Does the Mekong giant catfish *Pangasianodon gigas* grow as fast as a tuna?\(^1\)

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**Abstract**

Tentative parameters of the von Bertalanffy growth function (VBGF) of the Mekong giant catfish (*Pangasianodon gigas* Chevey, 1931) in the wild were estimated as \(L_\infty = 300\) cm (total length), \(K = 0.085\) year\(^{-1}\) and \(t_0 = -1.115\) year based on scattered information in the existing literature. These parameters suggest that *P. gigas* grows almost as fast as Atlantic bluefin tuna (*Thunnus thynnus*), which is attributed to the fact that adult *P. gigas* are air-breathers.

**Introduction**

The very high growth rates of air-breathing fishes are often noted in aquaculture manuals and invasive species reports (Knight 2010; Mäkinen *et al.* 2013). Yet, despite the growing literature on bi-modal respiratory behavior in aquatic animals, such information remains largely anecdotal. It is the purpose of this contribution to evaluate one such anecdote, the growth of the Mekong giant catfish (*Pangasianodon gigas* Chevey, 1931).

An FAO report on the fishes of the Mekong River delta states that this species shows “one of the fastest growth rates of any fish in the world, reaching 150 to 200 kg in 6 years” (Rainboth 1996, p. 153) and a 1991 revision of the Pangasiidae Family even reports a growth of “at least 200 kg in its first three years” (Roberts and Vidthayanon 1991, p. 97). The author of a major book on air-breathing fishes, Graham (1997, p. 256) suggested that “the growth rate of *Pangasius* is said to rival that of pelagic species such as tuna, a rare phenomenon for a freshwater species”.

This statement can be tested if “*Pangasius*” is understood as the now invalid synonym of *Pangasianodon gigas*, which was treated as a subgenus of *Pangasius* by Roberts and Vidthayanon (1991, p. 102)\(^2\). The Mekong giant catfish and the Chao Phraya giant catfish (*Pangasius sanitwongsei* Smith, 1931) are the only members of the Pangasiidae that reach sizes similar to those of tuna, thus enabling comparisons of their growth rate across their entire size range. This small contribution presents a test of this claim. Given the tentative nature of the data at hand, no formal statistical test, whether ‘frequentist’ or Bayesian, will be

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\(^2\) Graham’s nomenclatural references are often imprecise and despite the otherwise very important contributions of his book, it is sometimes hard to identify the exact species he had in mind. In some cases, he refers to names that were invalid for as long as 50 years at the time of publication, for example in the cases of *Pseudosphromenus cupanus*, which is referred to as “*Macropodus* cupanus” (Cuvier 1831), or *Macropodus ocellatus* Cantor, 1842 (referred to as *M. “chinensis*”). His statement that some *Macropodus* species are mouth brooders (Graham 1997, p. 256) suggest an even wider nomenclatural confusion and raise the question whether he did not confuse them with *Betta* spp., perhaps from the similar-looking *B. pugnax* species group. Graham also refers to *Pangasianodon hypophthalmus* as “*Pangasius*” which suggest that he used the same genus name for *P. gigas*. 
performed but the following calculations will hopefully inspire future research on the growth of large air-breathing fishes.

The Mekong giant catfish (*Pangasianodon gigas*) reaches a length of 300 cm (Baird et al. 1999) and weight of 350 kg (Kottelat 2001), data that are indeed similar to the maximum sizes reported for the 3 bluefin tuna species and for yellowfin tuna (i.e., *Thunnus* spp., see FishBase; www.fishbase.org). The notion that *P. gigas* reaches these large sizes as rapidly as these tuna species is, however, a strong claim because large tuna possess gills with very narrow interlamellar spaces and huge large surface area (Muir and Hughes 1969), which provides them with the large amount of oxygen required to sustain their elevated metabolism; Mekong giant catfish do not have such extraordinarily large gills.

In contrast to tuna, whose growth has been studied by numerous authors (see FishBase), the growth of Mekong giant catfish has not yet been well studied. Its growth in captivity has been reported upon (Lorenzen et al. 2006), but there are apparently no studies of its growth in the wild. Roberts and Vidthayanon (1991, pp. 119-120) mention specular growth rates in the early juvenile stages but their information is only based on personal communication. In their account, the fishes’ growth accelerates again during their second year, which is atypical for both marine and freshwater fishes and has so far only been demonstrated in *Arapaima gigas* (Schinz, 1822), also an air-breathing species (Wosnitza-Mendo 1984; Pauly 2019).

In addition to these more anecdotal accounts, Lorenzen et al. (2006) have presented two estimates of the parameters of the von Bertalanffy Growth Function (VBGF) for *P. gigas* from which a single growth curve for the for the remaining few specimens in the wild may be inferred. These two methods are presented here, following a presentation of the VBGF and related concepts.

The VBGF for length has the form:

\[ L_t = L_\infty (1-e^{-K(t-t_0)}) \]  

...1)

where \( L_t \) is the mean length at age \( t \) of the fish in question, \( L_\infty \), their asymptotic length, i.e., the mean length that would be attained after an infinitely long time, \( K \) a growth coefficient expressing how fast the asymptotic size is approached (here in year\(^{-1}\)) and \( t_0 \) is a parameter adjusting for the fact that VBGF usually fails to describe the growth of the earliest (larval and post-larval) stages of fishes.

The growth in length of fish with similar shapes can be compared using the parameter \( \alpha' \), (Pauly 1998), defined by the equation

\[ \alpha' = \log(K) + 2\cdot \log(W_\infty) \]  

...2)

which has a normal distribution when applied to numerous populations of the same species, e.g., in skipjack tuna *Katsuwonus pelamis* (see figure 9.4, p. 263 of Longhurst and Pauly 1987).

The VBGF for growth in weight is

\[ W_t = W_\infty (1-e^{-K(t-t_0)})^b \]  

...3)

where \( W_\infty \) is the asymptotic weight, as derived from a length-weight relationship (LWR) of the form \( W = a\cdot L^b \) (Froese 2006), with \( b \) often taking values of, or near 3. One of the advantages of a growth curve in weight is that it allows for comparing the growth performance of fishes of widely different shapes through the index

\[ \alpha = \log(K) + 2/3 \log(W_\infty) \]  

...4)

(Pauly 1998), which also is normally distributed when within taxa with similar life histories.
The first estimate
Lorenzen et al. (2006) wrote that *P. gigas* “are widely stocked into ‘semi-natural’ reservoirs in Thailand, where they appear to survive and grow well but are not known to mature or spawn. Stocking and recapture data were analysed for Sirikit reservoir in Thailand [and grow parameters] were estimated as \( L_\infty = 210 \text{ cm} \) and \( K = 0.2 \text{ year}^{-1} \). [...] The stocked fish thus appear to grow at a higher rate but to a lower asymptotic size than the wild fish in the Mekong. This is consistent with the general observation that cultured fish, even after release, show an accelerated life history (Lorenzen 2000, Thorpe 2004).”

Lorenzen et al. (2006) provide no textual details beyond the statement that “no data were collected for the first 7.5 years after release” and they did not specify the method they used to estimate growth parameters from the growth increment data that they casually mention. However, the graph they presented suggests that the stocked and released fish whose length increments were used to compute growth parameters were rather large, and thus did not grow much. This should result in a rather uncertain estimate of the parameter \( K \), because it is the more rapid growth of younger/small fish which stabilizes the estimation of this parameters.

The second estimate
Lorenzen et al. (2006) used the maximum size (they) recorded for *P. gigas*, i.e., 290 cm as an estimate of \( L_\infty \). However, the length type was not specified. There are 92 mentions of the word ‘length’ (or ‘lengths’) in Lorenzen et al. (2006), but only one of ‘total length’ (TL). Given this single mention, and especially because assuming that fork length (FL) or standard length (SL) was used in the 91 remaining instances would generate unrealistically high maximum weights in conjunction with the length-weight relationship (LWR) mentioned below, we suggest that Lorenzen et al. (2006) used TL throughout.

To estimate \( K \), they plotted the values of \( L_\infty \) and \( K \) in the compilation of Pauly (1980) as \( \ln(K) \) vs. \( \ln(L_\infty) \), from which they derived \( K = 3.3492 - L_\infty^{0.6673} \). They then solved the equation for \( L_\infty = 290 \text{ cm} \) (TL), which yielded \( K = 0.08 \text{ year}^{-1} \). They thought these values were reasonable and used them for assessing the (dire) state of their population in the Mekong basin.

The estimates of \( K \) in Pauly (1980) which will have most influenced this empirical equation (via a lever effect) will have been his largest species, i.e., the basking shark *Cetorhinus maximus* with \( L_\infty = 1226 \text{ cm} \) (and not ‘226’ cm as stated in Table 1 of Pauly 1980) and \( K = 0.045 \text{ year}^{-1} \), and the white sturgeon *Acipenser transmontanus*, with \( L_\infty = 350 \text{ and } 300 \text{ cm} \), and \( K = 0.5 \text{ and } 0.04 \text{ year}^{-1} \), respectively. These fishes are not known to be particularly fast growing, and thus Lorenzen et al.’s empirical equation may not predict values of \( K \) that are too high, even though some fast-growing fish (incl. tuna species) were also included in the dataset they used.

Combining the first and the second estimate
Applying Equation (2) to the first and the second estimate of growth parameters of *P. gigas* yields estimates of \( \tilde{\theta}' = 3.94 \text{ and } 3.83 \text{, respectively, with an average } \tilde{\theta}' = 3.88 \). The lower value of \( \tilde{\theta}' \) suggests that the second estimate of \( K = 0.08 \text{ year}^{-1} \) for ‘wild’ *P. gigas* was not excessively high.

Generally, \( L_\infty \) is slightly larger than the largest fish in a population, or \( L_{\text{max}} \) (Taylor 1958; Froese, and Binohlan 2000), and thus, for *P. gigas*, 300 cm may be more appropriate as estimate of \( L_\infty \) than \( L_{\text{max}} = 290 \text{ cm} \). Combined with an estimate of \( L_\infty = 300 \text{ cm} \), the mean \( \tilde{\theta}' \) yields an estimate of \( K = 0.085 \text{ year}^{-1} \).
An estimate of $t_0$ is provided, in the absence of any other estimate, by the empirical equation of Pauly (2019), which suggests that

$$\log(-t_0) = -0.3922 - 0.2752 \cdot \log(L_\infty) - 1.038 \cdot \log(K) \quad \ldots 5)$$

which here yields $t_0 = -1.115$ years.

The set of values for the growth parameters of $P. gigas$ in the wild is very tentative, but it is based on broader considerations than the previous estimates and, therefore, may be more accurate.

**Comparing the growth of $P. gigas$ with that of tuna**

Lorenzen et al. (2006) presented an LWR for $P. gigas$, i.e., $W = 0.04 \cdot L^{2.8}$, where weight is in g and length in cm. Thus, based on the previous considerations, its VBGF for weight growth is

$$W_t = 345,000 \cdot (1 - e^{-0.085 \cdot (t+1.115)})^{2.8} \quad \ldots 6)$$

which leads, via Equation (4) to an estimate of $\theta = 2.62$, which is close to estimates of $\theta$ for bluefin tuna ($Thunnus thynnus$; red dots in Figure 1), and within the ellipsoids that could be drawn around the Scombridae family (green dots in Figure 1).

![Auximetric plot of the fish with weight growth parameters in FishBase](www.fishbase.org), with each dot representing a $K$ & $W_\infty$ pair, i.e., the mean growth curve of the individual of a fish population. The non-Scombridae are represented by yellow dots (‘Miscellaneous species’), the fast-growing Scombridae (mackerels, tuna, etc.) by green dots (‘Family’), and Atlantic bluefin tuna by red dots (‘Current species’). The black dot (‘Current estimate’) represents the tentative growth curve for $P. gigas$ ($W_\infty = 345$ kg and $K = 0.085$ year$^{-1}$), which is suggested here to grow almost as fast as bluefin tuna.

**Figure 1.** Auximetric plot of the fish with weight growth parameters in FishBase (www.fishbase.org), with each dot representing a $K$ & $W_\infty$ pair, i.e., the mean growth curve of the individual of a fish population. The non-Scombridae are represented by yellow dots (‘Miscellaneous species’), the fast-growing Scombridae (mackerels, tuna, etc.) by green dots (‘Family’), and Atlantic bluefin tuna by red dots (‘Current species’). The black dot (‘Current estimate’) represents the tentative growth curve for $P. gigas$ ($W_\infty = 345$ kg and $K = 0.085$ year$^{-1}$), which is suggested here to grow almost as fast as bluefin tuna.
Figure 1 suggests that the Mekong giant catfish *Pangasianodon gigas* (black dot) grows almost as fast as Atlantic bluefin tuna (red dots), commonly and justifiably seen as the fastest-growing tuna. Thus, *P. gigas* is indeed a very fast-growing fish.

A total length of 300 cm in *P. gigas* roughly corresponds to fork length of 266 cm, which is smaller than the asymptotic fork lengths estimated by various researchers for Atlantic bluefin tuna. However, using the mean value of \( \Theta' = 4.00 \) in Atlantic tuna, which refers to LF, a estimate of \( K \) can be derived for hypothetical bluefin that would reach only 266 cm LF. This estimate of \( K \) would be 0.14 year\(^{-1}\); inserted into Equation (5), these estimates yield \( t_0 \approx -0.2 \) years. Figure 2A compares the growth curves in length for these two species, and also gives the impression that their growth is not very different.

![Figure 2A](image)

**Figure 2A.** Growth curves in length (A) and weight (B) of (hypothetical) bluefin tuna and Mekong giant catfish, all assuming an asymptotic length of 266 cm (FL; see text).

However, when comparing growth in weight between these two species (Figure 2B), what appears as a small difference in Figures 1 and 2A turns out to be substantial, with young tuna growing faster. This fast growth is made possible by huge gills, which supply the oxygen required to sustain a metabolic rate almost equivalent to that of a similar-sized mammal. Even by breathing air, *P. gigas* does not match the growth of Atlantic bluefin tuna, although it does grow very fast.

Lefevre *et al.* (2013), presumably because their first author believes that growing fish can always meet their oxygen requirements via their gills, failed to understand why they devoted energy to breathing air (see also Pauly 2021). Thus, they write that “[t]hough air-breathing is usually considered a beneficial
behaviour, we show that surfacing does indeed incur an energetic cost. Though air-breathing is important to swimming in hypoxia (McKenzie et al. 2012), it remains unclear what mechanisms drive the air-breathing behaviour in [Pangasianodon] hypophthalmus in normoxia.”

This self-created conundrum is easily resolved: air breathing is not only “a beneficial behavior” in *Pangasianodon* species, but absolutely necessary, because large individuals of this genus cannot meet their oxygen requirements by relying only on their gills at higher temperatures, even in normoxic water (see Mitamura et al. 2009, fig. 4). Being a migratory species, *P. gigas* experiences a relatively wide range of temperatures compared to other tropical freshwater fishes: it spawns in the cool regions of Chiang Rai and Chiang Kong in Northern Thailand (Eva et al. 2016; Ngamsiri et al. 2007; Pholprasith and Tavarutmaneegul 1997) and moves downstream into the lower delta region. The temperatures at its most northern habitats range from 18 to 26°C between January and August (Zhang et al. 2007), whereas the water in the delta is typically 10°C warmer. Some authors (Ngamsiri et al. 2007; Hogan et al. 2001; Pholprasit 1989) assume a historical distribution of *P. gigas* in the Chinese province of Yunnan where water temperatures can be as low as 14-16°C in the cold season and rarely exceed 22°C in the summer (Wang et al. 2014; Zhang et al. 2007). Hogan et al. (2001) and Hogan (2004) hypothesize that *P. gigas* might still be present in southern China and that its decline in Yunnan could be attributed to deforestation and the construction of dams in this region.

Even in the warmer regions of the delta, *P. gigas* may not constantly be exposed to the upper extremes of its thermal tolerance range. Like other large species of the Mekong delta, it is often reported in the vicinity of, or even inside, deep river pools (Eva et al. 2016). Some of these deep holes reach depths of up to 90 m (Gupta and Liew 2007) but it is unclear to which depths the Mekong giant catfish actually dives. Even in stagnant and warm water bodies such as the Mae Peum reservoir in Thailand, depths of only 6 to 12 m provide temperature differences of up to 6 °C between the water surface and the bottom (Mitamura et al. 2009). In this reservoir, *P. gigas* surfaces frequently in the hot season but less so in January and February, when the deeper water columns are well-oxygenated (Mitamura et al. 2009, fig. 6).

As for Graham’s claim of 1997, which appears credible when growth in length is considered (Figure 2A) is less convincing when growth in weight is considered (Figure 2B), at least when bluefin tuna is used as representative of ‘tuna’. However, the fact that a fish that inhabits warm and often deoxygenated freshwater bodies can reach growth rates that equal those of large marine fishes is remarkable in itself. There are only a few examples of very big tropical freshwater teleosts and those for which rapid growth rates are reported are typically air-breathers, for example, *Clarias gariepinus* Burchell, 1822, supposedly the fastest-growing large freshwater fish of Africa, and *Arapaima gigas* from South America, the largest scaled freshwater species in the world (Wosnitza-Mendoza 1984).

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**References**


