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Reproductive Biology, Induced Breeding and Cage-Culture Growth Performance of Climbing Perch (Anabas Testudineus, Bloch 1792): Implications for Small-Scale Aquaculture Extension

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ABSTRACT: Climbing perch, Anabas testudineus (Bloch, 1792), is a high-value air-breathing fish widely favoured by small and marginal farmers of eastern and north-western India for its hardiness, disease resistance and premium market price, yet its wider adoption in aquaculture is constrained by low natural fecundity and the absence of a standardized hatchery protocol. The present study examined (i) the fecundity-length-weight relationship of wild broodstock collected from two geographically separated wetland habitats, (ii) the comparative efficacy of carp pituitary extract (CPE) and the synthetic hormones Ovaprim and Ovatide for induced breeding, and (iii) the growth, survival and economic performance of A. testudineus fingerlings reared in bamboo cages installed within farmers' ponds. Fecundity increased with total length and body weight in both habitats (power-function fit; Habitat I: $r = 0.92$; Habitat II: $r = 0.87$), confirming length as a practical field predictor of egg output. Among the nine hormone-dose combinations tested, Ovatide at 0.4 ml/kg body weight of female (Group H) produced the highest fertilization (98.15 ± 1.8%) and hatching rate (94.50 ± 2.8%), followed closely by Ovaprim at 0.7 ml/kg (Group F). Cage-reared fingerlings attained a weight gain of 2871.43 ± 4.50% over a 7-month culture cycle with 91% survival, and economic appraisal indicated a benefit-cost ratio of 3.35 for the first crop. A parallel on-farm demonstration comparing genetically improved Jayanti rohu (Labeo rohita) with native rohu under mono- and composite-culture regimes showed the improved strain outperforming native stock by up to 52.9-fold in cumulative weight gain by the eleventh month. These findings provide an evidence base for extending standardized breeding and cage-culture protocols to resource-poor fish farmers as a low-input, high-return aquaculture diversification option.

1. INTRODUCTION

Inland aquaculture contributes nearly two-thirds of India's total fish production and remains the principal livelihood option for millions of small and marginal farm households in the hill and plateau regions where riverine and pond resources dominate the rural landscape. Within this diversification portfolio, climbing perch, Anabas testudineus (Bloch, 1792), has attracted growing attention because of its air-breathing accessory respiratory organ, tolerance of poor water quality and low dissolved oxygen, and strong consumer demand that commands a price premium over major carps in most regional markets.

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Despite this potential, seed availability continues to be the single largest bottleneck limiting commercial-scale culture of A. testudineus. Natural fecundity of the species is comparatively low and highly variable between water bodies, and spontaneous spawning under captive conditions is rare, so hatchery seed production depends on hormone-induced breeding. Several inducing agents have been evaluated for the species, including carp pituitary extract (CPE), the gonadotropin-releasing hormone analogue-based preparation Ovaprim, and the domperidone-combined analogue Ovatide, with reported fertilization and hatching outcomes that vary considerably with dose, brooder condition and season across studies conducted in West Bengal, Assam, Chhattisgarh and Bangladesh.

Parallel work on fecundity estimation in small indigenous and air-breathing fishes has consistently shown that egg output scales with body length, body weight and ovary weight through a power-law relationship, a pattern first systematized for temperate freshwater fish by Bagenal and subsequently confirmed for a range of tropical species. Such relationships are of direct extension value because they allow field workers to select high-fecundity brooders using simple morphometric measurements rather than destructive sampling.

Beyond the hatchery phase, on-growing performance under low-cost culture systems determines whether a breeding technology translates into farmer-level adoption. Bamboo-cage culture nested within existing carp polyculture ponds has been promoted as a way of intensifying production without additional land or water requirements, and comparable cage and recirculatory system trials on A. testudineus have reported survival in excess of 90% together with favourable feed conversion under properly managed stocking densities. Complementary genetic improvement efforts in Indian major carp aquaculture, exemplified by the release of the selectively bred Jayanti strain of rohu (Labeo rohita) by ICAR-CIFA, have likewise demonstrated substantial per-generation gains in growth over native farmed stock, offering a template for combining improved germplasm with improved husbandry at the farmer level.

Against this background, the present investigation was undertaken with three specific objectives: (i) to characterize the fecundity-length-weight relationship of A. testudineus broodstock from two wetland habitats of a hill district; (ii) to compare the breeding performance of carp pituitary extract, Ovaprim and Ovatide across a range of doses under identical hatchery conditions; and (iii) to evaluate the growth, survival and economic viability of bamboo-cage culture of the resulting seed in farmers' ponds, alongside a comparative on-farm demonstration of genetically improved versus native rohu. The results are intended to inform standardized, farmer-transferable protocols for climbing perch seed production and cage-based grow-out as a diversification pathway for small-scale freshwater aquaculture.

2. MATERIALS AND METHODS

The study was conducted over two consecutive culture seasons in a hill-district freshwater aquaculture system, combining a hatchery-based breeding trial with an on-farm cage-culture demonstration involving ten cooperating farmers' ponds. The overall methodological workflow is summarized in Figure 1.

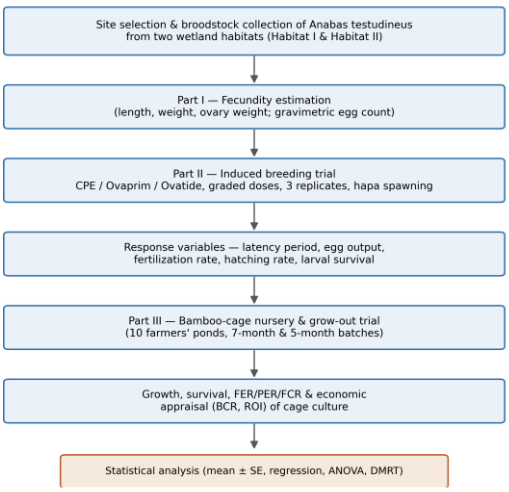

Figure 1: Schematic workflow of broodstock collection, fecundity estimation, induced breeding and cage-culture grow-out trial.

2.1 Broodstock collection and fecundity estimation

Sexually mature climbing perch of both sexes were collected from two geographically separated wetland habitats (designated Habitat I and Habitat II) using cast nets and hand nets during the pre-monsoon maturation period. For fecundity estimation, healthy female brooders spanning the natural size range available in each habitat were weighed (nearest 0.1 g) and measured for total length (nearest 0.1 cm) prior to dissection. Ovaries were excised, blotted and weighed, and the gravimetric sub-sample method was used to estimate total ovarian egg complement: three weighed sub-samples were taken from the anterior, middle and posterior regions of each ovary, ova were counted under a stereo-binocular microscope, and total fecundity was extrapolated from the mean sub-sample count and total ovary weight. The relationships between fecundity and total length, body weight and ovary weight were each fitted using least-squares regression on log-transformed variables (power function $F = a \cdot X^b$), following the standard approach for fecundity-morphometric relationships in freshwater teleosts.

2.2 Induced breeding trial

Mature brooders (mean weight 62-67 g for females, 62-66 g for males) were held in hapas installed within an earthen pond and acclimatized for 48 h prior to hormone administration. Nine treatment groups plus an untreated (saline-injected) control were established (n = 3 replicate pairs per group, 1 male : 1 female): three graded doses of carp pituitary extract (8, 10 and 12 mg/kg body weight of female with proportionally lower doses for males), three graded doses of Ovaprim (0.3, 0.5 and 0.7 ml/kg body weight of female) and three graded doses of Ovatide (0.3, 0.4 and 0.5 ml/kg body weight of female). All hormones were administered as a single intramuscular injection. Latency period, number of females that ovulated, egg output per female, fertilization rate and hatching rate were recorded for each treatment. Fertilization rate was computed as the percentage of eggs showing a clear blastodisc, and hatching rate as the percentage of fertilized eggs producing free-swimming larvae, both scored 24-30 h post-fertilization.

2.3 Nursery rearing and bamboo-cage grow-out

Hatchlings from the most successful spawning batches were nursed in nylon hapas and plastic troughs; first feeding commenced after complete yolk-sac absorption (day 3-4) using finely sieved zooplankton and formulated starter feed. Seven-to-ten-day-old fry were subsequently stocked into bamboo-frame cages (mesh-lined, submerged to two-thirds depth) installed within the ponds of ten cooperating farmers, with two cages per 0.1 ha pond. Two successive batches were monitored: a first batch cultured for seven months and a second batch cultured for five months. Body weight was recorded at monthly intervals on a sub-sample of 20-30 fish per cage. At harvest, survival, weight gain percentage, specific growth rate (SGR), feed efficiency ratio (FER), protein efficiency ratio (PER) and feed conversion ratio (FCR) were computed using standard formulae. In a subset of five ponds, an integrated demonstration compared cage-cultured A. testudineus with concurrent pond polyculture of Indian major carps to assess combined income potential.

2.4 Comparative demonstration of Jayanti rohu versus native rohu

In a parallel model demonstration, the genetically improved Jayanti strain of rohu (Labeo rohita), obtained from an ICAR-CIFA-linked hatchery lineage, was compared with locally sourced native rohu under two culture regimes: monoculture of Jayanti rohu (Mc_Jr), monoculture of native rohu (Mc_Nr) and composite culture of Jayanti rohu with other Indian major carps (Cc_Jr). Thirty fish per group (n = 30) were sampled monthly over an eleven-month culture period and percentage weight gain relative to stocking weight was computed for each group and each sampling month.

2.5 Economic analysis

Partial-budget economic analysis of cage culture was carried out for both the seven-month and five-month batches, accounting for capital costs (cage material, amortized over four crops), operational costs (seed, feed, labour, cage repair) and gross returns at prevailing farm-gate price. Net income, benefit-cost ratio (BCR) and return on investment (ROI) were computed for each batch and compared with the gross returns from conventional carp polyculture in the same ponds.

2.6 Statistical analysis

Data are expressed as mean ± standard error (SE). Differences among hormone-treatment groups and among monthly growth increments were tested using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) for post-hoc comparison, with significance set at $P < 0.05$. Regression and correlation coefficients were computed for fecundity-morphometric relationships using ordinary least squares on log-transformed data.

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3. RESULTS

3.1 Fecundity and its relationship with body length and weight

Fecundity of A. testudineus ranged from approximately 4,400 to 39,000 ova per female across both habitats and increased consistently with total length and body weight (Figure 2). A power-function fit gave F = 66.4 × L2.18 for Habitat I (r = 0.92) and F = 257.0 × L1.63 for Habitat II (r = 0.87), where F is fecundity and L is total length in cm, broadly consistent with the length-dependent fecundity relationships reported for other small and medium-bodied freshwater teleosts. Fecundity was more tightly correlated with ovary weight than with either total length or body weight, reflecting the direct contribution of ovary mass to egg complement. Brooders from Habitat I showed a modestly higher fecundity-at-length than those from Habitat II, suggesting habitat-linked differences in nutritional condition or age structure of the sampled populations that merit further investigation. The joint influence of length and weight on estimated fecundity is illustrated as a response surface in Figure 3, which shows the compounding effect of larger, heavier brooders on total egg output and reinforces field selection of larger females as high-fecundity brooders for hatchery use.

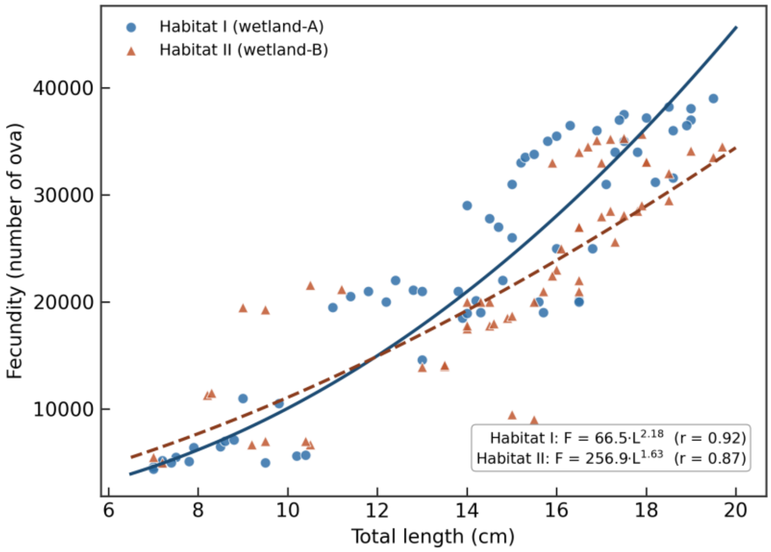

Figure 2: Fecundity-length relationship of Anabas testudineus broodstock from two wetland habitats (power-function regression fitted on log-transformed data).

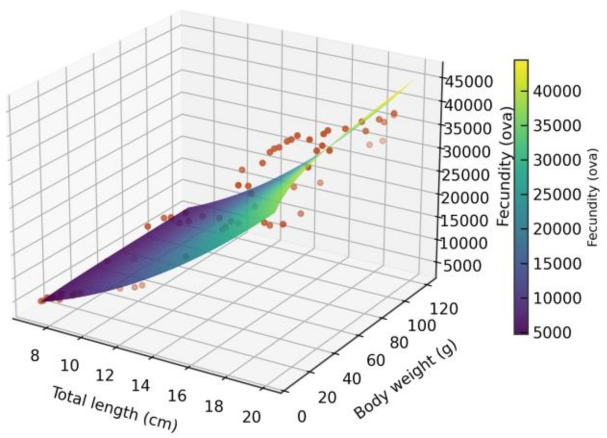

Figure 3: Response surface illustrating the joint effect of total length and body weight on estimated fecundity of A. testudineus (derived from the length- and weight-fecundity regressions).

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3.2 Induced breeding performance

No breeding occurred in the saline-injected control group, confirming the necessity of hormonal induction in this species under captive conditions. Among the nine treatments (Table 1, Figure 4), fertilization and hatching rates increased with dose within each hormone class. Ovatide at 0.4 ml/kg body weight of female (Group H) gave the highest performance, with 98.15 ± 1.8% fertilization and 94.50 ± 2.8% hatching, followed by Ovaprim at 0.7 ml/kg (Group F: 95.15 ± 1.9% fertilization, 92.50 ± 2.7% hatching) and Ovatide at 0.5 ml/kg (Group I: 88.14 ± 2.4% fertilization, 85.50 ± 2.4% hatching). The highest CPE dose tested (12 mg/kg; Group C) produced complete spawning but with comparatively lower fertilization (72.24 ± 2.6%) than the top-performing synthetic-hormone treatments. Latency period was inversely related to dose within each hormone group, ranging from 8-9 h at the highest doses to 13-14 h at the lowest. Egg output per female ranged from 52,000 (Group A) to 130,000 (Group H), and treatments producing complete spawning were consistently associated with fertilization rates above 80%. These results indicate that low-to-moderate doses of Ovatide or Ovaprim offer a more consistent and higher-yielding alternative to CPE for hatchery-scale seed production of A. testudineus, corroborating similar comparative findings reported for the species elsewhere in eastern and north-eastern India.

Table 1: Results of induced breeding of A. testudineus with carp pituitary extract (CPE), Ovaprim and Ovatide (mean ± SE, n = 3).

Group	Hormone / dose	Latency period (h)	Egg output (no./female)	Fertilization (%)	Hatching (%)
Control	Saline (0.5 ml/kg)	-	Nil	Nil	Nil
A	CPE 8 mg/kg	14	52,000	36.24 ± 2.5	51.50 ± 3.2
B	CPE 10 mg/kg	11	76,000	51.24 ± 2.3	59.50 ± 3.0
C	CPE 12 mg/kg	9	92,000	72.24 ± 2.6	74.50 ± 2.9
D	Ovaprim 0.3 ml/kg	13	87,000	62.14 ± 3.1	66.50 ± 2.3
E	Ovaprim 0.5 ml/kg	9	111,000	81.14 ± 3.4	81.50 ± 2.6
F	Ovaprim 0.7 ml/kg	9	126,000	95.15 ± 1.9	92.50 ± 2.7
G	Ovatide 0.3 ml/kg	12	104,000	69.14 ± 3.0	72.50 ± 2.3
H	Ovatide 0.4 ml/kg	8	130,000	98.15 ± 1.8	94.50 ± 2.8
I	Ovatide 0.5 ml/kg	9	122,000	88.14 ± 2.4	85.50 ± 2.4

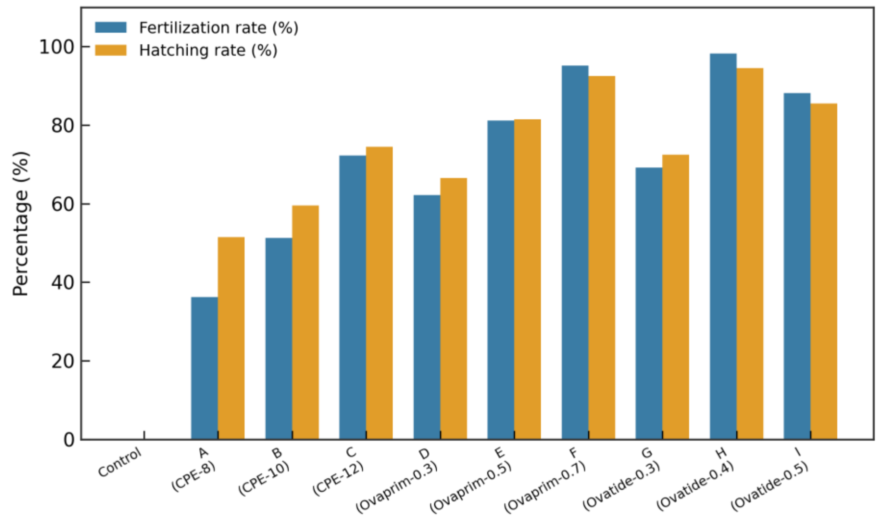

Figure 4: Fertilization and hatching rates of A. testudineus across the ten induced-breeding treatment groups.

3.3 Growth, survival and feed utilisation in cage culture

Fingerlings stocked in bamboo cages showed rapid early growth, with mean body weight increasing from 2.15 ± 0.25 g to 62.40 ± 2.10 g over the seven-month first batch (weight gain 2871.43 ± 4.50%; SGR 1.62 ± 0.12% day^{-1}) and from 15.00 ± 1.20 g to 63.50 ± 1.25 g over the five-month second batch (weight gain 323.33 ± 2.5%; SGR 0.69 ± 0.03% day^{-1}) (Table 2, Figure 5). Survival was 91.0% in the first batch and 97.0% in the second, and net biomass production per two-cage unit was 54.18 kg and 46.11 kg respectively. Feed conversion ratio was 3.79 ± 0.16 and 4.19 ± 0.21 for the two batches, with corresponding feed efficiency ratios of 0.263 ± 0.14 and 0.238 ± 0.08. Water quality parameters (temperature, pH, alkalinity, free CO2) generally remained within the optimum range for warm-water aquaculture, although reduced winter temperatures (December-February) were associated with slower growth increments, consistent with the known thermal sensitivity of A. testudineus growth and metabolism.

Table 2: Growth, survival and feed-utilisation parameters of A. testudineus reared in bamboo cages.

Parameter	7-month batch (First)	5-month batch (Second)
Initial weight (g)	2.15 ± 0.25	15.00 ± 1.20
Final weight (g)	62.40 ± 2.10	63.50 ± 1.25
Weight gain (%)	2871.43 ± 4.50	323.33 ± 2.50
Specific growth rate (% day^{-1})	1.62 ± 0.12	0.69 ± 0.03
Survival (%)	91.0	97.0
FER	0.263 ± 0.14	0.238 ± 0.08
PER	1.05 ± 0.07	0.954 ± 0.05
FCR	3.79 ± 0.16	4.19 ± 0.21

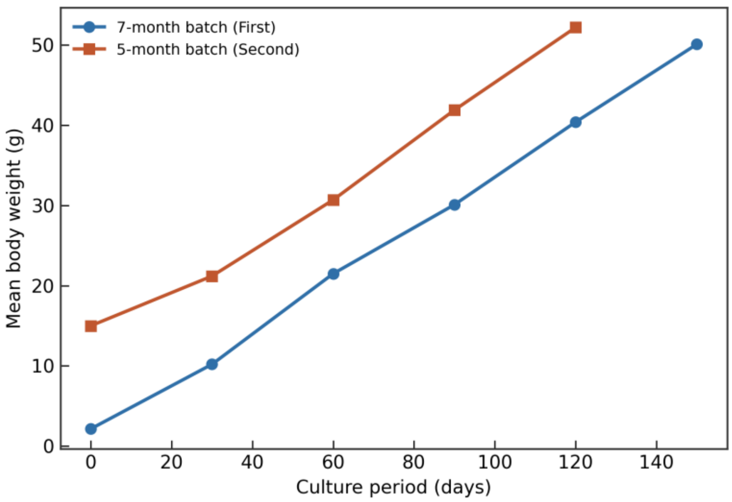

Figure 5: Monthly growth of A. testudineus fingerlings in bamboo-cage culture, 7-month and 5-month batches.

3.4 Economics of cage culture

Economic appraisal (Table 3) showed a benefit-cost ratio of 3.35 and return on investment of 235.71% for the seven-month batch, and a BCR of 2.84 and ROI of 184.31% for the five-month batch, with net incomes of Rs. 13,843 and Rs. 13,866 respectively per two-cage unit in a 0.1 ha pond. When cage culture of A. testudineus was integrated with concurrent carp polyculture in the same pond, combined gross income reached approximately Rs. 100,889 from 0.1 ha, compared with Rs. 59,784 from carp polyculture alone, indicating that cage-based intensification can substantially raise per-unit-area returns without additional land requirement.

Table 3: Economics of bamboo-cage culture of A. testudineus (2 cages / 0.1 ha pond).

Particulars	7-month culture (Rs.)	5-month culture (Rs.)
Capital cost / crop (amortized)	1,623	1,623
Operational cost	4,250	6,500
Cage repair cost	0	500
Total cost	5,873	7,523
Gross income	19,716	21,389
Net income	13,843	13,866
Benefit-cost ratio	3.35	2.84
Return on investment (%)	235.71	184.31

.5 Comparative growth performance of Jayanti rohu and native rohu

In the parallel demonstration (Table 4, Figure 6), monoculture Jayanti rohu (Mc_Jr) and composite-culture Jayanti rohu (Cc_Jr) tracked closely during the first three months but diverged thereafter, with Mc_Jr showing consistently higher weight gain from the fourth month onward. Native rohu in monoculture (Mc_Nr) showed the lowest growth throughout the culture period. By the eleventh month, cumulative weight gain reached 19,141.2 ± 738.3% for Mc_Jr, 16,310.4 ± 622.0% for Cc_Jr and 13,854.6 ± 505.9% for Mc_Nr, representing a 5,286.6 percentage-point advantage of monoculture Jayanti rohu over native rohu. These results are consistent with independent reports of 15-20% per-generation growth gain in the Jayanti strain over farmed native stock and confirm the value of pairing genetically improved germplasm with the same low-input culture systems used for A. testudineus in this study.

Table 4: Monthly weight gain (%) of Labeo rohita cultured as mono-cultured Jayanti rohu (Mc_Jr), mono-cultured native rohu (Mc_Nr) and composite-cultured Jayanti rohu (Cc_Jr) (mean ± SE, n = 30).

Month	Mc_Jr (%)	Mc_Nr (%)	Cc_Jr (%)
1	903.2 ± 27.2	656.2 ± 50.0	872.6 ± 92.9
3	2915.0 ± 95.2	1663.4 ± 98.1	2547.6 ± 155.6
5	4425.2 ± 161.3	2666.6 ± 129.1	3664.4 ± 96.9
7	7470.6 ± 289.8	4932.6 ± 214.1	6183.0 ± 231.0
9	13173.8 ± 546.1	8833.4 ± 193.8	10512.2 ± 355.6
11	19141.2 ± 738.3	13854.6 ± 505.9	16310.4 ± 622.0

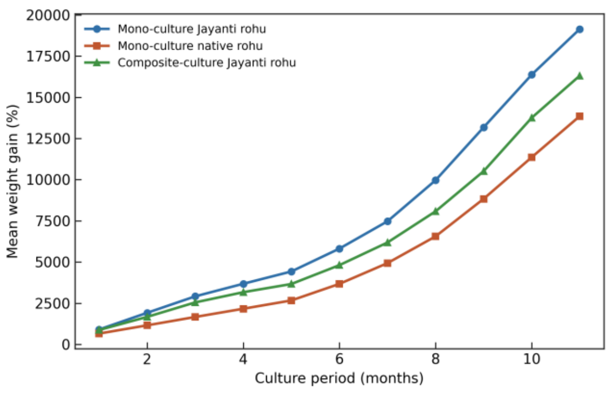

Figure 6: Comparative monthly weight-gain trajectories of mono-cultured Jayanti rohu, mono-cultured native rohu and composite-cultured Jayanti rohu.

4. DISCUSSION

The present findings reinforce and extend earlier reports that fecundity in A. testudineus scales positively with body size, and demonstrate that this relationship holds across two geographically distinct wetland populations, though with habitat-specific differences in the scaling exponent. Because ovary weight showed the tightest correlation with fecundity, field-level brooder selection based on visual assessment of gravidity combined with simple length measurement offers a practical, non-lethal screening approach for hatchery operators, consistent with fecundity-estimation practice recommended for other freshwater species.

The superior performance of Ovatide and Ovaprim relative to carp pituitary extract observed here parallels several independent trials on the species. Comparable studies conducted in Siliguri, Chhattisgarh and north-eastern India have similarly reported that low-to-moderate doses of GnRH-analogue-based synthetic hormones achieve fertilization and hatching rates equal to or exceeding those obtained with CPE, while avoiding the logistical difficulty of sourcing and standardizing donor pituitary glands. The present results, showing peak fertilization of 98% at 0.4 ml/kg Ovatide, sit at the upper end of the range reported in the wider literature and suggest that the specific hatchery conditions (water temperature, brooder conditioning period, sex ratio) employed in this study were favourable for spawning response.

Cage-culture growth and survival obtained in the present study compare favourably with reports from low-cost recirculatory and cage systems elsewhere in India and Bangladesh, where survival in the 80-100% range and feed conversion ratios of 2-4 have been documented depending on stocking density and system design. The comparatively higher FCR observed in the present five-month batch relative to the seven-month batch may reflect the influence of lower ambient winter temperatures on feed intake efficiency during part of that culture cycle, a pattern also noted in related thermal-tolerance work on the species.

From an extension standpoint, the economic performance recorded here — benefit-cost ratios above 2.8 for both cage-culture batches and a near doubling of total pond income when cage culture of A. testudineus was integrated with carp polyculture — provides a strong evidence base for promoting this technology among small and marginal farmers who otherwise lack additional land or water for expansion. Combined with the demonstrated superiority of genetically improved Jayanti rohu over native stock, these results argue for a two-pronged extension strategy: (i) dissemination of standardized, low-dose synthetic-hormone breeding protocols for A. testudineus seed production, and (ii) promotion of cage-based intensification and improved-strain adoption as complementary, land-neutral means of raising smallholder aquaculture income.

Some limitations should be noted. The fecundity dataset, while substantial, was drawn from two habitats within a single hill district and during a single spawning season; inter-annual and broader geographic validation would strengthen the generality of the reported regression coefficients. Similarly, the cage-culture and rohu-comparison trials, though replicated across ten farmers' ponds, represent a single agro-climatic setting, and performance under different water-quality regimes or feeding regimes would benefit from further multi-location trials before large-scale extension roll-out.

5. Conclusion

The study demonstrates that Anabas testudineus fecundity can be reliably predicted from simple morphometric measurements, that low-to-moderate doses of Ovatide (0.4 ml/kg) or Ovaprim (0.7 ml/kg) outperform carp pituitary extract for induced breeding, and that bamboo-cage culture of the resulting seed in farmers' ponds is both technically feasible and economically attractive, with benefit-cost ratios exceeding 2.8 across two culture batches. Complementary on-farm evidence confirms the substantial growth advantage of genetically improved Jayanti rohu over native stock under the same low-input culture conditions. Together, these results provide a practical, field-validated technology package — standardized breeding protocol, cage-based grow-out, and improved-strain adoption — that extension agencies can transfer to small and marginal fish farmers as a land-neutral means of aquaculture diversification and income enhancement.

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