RESULTS
4.4. RESULTS

4.1. PRECISION OF AGE ESTIMATES

4.1.1. Channa marulius

In Channa marulius (N = 265), percentage of agreement (PA) on age estimates between two independent readers was higher for scales followed by otoliths, opercular bones, vertebrae and dorsal fin rays (Table 1). Scales showed lowest values of average percentage of error (APE) and coefficient of variation (CV) as compared to other structures. When age estimates of scales were compared with other alternative structures (i.e. opercular bones, otoliths, vertebrae and dorsal fin rays), highest PA was found between scales vs. otoliths followed by scales vs. opercular bones, scales vs. vertebrae and scales vs. dorsal fin rays. Scales vs. otoliths showed lowest values of APE and CV as compared to other structures (Table 1). Mean age estimates from all ageing structures except dorsal fin rays showed comparable (P > 0.05) values to those of scales (Table 2). However, mean age estimates from dorsal fin rays were insignificantly (P > 0.05) different from the values obtained for all other structures except scales. Age bias graphs between two readers for scales, opercular bones, otoliths, vertebrae, and dorsal fin rays have been presented in Figure 3. In case of scales and otoliths, no age bias was found between readers, while small age bias was noted in opercular bones and vertebrae age estimates. Differences between readers increased with age for dorsal fin rays, as indicated by larger standard error bars for older fishes.

4.1.2. Channa punctata

In C. punctata (N = 221), PA on age estimates between readers was highest for otoliths followed by opercular bones, scales and vertebrae (Table 3). APE and CV values were lowest for otoliths as compared to other structures. When otoliths age estimates
were compared with other ageing structures (i.e. opercular bones, scales, and vertebrae), least age difference was observed between otoliths vs. opercular bones age estimates as indicated by highest PA and lowest APE and CV values followed by otoliths vs. scales and otoliths vs. vertebrae (Table 3). A comparison of mean values of age estimates from different bony structures has been presented in Table 4. In *C. punctata*, otoliths recorded highest (P < 0.05) mean age estimates which was comparable (P > 0.05) to the values from opercular bones. Mean age estimates from opercular bones were also comparable (P>0.05) to those from scales. However, the least (P < 0.05) mean age estimates were exhibited by vertebrae, which was insignificantly different to those from scales (Table 4). Age bias graphs between two readers for scales, opercular bones, otoliths and vertebrae have been presented in Figure 4. Age estimated from otoliths showed no age dependent bias between readers, while slight variation was observed between readers for opercular bones. When using scales and vertebrae, differences in age estimates between readers increased with age as indicated by larger standard error bars.

4.1.3. *Labeo bata*

In *L. bata* (N = 250), PA of ages between the age readings of two independent readers was highest for scales followed by opercular bones, vertebrae and otoliths (Table 5). Scales exhibited lowest values of APE and CV as compared to other ageing structures. When scale age estimates were compared with other alternative structures (i.e. opercular bones, vertebrae and otoliths), highest PA and lowest APE and CV values were found between scales vs. opercular bones, followed by scales vs. vertebrae and scales vs. otoliths (Table 5). Mean values of age estimates from different structures, when compared using ANOVA followed by DMRT, showed that mean age estimates from scales were significantly (P < 0.05) higher from otoliths, but comparable (P > 0.05) to the values obtained from opercular bones (Table 6). The values of age estimates from vertebrae and otoliths were insignificantly (P > 0.05) different to each other. Age bias graphs between two readers for scales, opercular bones, vertebrae and otoliths are presented in Figure 5. No age bias was found between readers for scales, while small
error was present in opercular bones. Disparity between readers’ age estimates increased with age for otoliths and vertebrae after age 2, as evident from large standard error bars.

4.1.4. *Hypophthalmichthys molitrix*

In *H. molitrix* (N = 180), PA between the age estimates of two independent readers was highest for opercular bones followed by vertebrae, scales and otoliths (Table 7). Opercular bones showed lowest values of APE and CV. When opercular bone age estimates were compared with other alternative structures, highest PA and lowest APE and CV values were found between opercular bones vs. vertebrae, followed by opercular bones vs. scales and opercular bones vs. otoliths (Table 7). When mean values of age estimates from different structures were compared using ANOVA followed by DMRT, mean age estimates from vertebrae were significantly (P < 0.05) different from otoliths and scales but comparable (P > 0.05) to the values obtained from opercular bones (Table 8). Also, the values of age estimates from scales and otoliths did not differ significantly (P > 0.05). Age bias graphs between two readers for opercular bones, vertebrae, scales and otoliths are presented in Figure 6. The age readings from opercular bones showed very slight difference between two readers. No age bias was found between readers in vertebrae and scales age estimates up to 4 years of fish age. Difference between readers for age estimates increased with age for otoliths, as indicated by larger standard error bars for older fishes. In case of otoliths, there was also a consistent pattern of underestimation of ages.

4.1.5. *Mastacembelus armatus*

In *M. armatus* (N = 85), PA between the age readings of two independent readers was highest for vertebrae followed by opercular bones and pectoral spines. CV and APE values were lowest for age estimates from vertebrae (Table 9). When vertebrae age estimates were compared with other alternative structures, highest PA and lowest APE
and CV values were found between vertebrae vs. opercular bones, followed by vertebrae vs. pectoral spines. Vertebrae vs. opercular bones showed lowest values of APE and CV (Table 9). When mean values of age estimates from different ageing structures were compared using ANOVA followed by DMRT, age estimates from vertebrae were significantly (P < 0.05) different from pectoral spines and opercular bones. The values of age estimates from opercular bones and pectoral spines were insignificantly (P > 0.05) different to each other (Table 10). Age bias graphs between two readers for opercular bones, vertebrae and pectoral spines have been presented in Figure 7. The age estimates from vertebrae by the two readers did not differ, while small variation was observed in case of opercular bones age estimates. For pectoral spines, differences in readings were observed after age 3 that increased with fish age as indicated by larger standard error bars.

4.1.6. *Heteropneustes fossilis*

In *H. fossilis* (N = 385), PA of age estimates between the two independent readers was highest for vertebrae followed by otoliths and pectoral spines (Table 11). However, APE and CV values were lowest for vertebrae. When vertebrae age estimates were compared with other alternative structures, highest PA and lowest APE and CV values were found between vertebrae vs. otoliths, while the lowest PA and highest APE and CV values were reported between age estimates from vertebrae vs. pectoral spines (Table 11). Mean values of age estimates from different ageing structures, when compared using ANOVA followed by DMRT, showed that age estimates from vertebrae were significantly (P < 0.05) higher than those of pectoral spines, but comparable (P > 0.05) to the values obtained from otoliths. The values of age estimates from otoliths and vertebrae did not differ significantly (P > 0.05) either (Table 12). Age bias graph between two independent readers for vertebrae, otoliths and pectoral spines have been presented in Figure 8. No age bias was found between two independent readers for vertebrae age estimates. Slight differences between readers were noticed for otoliths age estimates. Differences in age estimates were found for pectoral spines after age 3 that increased with fish age as evident from larger standard error bars.
4.1.7. *Clarias gariepinus*

In *C. gariepinus* (N = 182), PA between the age estimates of two independent readers was highest for otoliths followed by vertebrae and pectoral spines. CV and APE were lowest for age estimates from otoliths (Table 13). Comparison of age estimates from different ageing structures revealed highest PA and lowest APE and CV values between age estimates from otoliths and vertebrae while the lowest PA and highest APE and CV were observed between age estimates from otoliths and pectoral spines (Table 13). Mean values of age estimates from different structures, when compared using ANOVA followed by DMRT, showed that the mean age estimates from otoliths were significantly (P < 0.05) different from the values obtained from pectoral spine sections. However, age estimates obtained from otoliths were comparable (P > 0.05) to those from vertebrae. The values of age estimates from vertebrae and pectoral spine sections were comparable to each other (P > 0.05) (Table 14). Age bias graphs between two independent readers for otoliths, vertebrae and pectoral spines have been presented in Figure 9. The age estimates from otoliths by the two readers did not differ. In the age estimates from vertebrae, no differences were observed up to 5 years of fish age, while slight differences were noticed in the fish of 6 years of age. Differences in age estimates between the readers were found for pectoral spine sections after age 2, and these increased with fish age as indicated by larger standard error bars.

4.1.8. *Clarias batrachus*

In *C. batrachus* (N = 165), PA of ages between the two readers was highest for otoliths followed by vertebrae and pectoral spines (Table 15). Also, otoliths had the lowest APE and CV values followed by vertebrae and pectoral spine sections. When otoliths age estimates were compared with other ageing structures (i.e. vertebrae and pectoral spines), highest PA and lowest APE and CV values were reported between otoliths and vertebrae (Table 15). Mean values of age estimates from different ageing structures, when compared using ANOVA followed by DMRT, showed that mean age
estimates obtained from otoliths were significantly (P < 0.05) different to the values obtained from pectoral spine sections (Table 16). However, age estimates obtained from otoliths did not differ significantly (P > 0.05) to those from vertebrae. Also, the values of age estimates from vertebrae were comparable (P > 0.05) to those from pectoral spine sections. Age bias graphs between readers for otoliths, vertebrae and pectoral spines have been presented in Figure 10. No age bias was found between readers for otoliths age estimates. In case of vertebrae no differences were noticed between age estimates of two readers up to 4 years of fish age, while slight variation was found in the fish of 5 and 6 years of age. Differences in age readings between the readers were reported for pectoral spine sections after age 4 and these increased with age of fish as indicated by larger standard error bars (Figure 10).

4.1.9. Wallago attu

In *W. attu* (N = 175), PA of age estimates between two independent readers was highest for otoliths compared to pectoral spines and vertebrae (Table 17). However, APE and CV values were lowest for otoliths. When otoliths age estimates were compared with other alternative structures, highest PA and lowest APE and CV values were found between otoliths vs. pectoral spines followed by otoliths vs. vertebrae age estimates (Table 17). Mean values of age estimates from otoliths were comparable (P > 0.05) to those from pectoral spines but significantly (P < 0.05) different to those from the vertebrae (Table 18). Age bias graphs between two independent readers for vertebrae, otoliths and pectoral spines have been presented in Figure 11. The age estimates from otoliths by the two readers did not differ. No differences were observed in age estimates between the readers from pectoral spines up to 4 years of fish age, while slight differences in age readings were noticed in the fish of 5, 6 and 7 years of age (Figure 11). Differences were found in age estimates between the readers for vertebrae.
4.1.10. *Ompok pabda*

In *O. pabda* (*N* = 118), PA of ages between the two readers was highest for vertebrae followed by opercular bones and pectoral spines (Table 19). Vertebrae had the lowest APE and CV values followed by opercular bones and pectoral spines. When vertebrae age estimates were compared with other ageing structures (i.e., opercular bones and pectoral spines), highest PA and lowest APE and CV values were reported for vertebrae vs. opercular bones (Table 19). Mean values of age estimates from different ageing structures, when compared using ANOVA followed by DMRT, showed that mean age estimates obtained from vertebrae were significantly (*P* < 0.05) different to the values obtained from pectoral spines (Table 20). However, the values of age estimates from vertebrae were comparable to those from opercular bones (*P* > 0.05). Age bias graphs between readers for vertebrae, pectoral spines and opercular bones have been presented in Figure 12. No age bias was found between readers for vertebrae age estimates. Differences in age readings between the two readers were reported for opercular bones and pectoral spines.

4.10. **GROWTH ESTIMATION**

4.2.1. *Channa marulius*

The estimated ages in *C. marulius* ranged from 1 to 5 years. The von Bertalanffy growth curve, based on age estimates from scales, has been presented in Figure 13. The maximum TL (91cm) derived from the VBGF equation is smaller than that of the largest specimens collected (94.2 cm). Following was the growth equation:

\[
L_t = 91 \left( 1 - e^{-0.435(t+0.31)} \right)
\]

Growth rate in TL showed declining trend with age, 39 cm at age 1, 57.6 cm at age 2, 69.1 cm at age 3, 76.4 cm at age 4 and 81.4 cm at age 5. Observed total lengths and
calculated total lengths have been presented in Figure 14. No significant differences were found between calculated lengths and observed lengths (t = 1.23, P > 0.05) of _C. marulius_.

4.2.2. _Channa punctata_

Age readings in _C. punctata_ specimens ranged from 1 to 5 years. The von Bertalanffy growth curve, based on age estimates from otoliths, has been shown in Figure 15. The maximum TL (L∞ = 30.1 cm) derived from von Bertalanffy growth equation is a little smaller than that of the largest specimens collected (31cm). The estimated equation for length at age was as follows:

\[ L_t = 30.1 \left(1-e^{-0.324(t+1.28)}\right) \]

According to the calculation, the growth rate in TL declined with age, 15.7 cm at age 1, 19.6 cm at age 2, 22.5 cm at age 3, 24.6 cm at age 4 and 26.1 cm at age 5. Calculated total lengths were close to the observed total lengths (Figure 16). No significant differences were found between calculated lengths and observed lengths (t = 1.41, P > 0.05). In _C. punctata_, length-at-age data obtained from scales (non-lethal structure) and otoliths (most suitable ageing structure) were insignificantly different (t = 3.90, P > 0.01) with each other (Figure 17).

4.2.3. _Labeo bata_

The estimated ages in _L. bata_ specimens were 1-6 years. The von Bertalanffy growth curve fitted to the length-at-age data, based on age estimates from scales, has been presented in Figure 18. The maximum TL (38.3 cm) derived from the VBGF equation is smaller than that of the largest specimens collected (41.6 cm) for the study. The derived von Bertalanffy growth equation for _L. bata_ was as follows:
\[ Lt = 38.3 \ (1-e^{-0.266 \ (t+1.62)}) \]

The von Bertalanffy growth equation indicated that total length of \( L. \ bata \) at age 1 was 13.4 cm, at age 2 was 19.1 cm, at age 3 was 23.3 cm, at age of 4 was 26.8 cm, at age 5 was 29.5 cm and at age 6 was 31.4 cm. Calculated total lengths were close to the observed total lengths (Figure 19). No significant differences were found between calculated lengths and observed lengths (\( t = 1.74, P > 0.05 \)).

4.2.4. Hypophthalmichthys molitrix

Age estimates in \( H. \ molitrix \) specimens ranged from 1 to 9 years. The von Bertalanffy growth curve based on opercular bones, has been shown in Figure 20. The maximum TL (80.5 cm) derived from the VBGF equation is smaller than that of the largest specimen collected (86.2 cm). The derived von Bertalanffy growth equation for \( H. \ molitrix \) was as follows:

\[ Lt = 80.5 \ (1-e^{-0.281 \ (t+0.31)}) \]

Observed and back-calculated lengths through VBGF have been presented in Figure 21. Growth rates from back-calculated length at age were 24.7 cm in the first year, 38.3 cm in the second year, 48.7 cm in the third year, 56.5 cm in the fourth year, 62.3 cm in the fifth year, 66.8 cm in sixth year, 70.1 cm in the seventh year, 72.1 in the eighth year and 74.1 cm in the ninth year. No significant differences were found between calculated lengths and observed lengths (\( t = 0.78, P > 0.05 \)). The mean total length (VBGF) derived from scales (non-lethal structure) and opercular bones (most suitable ageing structure) were significantly different (\( t = 12.73, P < 0.001 \)) with each other (Figure 22).
4.2.5. *Mastacembelus armatus*

Age readings in *M. armatus* specimens ranged from 1 to 5 years. The von Bertalanffy growth curve, based on age estimates from vertebrae, has been shown in Figure 23. The maximum TL (39.61 cm) derived from the VBGF equation is smaller than that of the largest specimen collected (46.7 cm). The estimated von Bertalanffy growth equation for *M. armatus* was as follows:

\[ \text{Lt} = 39.61 \left(1-e^{-0.434(t+0.21)}\right) \]

The von Bertalanffy growth equation indicated that total length of *M. armatus* at age 1 was 15.8 cm, at age 2 was 24.3 cm, at age 3 was 29.7 cm, at age 4 was 33.1 cm and at age 5 was 35.4 cm. Calculated total lengths were close to the observed total lengths (Figure 24). No significant differences were found between calculated lengths and observed lengths (t = 1.16, P > 0.05). In *M. armatus*, length-at-age data obtained from pectoral spines (non-lethal structure) and vertebrae (most suitable ageing structure) were significantly different (t = 10.73, P < 0.001) with each other (Figure 25).

4.2.6. *Heteropneustes fossilis*

Age estimates in *H. fossilis* specimens ranged from 1 to 5 years. The von Bertalanffy growth curve, based on age readings from vertebrae, has been shown in Figure 26. The maximum TL (\(L_\infty = 27.8\) cm) derived from von Bertalanffy growth equation was a little smaller than that of the largest specimens collected (31 cm). Following was the estimated VBGF equation:

\[ \text{Lt} = 27.8 \left(1-e^{-0.490(t+0.81)}\right) \]

According to the calculation, the growth rate in TL declined with age, 15.84 cm at age 1, 24.3 cm at age 2, 29.7 cm at age 3, 33.1 cm at age 4 and 35.4 cm at age 5. Calculated
total lengths at age were close to the observed total lengths (Figure 27). No significant
differences were found between calculated lengths and observed lengths ($t = 1.63, P >
0.05$). The length-at-age data obtained from pectoral spines (non-lethal structure) and
vertebrae (most suitable ageing structure) were insignificantly different ($t = 3.674, P >
0.02$) with each other (Figure 28).

4.2.7. *Clarias gariepinus*

The estimated ages in *C. gariepinus* specimens were 1 to 6 years. The von
Bertalanffy growth curve, based on age readings from otoliths, has been presented in
Figure 29. The maximum total length ($L_\infty$) calculated from the equation was 85 cm. The
$L_\infty$ was smaller than the largest specimen collected (98.5 cm). The derived von
Bertalanffy growth equation for *C. gariepinus* was as follows:

$$L_t = 86 \left(1-e^{-0.216(t+0.48)}\right)$$

Observed and back-calculated lengths through VBGF have been presented in Figure 30.
Growth rates from back-calculated length at age were 23.4 cm in the first year, 35.9 cm
in the second year, 45.9 cm in the third year, 53.3 cm in the fourth year, 59.5 cm in the
fifth year and 64.4 cm in sixth year of life. No significant differences were found between
calculated lengths and observed lengths ($t = 1.88, P > 0.05$). In *C. gariepinus*, length-at-
age data obtained from pectoral spines (non-lethal structure) and vertebrae (most suitable
ageing structure) were insignificantly different ($t = 6.306, P > 0.001$) with each other
(Figure 31).

4.2.8. *Clarias batrachus*

Age estimates in *C. batrachus* specimens ranged from 1 to 6 years. The von
Bertalanffy growth curve, based on age readings from otoliths, has been shown in Figure
The theoretical maximum total length \( L_\infty = 39.2 \text{ cm} \) calculated as 39.2 cm. The \( L_\infty \) was little smaller than the largest specimen collected (42.4 cm). The von Bertalanffy growth equation was as follows:

\[
L_t = 39.2 \left(1-e^{-0.48 (t+0.07)}\right)
\]

Observed and back-calculated lengths through VBGF have been presented in Figure 33. Growth rates from back-calculated length at age were 15.6 cm in the first year, 24.3 cm in the second year, 30.1 cm in the third year, 33.3 cm in the fourth year, 35.6 cm in the fifth year and 36.8 cm in sixth year of life. No significant differences were reported between calculated lengths and observed lengths \((t = 0.835, P > 0.05)\). The length-at-age data obtained from pectoral spines (non-lethal structure) and vertebrae (most suitable ageing structure) were significantly different \((t = 7.596, P < 0.001)\) with each other (Figure 34).

### 4.2.9. Wallago attu

Age estimates in \( W. \text{attu} \) specimens ranged from 1 to 7 years. The von Bertalanffy growth curve, based on age readings from otoliths, has been shown in Figure 35. The maximum TL \( (L_\infty = 141 \text{ cm}) \) derived from the VBGF equation is closer to the length of the largest specimens collected (143.8 cm). The derived von Bertalanffy growth equation for \( W. \text{attu} \) was as follows:

\[
L_t = 141 \left(1-e^{-0.462 (t+0.32)}\right)
\]

Observed and back-calculated lengths through VBGF have been presented in Figure 36. Growth rates from back-calculated length at age were 64.2 cm in the first year, 91.6 cm in the second year, 109.9 cm in the third year, 121.2 cm in the fourth year, 128.3 cm in the fifth year, 132 cm in sixth year and 135 cm in the seventh year of life. No significant differences were found between calculated lengths and observed lengths \((t = 1.28, P > 0.05)\). In \( W. \text{attu} \), length-at-age data obtained from pectoral spines (non-lethal structure)
and otoliths (most suitable ageing structure) were insignificantly different ($t = 0.766$, $P > 0.40$) with each other (Figure 37).

4.2.10. Ompok pabda

The estimated ages in *O. pabda* specimens were 4 years. The von Bertalanffy growth curve, based on age readings from vertebrae, has been shown in Figure 38. The maximum TL ($L_{\infty} = 27.6$ cm) derived from the VBGF equation was closer to the length of the largest specimens collected i.e. 28.5 cm. The estimated von Bertalanffy growth equation for *O. pabda* was as follows:

$$Lt = 27.6 \left(1-e^{-0.421(t+0.29)}\right)$$

The von Bertalanffy growth equation indicated that total length of *O. pabda* at age 1 was 11.3 cm, at age 2 was 16.8 cm, at age 3 was 20.4 cm and at age 4 was 23.01 cm. Calculated total lengths were close to the observed total lengths (Figure 39). No significant differences were found between calculated lengths and observed lengths ($t = 2.12$, $P > 0.05$). The length-at-age data obtained from pectoral spines (non-lethal structure) and vertebrae (most suitable ageing structure) were significantly different ($t = 7.324$, $P < 0.005$) with each other (Figure 40).

4.3. LENGTH-WEIGHT RELATIONSHIP (LWR)

Length-weight relationships were calculated for a total of 2,555 individuals of ten species belonging to six families (Channidae, Cyprinidae, Mastacembelidae, Heteropneustidae, Clariidae, Siluridae). The parameters of the length-weight relationship for each fish species has been given in Table 21, together with the regression coefficient ($R^2$), the number of samples measured (n), standard error of slope b and the size range of
the specimens. Linear regressions on log transformed data were highly significant (P < 0.001) for all analyzed species, showing $R^2 > 0.91$.

The calculated allometric coefficient $b$ ranged from a minimum of 2.586 for *C. batrachus*, to a maximum of 3.14 for *H. fossilis*. The results revealed that *C. marulius* (Figure 41), *L. bata* (Figure 43), *C. gariepinus* (Figure 47) and *W. attu* (Figure 49) showed isometric ($b = 3$) pattern of growth, *C. punctata* (Figure 34), *H. fossilis* (Figure 46) and *O. pabda* (Figure 50) exhibited positive allometric growth ($b > 3$) while *H. molitrix* (Figure 44), *M. armatus* (Figure 45) and *C. batrachus* (Figure 48) showed negative allometric growth ($b < 3$).

### 4.4. LENGTH–LENGTH RELATIONSHIP (LLR)

The relationship between TL (total length), FL (fork length) and SL (standard length) of the selected ten fish species, along with the estimated parameters of LLR and the coefficient of determination ($R^2$) have been presented in Table 22. All LLRs were highly significant (P < 0.001), with the coefficient of determination ($R^2$) ranging from 0.74 to 0.99.

### 4.5. CONDITION FACTOR (K)

The mean calculated condition factor (K) was 1.34 (±0.0731) for *C. marulius*, 0.9067 (± 0.5388) for *C. punctata*, 0.9251 (± 0.0440) for *L. bata*, 1.33 (± 0.078) for *H. molitrix*, 1.43 (± 0.1620) for *M. armatus*, 1.00 (± 0.0738) for *H. fossilis*, 1.3240 (± 0.6549) for *C. gariepinus*, 0.9812 (± 0.0515) for *C. batrachus*, 1.020 (± 0.0584) for *W. attu* and 1.14 (± 0.2091) for *O. pabda* (Table 23).