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Reproductive biology, gonadal histology and feeding ecology of the damselfish *Neopomacentrus cyanomos* (Bleeker, 1856) from the south-west coast of India

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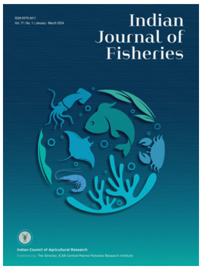

Abstract

The present study documents the reproductive biology, gonadal histology, and feeding ecology of the damselfish *Neopomacentrus cyanomos* (Bleeker, 1856) from the Vizhinjam coast, south-west India. Gonadal development was examined through detailed morphological and histological analyses to characterise gametogenesis and seasonal reproductive patterns. Ovarian development was categorised into five maturity stages, with oocyte diameters ranging from 36.89±8.01 μm in oogonia to 830±21.67 μm in fully mature oocytes, indicating asynchronous oocyte development and prolonged spawning activity. Testicular development also progressed through five distinct stages, from spermatogonia to mature spermatozoa, reflecting continuous spermatogenic activity. Gut content analysis revealed that *N. cyanomos* is predominantly zooplanktivorous, with copepods forming the major dietary component (41%), followed by ostracods (17%), decapod crustaceans (14%), amphipods (8%) and cirripeds (6%). Seasonal variation in feeding intensity was evident, with peak gastrosomatic index (GaSI) values recorded during July (3.7) and August (3.6), and the lowest values during January (0.74) and June (0.55). These trends coincided with periods of enhanced reproductive activity. This study provides the first comprehensive histological description of gonadal development in *N. cyanomos* from Indian waters and offers insights into its reproductive strategy and trophic ecology. The findings contribute baseline biological information essential for understanding the reproductive dynamics of pomacentrid fishes and for supporting future ecological assessments and management of coral reef-associated fish populations.

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Introduction

Pomacentrid fishes constitute an ecologically important group of reef-associated teleosts, playing a key role in coral reef food webs and energy transfer. Their reproductive strategies, feeding ecology, and life-history traits are closely linked to reef structure, environmental stability, and food availability. Consequently, an understanding of their reproductive biology and feeding ecology is essential for evaluating population dynamics, habitat use, and ecosystem functioning (MacDonald, 1981; Wootton, 1990).

Considerable research has been carried out on various aspects of pomacentrid biology, including spawning behaviour, parental care, larval development, and trophic ecology. Early studies documented reproductive strategies and feeding patterns in several species such as *Chromis caeruleus*, *Dascyllus aruanus*, *Abudefduf glaucus*, and *Chrysiptera* spp. (Pillai *et al*., 1985a; Mohan *et al*., 1986; Pillai and Mohan, 1990; Anand, 1994). Subsequent investigations have examined reproductive cycles, growth, and feeding ecology in different pomacentrids from diverse geographical regions, including *Dascyllus trimaculatus*, *Chromis pelloura*, *Stegastes fuscus*, and *Teixeirichthys jordani* (Al-Zibdah and Kan'an, 2009; Canan *et al*., 2010; González-Félix *et al*., 2019).

Histological investigations of gonadal development have provided deeper insights into reproductive strategies in pomacentrids, revealing variations in gametogenic patterns and spawning modes. Detailed studies on gonadal morphology and gametogenesis have been reported for species such as *Dascyllus aruanus* (Cole, 2002; Choi *et al*., 2014), *Chrysiptera cyanea* (Bapary *et al*., 2009), *Chromis notata* (Lee *et al*., 2017), and *Amphiprion frenatus* (Nakamura *et al*., 1994). However, such histological information remains limited for many Indian reef-associated pomacentrids, particularly with respect to seasonal reproductive dynamics and oocyte development. Specifically, within this underexplored group, the genus *Neopomacentrus* is widely distributed along the Indian coastline, yet detailed histological studies on its reproductive biology are lacking.

Despite the ecological significance and diversity of pomacentrids along the south-west coast of India, particularly in the Vizhinjam reef ecosystem, detailed studies on their reproductive biology remain limited. The genus *Neopomacentrus* is widely distributed in tropical and subtropical Indo-Pacific waters and is commonly associated with coral reef habitats. *Neopomacentrus cyanomos* occurs abundantly along the Indian coastline, including the Vizhinjam region, inhabiting coral-rich and nearshore reef environments. Although preliminary observations on its reproductive biology have been reported (Sreeraj and Gopakumar, 2004), comprehensive studies integrating gonadal histology, reproductive staging, and feeding ecology are lacking. The present study provides a comprehensive assessment of reproductive biology through detailed gonadal histology and maturity staging, together with an analysis of feeding ecology. Given its ecological importance and abundance, a detailed understanding of its reproductive and feeding biology is essential for evaluating its role in reef ecosystems and for developing baseline data relevant to conservation and resource management.

Previous studies on pomacentrids have demonstrated that reproductive output and feeding intensity are strongly influenced by environmental factors such as food availability, habitat structure, temperature, and seasonal variability (Al-Zibdah and Kan'an, 2009; Castellanos-Galindo *et al*., 2010). Feeding studies have further shown that many pomacentrids are opportunistic zooplanktivores, consuming a wide range of prey items including copepods, amphipods, decapods, and other planktonic organisms (Hiatt and Strasburg, 1960; Vijay Anand, 1994). However, detailed quantitative data linking feeding intensity with reproductive cycles remain scarce for several species, including *N. cyanomos*.

In this context, the present study aims to describe the gonadal histology and reproductive cycle of *N. cyanomos*, quantify oocyte developmental stages and associated morphometric characteristics, and analyse feeding ecology and seasonal variation in feeding intensity. The study provides baseline biological information that contributes to a better understanding of reproductive strategies and trophic dynamics of pomacentrid fishes and supports future ecological and conservation-oriented assessments of coral reef fish populations.

Materials and methods

Ethics statement

The study was conducted with a focus on the materials collected from commercial fish catches by authorised fishing vessels operated along the Indian coast. All experiments/studies were conducted with strict adherence to the guidelines set forth by the Institutional Animal Ethics Committee of India, registered with the Committee for Control and Supervision of Experiments (CPCSEA) established under Section 15(1) of the Prevention of Cruelty to Animals Act, 1960 (Reg. no.: 326/GO/ReBiBt/S/2001/CPCSEA).

Study area and sample collection

Specimens of *N. cyanomos* were collected from the Vizhinjam coast (8°22'42.54" N; 76°59'14.20" E), south-west India, between January 2014 and December 2016. Sampling was carried out monthly using hand nets during SCUBA and skin-diving operations, as well as drag nets depending on availability and habitat conditions. A minimum of 30 individuals were collected each month to ensure adequate representation across size classes and maturity stages. All specimens were transported to the Vizhinjam Regional Centre of ICAR–CMFRI for further analysis.

All sampling and handling procedures were carried out in accordance with institutional and national ethical guidelines for the use of animals in research. No protected or endangered species were involved, and sampling was limited to the minimum number required for scientific analysis.

Morphometric measurements and biological indices

Each specimen was measured for total length (TL) and standard length (SL) to the nearest millimetre and weighed to the nearest gram. Gonadal and gut measurements included ovary/testis length and width, gonad weight, gut weight, and body weight. Derived indices such as the gonadosomatic index (GSI) and gastrosomatic index (GaSI) were calculated using standard formulae:

$$\text{GaSI} = \frac{\text{Gut weight (g)}}{\text{Body weight (g)}} \times 100$$

$$\text{GSI} = \frac{\text{Gonad weight (g)}}{\text{Body weight (g)}}$$

Gonadal maturity assessment

Maturity stages were determined following the criteria of Qasim (1973) and Schreck and Moyle (1990). Ovaries were classified into five stages: immature, maturing, mature, spawning, and spent, based on macroscopic appearance and microscopic characteristics. Oocyte diameter measurements were taken from subsamples of ovarian tissue using a stereo zoom microscope. Only Stage IV and V ovaries were used for detailed oocyte measurements. Oocytes were measured along their longest axis due to their capsule-shaped morphology.

Histological analysis of gonads

For histological analysis, gonads and sections of the alimentary canal were dissected and fixed in 10% neutral buffered formalin. Tissue processing, dehydration, embedding, sectioning, and staining were performed using standard histological procedures (Kiernan, 2008; Kerr, 2009). Briefly, tissues were dehydrated through graded alcohol series, cleared in xylene, embedded in paraffin, and sectioned at 6 µm thickness using a rotary microtome (Leica RM2235). Sections were stained with Harris' haematoxylin and eosin, mounted in DPX, and examined under a compound microscope (Leica DMLS) and stereo zoom microscope (Leica S8APO). Histological staging was based on cellular composition, relative abundance of germ cells, and organisation of gonadal tissue.

Feeding ecology and gut content analysis

For gut content analysis, the alimentary canal was carefully dissected, and the stomach contents were removed and examined under a stereo zoom microscope. Feeding intensity was assessed visually based on stomach fullness and classified as gorged, full, three-fourths full, half-full, quarter-full, trace, or empty (Pillay, 1952). Food items were identified to the lowest possible taxonomic level, and their relative contribution was estimated using percentage occurrence.

Monthly variations in feeding activity were evaluated using the gastrosomatic index (GaSI). The degree of feeding activity was categorised into active and poor feeding based on stomach fullness, and seasonal trends were analysed accordingly.

A minimum of 30 specimens were examined per month throughout the study period (January 2014 to December 2016), resulting in a total sample size of 720 individuals. This ensured adequate representation of size classes, maturity stages, and seasonal variation in reproductive and feeding parameters.

Statistical analysis

All quantitative data are presented as mean±standard deviation (SD). Mean values for morphometric, reproductive, and feeding parameters were calculated in Microsoft Excel 2019, and descriptive statistical analyses were performed to summarise seasonal variations and biological indices. Seasonal variations in the GaSI were analysed using one-way analysis of variance (ANOVA). Statistical analysis was performed using IBM SPSS Statistics (Version 25.0), and differences were considered significant at $p<0.05$.

Results

Reproductive system

The reproductive system of *N. cyanomos* is located within the body cavity, where the gonads are suspended by mesenterie tissues that provide structural support and maintain their anatomical position.

Female reproductive system

The ovaries are bilobed and symmetrical, with the two lobes fused to form a club-shaped structure that tapers anteriorly and broadens posteriorly. The oviduct is relatively short and narrow. In fully mature females, the ovaries measure 10–15 mm in length, with their size varying according to the size and maturity of the fish. The maximum width occurs in the mid part of the ovary and is about half of its total length.

Reproductive maturity stages of *N. cyanomos* (female)

Stage I (Virgin or Immature): The ovaries are small, transparent and readily distinguishable, occupying approximately one-fourth of the body cavity (Fig.1a). The oocytes are transparent, each containing a prominent centrally located nucleus. Oocyte diameters range from 20.03 to 58.40 µm, with a mean value of 38.55±9.69 µm. Stage I oocytes are present in ovaries across all maturity stages, indicating the asynchronous development of oocytes and suggesting that *N. cyanomos* is a continuous spawner.

Stage II (Immature): Ovary is enlarged and slightly yellowish (Fig.1b). Oocytes are more enlarged and conspicuous than in Stage I. Ovum diameter has a mean value of 82.89±7.96 µm with a range of 71.039–91.619 µm. The ovary occupies about one-third of the body cavity.

Stage III (Maturing): The ovaries become more enlarged and are clearly visible to the naked eye (Fig.1c). Three distinct groups of ova can be discerned, reflecting asynchronous oocyte development. The largest oocytes attain a maximum diameter of 233.409 µm, with a mean value of 169.67±48.66 µm, and are clearly distinct from the smaller cohorts. Progressive yolk deposition imparts a yellowish colouration to the oocytes, while the ovarian blood vessels become conspicuously dilated indicating active vitellogenesis and advanced maturation.

Stage IV (Mature): The ovaries are fully developed, club-shaped, and yellow or yellowish-brown in colour, with with prominently enlarged blood vessels visible on the ovarian surface (Fig.1d). Mature oocytes measure 307.57–472.76 µm in diameter, with a mean value of 360.11±66.16 µm and are densely packed with yolk granules, indicating complete vitellogenic development and readiness for spawning.

Stage V (Spawning): The ovaries are fully ripe, firm and deep orange in colour, occupying up to two-thirds of the body cavity (Fig.1e). Multiple cohorts of oocytes, including immature, developing, mature and fully hydrated spawning stage ova, are simultaneously present, reflecting asynchronous ovarian development and batch spawning. The spawning stage oocytes are yellow in colour (Fig.1f) and range from 587.27 to 846.15 µm with a mean value of 808.33±164.04 µm.

Stages of oocyte differentiation (Oogenesis)

Primary oogonia: Oogonia occurred in clusters embedded within the finger-like epithelial folds of the ovary. Both the cytoplasm and nucleus were pale and extremely translucent, making the cell boundaries difficult to distinguish. The nucleolus was not discernible at this stage (Fig. 2a). The mean cell diameter was 36.89±8.01 µm (Table.1).

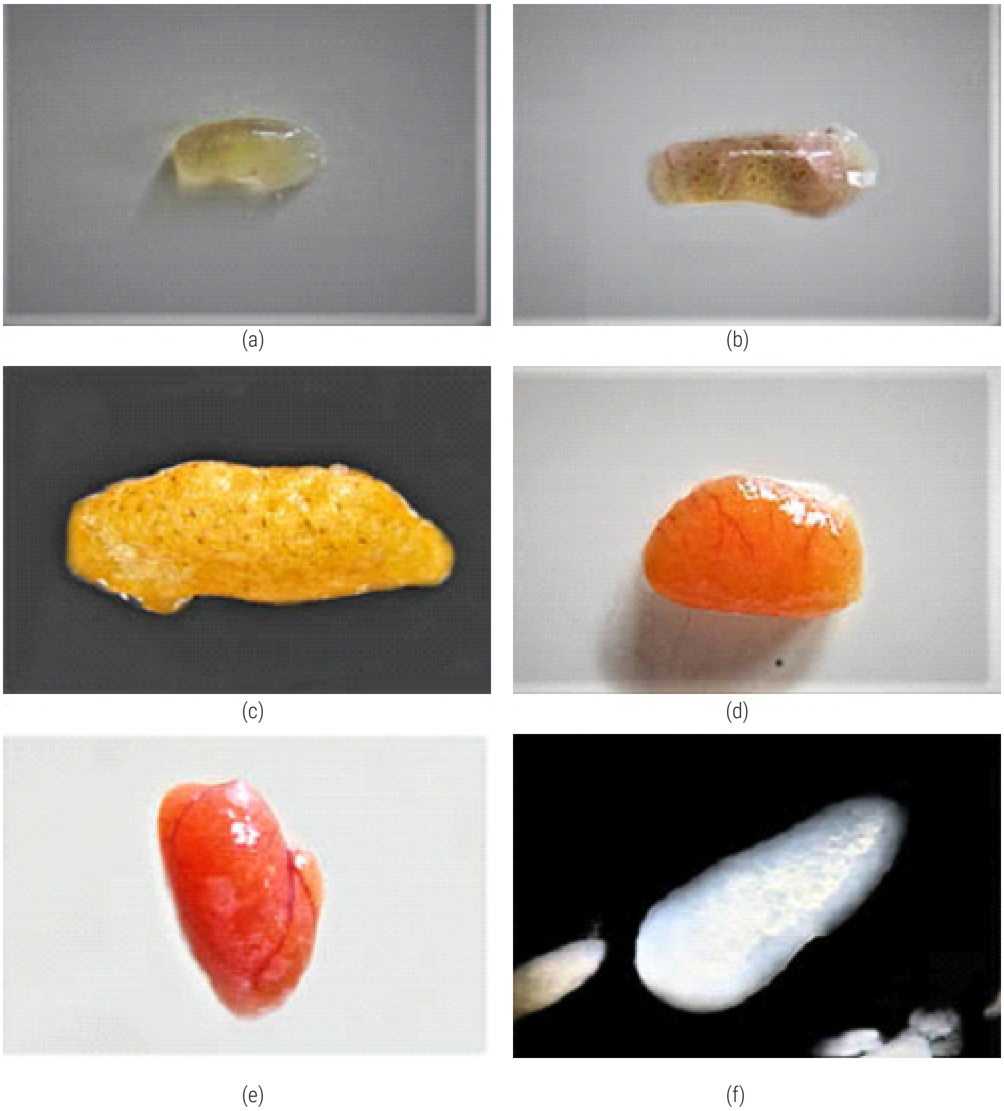

(a) (b) (c) (d) (e) (f)

Fig. 1. Gross morphology of the ovarian maturity stages in female *N. cyanomos*. (a) Stage I ovary; (b) Stage II ovary; (c) Stage III ovary; (d) Stage IV ovary; (e) Stage V ovary; (f) Stage V ova

Early peri-nucleolar stage (EPNS): These immature previtellogenic oocytes are characterised by a large, centrally located nucleus surrounded by a thin layer of cytoplasm containing about 9 nucleoli. The cytoplasm exhibits strong affinity for haematoxylin staining **(**Fig. 2a). Oocytes have a mean diameter of 65.23±33 µm **(**Table.1). At this stage, the nucleus is enlarged and distinctly separated from the surrounding cytoplasm, while extracellular membranes have not yet developed.

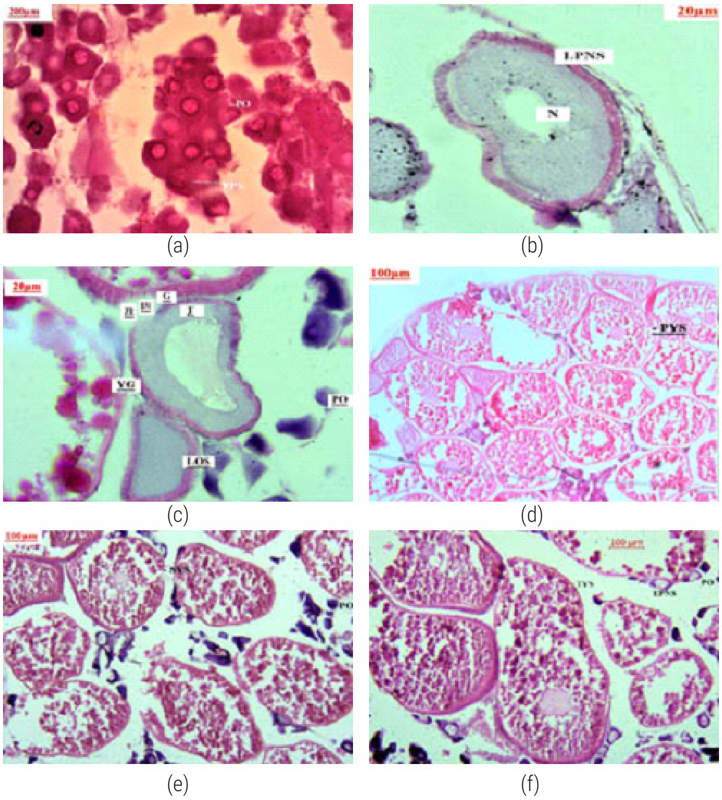
Late peri-nucleolar stage (LPNS): These oocytes are also known as previtellogenic oocytes and are characterised by a large, centrally located nucleus surrounded by a thin layer of cytoplasm. With haematoxylin-eosin staining, the cytoplasm appears pale purple (Fig. 2b). The nucleoli increase in size, and are located at the periphery, exhibiting considerable variation in size. During this stage, a large number of primary oocytes are observed, with the nucleus occupying about 50-75% of the total cell volume **(**Fig. 2b). Mean oocyte diameters were 105±35 µm (Table 1). Throughout this stage, the developing oocytes are surrounded by a thick layer of spindle-shaped follicular cells referred to as primary theca.

Oil droplet stage: Vesicles that were assumed to be lipids appeared in the cytoplasm of the oocytes. The oocyte and oocyte nucleus started increasing in size. The yolk nucleus with an oval shape was seen located at the periphery of the cytoplasm. As the oocytes increased in size, the size of the lipid vesicles also increased considerably. The zona radiata became apparent just before the initiation of yolk deposition, which became distinguishable for the first time. Towards the end of this phase, lipid vesicles organised themselves around the nucleus. The formation of yolk granules marked the end of this stage **(**Fig.2c). The mean oocyte diameter was 147.44±56.05 µm **(**Table.1).

Yolk stage I: This stage is known as the early primary vitellogenic stage or yolk vesicle stage. In the early YVS, the cytoplasm is more granular in appearance and there were spaces on the periphery of the oocyte. The early YVS oocytes were less frequently stained, they were dark purple with tiny vesicles. The nucleus was irregular in outline and smoother in texture, and contained up to six nucleoli (Fig.2d). The mean oocyte diameter was 360±66.16 µm (Table1). As vitellogenesis started, the size of oocytes began to increase considerably. A small number of yolk vesicles started making their appearance in the cytoplasm, initially in the outer cortex and the number of oil vesicles started decreasing in number. Spherical vesicles started to appear at the periphery of the cytoplasm. By the end of yolk stage I the different membranes that were visible in the oil droplet stage became well established and these membranes were seen concentrically arranged around the primary membrane oolemma. The membrane immediately surrounding the oolemma is non-cellular in nature and is called corona radiata. Outer to the corona radiata is a capsular layer of cuboidal cells derived from the theca granulosa of the follicle. In between the zona radiata and granulosa derived capsular layer there is a distinct basement membrane. Later, the chorion separated into the inner and outer zona radiata.

Yolk stage II: This stage corresponds to the early secondary vitellogenetic phase of oocyte development. In these larger oocytes, the cytoplasm appears paler than that observed during early yolk stage. The zona radiata becomes thicker and exhibits a distinct striated appearance. Oil droplets occupy a smaller proportion of the cytoplasm than yolk granules, which are predominantly distributed around the nucleus. The oil vesicles contain pale pink or purple-staining inclusions, and rapid proliferation results in a marked increase in cytoplasmic volume leading to enlargement of the oocyte. Consequently, the cytoplasm assumes proportionately greater size in comparison to the spherical nucleus. The nucleus appears eosinophilic and granular (Fig. 2e). The mean oocyte diameters at this stage is 560±47.85 µm (Table.1).

Yolk stage III: This stage represents the advanced secondary vitellogenic phase of oocyte development. The late vitellogenic oocytes are characterise by yolk vesicles occupying up to 50% of the cytoplasmic area, while the eosinophilic cytoplasm makes up most of the oocyte volume. In the largest oocytes, the cytoplasm appears uniformly dark red with a peripheral band of purple- staining yolk vesicles. The size of the oocytes increases significantly due to yolk accumulation. Numerous oil globules coalesce and come in close contact with the oolemma. The zona radiata further increases in thickness and and exhibits characteristic transverse striations. At this stage, the nucleus undergoes degeneration, leaving distinct central space within the oocyte. The capsular layer derived from the granulosa cells and the well-developed zona radiata are clearly visible (Fig.2f). The mean oocyte diameter at this stage is 830±21.67 µm (Table.1).



(a) (b) (c) (d) (e) (f)

Fig. 2. Histological sections showing successive stages of oocyte development in *N. cyanomos* ovary . (a) Early perinucleolar stage (PO - Primary oocyte, EPNS - Early perinucleolar stage); (b) Late perinucleolar stage (LPNS - Late perinucleolar stage, N -Nucleolus); (c) Oil droplet stage (PO - Primary oocyte, EOS - Early oil droplet stage, LOS -Late oil droplet stage, T - Theca, G - Granulosa, BM, - Basal membrane, ZR - Zona radiata, YG - Yolk granules; (d) Yolk vesicle stage (PYS – Primary yolk stage); (e) Secondary yolk vesicle stage (SYS - Secondary yolk stage); (f) Tertiary yolk vesicle stage (TYS - Tertiary yolk stage, EPNS - Early perinucleolar stage, PO - Primary oocyte)

Table 1. Oocyte diameter (µm) at different stages of ovarian maturation in *N. cyanomos*

Cell type	Oocyte diameter (µm) (Mean±SD)
Oogonia	36.89 ± 8.01
Perinucleolar stage	65.23 ± 33.00
Oil droplet stage	147.44 ± 56.05
Yolk stage I	360 ± 66.16
Yolk stage II	560.11 ± 47.85
Yolk stage III	830 ± 21.67

Male reproductive system

The testes are bilobed thick and flat structures located within the body cavity. In immature fish, the testes are slender, delicate, and thread-like. As the fish matures, the testes progressively increase in width and volume, and in fully mature males they occupy about two-thirds of the body cavity.

Reproductive maturity stage of male *N. cyanomos*

Stage I (Immature): At this stage, the testes are extremely small and whitish in colour and occupy around one fourth of the body cavity. Histologically, the testicular lobules were composed predominantly of primary spermatogonia of varying sizes, which are distributed both singly and in small clusters throughout the lobules (Fig. 3a).

Stage II (Immature): Testes are larger and longer than stage I, still retaining the whitish colouration, occupying around one third of the body cavity. Although still transparent and thread-like, they exhibit the onset of maturation, with a slight increase in firmness and width. They are broader anteriorly and gradually taper posteriorly, while remaining slender and translucent overall. This stage exhibits active spermatogenesis characterised by the the presence of spermatogonia and primary spermatocytes within testicular lobules (Fig. 3b).

Stage III (Maturing): At this stage, the testes become broader and ribbon-like occupying half of the body cavity. As maturation progresses, they continue to increase in thickness and width, with the colour becoming milky white. Histologically, this stage is characterised by the formation of a distinct lumen within the testicular lobules. Secondary spermatocytes predominate, while primary spermatocytes, spermatogonia and a few spermatids are also present, indicating active spermatogenic progression (Fig. 3c).

Stage IV (Mature): The testes are well developed, firm and slightly pinkish in colour, with an irregular outer margin, occupying around three fourth of the body cavity. Histologically, this stage is characterised by the predominance of spermatids over other spermatogenic cell types, indicating advanced spermatogenesis and readiness for spawning (Fig. 3d).

Stage V (Spawning): The testes attains their maximum size and appear large, flattened and pinkish-white in colour, with a mildly lobulated appearance. Gentle pressure on the abdomen readily extrudes milt, indicating reproductive maturity. Histological examination reveals abundant spermatozoa and spermatids, with the testicular lobules densely packed with spermatozoa. Spermatozoa are predominantly concentrated within the lobular lumen, whereas spermatogonia and primary spermatocytes are comparatively few in number (Fig.3e)

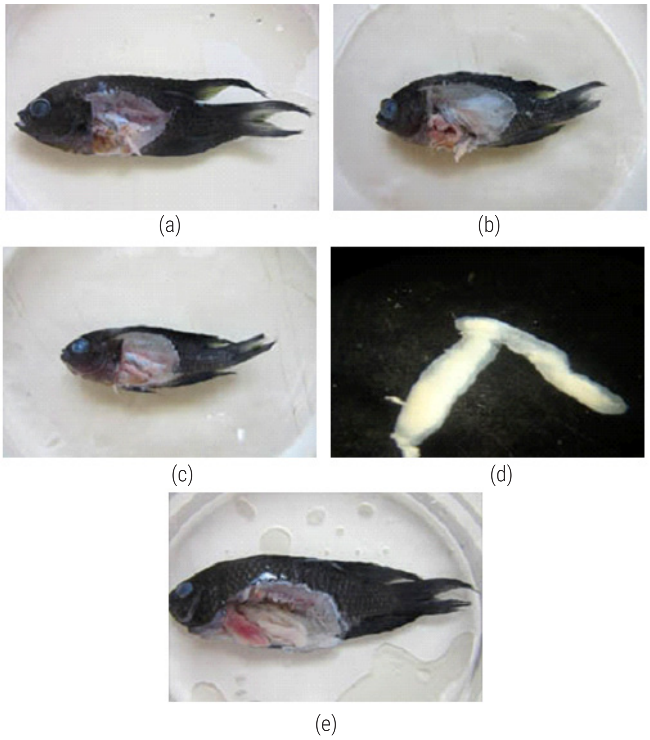

(a) (b) (c) (d) (e)

Fig. 3. Reproductive maturity stages of male *N. cyanomos*. (a) Stage I testis; (b) Stage II testis; (c) Stage III testis; (d) Stage IV testis; (e) Stage V testis

Histology of testis

Immature testis: In the immature testes, the predominant germ celss are spermatogonia, which are arranged in distinct nests, separated into lobules by fine partitions of connective tissue. As these cells increase in number, presumably by mitotic division rather than differentiation from epithelial cells, the nests become larger, while the individual germ cells become relatively smaller. In the larger nests, a central lumen begins to develop, marking the early structural organisation of the testicular lobules.

Maturing testis This stage is characterised by the presence of 5 distinct germ cell types *viz*., spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and spermatozoa. The primary spermatogonia are large ovoid cells with a large vesicular central nucleus and distinct nucleolus and are located along the periphery of the testicular lobules. Many of the spermatogonia are in transition stage to primary spermatocytes showing nuclear condensation. The secondary spermatocytes have a nuclear diameter of two-thirds that of the primary spermatocytes, whereas the spermatids have a nuclear diameter of about half that of the primary spermatocytes. During spermiogenesis, the nuclear material of the spermatids undergoes marked condensation, forming a homogeneous, dark-staining spherical structure.

Mature testis: The mature spermatozoon possesses an oval-shaped head, that tapers anteriorly and stains intensely dark in haematoxylin preparations. As maturation progress, the spermatozoa migrate towards the centre of the lobular lumen, where they become organised into irregularly-shaped sperm masses, with their tails oriented towards the centre. The spermatozoa remain free within the lumens of the lobules and are not attached to surrounding cells. Occasional resting spermatogonia are observed singly or in small groups from two to ten cells, irregularly distributed along the lobular walls or embedded within the stromal tissue (Fig. 4).

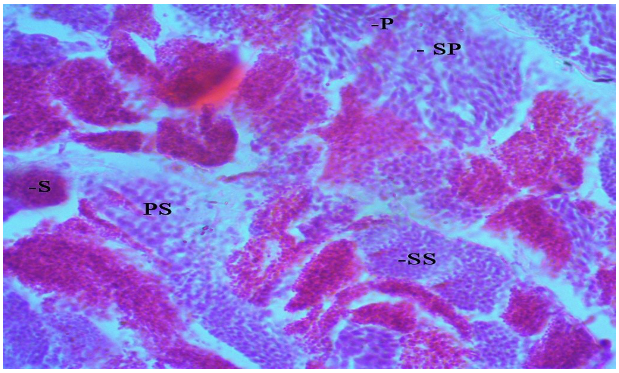


Fig. 4. Histological sections of *N. cyanomos* testis. S - Spermatogonia, PS - Primary spermatocytes, SS - Secondary spermatocyte, SP - Spermatid, P - Sperms

Stomach content analysis

Diet composition

Composition of gut contents of *N. cyanomos* is presented in Fig. 5. Copepods dominated the gut contents (41%), followed by ostracods (17%) and decapod crustaceans (14%). Amphipods (8%), cirripeds (6%)

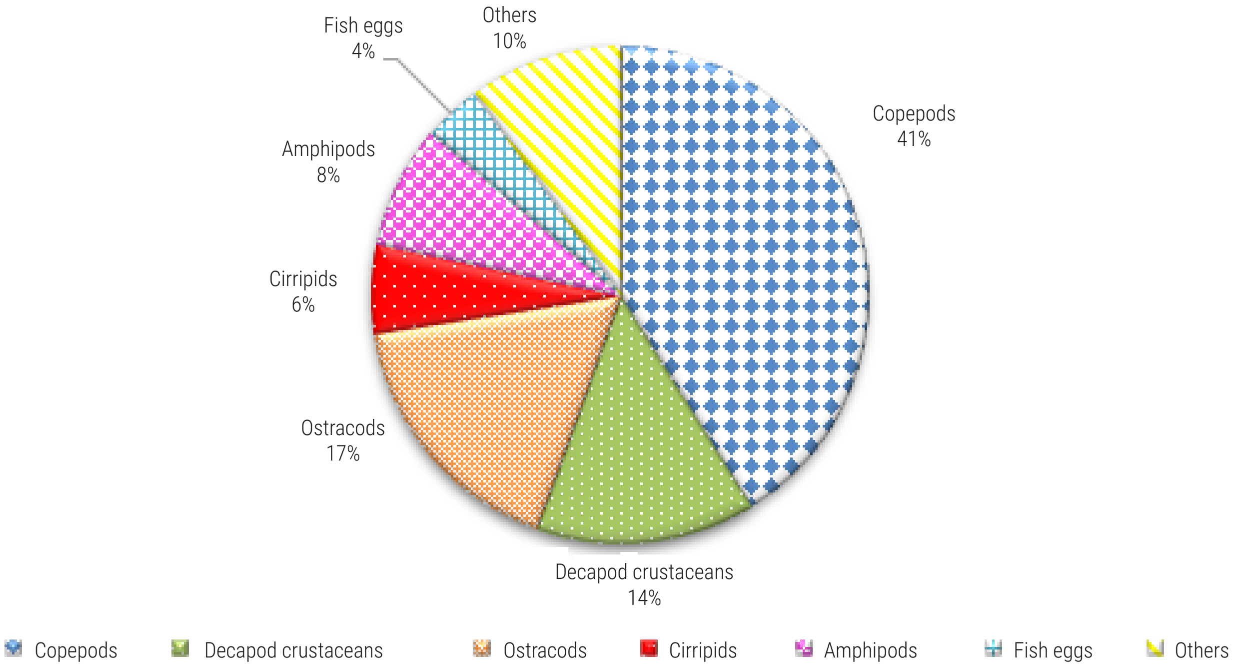


Fig. 5. Composition in the gut contents of *N. cyanomos*

and fish eggs were the other major components recorded from the gut of *N. cyanomos*. These contributed to about 90% of the gut contents. Minor dietary components included mysids (1.3%), green algae (1.3%), bryozoans (0.92%), *Lucifer* spp. (0.83%), crustacean eggs (0.83%), sabellid worms (0.83%), zoea larvae (0.5%), molluscs (0.42%), megalopa larvae (0.42%), nematode worms (0.42%), red algae (0.33%), *Podon* spp. (0.3%), sand particles (0.3%), chaetognaths (0.3%), bivalve larvae (0.17%) and medusae (0.08%). Overall, the gut content analysis indicates that *N. cyanomos* feeds predominantly on zooplanktonic crustaceans, reflecting its opportunistic planktivorous feeding habit.

Monthly variation in dietary composition

Monthly variations in the diet composition of *N. cyanomos* are presented in Table 2. Copepods were the most dominant food item throughout the study period, except June and constituted the sole dietary component recorded in May. The next dominant food item was decapod crustaceans which formed about half of the gut contents during January and February. Ostracods also formed a substantial proportion of the diet of *N. cyanomos,* contributing nearly about half of the gut contents during June, August and October. Cirripeds formed 50% of the gut contents during June, while amphipods accounted for a similar proportion in March, Green algae were present in trace amounts during January, April, September, October and November. Fish eggs were observed in the gut contents during April, July, August and November. Other dietary components occurred sporadically and in low proportions, generally being observed only during one to three months of the study period. Although copepods consistently dominated in the gut contents, no seasonal preference for any particular prey category was evident, which indicates that the fish is an opportunistic feeder readily accepting a wide range of available food resources in its environment.

The monthly variation in the feeding intensity of *N. cyanomos* is given in Table 3. The species exhibited active feeding behaviour, with the

Table 2. Monthly percentage occurrence of dietary components in the gut contents of *N. cyanomos*

Food items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Copepods	30	25	50	30	100	-	80	20	40	10	49	60
Decapods	47	50	-	-	-	-	-	-	10	10	15	40
Ostracods	10	25	-	-	-	50	-	50	10	60	-	-
Cirripeds	10	-	-	-	-	50	-	-	-	5	3	-
Molluscs	-	-	-	-	-	-	-	-	-	2	3	-
Amphipods	-	-	50	20	-	-	-	-	20	-	5	-
Zoea larvae	1	-	-	-	-	-	-	-	5	-	-	-
Megalopa larvae	-	-	-	-	-	-	-	-	-	-	5	-
Green algae	1	-	-	2	-	-	-	-	3	5	5	-
Red algae	1	-	-	3	-	-	-	-	-	-	-	-
Fish eggs	-	-	-	20	-	-	10	10	-	-	5	-
Crustacean eggs	-	-	-	10	-	-	-	-	-	-	-	-
Lucifer spp.	-	-	-	10	-	-	10	-	-	-	-	-
Bryozoans	-	-	-	4	-	-	-	-	5	-	2	-
Mysids	-	-	-	1	-	-	-	10	-	-	5	-
Sabellid worms	-	-	-	-	-	-	-	10	-	-	-	-
Nematode worms	-	-	-	-	-	-	-	-	-	5	-	-
Bivalves	-	-	-	-	-	-	-	-	2	-	-	-
Podon spp.	-	-	-	-	-	-	-	-	4	-	-	-
Medusae	-	-	-	-	-	-	-	-	1	-	-	-
Sand particles	-	-	-	-	-	-	-	-	-	3	-	-
Chaetognaths	-	-	-	-	-	-	-	-	-	-	3	-

Table 3. Monthly variation of feeding intensity (%)(pooled data)

		Active feeding				Poor feeding		
Months	No. of observations	Gorged	Full	3/4	1/2	1/4	Trace	Empty
January	45	0	6	2	8	18	4	7
February	54	3	9	5	14	9	5	9
March	18	3	4	4	7	0	0	0
April	38	6	9	4	14	3	2	0
May	32	9	5	3	5	6	2	2
June	18	3	5	2	5	0	1	2
July	34	1	5	1	5	7	10	5
August	17	0	2	0	4	3	3	5
September	24	0	1	0	5	6	8	4
October	19	1	1	3	5	7	1	1
November	32	4	7	2	10	4	2	3
December	27	1	3	6	9	5	3	0
Total	358	31	57	32	91	68	41	38

number of actively feeding individuals (211) exceeding that of poor feeders (147), with an active to poor feeder ratio of approximately 1.43:1. This indicates predominance of active feeding behaviour among the sampled population. Exceptions to this pattern were observed during January, July, August and September, when the ratios of active to poor feeders were 16:29, 12:22, 6:11 and 6:18 respectively, indicating a greater proportion of poorly fed individuals during these months. In contrast, all examined fish were active feeders during March, while October showed an equal proportion of active and poor feeders. Analysis of the overall feeding intensity revealed that about 25% of the fishes had half-full stomachs (Fig. 6). During the entire study period, 59% of fishes were found to be active feeders and 41% as poor feeders. Empty stomachs were observed during March, April and December.

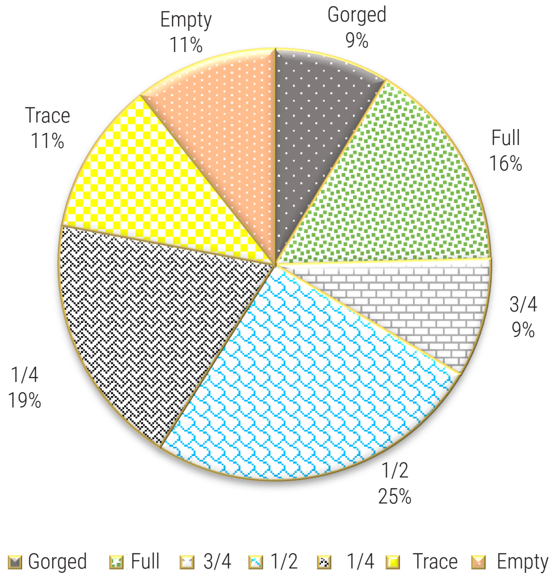


Fig. 6. Feeding intensity (%) in *N. cyanomos*

Monthly variation in GaSI

Monthly variation in the GaSI of *N. cyanomos* (Fig. 7) collected from Vizhinjam coast during 2015–2016 shows that the highest mean GaSI values were recorded during July (3.7) and August (3.6), whereas the lowest values occurred in January (0.74) and June (0.55).

One-way analysis of variance (ANOVA) performed to evaluate seasonal variations in the GaSI of *N. cyanomos*, yielded an F-value of 2.74 (df=3, 8) with a p-value of 0.113, indicating that seasonal differences in GaSI were not statistically significant ($p>0.05$). Nevertheless, relatively higher GaSI values recorded during the monsoon months, with a pronounced peak in July (3.72±SE), suggest enhanced feeding activity during this period.

Discussion

N. cyanomos is a widely distributed pomacentrid inhabiting coral reef–associated environments along the Indian coastline. Members of this genus play an important ecological role in reef ecosystems, contributing to energy transfer and trophic structuring. Their growth, reproduction, and feeding behaviour are strongly influenced by environmental factors such as food availability, habitat complexity, temperature, and seasonal variability (Allen, 1998; Al-Zibdah and Kan'an, 2009). In the present study, gonadal development in *N. cyanomos* exhibited clear seasonal and histological patterns. While testicular mass showed relatively minor fluctuations, ovarian mass varied considerably, reflecting differences in reproductive investment across seasons. Similar trends have been reported in other pomacentrids, where gonadal development is strongly influenced by habitat quality, food availability, and environmental stability (Castellanos-Galindo *et al*., 2010; Santhosh Kumar, 2016). Coral-rich habitats with greater structural complexity often support enhanced gonadal development compared to resource-limited environments.

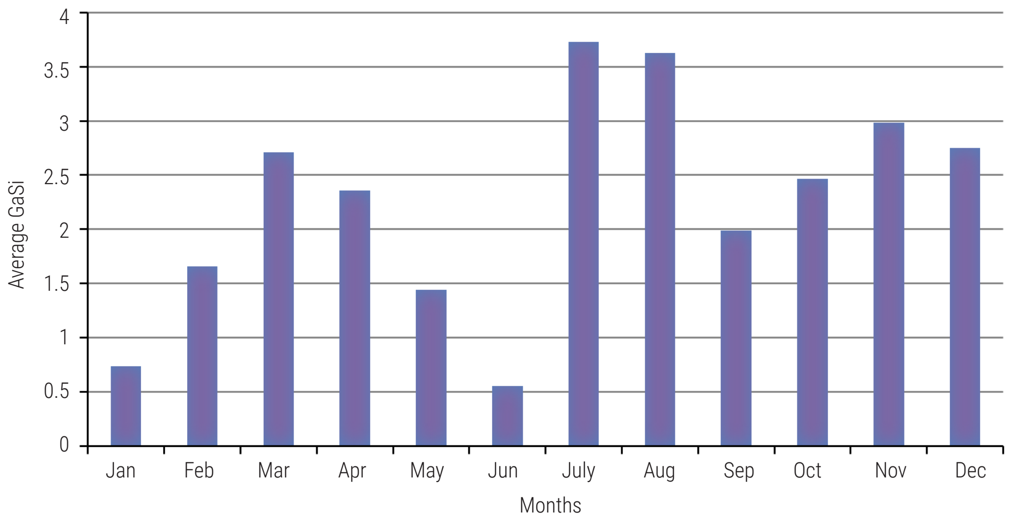


Fig. 7. Monthly variation in the GaSI of *N.cyanomos*

Histological examination revealed five distinct stages of ovarian development, consistent with earlier descriptions for pomacentrids (Pillai and Mohan, 1990; Sreeraj and Gopakumar, 2004). The presence of multiple oocyte developmental stages within a single ovary confirms asynchronous oocyte development and indicates a prolonged or continuous spawning strategy. Similar reproductive patterns have been documented in *Dascyllus aruanus*, *Chrysiptera cyanea*, and *Chromis notata* (Cole, 2002; Bapary *et al*., 2009; Lee *et al*., 2017). The wide range of oocyte diameters observed in *N. cyanomos* (36.89–830 µm) further supports this interpretation and closely matches values reported for related pomacentrids. The progression of oogenesis in *N. cyanomos,* from oogonia through perinucleolar, oil droplet, and successive yolk stages, closely resembles that described for other reef-associated species (Emel'yanova and Makeeva, 1989; Emel'yanova *et al*., 2009). The development of a distinct zona radiata during the oil droplet stage and its subsequent thickening during vitellogenesis are characteristic features of teleost oocyte maturation. In contrast to some species exhibiting multilayered egg envelopes, *N. cyanomos* shows a predominantly single-layered zona radiata, similar to observations in *Abudefduf sexfasciatus* and *Neopomacentrus nemurus* (Shadrin and Emel'yanova, 2007). Male gonadal development also followed typical pomacentrid patterns, progressing from spermatogonial proliferation to spermiogenesis. Mature testes were dominated by spermatozoa, with only sparse spermatocytes remaining, indicating readiness for spawning. Unlike certain pomacentrids that exhibit hermaphroditism, *N. cyanomos* showed clear gonochorism, with no evidence of sex reversal, consistent with earlier reports (Sreeraj and Gopakumar, 2004).

Feeding ecology revealed that *N. cyanomos* is predominantly zooplanktivorous, with copepods forming the major dietary component (41%), followed by ostracods and decapod crustaceans. This feeding pattern aligns with observations in several pomacentrids such as *Dascyllus trimaculatus*, *Chromis pelloura*, and *Teixeirichthys jordani* (Al-Zibdah and Kan'an, 2009). However, the relative contribution of dietary components varied among species. While polychaetes and algae dominate in some pomacentrids, algal material in *N. cyanomos* was minimal, suggesting incidental ingestion rather than targeted herbivory. The presence of benthic prey items such as bivalve larvae, polychaetes, and sand particles indicates occasional benthic foraging, consistent with observations by Hiatt and Strasburg (1960). The occurrence of fish eggs and gelatinous zooplankton further highlights opportunistic feeding behaviour. Seasonal variation in feeding intensity was evident, with peak feeding during March–April and December, corresponding closely with periods of elevated gonadal activity. This synchrony between feeding intensity and reproductive development underscores the energetic coupling between nutrition and gametogenesis. Comparatively, feeding peaks in *N. cyanomos* differed from those reported in other pomacentrids, such as *D. trimaculatus* and *C. pelloura*, reflecting species-specific ecological strategies and local environmental conditions. Despite these differences, the overall trophic plasticity observed in *N. cyanomos* is characteristic of reef-associated fishes adapted to fluctuating resource availability.

Overall, the present study demonstrates that *N. cyanomos* exhibits asynchronous oocyte development, prolonged spawning, and flexible feeding strategies, enabling successful reproduction under variable environmental conditions. The integration of histological, morphometric, and dietary data provides a comprehensive understanding of its reproductive ecology. These findings contribute valuable baseline information for reef fish biology and offer insights relevant to conservation planning and ecosystem-based management of coral reef fisheries.

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