported 15 (male) and 17 cm (female). From their study at eastern part of China, Lee and Jin (1989) have documented 16.7 and 18.6 cm as lengths at first maturity for male and female, respectively. Dadzie et al. (2000b) also have observed early maturation of males (minimum size at maturity 12.5-14.4 cm) than females (minimum size at maturity 20.5-22.4 cm) in populations of silver pomfret from Kuwait waters. Narges et al. (2007) also have documented early maturation of males (18 cm) than females (22.2 cm), but that is based on fork length (FL). Mean lengths of 11.2 and 15.5 cm have been documented as length at first maturity for male and female, respectively in Iraqi water by Mohamed et al. (2008). Sivakami et al. (2003) have reported 15 and 17 cm in standard length as length at maturity for male and female, respectively. Almatar et al. (2004) have documented smallest mature male and female at the standard lengths of 12.7 and 16.5 cm, respectively in Kuwait waters.

Gonad maturity stages: Dadzie et al. (1998) have reported six maturity stages based on some macroscopic and microscopic characters to identify different maturity stages of testes which have been summarized in Table 1. Only two maturity stages namely immature and mature has been identified by Lone et al. (2008a); they have reported that the immature fishes have very thin, streak like organ which become steadily thicker and bigger with maturity. The mature testes are creamy in colour and with increased blood supply. Almatar et al., (2004) and Lone et al. (2008b) have documented eight gonad maturity stages namely (i) developing virgin, (ii) developing, (iii) developed, (iv) gravid, (v) running-ripe, (vi) partially spent, (vii) recovery and (viii) resting in female. The macroscopic and microscopic characters which have been documented for these different maturity stages have been summarized in Table 2. Dadzie et al. (1998) have reported seven maturity stages namely (i) immature, (ii) maturing virgin/ recovering spent, (iii) developing, (iv) maturing, (v) mature, (vi) running and (vii) spent depending on macroscopic and microscopic characters; these have been summarized in Table 3.

Fecundity: Pati (1981) has reported fecundity range of 40,610-90,460 for this species. Mohamed and Ali (1993) have reported fecundity range of 51,316-2,45,356 in their study while fecundity range of 7,65,675-25,37,744 and 28,995-4,55,661 have been documented by Abu-Hakima (1984) and Dadzie et al. (2000b), respectively. Almatar et al. (2004) have assumed total fecundity of 3,58,542 for an average sized (~500 gm in weight). Absolute fecundity of 90,071.1±29,750.9 and relative fecundity of 349.34±119.11 eggs/gm of body weight has been reported by Qinman et al. (2009) in their study at

Table 1. Distinguishing characters of different maturity stages of male *Pampus argenteus* as has been documented by Dadzie et al. (1998).

Maturity Stages	Macroscopic Characters	Microscopic Characters
Immature	Testis is thin, tiny, translucent thread like.	Numerous primary germ cells and spermatognia, which are mostly occupying the periphery of the testis, can be observed. Groups of primary and secondary spermatocytes confined to cysts within the lobule can be observed at the centre of the organ.
Maturing virgin/recovering spent	Testis is still translucent, greyish in colour and used to occupy about 8% the peritoneal cavity.	Primary germ cells and spermatognia can be seen with increasing number of the primary and secondary spermatocytes. Appearance of few cysts containing spermatids can also be observed.
Maturing	Testis is enlarging, opaque and cream-grey in colour with few blood capillaries around it. It used to occupy about 12% of the peritoneal cavity.	Germ cells at all stages of spermatogenesis in varying quantities are present. Cysts of spermatozoa, mainly confined within lobules, appear late in this stage.
Mature	Testis is enlarged, turgid and whitish in colour with undulating margin. It used to occupy about 14.4% of the peritoneal cavity.	Large numbers of lobules are present packed with spermatozoa. Lobules bounded by seminiferous tubules contain germ cells at different stages of spermatogenesis.
Running	Testis is pinkish white in colour, used to occupy about 17% of the peritoneal cavity. With slight pressure on the peritoneum, oozing of milt can be observed.	Lobules containing spermatozoa are still dominate though empty ones can also be encountered.
Spent	Testis is shrunken, flaccid and greyish in colour with visible blood capillaries. Testis used to occupy about 7% of the peritoneal cavity. No evidence of undulating margin of the testis is visible and with slight pressure on peritoneum, oozing of milt cannot be observed.	Numerous convoluted lobules are present in the testis; some of them are revealing the presence of residual and relict spermatozoa.

Bohai bay, China. Sivakami et al. (2003) have reported 40,610-90,640 as the fecundity range for silver pomfret in their study. Pati (1981), Abu-Hakima (1984) and Dadzie et al. (2000b) have reported *Pampus argenteus* as having determinate fecundity (i.e. the potential annual fecundity is fixed prior to the onset of spawning) though Almatar et al. (2004) have documented it as an indeterminate fecund fish.

Spawning seasonality: Most of the earlier researchers (Gopalan, 1967; Hussain and Abdullah, 1977; Bapat et al., 1982; Pati, 1982; Abu-Hakima, 1984; Mohamed and Ali, 1993; Safikhani, 1998; Dadzie et al., 1998, 2000b; Sivakami et al., 2003; Almatar et al., 2004; Mohammad and Ehsan, 2007; Narges et al., 2007; Lone et al., 2008a,b; Ghosh et al., 2009; Nekuru et al., 2013) have reported a prolonged spawning season for *P. argenteus* except Kuthalingam (1963) and Shi et al. (2006). Hussain and Abdullah (1977) have observed April to September as the breeding season with two spawning peaks, one in April-May and another in September in Kuwait waters while Abu-Hakima (1984) have documented March to August as the breeding season with the first peak in April and the second one in October. Dadzie et al. (1998, 2000b) have reported May to August as the breeding period with two spawning peaks; one in May and another in August in Kuwait waters. Almatar et al. (2004) have documented late May to October as the breeding season with two spawning peaks in July and October in Kuwait waters. Later, Lone et al. (2008a, b) have documented June to October as the breeding season with two spawning peaks, one in June and another in October in Kuwait coastal waters. Prolonged spawning season from May to October with two spawning peaks, one during May-July and another during October has been reported for this fish species in northwest of Persian Gulf by Narges et al. (2007) while Mohammad and Ehsan (2007) have reported March to September as the breeding season in Persian Gulf. Nekuru et al. (2013) have reported April to

Table 2. Distinguishing characters of different ovarian maturity stages of *Pampus argenteus* as has been documented by Almatar et al. (2004) and Lone et al. (2008b).

Maturity Stages	Macroscopic Characters	Microscopic Characters
Developing virgin	Ovary is very thin and thread like.	The tunica albugenia is thick and the stroma is very well developed. Oogonia are very common. The cytoplasm of the oocytes is very basophilic and the nucleus to cytoplasm ratio is lower than one. All oocytes are in the chromatin nucleolus stage or in the early peri-nucleolus stage. The sizes of the oocytes never surpass the 100 μm mark and majority of the oocytes is in the range of 50 to 70 μm.
Developing	Ovary is pale yellow in color with quite visible blood vessels on the surface. The texture of the ovary is compact and hard. Opaque oocytes are present.	The primary oocytes dominate, but some early stages of secondary oocytes in the yolk vesicle stage can also be seen. Oocytes are with increasing size due to yolk vesicle deposition. The nucleus-to cytoplasm ratio is increased. The cytoplasm is less basophilic and looks pinkish-blue rather than dark blue, as is seen in very early oocytes. In the secondary oocytes, zona radiata is established. The size distribution of the oocytes at this stage ranged up to a maximum of 600 μm. However, this size distribution is season dependent. Early in the season, oocytes in the smaller range can be found but during the peak breeding month comparatively large sized oocytes dominate over small oocytes. These are arranged generally in two groups; the first peak can be seen around 200 μm, while the second peak is in between 450 and 550 μm. Some atresia can be observed.
Developed/maturing	Ovaries are large, yellowish in colour. Opaque oocytes can be visible. The ovarian texture is still solid with increased blood circulation. The entire surface of the ovary is covered with big and small arteries.	Three groups of oocytes are present. A very small group of primary oocytes is present between the crevices made by the growing oocytes. Some are in the secondary stage, but by far, the largest group is of tertiary-stage oocytes. These oocytes are characterized by a well-developed zona radiata. This is further divided into zona externa and zona interna. The theca and granulosa cells are seen around the zona externa. The tertiary-stage oocytes have well developed, true yolk granules and some fat droplets. The nucleus or germinal vesicle has nucleoli in it. The stroma is thinner and all stages of atresia (α, β, γ and δ) of the tertiary yolked oocytes can be commonly seen. The tunica is thinner than in the previous stages, and the yolked oocytes can be seen through the tunica. The maximum size of the oocytes never surpasses 800 μm. Some old Post Ovulatory Follicles (POF) may also be seen. This is most true of those fish that have spawned earlier.
Gravid/ripening	Ovary at this stage exhibits a softer, speckled appearance when seen through the surface because the tunica is thin, completely stretched and transparent. This speckled nature is due to the appearance of hydrated oocytes in the ovaries. The overall color is light yellow with a spotted appearance of yellow (yolked oocytes) and white (hydrated oocytes). The blood supply is at its peak, and the surface is completely covered with the thick arteries and their capillaries. No eggs can be released with light pressure on the abdomen.	Only two types of oocytes can be seen; the primary oocytes present in the crevasses, and the tertiary stage oocytes and oocytes entering the Final Oocyte Maturation (FOM) stage. This stage is characterized by the movement of the (nucleus) germinal vesicle. Along with this, there is sequestration of the oil droplets and the yolk granules. In the later stages, the nuclear membrane of the germinal vesicle breaks down and the chromosomes are free in the cytoplasm. This stage is a clear-cut indication of the final maturity of the oocyte. By this time, the yolk is completely liquefied and nuclear elements are completely masked by this. These stages are very much interrelated and occur in quick succession, and may take 8 to 12 h before ovulation and actual spawning. The oocytes of this type are tightly packed and are at the same stage of development. The hydrated oocytes are filled with liquefied yolk, and the tunica is very thin. Size wise, three groups of oocytes can be seen in such ovaries. One group, or peak, is around 200 μm for primary oocytes, the second peak is around 500 to 600 μm for tertiary oocytes ready to enter the FOM stage, and the third peak is between 900 and 1200 μm for hydrated oocytes and those oocytes that are at different stages of FOM.

Table 2. Continued.

Maturity Stages	Macroscopic Characters	Microscopic Characters
Running/spawning	Ovary is whitish and jelly-like because of the overwhelming presence of the hydrated oocytes. The tunica is very thin, and oocytes can be clearly seen through it. The oviduct is well developed and full of mature, ovulated oocytes or eggs. Blood supply to the ovaries is similar to that described for ripening stage. Some ovaries are bloodshot because of the bleeding that ensued at the time of ovulation. Oocytes are freely oozing out naturally or with light pressure.	Only two types of oocytes i.e. primary and tertiary oocytes are present. Occasionally, a secondary oocyte can also be seen. The major difference between ripening and spawning ovaries is the absence or presence of POFs. The POFs are absent in ripening fish but are an integral part of the spawning ovary. The oocytes in the spawning ovary generally form two groups, but in some fish, a third peak of mature eggs is also present. The first peak of primary cells is around 200 µm, the second peak of tertiary oocytes is around 600 µm, and third one is around 900 to 1300 µm. This third peak is due to residual oocytes or eggs that have not been spawned and are present in the ovarian lumen. These eggs are to be involuted and recycled by the process of atresia.
Partially spent	Grossly, the ovarian outline is saggy and flaccid, and sometimes bloodshot. The tunica is wavy, and oocytes can be seen through them. However, in bloodshot ovaries, this is somewhat difficult.	Three groups, primary, secondary and tertiary oocytes are present. POFs of different types nearly always present. Nearly all stages of atresia of tertiary and hydrated oocytes can be seen. Atresia is more common in ovulated eggs that have not spawned during previous spawning.
Recovery	Ovaries are flaccid and reddish in colour. The ovarian outline is loose and baggy, and the tunica is thick. Nothing can be seen through it. This may be because of involution of the ovarian parts and the diminishing blood supply.	Only the primary oocytes predominate in the ovarian cavity; these are in the peri-nucleolar or chromatin-nucleolar stage. In fishes where some development used to occur because of favourable temperatures, secondary and tertiary oocytes can also be seen; though majority of these are undergoing atresia. A lot of empty spaces can be seen in the ovary and in between the ovigerous folds. Stroma can be seen in developing status again, and occasionally, old POFs can also be seen. Size wise, only one peak of oocytes between 150 and 300 µm can be observed.
Resting	Ovary creamy to pale yellow in colour. Black spots may be seen scattered on the ovary of older individuals. No opaque oocytes are visible.	Majorities of the oocytes are small and is comprised of oogonia and primary oocytes. Some oocytes are in the chromatin nucleolar stage. The biggest oocytes present are in the early peri-nucleolus stage. The sizes of the oocytes never surpass 200 µm; however, the majority can be observed in the range of 75 to 150 µm. The oogonia are basophilic in nature. The nucleus is quite big, while the cytoplasm is in the form of a narrow rim around the nucleus. The stroma of the ovary is well developed, while the tunica albugenia is thick.

September as the breeding season with two spawning peaks in May and July in Persian Gulf. Mohamed and Ali (1993) have reported May-September as the breeding season with a single spawning peak in June-July in Iraq waters while March to September has been documented as the breeding season with two spawning peaks in June and September in Mahshahr Estuary, Persian Gulf, Iran by Safikhani (1998).

Gopalan (1967) has reported February to August as its breeding season with a single spawning peak during April-June in Arabian Sea while Pati (1982) has documented February to August as the breeding season with two spawning peaks in April and August in the Bay of Bengal. In northwest coast of India, Bapat et al. (1982) have reported two spawning periods for this fish species, one in February and another in August. Sivakami et al. (2003) have reported February to August as the breeding period at Orissa with two peaks, during February-April and June-August. Ghosh et al. (2009) have reported silver pomfret as a perennial breeder with a spawning peak in June-November at Arabian Sea. Kuthalingam (1963) has documented winter breeding (January-February) for silver pomfret in Bay of Bengal. Shi et al. (2006) have documented early April to early June as the breeding season in China. Lee and Jin (1989) observed one peak from June to July in the Eastern China sea. In silver pomfret, spawning occurs in the East China Sea from early April to late May, but occurs later (from May to June) in the Yellow Sea (Shi et al., 2005; Zhao et al., 2010). An interesting phenomenon of spawning in silver pomfret has been reported by Almatar et al. (2004) from Kuwait waters. They have documented semi-lunar spawning

Table 3. Distinguishing characters of different ovarian maturity stages of *Pampus argenteus* as has been documented by Dadzie et al. (1998).

Maturity Stages	Macroscopic Characters	Microscopic Characters
Immature	Ovary is thin, tiny and translucent thread like.	Ovigerous folds with spaces are oriented towards the centre of the ovary containing both oogonia (8.6±1.9 µm) and primary oocytes at the early perinucleolar (43.3±13.6 µm) and few late perinucleolar stages.
Maturing virgin/recovering spent	Ovary is creamy to pale yellow in colour; used to occupy 15% of the peritoneal cavity. Oocytes are not discernible.	Oogonia are still present as also the spaces between the ovigerous folds. Primary oocytes are present at all stages, especially late perinucleolar oocytes (74.0±8.8 µm). A few ovaries can also be seen with small lipid vesicles in cytoplasm, characteristic of early secondary phase.
Developing	Ovary is light yellow in colour with a reddish hue due to the presence of distinct network of blood capillaries. Ovary is used to occupy 19% of the peritoneal cavity. Oocytes are discernible.	Majority of the oocytes are at the late perinucleolus stage; a number of the primary oocytes can be seen to initiate the secondary growth phase (124.6±79.4 µm).
Maturing	Ovary is large in size and bright yellow in colour with conspicuous blood capillaries. Ovary is used to occupy 24% of the peritoneal cavity. Oocytes are clearly discernible.	Oocytes are at the vitellogenic stage (304.0±74.8 µm) with yolk granules and lipid vesicles present.
Mature	Ovary is very much enlarged and yellowish in colour; used to occupy 48% of the peritoneal cavity.	Active vitellogenesis can be observed with many oocytes attaining their maximum size (404.54±71.5 µm). Large lipid vesicles coalesce to form lipid globules. The process ends with nuclear polarization.
Running	Ovary is greatly distended, yellow in colour and jelly like in appearance; used to occupy 64% of the peritoneal cavity. Ripe eggs can be seen through the thin tunica. Ova with oil globules can be seen to extrude out with slight pressure on the abdomen.	Oocytes are at nuclear polarization phase undergoing pre-ovulatory nuclear changes, followed by ovulation.
Spent	Ovary is flaccid, shrunken, purplish in colour and bloodshot; used to occupy 46% of the peritoneal cavity.	Ovigerous folds are convoluted. Residual, ruptured and atretic follicles are visible in the ovaries as well as primary oocytes. Many oocytes are with small lipid vesicles in the cytoplasm, characteristic of the early secondary growth phase.

frequency (spawning occurs in first and third quarters of the moon phase) rather than a continuous daily spawning in this fish species.

Spawning habitat preference: Inshore waters have been reported to be preferred by silver pomfret for spawning (Rege, 1958; Kuthalingam, 1963; Gopalan, 1967; Pati, 1982; Khan, 2000; Almatar et al., 2004). Gopalan (1967) has reported 25.2-28.6°C as preferable temperature and salinity of 28.3‰ for spawning while Almatar et al. (2004) have documented 26-32.5°C and salinity of 39‰ for the same in silver pomfret. Al-Abdul-Elah et al. (2002) in their experiment have also reported 28-30°C as preferable temperature range for spawning and salinity range of 35-40‰ as the best to get maximum hatching rate. Dadzie et al. (1998) have speculated that the spawning of *P. argenteus* is triggered by the low salinity discharge of the river mouth in the northern Persian Gulf (north of Kuwait).

Aquaculture of silver pomfret

The wild stock of silver pomfret is under threat mainly due to over-fishing that is putting high pressure on mature stocks and the young fishes smaller than their first maturity length (Wen et al., 2006; Narges et al., 2007, 2011; Ghosh et al., 2009; Siyal et al., 2013). Apart from over-fishing, ecological alterations like changes in salinity and nutrients status (Saad, 1982), reduction in freshwater inflow to the river due to drought and other influential factors (Archangi et al.,

2013) have been documented as important factors behind reduction in stock of silver pomfret. The decreasing trend of the market size of *P. argenteus* with deteriorating resources has been reported from different countries (Liu and Zhan, 1999; Al-Hussaini, 2003). So, in this regard, the most desirable solution can be "aquaculture" which will reduce the pressure of over-fishing and will allow the wild stocks some time to recover (Peng et al., 2012b). Considering its potential as an aquaculture species (Shi et al., 2005; James and Almatar, 2008; Peng et al., 2012b); so far researches have been conducted on various aspects, such as artificial breeding (Shi et al., 2009b), larval rearing in hatchery condition (Al-Abdul-Elah et al., 2002, 2008; Shi et al., 2009a,b), feeding behaviour and growth under tank culture conditions (Cruz et al., 2000, 2003; Almatar and James, 2007) and health management (Azad et al., 2007) to standardize the techniques to get success in its culture. Seed transportation is an important issue related to aquaculture, and research (Peng et al., 2012a) has also been made to quantify the optimum stocking density to get maximum survivability during the seed transportation of silver pomfret.

Captive culture and rearing: Experiments to formulate the proper methodologies for rearing of silver pomfret larvae and juvenile stages have been initiated long back in the end part of 1960's. Mito and Senta (1967) after obtaining fertilized eggs through stripping wild broodstock studied the egg and embryonic development but the hatched out larvae did not survive beyond five days. In further study by Oda and Namba (1982), larvae survived only for 28 days. The first complete larval developmental stages of laboratory reared silver pomfret were reported by Almatar et al. (2000).

Possibility of producing silver pomfret in hatchery condition first has been reported by Al-Abdul Elah et al. (2002) with hatching rate of 36.5-51.8% in temperature range of 29-30°C and salinity range of 35-40‰. They also have reported no significant difference in larval survivability between stocking densities of 20, 30 and 40 larvae/L; though with further increase in stocking density, increased rate of larval mortality has been reported. In 45 days culture period, they have reported achievement of 1.5% larval survivability. Their further study (Al-Abdul Elah et al., 2008) has reported an increased larval survivability (3.6%) with supply of nutritionally enriched live feed [rotifers cultured with mixed algae (*Chlorella*, *Isochrysis* and *Nannochloropsis*) plus commercial enrichment media `Super Selco' and `DHA Protein Selco'] after 38 days of rearing. The high larval survivability has been reported to be due to the presence of more ω-3 Highly Unsaturated Fatty Acid (ω-3 HUFA) in the rotifers. The presence of microalgae in the larval rearing media has been suggested to enrich the nutritional quality of the rotifers. Shi et al. (2009b) have documented 16-18.5°C water temperature and 28.0±0.5‰ salinity as conducive for hatching of fertilized eggs following the results of their experiment to breed silver pomfret in captivity. Fertilization rate of 18.50-33.50% and hatching rate of 43.83-51.00% have been documented by them in their experiment.

Shi et al. (2009a) have further tried to standardize the techniques for rearing larvae in captivity. The hatched-out larvae were reared in concrete tanks containing saline water (salinity 25-28 ppt; temperature 19-24°C) and were fed with rotifers (*Brachionus plicatilis*), *Artemia*'s nauplii and formulated feed. Larval survivability of 5-14% was achieved after the completion of 50 days' rearing.

Cruz et al. (2000) first tried to analyze the acceptability of commercial feed for the culture of silver pomfret fingerlings. They used commercially available turbot feed (Ecostart 15 by Biomar of France; with 10.08% moisture, 51.0% crude protein, 14.46% crude lipids and 8.13% ash content) for the experiment and observed better Food Conversion Ratio (FCR) and growth rate with the use of dry pellets than the moist pellets. They did not achieve optimum growth for silver pomfret fingerlings in the study and recommended for further analysis using other commercially available foods. Based on their observation, they suggested that better performance can be obtained if silver pomfret fingerlings are fed with dry pellets and fed based on the natural feeding

rhythm, i.e., providing more feeds towards the end of the day and fed at least five times a day. As the smaller fishes tend to feed on the upper column while bigger fishes prefer to feed below the smaller fish and only the big fishes used to feed at the bottom of the tank; a need to install the feed catching tray has also been suggested by them when the fishes are small in size. Further study (Cruz et al., 2003) using semi moist salmon feed and re-pelletized salmon feed mixed with shrimp meat, encapsulated larval diets, fish oil, vitamin, and mineral mix provided comparative better result; though no conclusive statement was made by them on the efficiency of these feed components on the growth of silver pomfret.

Almatar and James (2007) studied the efficiency of using salmon feed mixed with cyclopeeze (commercially available copepods; marketed by Argent Chemical Laboratory, Redmond, WA, USA), salmon feed mixed with shrimp meat, salmon feed alone, and shrimp meat alone in the diet and concluded that the inclusion of shrimp meat in the diet either with salmon feed or alone can provide significantly high FCR and weight gain compared to that of feeds without shrimp meat in silver pomfret juveniles. Further they compared the efficiency of three commercially available marine fish feed namely Gemma (marketed by Skretting, Fontaine les Vervins, France), Salmon feed (marketed by Dana Feed A/S), and Pompano feed (marketed by Tsai Seafoods Inc., Kaohsiung, Taiwan) and showed that feeding with Gemma feed (54.0% crude protein and 19.0% crude fat) or salmon feed (41.4% crude protein and 23.9% crude fat) can provide significantly high growth rates compared to that of pompano feed (with 43.0% crude protein and 6.0% crude fat). The results of these investigations although showed high growth rate; they concluded that there is yet further need to formulate a suitable feed with optimum protein and fat content for commercial ventures of this fish species. In this context, the finding of Hossain et al. (2011a) can be put up; they have reported dietary lipid level of 16% in a 49% protein diet corresponding to a protein to energy ratio of 22.6 is optimum for better growth, feed utilization and whole-body fatty acid profiles in silver pomfret. They further have reported the higher requirement of DHA (Hossain et al., 2012a) and increasing dietary supplementation of vitamin E in high lipid diets (Hossain et al., 2016) for optimum growth and survival of silver pomfret juveniles.

Utilization of lipid content in the diet as an energy source in silver pomfret has been reported by Peng et al. (2012b). They additionally have reported that significant higher growth can be obtained by supplying a diet mixture of fish meat, artificial feed, agamaki clam and copepods. Liu et al. (2014a) have reported for the first time that jellyfish (*Aurelia aurita* and *Rhopilema esculentum*) can be used as prey for artificial rearing of silver pomfret juveniles. Later, in their experiment (Liu et al., 2014b), they have reported that artificial diet mixed with jelly fish is more appropriate than the pure artificial diet in the rearing of silver pomfret juveniles to achieve good growth as jellyfishes have high amino acid contents.

Successful reproduction and offspring survival depend on lipid content and fatty acid composition of the brood-stock diets (Izquierdo et al., 2001). Lund et al. (2008) have reported the importance of Poly-Unsaturated Fatty Acids (PUFAs) with 20 or more carbon atoms on fish maturation and steroidogenesis. Thus, proper formulation of feed for the brood stock is also essential to get success in captive culture. Hossain et al. (2011c) have reported the requirement of higher proportions of PUFA, EPA and DHA in the diet of silver pomfret brood-stock. Hossain et al. (2011b) have further reported the importance of higher levels of arginine and leucine, two essential amino acids in the silver pomfret brood stock diet.

Seed transportation: Peng et al. (2012a) have reported that depletion of dissolved oxygen along with increasing pH and ammonia concentration may be the possible reasons behind juvenile mortality at the higher loading densities and temperatures. Keeping the temperature of the transport bags' water at low level may decrease the ammonia excretion rate; thus, may reduce lower ammonia concentration and reduce mortality. They have reported that to achieve 100% survivability of juvenile silver pomfret to be transported in plastic bags for 8-hour transport period,

a loading density of 5 gm/L and temperature range of 15-25°C should be used while for 4-hour transport duration, a loading density of 20 gm/L and temperature of 15-20°C should be used.

Concluding remarks

The present review represents that ample information is available on the food, feeding habit and reproductive biology of silver pomfret; though research on the aquaculture sector of this species has just started its journey.

Feeding biology: Earlier researchers have conducted extensive studies on the food and feeding habit of this fish species and most of them have reported it mainly as a copepod and detritus feeder. The exceptional observations in some cases may be due to difference in availability of food components in the respective habitats or difference in food preference. Gut content analysis, study of the types of extra-cellular enzyme-producing bacteria present in the digestive tract, study of the digestive tract histology are some of the modern techniques to conclude firmly on the food and feeding habit of any fish species (Gupta, 2016, 2018; Gupta and Banerjee, 2015, 2016a, b). The earlier researchers have concluded on the feeding habit and food preference of silver pomfret mainly based on gut content analysis. Thus, further study should be conducted focusing on the rest two techniques to strengthen the already concluded observations. This will also help to remove the so far existing little controversy regarding the mostly preferred food items of the species.

Interesting observations on the seasonal and depth wise variation in feeding, change in feeding intensity with increasing temperature and breeding season and ontogenetic shift in food preference have been documented by many researchers which will definitely help in designing appropriate rearing technologies for captive culture of silver pomfret. Seasonal and depth wise variation in the diet has been reported to be due to seasonal variation in availability of food items in the particular habitat. Ontogenetic shift in food preference has been studied by number of researchers; but there is no such synchronized report available so far on this particular issue. High preference for copepods in juveniles and crustaceans in adults has been reported by Pati (1980), Kuthalingam (1963) and Sivakami et al., (2003); Dadzie et al., (2000a) have documented maximum preference for copepods and crustaceans in most of the size groups studied with little shift in preference in the middle size group towards bacillariophyceae; Abdurahiman (2006) and Thangavelu et al. (2012) have reported high preference of copepod and detritus in all size groups with comparative high preference for copepods and low preference for detritus with increasing size groups. This kind of variation in observation may be due to difference in availability of the food items in the different habitats. Age-wise, stage-wise and sex-wise study on feeding habit using enzymatic analysis of the digestive tract can be effective technique to delineate the underlying reasons for this opposing trend. In a nut shell, it can be concluded that overall satisfactory information on the feeding habit and food preference of this fish species is available but further study can be conducted to fill up the information gap which has been pointed out here in this report.

Reproductive biology: Plenty of information is available on the different aspects of reproductive biology of silver pomfret such as sex ratio, length at first maturity, gonadal maturity stages, fecundity, spawning seasonality and spawning habitat preference. Female dominance over male has been reported by maximum of the earlier researchers except few contradictory information from Oda and Namba (1982), Dadzie et al. (2000b), Sivakami et al. (2003), Shi et al. (2006) and Ghosh et al. (2009). High metabolic strain of spawning, specific strategy to regulate the population etc. (Fagade et al., 1984; Lambert and Dutil, 2000) may be the reasons behind this contradiction. Thus, further studies in this aspect are needed to clarify the confusion.

All the earlier documentations have reported early maturation of male than female in this fish species; though the information on length at first maturity in different sexes documented by different researchers is varying. Change in food availability, health status,

physico-chemical parameters etc. may be the reasons behind this kind of variations. High fecundity has been reported by all the earlier researchers for this fish species; though the difference in the range of fecundity documented may be due to variation in age, condition, health status, food availability etc.

Prolonged breeding season for silver pomfret has been reported by all the earlier researchers; though variation has been observed in respect to the number of spawning peaks. Most of the researchers have documented two spawning peaks for this fish species except Gopalan (1967), Lee and Jin (1989) and Mohamed and Ali (1993). The presence of variation in respect to the duration of the breeding season in different countries and number of spawning peaks may be due spatial and temporal fluctuations in climatic and physico-chemical parameters. Information availability on the preferred habitat and environmental cues that stimulate breeding initiation of any fish species are also important. Silver pomfret has been reported to prefer inshore water for spawning. Most of the researchers have documented moderate temperature range and high salinity requirement for the breeding initiation in silver pomfret except Dadzie et al. (1998) who have reported low salinity as the stimulant for the initiation of breeding. Further study in this aspect can be done to resolve the contradiction.

Captive culture and rearing: Till date, not much research has been performed to assess the suitability of silver pomfret for captive culture. Al-Abdul Elah et al. (2002) first tried the captive culture of silver pomfret followed by Shi et al. (2009b). Though there was not much difference in results regarding the achieved hatching percentage, Shi et al. (2009b) have reported the suitability of comparative low temperature and low salinity to achieve good hatching rate. The reasons behind this difference between the tested parameters are not clear; and thus, further study is required to determine the ambient temperature, salinity and other physico-chemical parameters conducive for hatching in silver pomfret.

Studies to determine the specific food to enhance the larval survivability in silver pomfret were performed by Al-Abdul Elah et al. (2002) and Shi et al. (2009a); the former researchers reported the suitability of nutritionally enriched live feed i.e. rotifer cultured with mixed algae while Shi et al. (2009a) documented further addition of artemia nauplii and formulated feed with rotifer to enhance the larval survivability. Further Cruz et al. (2000) and Almatar and James (2007) studied the acceptability and suitability of commercial feed in respect to better Food Conversion Ratio (FCR) and growth rate for the culture of silver pomfret fingerlings. While Cruz et al., (2000) suggested the suitability of turbot feed, Almatar and James (2007) reported the suitability of shrimp meat alone or with salmon feed to achieve good growth rate. Almatar and James (2007) further reported that formulated feed should be with optimum protein and fat content and that observation was further supported by Hossain et al. (2011a). Hossain et al., (2012a, 2016) further documented that growth rate in silver pomfret juveniles can be enhanced with increasing supplementation of vitamin E in high lipid diet and DHA. Liu et al. (2014a, b) have reported that jelly fish along with artificial feed can produce good result than pure artificial food in silver pomfret juveniles.

Considering all the earlier experiments on captive culture and rearing, it can be concluded that though researchers achieved success in enhancing the hatching rate nevertheless they failed to get the ultimate success due to the low survivability of the larvae. Even after supplying rotifers, artemia nauplii and formulated feed, they did not manage to achieve more than 15% of larval survivability. The reasons behind low survivability may be due to high stocking density, change in physico-chemical parameters etc. Thus, further study is needed to assess the reasons behind low survivability of silver pomfret larvae in captivity. The good acceptability of the commercial fish feed along with their suitability in enhancing growth rate has been reported. High percentage of lipid with increasing amount of vitamin E and protein in diets has been reported to promote growth in silver pomfret juveniles. Thus, feed formulated with optimum ratio of protein and lipid with vitamin E

supplement can be supplied in captive culture of silver pomfret to enhance the growth rate so as to achieve the marketable size quickly. On the other hand, brood stock feed should be formulated keeping higher proportions of PUFA, EPA and DHA.

Finally, it can be concluded that further studies are needed to gather more information to fill up the information gap pointed out in this report; more specifically in the areas like improvement of larval survival and rearing techniques, brood stock management for successful captive spawning, suitable feed developments for different life history stages etc. Pilot scale study can be supported to aid in mass production of the fry and commercial culture of the species using tanks, cages and costal ponds etc to support its fishery in long run.

References

Abdurahiman K.P. (2006). Studies on food and feeding of marine demersal finishes with special reference to trophic interactions. Ph.D. Thesis, Cochin University of Science and Technology, Kochi, India. 251 p.

Abdurahiman K.P., Zacharia P.U., Nayak T.H., Mohamed K.S. (2006). Diet and trophic ecology of silver pomfret, *Pampus argenteus* (Euphrasen, 1788) exploited from the Southeast Arabian Sea. Journal of Marine Biological Association of India, 48(2): 206-212.

Abu-Hakima R. (1984). Comparison of aspects of the reproductive biology of *Pomadasys*, *Otolithes* and *Pampus* spp. in Kuwaiti waters. Fisheries Research, 2(3): 177-200.

Al-Abdul-Elah K.M., Almatar S., Abu-Rezq T., James C.M. (2008). Development of hatchery technology for the silver pomfret *Pampus argenteus* (Euphrasen): effect of microalgal species on larval survival. Aquaculture Research, 32(10): 849-860.

Al-Abdul-Elah K.M., Almatar S., Abu-Rezq T.S., James C.M., El-Dakour S. (2002). Development of hatchery techniques for the silver pomfret *Pampus argenteus* (Euphrasen). Asian Fisheries Science, 15: 107-121.

Al-Husaini M. (2003). Fishery of shared stock of the silver pomfret, *Pampus argenteus*, in the northern gulf: a case study. In: Norway-FAO Expert Consultation on the Management of Shared Fish Stocks, Bergen, Norway, 7-10 October, 2002. FAO Fisheries Report No. 695. pp: 44-56.

Ali T.S., Mohamed A.R.M., Hussain N.A. (2000). Growth, mortality and stock assessment of silver pomfret, *Pampus argenteus* in the northwest Arabian Gulf, Iraq. Marina Mesopotamica, 15(2): 373-387.

Almatar S.M., Al-Abdul Elah K., Abu-Rezq T.S. (2000). Larval developmental stages of laboratory-reared silver pomfret *Pampus argenteus*. Ichthyological Research, 47(2): 137-141.

Almatar S.M., James C.M. (2007). Performance of different types of commercial feeds on the growth of juvenile silver pomfret, *Pampus argenteus*, under tank culture conditions. Journal of the World Aquaculture Society, 38(4): 550-556.

Almatar S.M., Lone K.P., Abu-Rezq T.S., Yousef A.A. (2004). Spawning frequency, fecundity, egg weight and spawning type of silver pomfret, *Pampus argenteus* (Euphrasen) (Stromateidae), in Kuwait waters. Journal of Applied Ichthyology, 20(3): 176-188.

Al-Qattan E. (1998). The food, feeding habits and feeding structures of silver pomfret, *Pampus argenteus* (Euphrasen) in Kuwait waters. M.Sc. Thesis, Kuwait University.

Al-Qattan E., Dadzie S., Abou-Seedo F. (2000). Feeding structures in the silver pomfret *Pampus argenteus* (Euphrasen) as observed by scanning electron microscopy. Kuwait Journal of Science and Engineering, 27(2): 329-341.

Archangi B., Bazrafshan K.H., Ronagh M.T., Savari A., Abadi M.A.S.A. (2013). Population genetic structure of silver pomfret (*Pampus argenteus*) in Persian Gulf and Oman Sea, inferred from 11 microsatellite loci. World Journal of Fish Marine Sciences, 5: 227-232.

Azad I.S., Al-Marzouk A., James C.M., Almatar S., Al-Gharabally H. (2007). Scuticociliatosis-associated mortalities and histopathology of natural infection in cultured silver pomfret (*Pampus argenteus* Euphrasen) in Kuwait. Aquaculture, 262(2-4): 202-210.

Bapat S.V., Deshmukh V.M., Krishnamoorthi B., Muthiah C., Kagwade P.V., Ramamirtham C.P., Mathew K.J., Pillal S.K., Mukundan C. (1982). Fishery resources of the Exclusive Economic Zone of the North West coast of India. CMFRI Bulletin 33, Central Marine Fisheries Research Institute, Cochin, India. 81 p.

Cho K.D., Kim J.C., Choe Y.K. (1989). Studies on the biology of pomfrets, *Pampus* spp. in the Korean waters. 5. Distribution and fishing condition. Bulletin of the Korean Fisheries Society, 22: 294-305 (In Korean).

Chopra S. (1960). A note on sudden outburst of

ctenophores and medusae in the waters off Bombay. Current Science, 29(10): 392-393.

Cruz E.M., Almatar S.M., Abdul-Elah K., Al-Yaqout A. (2000). Preliminary studies on the performance and feeding behavior of silver pomfret (*Pampus argenteus* Euphrasen) fingerlings fed with commercial feed and reared in fibreglass tanks. Asian Fisheries Science, 13: 191-199.

Cruz E.M., Almatar S.M., Al-Sabbah I. (2003). Preliminary studies on the growth performance and feeding behavior of zobaidy reared in tanks. Culture of Zobaidy, *Pampus argenteus*, in Kuwait. Phase-I, Final Report KISR 6910.

Dadzie S., Abou-Seedo F., Al-Shallal T. (1998). The onset of spawning in the silver pomfret, *Pampus argenteus* (Euphrasen), in Kuwait waters and its implications for management. Fisheries Management and Ecology, 5(6): 501-510.

Dadzie S., Abou-Seedo F., Al-Qattan E. (2000a). The food and feeding habits of the silver promfret, *Pampus argenteus* (Euphrasen), in Kuwait waters. Journal of Applied Ichthyology, 16(2): 61-67.

Dadzie S., Abou-Seedo F., Al-Shallal T. (2000b). Reproductive biology of the silver pomfret, *Pampus argenteus* (Euphrasen), in Kuwait waters. Journal of Applied Ichthyology, 16(6): 247-253.

Davis P., Wheeler A. (1985). The occurrence of *Pampus argenteus* (Euphrasen, 1788), (Osteichthyes, Perciformes, Stromateoidei, Stromateidae) in the North Sea. Journal of Fish Biology, 26(2): 105-109.

Day F. (1878). The Fishes of India being a Natural History of the Fishes Known to Inhabit the Seas and Fresh Waters of India, Burma and Ceylon, 1st Ed., William Dowson and Sons, London. 778 p.

Din N., Khawar M., Masood Z., Yasinzai M.I., Nazeer N., Zakir M., Iqbal F., Razzaq, W. (2015). Length-Weight Relationship, condition and relative condition parameters of Silver Pomfret, *Pampus argenteus* collected from Quetta City of Pakistan. Global Veterinaria, 14(6): 879-882.

Dwiponggo A. (1984). Notes on the demersal fishery of the Java Sea and population parameters of some demersal species. FAO Fisheries Report 318. pp: 58-71.

Eagderi S., Fricke R., Esmaeili H.R., Jalili P. (2019). Annotated checklist of the fishes of the Persian Gulf: Diversity and conservation status. Iranian Journal of Ichthyology, 6(Suppl. 1): 1-171.

Fagade S.O., Adebisi A.A., Atanda A.N. (1984). The breeding cycle of *Sarotherodon galilaeus* in the IITA. Lake, Ibadan, Nigeria. Archive Hydrobiologie, 100(4): 493-500.

Fei Y., Shiming P., Peng S., Zhaohong S. (2011). Effects of low salinity on antioxidant enzymes activities in kidney and muscle of juvenile silver pomfret *Pampus argenteus*. Acta Ecologica Sinica, 31(1): 55-60.

Ghosh S., Mohanraj G., Asokan P.K., Dhokia H., Zala M.S., Bhint H.M. (2009). Fishery and stock estimates of the silver pomfret, *Pampus argenteus* (Euphrasen), landed by gill netters at Veraval. Indian Journal of Fisheries, 56(3): 177-182.

Gopalan U.K. (1967). Studies on the maturity and spawning of Silver Pomfret, *Pampus argenteus* (Euphs.) in the Arabian Sea. Bulletin of National Institute of Sciences of India, 38: 785-796.

Gupta S. (2016). An overview on morphology, biology and culture of *Scatophagus argus* (Linnaeus, 1766). Reviews in Fisheries Science and Aquaculture, 24(2): 203-212.

Gupta S. (2018). A review on feeding and reproductive biology of *Ompok pabda* with an emphasis on its conservation. Journal of Aquaculture Research and Development, 9(2): 525.

Gupta S., Banerjee S. (2015). A review on *Labeo calbasu* (Hamilton) with an emphasis on its conservation. Journal of Fisheries, 3(3): 301-308.

Gupta S., Banerjee S. (2016a). *Eutropiichthys vacha* (Hamilton, 1822), a threatened fish of Indian subcontinent. Journal of Fisheries, 4(2): 397-400.

Gupta S., Banerjee S. (2016b). A note on *Clupisoma garua* (Hamilton, 1822), a freshwater catfish of Indian subcontinent (Teleostei: Siluriformes). Iranian Journal of Ichthyology, 3(2): 150-154.

Haedrich R.L. (1984). Stromateidae. In: W. Fischer, G. Bianchi (Eds.). FAO species identification sheets for fishery purposes, Western Indian Ocean (Fishing Area 51). Vol. 4, FAO, Rome. pp: 1-6.

Hossain M.A., Almatar S.M., James C.M. (2011a). Effect of dietary lipid levels on growth performance, feed utilization and body composition of juvenile silver pomfret, *Pampus argenteus* (Euphrasen, 1788). Asia Pacific Journal of Life Sciences, 4(2): 1-16.

Hossain M.A., Almatar S.M., James C.M. (2011b). Whole body and egg amino acid composition of silver pomfret, *Pampus argenteus* (Euphrasen, 1788) and prediction of dietary requirements for essential amino acids. Journal of Applied Ichthyology, 27(4): 1067-1071.

Hossain M.A., Almatar S.M., James C.M., Al-Yaqout A.,

Yaseen S.B. (2011c). Seasonal variation in fatty acid composition of silver pomfrets, *Pampus argenteus* (Euphrasen) in Kuwait waters. Journal of Applied Ichthyology, 27(3): 901-907.

Hossain M.A., Almatar S.M., James C.M. (2012a). Effects of varying dietary docosahexaenoic acid (DHA) levels on growth, proximate composition and tissue fatty acid profile of juvenile silver pomfret, *Pampus argenteus* (Euphrasen, 1788). Aquaculture Research, 43(11): 1599-1610.

Hossain M.A., Almatar S.M., Al-Abdul Elah K.M., Yaseen S.B. (2012b). Comparison of proximate composition and fatty acid profiles of some popular cultured and wild fishes in Kuwait. Journal of Applied Aquaculture, 24(3): 199-209.

Hossain M.A., Almatar S.M., Yaseen S.B. (2016). Effects of varying levels of dietary vitamin E (α-tocopherol) on growth performance, proximate and fatty acid composition of juvenile silver pomfret (*Pampus argenteus* Euphrasen, 1788). Journal of Applied Ichthyology, 32(1): 55-60.

Hussain N.A., Abdullah M.A.S. (1977). The length-weight relationship, spawning season and food habits of six commercial fishes in Kuwaiti waters. Indian Journal of Fisheries, 24(1 & 2): 181-194.

Izquierdo M.S., Fernandez-Palacios H., Tacon A.G.J. (2001). Effect of brood stock nutrition on reproductive performance of fish. Aquaculture, 197(1-4): 25-42.

James C.M., Almatar S.M. (2008). Potential of silver pomfret (*Pampus argenteus*) as a new candidate species for aquaculture. Aquaculture Asia Magazine, 13: 49-50.

Kagwade P.V. (1988). Pomfret resources along north-west coast of India. In: Living resources of the Indian Seas. Bombay Research Centre, Central Marine Fisheries Research Institute, Bombay, India. pp: 219-224.

Khan M.Z. (1982). A probable nursery ground of silver pomfret *Pampus argenteus* (Euphr.) off Nawabander (Gujarat). Indian Journal of Fisheries, 29: 257-261.

Khan M.Z. (2000). The fishery and resource characteristics of pomfrets. In: V.N. Pillai, N.G. Menon (Eds.). Marine Fisheries Research and Management. Central Marine Fisheries Research Institute, Kerala, India. pp: 364-373

Kim Y.M., Lee D.W. (1992). Stock assessment of silver pomfret, *Pampus argenteus* (Euphrasen), in Korean water. Bulletin of National Fisheries Research and Development Agency (Korea), 61: 41-51.

Kulkarni A.V. (1958). Studies on alimentation and rate of digestion in some of the teleosts of Bombay. M.Sc. Thesis, University of Bombay, India.

Kuthalingam M.D.K. (1963). Observations of the fishery and biology of the silver pomfret, *Pampus argenteus* (Euphrasen) from the Bay of Bengal. Indian Journal of Fisheries, 10A (1): 59-74.

Lambert Y., Dutil J.D. (2000). Energetic consequences of reproduction in Atlantic cod (*Gadus morhua*) in relation to spawning level of somatic energy reserves. Canadian Journal of Fisheries and Aquatic Sciences, 57(4): 815-825.

Lee T.Y., Jin J.J. (1989). Studies on the biology of pomfrets, *Pampus* spp. in the Korean waters. 2. Gonadal maturation and spawning. Bulletin of Korean Fisheries Society, 22: 266-280. (In Korean)

Liu C., Zhuang Z., Chen S., Shi Z., Yan J., Liu C. (2014a). Medusa consumption and prey selection of silver pomfret *Pampus argenteus* juveniles. Chinese Journal of Oceanology and Limnology, 32(1): 71-80.

Liu C., Chen S., Zhuang Z., Yan J., Liu C., Cui H. (2014b). Potential of utilizing jellyfish as food in culturing *Pampus argenteus* juveniles. Hydrobiologia, 754(1): 189-200.

Liu W.H., Zhan B.Y. (1999). Analysis on the exploitation of *Pampus* spp. in the East China Sea. Journal of Zhanjiang Ocean University, 19: 30-34.

Lone K.P., Al-Ablani S., Almatar S. (2008a). Spermatogenesis, maturation, seasonal variations and spawning season of silver pomfret (*Pampus argenteus*, Euphrasen) collected from the natural spawning grounds of the shore of Kuwait. Pakistan Journal of Zoology, 40(4): 263-273.

Lone K.P., Al-Ablani S., Almatar S. (2008b). Oogenesis, histological gonadal cycle, seasonal variations and spawning season of female silver pomfret (*Pampus argenteus*, Euphrasen) from the spawning grounds of Kuwait. Pakistan Journal of Zoology, 40(6): 397-407.

Lund I., Steenfeldt S.J., Suhr K.I., Hansen B.W. (2008). A comparison of fatty acid composition and quality aspects of eggs and larvae from cultured and wild brood stock of common sole (*Solea solea* L.). Aquaculture Nutrition, 14(6): 544-555.

Luo B., Lu J., Lan Y., Huang S., Zhu D., Kong X. (1993). Population dynamics and life history patterns for main marine fishes in the coastal waters of China. Studia Marina Sinica/Haiyang Kexue Jikan, 34: 123-138.

Masuda A., Araga C., Yoshino T. (1975). Coastal Fishes of Southern Japan. Tokai University Press, Japan. 382 p.

Mito S., Senta T. (1967). On the egg development and

prelarval stages of silver pomfret with reference to its spawning in the Seto Inland Sea. Bulletin of the Japanese Society of Scientific Fisheries, 33: 948-951. (In Japanese)

Mohamed A.M., Ali T.S. (1992). Fishery and ecology of silver pomfret *Pampus argenteus* (Euphrasen) in the north western Persian Gulf. IPA Journal of Agricultural Research (Iraq), 2: 271-283.

Mohamed A.M., Ali T.S. (1993). The reproductive biology of silver pomfret *Pampus argenteus* (Euphrasen) in the North Western Persian Gulf. IPA Journal of Agricultural Research (Iraq), 3: 190-201.

Mohamed A.M., Ali T.S. (1994). Feed habit of silver pomfret *Pampus argenteus* (Euphrasen) in the north western Persian Gulf. IPA Journal of Agricultural Research (Iraq), 4(1): 38-44.

Mohamed A.M., Resean A.K., Hashim, A.A. (2008). The stock assessment of silver pomfret *Pampus argenteus* (Euphrasen, 1788) in Iraqi marine waters during the period 2004-2005. Basrah Journal of Agricultural Science, 21: 1-16.

Mohammad M., Ehsan K. (2007). Reproductive biology of silver pomfret *Pampus argenteus* in Banadar Abbas fishing ground. Journal of Marine Sciences and Technology, 5(3&4): 53-64.

Narges A., Preetha K., Jasem M., Gholam-reza E., Vahid Y. (2007). Spawning season of *Pampus argenteus* (Euphrasen, 1788) in the Northwest of the Persian Gulf and its implications for management. Pakistan Journal of Biological Science, 10(24): 4551-4554.

Narges A., Preetha K., Jasem M., Gholam-reza E., Vahid Y. (2011). Stock Assessment of silver pomfret *Pampus argenteus* (Euphrasen, 1788) in the Northern Persian Gulf. Turkish Journal of Fisheries and Aquatic Sciences, 11: 63-68.

Nasir N.A. (2016). Distribution of silver pomfret (*Pampus argenteus*) in Iraqi marine water. Mesopotamia Environmental Journal, 2(4): 67-77.

Nath P.R. (1966). Biology and seasonal distribution of the food fishes of Travancore coast. Kerala University Publication, India. 144 p.

Nekuru A., Imanpur M.R., Taqizade V., Shabani A., Momeni M. (2013). A histological study of ovarian development and spawning peak of Silver pomfret (*Pampus argenteus*, Euphrasen, 1788) in the Persian Gulf (Qeshm coastal waters). Journal of Aquatic Ecology, 2(4): 52-61.

Oda T., Namba Y. (1982). Attempt to artificial fertilization and rearing of larvae of silver pomfret, *Pampus argenteus*. Okayama Suishi Jiho, 56: 195-197.

Pati S. (1980). Food and feeding habits of silver pomfret *Pampus argenteus* (Euphrasen) from Bay of Bengal with a note on its significance in fishery. Indian Journal of Fisheries, 27: 244-255.

Pati S. (1981). Observations of the length-weight relationship of pomfrets from the Bay of Bengal. Mahasagar- Bulletin of the National Institute of Oceanography, 14(1): 83-85.

Pati S. (1982). Studies on the maturation spawning and migration of silver pomfret, *Pampus argenteus* (Euphrasen) from Bay of Bengal. Matsya, 8: 12-22.

Peng S.M., Shi Z.H., Yin F., Sun P., Wang J.G. (2011). Feeding habits of silver pomfret (*Pampus argenteus*) in East China Sea based on stable isotope techniques. Chinese Journal of Ecology, 30(7): 1565-1569.

Peng S.M., Chen X.Z., Shi Z.H., Yin F., Sun P. (2012a). Survival of juvenile silver pomfret, *Pampus argenteus*, kept in transport conditions in different densities and temperatures. The Journal of Aquaculture – Bamidgeh, 64: 1-6.

Peng S.M., Shi Z.H., Yin F., Sun P., Wang J. (2012b). Selection of diet for culture of juvenile silver pomfret, *Pampus argenteus*. Chinese Journal of Oceanology and Limnology, 30(2): 231-236.

Qinman C., Chunying Y., Xiaoshuang L. (2009). The study on fecundity of silver pomfret *Pampus argenteus* in Bohai Bay. Marine Science Bulletin, 28(6): 66-69.

Rao K.S. (1967). Food and feeding habits of fishes from trawl catches in the Bay of Bengal with observations on the diurnal variation in the nature of the feed. Indian Journal of Fisheries, 11(1): 277-314.

Rege M.S. (1958). A study of the stromateid fishes of Bombay. Ph.D. Thesis, University of Bombay, India. 160 p.

Saad M.A.H. (1982). Distribution of nutrient salts in the lower researches of the Tigris and Euphrates, Iraq. Water Supply and Management, 6(5): 443-453.

Safikhani H. (1998). Studies on the biology of silver pomfret, *Pampus argenteus* (Euphrasen) from Mahshahr estuaries of Iran. M.Sc. Thesis, Azad University of Tehran.

Shafi M., Quddus M.M.A. (2003). Bangopshagorer matsho shampad. Kabir Publications, Dhaka, Bangladesh. 389 p. (In Bengali)

Shi Z.H., Wang J.G., Gao L.J., Ling J.Z. (2005). Advances on the studies of reproductive biology and artificial

breeding technology in silver pomfret *Pampus argenteus*. Marine Fisheries, 27: 246-250.

Shi Z.H., Gao L.J., Xie Y.L., Luo H.Z., Wang H.P., Chen B. (2006). Comparison of reproductive characteristics between *Pampus argenteus* and *Pampus cinereu* in Zhoushan fishing ground. Journal of Fisheries of China, 30: 247-252. (In Chinese)

Shi Z.H., Zhao F., Fu R., Huang X., Wang J. (2009a). Study on artificial larva rearing techniques of silver pomfret (*Pampus argenteus*). Marine Fisheries, 31(2): 53-57. (In Chinese)

Shi Z.H., Zhao F., Wang J., Peng S., Wang H. (2009b). Artificial insemination and incubation of silver pomfret (*Pampus argenteus*) from Zhoushan fishing ground. Fishery Modernization, 36(1): 18-21. (In Chinese)

Sivakami S., Vivekanandan E., Raje S.G., Shoba J.K., Rajkumar U. (2003). Lizard fishes, Pomfrets and Bullseye. In: M. Mohan Joseph, A.A. Jayaprakash (Eds.). Status of exploited marine fishery resources of India, CMFRI, Kochi, India. pp: 141-157.

Siyal F.K., Li Y., Gao T., Liu Q. (2013). Maximum sustainable yield estimates of silver pomfret, *Pampus argenteus* (Family: Stromatidae) fishery in Pakistan. Pakistan Journal of Zoology, 45(2): 447-452.

Solanki K.K., Kandoran M.K., Venkataraman R. (1976). Seasonal variation in the chemical composition of pomfret- II Silver pomfret (*Pampus argenteus*). Fisheries Technology, 13(1): 49-53.

Suyehiro Y. (1942). A study in the digestive system and feeding habits of fish. Japanese Journal of Zoology, 10(1): 1-303.

Talwar P.K., Jhingran A.G. (1991). Inland Fishes of India and Adjacent Countries. Vol. 1 and Vol. 2, 1st Ed., Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Bombay and Calcutta. 1063 p.

Tang W.C. (1987). Chinese medicinal materials from the sea. Abstracts of Chinese Medicine, 1(4): 571-600.

Thangavelu R., Anbarasu M., Zala M.S., Koya K.M., Sreenath K.R., Mojjada S.K., Shiju P. (2012). Food and feeding habits of commercially important demersal fin-fishes off Veraval coast. Indian Journal of Fisheries, 59(4): 77-87.

Wen T.Y., Jian L., Gen H.Y. (2006). Multiplex genotyping of novel microsatellites from silver pomfret (*Pampus argenteus*) and cross-amplification in other pomfret species. Molecular Ecology Notes, 6(4): 1073-1075.

White T.F. (1984). Marine fisheries resources survey demersal trawling. Survey cruise report No. 5 November 27 to December 6, 1984. FAO/UNDP Chittagong, Bangladesh.

Zhao F., Zhuang P., Zhang L., Shi Z.H. (2010). Biochemical composition of juvenile cultured vs. wild silver pomfret, *Pampus argenteus*: determining the diet for cultured fish. Fish Physiology and Biochemistry, 36(4): 1105-1111.

Zhao F., Dong Y., Zhuang P., Zhang T., Zhang L., Shi Z. (2011). Genetic diversity of silver pomfret (*Pampus argenteus*) in the Southern yellow and East China Seas. Biochemical Systematics and Ecology, 39(2): 145-150.