Estimation of Relative Growth of *Anabas testudineus* through multiple linear dimensions

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## INTRODUCTION

*Anabas testudineus* (Bloch, 1792) is an exceedingly costly freshwater fish species belonging to the order Perciformes and the family Anabantidae (Marimuthu *et al.*, 2009; Khatun *et al.*, 2019). This order comprises seven families containing at least 252 species (Collins *et al.*, 2015; Nelson *et al.*, 2016). The family Anabantidae comprising about 33 species in 4 genera (Froese and Pauly, 2019) possess a labyrinth organ *i.e.*, accessory
air-breathing organ (Alleng, 1991; Khatun et al., 2019) which allows it to breathe atmospheric oxygen (Rahman, 1989) and can survive out of water for a long period of time also make them able to resist poor water condition (Attak, 2006). It is commonly called a climbing perch due to its ability to walk on land (Talwar and Jhingran, 1991). A. testudineus locally known as ‘koi’ in Bangladesh and India, pla mor thai in Thailand, puyo in Philippine, kavaiya in Sri Lanka is a bottom dweller and insectivorous fish (Foresee and Pauly, 2020). It is extensively distributed in Bangladesh, India, Pakistan, Sri Lanka, Burma, Singapore, Malay Archipelago, Philippines, Indonesia, southern China and Taiwan (Rainboth, 1996; Wang et al., 1999; Kottelat, 2001, Tan and Lim, 2004). This species inhabits both in fresh water and brackish water mostly found in beels, canals, lakes, ponds, swamps, haors, ditches, floodplains, baors and estuaries (Talwar and Jhingran, 1991; Menon, 1999; Vidthayanon, 2002). A. testudineus is an omnivorous fish primarily dependent on organic debris algae, crustaceans, insects, worms, molluscs and soft plant parts (Nagris and Hossain, 1987; Pandey et al., 1992; Prasanth, 2006). The species contains a huge amount of iron and copper, which are essentially required for hemoglobin synthesis. It is a reasonable source of protein in Southeast Asian states like Bangladesh and Malaysia (Alam et al., 2010; Zalina et al., 2011). Anabas can survive in temperature fluctuations, low pH and low dissolved oxygen (Kohinoor et al., 2009; Sarma et al., 2010; Be et al., 2017). Overfishing, Pollution, and wetland conversion may possibly threaten to it (Hossain et al., 2015a). A. testudineus is listed as least concerned (LC) in Bangladesh (IUCN Bangladesh, 2015) and data deficient species according to IUCN (2020) for worldwide water bodies.

A land, which is inundated by water, annually or seasonally, permanently or temporarily that is called wetland (Keddy, 2010). The wetlands can be freshwater, brackish, or saltwater (Ramsar conservation, 1971). Gajner Beel is situated at Sujanagar, Pabna in the northwestern (NW) Bangladesh. This Beel used as an imperative feeding and spawning ground by many freshwater fish species. Near about 0.5 million people of surrounding villages of this Beel are directly or indirectly reliant on this wetland for their livelihood (Mazid et al., 2005).

Regression analysis is the one of the statistics analysis that used to explore and modeling the relationship between variables. Multiple linear regressions are the method of statistics in regression that used to analyze the relationship between single response variable (dependent variable) with two or more controlled variables (independent variables) (Ghani and Ahmed, 2011).

Fish length is often considered more significant than fish age, as many ecological and physiological factors depend more on the length than the age (Erzini et al., 1997). Length-length (L-L) relationships of fishes are essential in management for relative growth studies (Sandoval-Huerta et al., 2015). In that case, where only lengths data are available we can easily estimate the weight and biomass by using (Park and Huh, 2015) and LWRs also help in conservation and control of wild populations and also for observing the well-being of fishes (Hossain et al., 2012a; Hassan et al., 2020; Hasan et al., 2020) Further, the knowledge about growth pattern is essential for different studies in biology, physiology, and ecology of the natural and commercially exploited population of fishes (Czerwinski et al., 2008). Meristic study relates to count the quantitative characteristics of fish, such as the number of fins or scales (Islam et al., 2020). In addition, meristics and morphometrics features have been used to identify stocks of fish,
differentiate the species taxonomically, and distinct various morpho types (Lourie et al., 1999; Doherty and McCarthy, 2004; Jayasankar et al., 2004; Islam et al., 2020). However, morphometric characters are less heritable than meristic characters (Beacham, 1990; Islam et al., 2020) that’s why morphometric features were the more preferred method to identifying intraspecific deviation within a stock (Murphy et al., 2007).

Therefore, a very few works have been dedicated on growth of A. testudineus from worldwide water bodies that were given in Table 1. There is no existing info on estimating relative growth of A. testudineus from the Gajner Beel on the basis of morphometric and meristic features. This study was therefore undertaken to investigate the relative growth of A. testudineus populations inhabiting the Gajner Beel, NW Bangladesh using multiple linear dimensions.

Table 1. Available literature on Anabas testudineus from worldwide water bodies.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Water body</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length-weight relationship and condition factor</td>
<td>Kausalyaganga, Orissa, India</td>
<td>Kumar et al. (2013)</td>
</tr>
<tr>
<td>Length-weight relationship</td>
<td>Tetulia River, Bangladesh</td>
<td>Hossain et al. (2015b)</td>
</tr>
<tr>
<td>Morphometrical and gonadal studies</td>
<td>West Bengal, India</td>
<td>Ziauddin et al. (2016)</td>
</tr>
<tr>
<td>Length-weight relationship and relative condition factor</td>
<td>Deepar Beel (wetland), Assam, India</td>
<td>Rahman et al. (2015)</td>
</tr>
<tr>
<td>Length-weight relationship and Species composition</td>
<td>Candaba wetland, Philippines</td>
<td>Garcia (2010)</td>
</tr>
<tr>
<td>Growth and morphological development</td>
<td>Vientiane City, Laos</td>
<td>Morioka et al. (2009)</td>
</tr>
<tr>
<td>Length-weight and length-length relationships</td>
<td>Chi River, thailand</td>
<td>Satrawaha and Pilasamorn (2009)</td>
</tr>
<tr>
<td>Fecundity</td>
<td>Kedah, Malaysia</td>
<td>Marimuthu et al. (2009)</td>
</tr>
<tr>
<td>Stocking density, growth and production</td>
<td>Mymensingh, Bangladesh</td>
<td>Jannat et al. (2012)</td>
</tr>
<tr>
<td>Length weight relationships and condition factor</td>
<td>Semayang Lake, East Kalimantan, Indonesia</td>
<td>Mustakim et al. (2019)</td>
</tr>
</tbody>
</table>

**MATERIALS AND METHODS**

**Fish sampling**

A total number of 454 specimens of A. testudineus were collected occasionally from the Gajner Beel, a wetland ecosystem, NW Bangladesh (Fig.1) during July to
December 2018 through cast net (mesh size, 2.5 cm). These samples were stored as soon as possible with 10% buffered solution for the further process.

**Fish measurements**

Digital electronic balance was used to take body weight (BW) of the sample to the nearest 0.01g accuracy. The morphometric characters *i.e.*, ten different lengths (*Fig. 2*) were measured following *Hubbs and Lagler (1958)* with slight modification by digital slide calipers to the nearest 0.01cm accuracy.

**Growth pattern**

LWRs were estimated by the model; \( W = a L^b \). LLRs were also assessed by linear regression analysis (*Le Cren, 1951*).

![Fig. 1. Sampling sites in the Gajner Beel (indicated by red circle), northwestern Bangladesh.](image)

**Meristic counts**

A magnifying glass was used to count the number of fin rays and scale (lateral line).

**Statistical analyses**

All statistical analyses were completed through the GraphPad Prism 6.5 software and Microsoft Excel program with consideration of 5% significant level.
Fig. 2. Showing the morphometric measurements of *Anabas testudineus* from the Gajner Beel.

**RESULTS**

**Growth pattern**

In our study, total length (TL) was varied within 7.40-14.50 cm (mean ± SD, 10.88 ± 1.39) and BW was 7.89-64.00 g (26.52 ± 10.68) (Table 2).

**Table 2.** Descriptive statistics of *Anabas testudineus* (*n* = 454) captured from the Gajner Beel, NW Bangladesh

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Min (cm)</th>
<th>Max (cm)</th>
<th>Mode (cm)</th>
<th>Mean ±SD</th>
<th>95% CL (cm)</th>
<th>% TL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL (Total length)</td>
<td>7.40</td>
<td>14.50</td>
<td>9.80</td>
<td>10.88 ±1.39</td>
<td>10.70 to 11.05</td>
<td>100</td>
</tr>
<tr>
<td>SL (Standard length)</td>
<td>6.10</td>
<td>11.90</td>
<td>8.00</td>
<td>8.6 ±1.11</td>
<td>8.52 to 8.80</td>
<td>82.07</td>
</tr>
<tr>
<td>HL (Head length)</td>
<td>1.70</td>
<td>3.60</td>
<td>2.90</td>
<td>2.73±0.34</td>
<td>2.69 to 2.78</td>
<td>24.83</td>
</tr>
<tr>
<td>PrDL (Pre-dorsal length)</td>
<td>1.90</td>
<td>4.30</td>
<td>3.10</td>
<td>2.99±0.42</td>
<td>2.94 to 3.04</td>
<td>29.66</td>
</tr>
<tr>
<td>PoDL (Post-dorsal length)</td>
<td>5.20</td>
<td>10.40</td>
<td>8.10</td>
<td>7.81±0.62</td>
<td>7.68 to 7.94</td>
<td>71.72</td>
</tr>
<tr>
<td>PcL (Pectoral length)</td>
<td>2.10</td>
<td>4.00</td>
<td>3.00</td>
<td>2.98±0.33</td>
<td>2.94 to 3.02</td>
<td>27.59</td>
</tr>
<tr>
<td>PvL (Pelvic length)</td>
<td>2.30</td>
<td>4.60</td>
<td>3.20</td>
<td>3.28±0.43</td>
<td>3.23 to 3.34</td>
<td>31.72</td>
</tr>
<tr>
<td>AnsL (Anus length)</td>
<td>3.10</td>
<td>6.50</td>
<td>4.60</td>
<td>4.65±0.62</td>
<td>4.58 to 4.73</td>
<td>44.83</td>
</tr>
<tr>
<td>PrAnL (Pre-anal length)</td>
<td>3.20</td>
<td>6.60</td>
<td>4.70</td>
<td>4.81±0.64</td>
<td>4.73 to 4.89</td>
<td>45.52</td>
</tr>
<tr>
<td>PoAnL (Post-anal length)</td>
<td>5.70</td>
<td>11.00</td>
<td>8.20</td>
<td>8.13±1.07</td>
<td>7.996 to 8.6</td>
<td>75.86</td>
</tr>
<tr>
<td>BW (Body weight)*</td>
<td>7.89</td>
<td>64.00</td>
<td>13.14</td>
<td>26.52±10.68</td>
<td>25.18 to 27.87</td>
<td>-</td>
</tr>
</tbody>
</table>

*n*, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean value; BW, body weight; *, weight in g.
The regression parameters $a$ and $b$, 95% confidence limit and coefficients of determination ($r^2$) for LWRs of *A. testudineus* were documented in *Table 3 and Fig. 3*. All LWRs were highly significant ($p < 0.0001$) with $r_s$ values $\geq 0.901$. Based on $r^2$ and $r_s$ value, LWR by BW vs. TL was the best fitted model among the ten equations.

**Table 3.** Descriptive statistics and estimated parameters of length-weight relationships of *Anabas testudineus* ($n = 454$) captured from the Gajner Beel, NW Bangladesh

<table>
<thead>
<tr>
<th>Equation</th>
<th>Regression parameter $a$</th>
<th>$95%$ CL of $a$</th>
<th>$95%$ CL of $b$</th>
<th>$r^2$</th>
<th>$r_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$BW= a \times TL^b$</td>
<td>0.0164</td>
<td>3.07</td>
<td>0.0136 to 0.0198</td>
<td>2.99 to 3.15</td>
<td>0.961</td>
</tr>
<tr>
<td>$BW= a \times SL^b$</td>
<td>0.0353</td>
<td>3.04</td>
<td>0.0287 to 0.0434</td>
<td>2.94 to 3.13</td>
<td>0.941</td>
</tr>
<tr>
<td>$BW= a \times HL^b$</td>
<td>1.4377</td>
<td>2.84</td>
<td>1.2180 to 1.6971</td>
<td>2.69 to 3.00</td>
<td>0.827</td>
</tr>
<tr>
<td>$BW= a \times PrDL^b$</td>
<td>1.4242</td>
<td>2.62</td>
<td>1.2330 to 1.6450</td>
<td>2.49 to 2.76</td>
<td>0.864</td>
</tr>
<tr>
<td>$BW= a \times PoDL^b$</td>
<td>0.0571</td>
<td>2.96</td>
<td>0.0474 to 0.0687</td>
<td>2.87 to 3.05</td>
<td>0.945</td>
</tr>
<tr>
<td>$BW= a \times PoCL^b$</td>
<td>0.6556</td>
<td>3.34</td>
<td>0.5462 to 0.7868</td>
<td>3.17 to 3.51</td>
<td>0.865</td>
</tr>
<tr>
<td>$BW= a \times PvL^b$</td>
<td>0.8264</td>
<td>2.87</td>
<td>0.6979 to 0.9786</td>
<td>2.73 to 3.01</td>
<td>0.867</td>
</tr>
<tr>
<td>$BW= a \times AnSL^b$</td>
<td>0.3032</td>
<td>2.87</td>
<td>0.2544 to 0.3614</td>
<td>2.76 to 2.99</td>
<td>0.909</td>
</tr>
<tr>
<td>$BW= a \times PrAnL^b$</td>
<td>0.2741</td>
<td>2.88</td>
<td>0.2282 to 0.3294</td>
<td>2.76 to 2.99</td>
<td>0.906</td>
</tr>
<tr>
<td>$BW= a \times PoAnL^b$</td>
<td>0.0487</td>
<td>2.98</td>
<td>0.0407 to 0.0583</td>
<td>2.89 to 3.07</td>
<td>0.950</td>
</tr>
</tbody>
</table>

$n$, sample size; $a$ and $b$ are the regression parameters of LWRs; CL, confidence intervals; $r^2$, co-efficient of determination.
Estimation of relative growth of *Anabas testudineus*

\[
BW = 1.4242(PrDL)^{2.62}
\]
\[r^2 = 0.864\]

\[
BW = 1.4377(HL)^{2.84}
\]
\[r^2 = 0.827\]

\[
BW = 0.0571(PoDL)^{2.96}
\]
\[r^2 = 0.945\]

\[
BW = 0.0353(SL)^{3.04}
\]
\[r^2 = 0.941\]

\[
BW = 0.0167(TL)^{3.0657}
\]
\[r^2 = 0.962\]

\[
BW = 0.8264(PvL)^{2.87}
\]
\[r^2 = 0.867\]

\[
BW = 0.6556(PcL)^{3.34}
\]
\[r^2 = 0.865\]

\[
BW = 0.3032(AnSL)^{2.87}
\]
\[r^2 = 0.910\]

\[
BW = 0.2741(PrAnL)^{2.88}
\]
\[r^2 = 0.906\]

\[
BW = 0.0487x^{2.98}
\]
\[r^2 = 0.950\]

**Fig. 3.** Relationships (\(BW = a \times L^b\)) between lengths vs. body weight of male (lower) and female (upper) *Anabas testudineus* in the Gajner Beel.

The LLRs were shown in Table 4 and Fig. 4. All relationships were also highly correlated \((p<0.0001)\) with \(r_s\) values \(\geq 0.909\) (Spearman rank test). On the basis of maximum \(r^2\) and \(r_s\) value, LLR by TL vs.SL and TL vs. PoAnL was the best fitted model among nine equations.
Table 4. Descriptive statistics and estimated parameters of length-length relationships of *Anabas testudineus* (*n* = 454) captured from the Gajner Beel, NW Bangladesh

<table>
<thead>
<tr>
<th>Equation</th>
<th>Regression parameter</th>
<th>95% CL of <em>a</em></th>
<th>95% CL of <em>b</em></th>
<th><em>r</em>&lt;sup&gt;2&lt;/sup&gt;</th>
<th><em>r</em>&lt;sub&gt;s&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TL = a + b× SL</strong></td>
<td>0.2744</td>
<td>1.22</td>
<td>0.0163 to 0.5325</td>
<td>1.19 to 1.25</td>
<td>0.965</td>
</tr>
<tr>
<td><strong>TL = a + b× HL</strong></td>
<td>0.7320</td>
<td>3.71</td>
<td>0.1755 to 1.2886</td>
<td>3.51 to 3.91</td>
<td>0.844</td>
</tr>
<tr>
<td><strong>TL = a + b× PrDL</strong></td>
<td>1.7268</td>
<td>3.06</td>
<td>1.2857 to 2.1680</td>
<td>2.92 to 3.21</td>
<td>0.876</td>
</tr>
<tr>
<td><strong>TL = a + b× PoDL</strong></td>
<td>0.4787</td>
<td>1.33</td>
<td>0.2150 to 0.7423</td>
<td>1.30 to 1.37</td>
<td>0.962</td>
</tr>
<tr>
<td><strong>TL = a + b× PcL</strong></td>
<td>-0.7796</td>
<td>3.92</td>
<td>-1.3440 to -0.2150</td>
<td>3.73 to 4.11</td>
<td>0.874</td>
</tr>
<tr>
<td><strong>TL = a + b× PvL</strong></td>
<td>0.9472</td>
<td>3.02</td>
<td>0.4637 to 1.4307</td>
<td>2.88 to 3.17</td>
<td>0.873</td>
</tr>
<tr>
<td><strong>TL = a + b× AnSL</strong></td>
<td>0.8670</td>
<td>2.15</td>
<td>0.4842 to 1.2499</td>
<td>2.07 to 2.23</td>
<td>0.918</td>
</tr>
<tr>
<td><strong>TL = a + b× PrAnL</strong></td>
<td>0.9007</td>
<td>2.07</td>
<td>0.5139 to 1.2876</td>
<td>1.99 to 2.15</td>
<td>0.916</td>
</tr>
<tr>
<td><strong>TL = a + b× PoAnL</strong></td>
<td>0.4844</td>
<td>1.28</td>
<td>0.2429 to 0.7260</td>
<td>1.25 to 1.31</td>
<td>0.968</td>
</tr>
</tbody>
</table>

Fig. 4. Relationships (TL = a + *b*L) between length vs. length of male and female *Anabas testudineus* Gajner Beel.
Meristic characteristics

The body shape of *A. testudineus* was oblong, moderately deep and compressed. Body color was greenish brown or blackish brown. Mouth was anterior with villiform teeth on jaws and the lower jaw was slightly longer. Dorsal and anal fin were long, pectoral and caudal fin is rounded. Dorsal fin, pelvic fin and anal fin rays were modified to spine. Lateral line was interrupted; the first lateral line contained 14-17 scales and the second 10-13 scales. Body covered with ctenoid large scales arranged regularly. The observed fin formula of *A. testudineus* was dorsal, D. 26-28 (XVI-XVIII 1-2/7-10); pectoral, P₁. 13-15(1-2/11-14); pelvic, P₂. 6 (15); anal, A. 18-21 (VIII-XII 2/8-10); caudal, C.15-17(2/13-15) respectively (*Table 5 & Fig. 5*).

**Table 5.** Meristic counts of *Anabas testudineus* (*n* = 454) captured from the Gajner Beel, NW Bangladesh

<table>
<thead>
<tr>
<th>Meristic data</th>
<th>Numbers</th>
<th>Spine</th>
<th>Unbranched</th>
<th>Branched</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal fin rays</td>
<td>26–28</td>
<td>XVI–XVIII</td>
<td>1–2</td>
<td>7–10</td>
</tr>
<tr>
<td>Pectoral fin rays</td>
<td>13–15</td>
<td>-</td>
<td>1–2</td>
<td>11–14</td>
</tr>
<tr>
<td>Pelvic fin rays</td>
<td>6</td>
<td>I</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Anal fin rays</td>
<td>18–21</td>
<td>VIII–XI</td>
<td>1–2</td>
<td>8–10</td>
</tr>
<tr>
<td>Caudal fin rays</td>
<td>15–17</td>
<td>-</td>
<td>2</td>
<td>13 – 15</td>
</tr>
<tr>
<td>1st lateral line scale</td>
<td>14 – 17</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2nd lateral line scale</td>
<td>10 – 13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale above the lateral line to dorsal fin base</td>
<td>3 – 4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scale below the lateral line to pelvic fin base</td>
<td>6 – 7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*n*, sample size; Unbranched, single fin ray; Branched, upper portion of fin is divided into several rays; Spine, upper portion of unbranched fin ray is pointed.
DISCUSSION

Although some authors have been working on some biological aspects (Hubbs and Lagler, 1958; Hassan et al., 2005; Alam et al., 2007) of *A. testudinesus* but this is the first study which estimates the relative growth using ten linear dimensions and also studies the meristic features. A total of 244 individuals comprised altered body sizes were used for the current study and the recorded maximum length was 14.50 cm TL, which is moderately similar with Hassan et al. (2005) who recorded TL as 14.20 cm in the Chittagong region but is lower than the maximum length reported by Shafi and Quddus (1982), Talwar and Jhingran (1991) and Rahman (2005) (22.00 cm, TL 25.00 cm and 17.60 cm, respectively). Maximum length is helpful for the estimation of growth.
parameters that is needed for planning of fisheries capital and sustainable management (Ahmad et al., 2012).

In our present study, the allometric co-efficient, $b$ value was ranged from 2.62-3.34 which is in the limit reported by Froese (2006) (2.50-3.50) and Carlender (1969) (2.00-4.00). According to Tesch (1971), $b=3$, means the growth isometric and $b>3$, means the growth is positive allometric and $b<3$, means the growth is negative allometric. Shafi and Mustafa (1976) and Hossain et al. (2015b) reported $b$ value as 2.72 and 2.9 from Dhaka Bangladesh and Tetulia River, southern Bangladesh, respectively. However, the values of $b$ may divers because of differences growth of organs, sex and preservation process and variation in the physiology (Hossain et al., 2012b; 2015b), which were not observed in the current study. Furthermore, LLRs were highly correlated ($P<0.001$).

In the current study, the observed spine fin rays (16-17) in dorsal fin rays were similar to Shafi and Quddus (1982), Talwar and Jhingran (1991) and Rahman (2005) as well as soft fin rays (7-10) is similar with Shafi and Quddus (1982), pectoral fin contained 13-15rays and pelvic fin (Riede, 2004) that was more or less similar to the findings of Bhuiyan (1964), Shafi and Quddus (1982), Talwar and Jhingran (1991) and Rahman (2005). Anal fin (18-21) is disparate with their study Caudal fin is somewhat similar to the number reported Shafi and Quddus (1982). However, no one mentions spine and unbranched fin rays separately but the present study does that. First lateral line containing 14-17 scales was similar (16-17) with the results of Rahman (2005) and the second (10-13 scales) deviated from Rahman (2005). Meristic counts of the current study were done in pictorial form which helps to easily identify this species and comparable with the future study. Above lateral line (3–4) scales was similar to the findings of Rahman (2005) but the below lateral line scales (6–7) differ with the findings Rahman (2005).

CONCLUSION

These findings will help to more accurately understand the growth pattern of Anabas testudineus and serve as baseline data for this species, a wetland ecosystem Gajner Beel, and nearby ecosystem for evaluation with future studies of this fish.

ACKNOWLEDGMENTS

The authors extend their sincere appreciation to the PIU-BARC, NATP-2, Sub-Project ID: 484 for funding the project (Management of indigenous fishes in the wetland (Gajner Beel, Pabna) ecosystem) and it is a partial work of this CRG (Competitive Research Grants) Project.
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