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Methods for Predicting Food Allowances from Body Length in Tropical and Temperate Ornamental Fish Species[1,2]

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EXPANDED ABSTRACT

KEY WORDS: • *ornamental fish* • *predicting body weight* • *energy requirement* • *food allowance* • *aquarium*

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Aquarists often overlook the importance of feeding an appropriate amount of a balanced diet for fish health and maintenance of water quality in an aquarium. Although most commercial food manufactures do offer an on-package feeding guide containing statements like "feed between 2–4 times per day, sprinkling a few flakes per fish on the water until the fish stop feeding," such guidelines are vague, and may result in overfeeding. The overfeeding of fish in an aquarium results in increased pollution (ammonia and/or nitrite) and ultimately causes system failure if the tank is not maintained properly through husbandry procedures like water changes. These on-package instructions are deliberately vague mainly because of the limited information available on factors such as different species requirements for size, activity, age, environment, and water temperature. The aim of this research is to establish simple mathematical models that can predict body weight (BW) from body length in fish. By linking predicted BW with a known energy requirement and energy density of the food, it becomes possible to calculate accurate food allowances. This is particularly useful because, although BW cannot easily be determined by owners of ornamental fish, an estimate of body length is usually possible.

MATERIALS AND METHODS

Experimental trials were conducted at the WALTHAM Aquacentre, Birstall, Yorkshire, England. All husbandry and handling procedures were approved by the WALTHAM Ethical Review Committee.

Weight prediction models

Mathematical models were developed using fish weight and length data. A total of 472 Oranda Goldfish, 2612 Common Goldfish (2594 with BW between 1.5 and 60 g and 18 with BW between 150 and 450 g), and 6161 tropical fish from 15 different species were measured.

Fish weighing (g) was conducted by placing a beaker of water on a MC1 Sartorius balance, taring off the balance and placing the fish into the beaker. Length (mouth to caudal peduncle) was estimated by placing the fish on 1-mm laminated graph paper. To carry out the measurements, fish were removed from the tank using a net and placed into a holding bucket containing tank water. Fish were removed from the bucket individually and placed on laminated graph paper. Length from the mouth to caudal peduncle and depth from the deepest point of the body to base of dorsal fin were measured (mm). Fish were then placed in a tared beaker of tank water on a MC1 Sartorius balance scale for BW measurements before being returned to their original tank. Total time spent out of the water was <5 s.

Only the relation between weight and length was considered for model development because the predictive relation between length and weight has already been defined as a power function (1–5). The equations fitted to the data were of the form $Y = a(\text{length})^b$, or $Y = Y_0 + a(\text{length})^b$, where Y is the predicted weight of the fish in g, Y_0 and a are specific constants, b is the exponent relative to that species and length is measured in mm.

All models were fitted using SigmaPlot, version 8.0.2 (Systat Software). The adjusted R^2 value was used as a measure of the goodness-of-fit for each model, with values of ≥0.80 (80%) selected as being significant for the purposes of this study.

Energy requirements

To determine food allowances from predicted BW, energy requirements relative to BW were needed for the relevant species. Energy requirements were determined by examining the relation between growth rate and energy intake. Most fish grow continuously throughout their life, with the rate of growth decreasing with age. This presents a challenge when trying to determine a healthy feeding allowance, because there is no adult phase where growth ceases. For this reason, the aim of our study was to determine the food requirements and therefore energy requirements to achieve a specific growth rate (SGR) as close to 0.1%/d, for adult ornamental aquarium fish. This figure could then be used as a realistic and healthy growth rate for ornamental fish housed in a confined space like an aquarium where rapid growth may result in overcrowding and suboptimal husbandry conditions.

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TABLE 1

Energy requirements for individual fish species to achieve 0.1% SGR[1]

Species	Energy requirement to promote 0.1% SGR, *J/g BW/d*
Tinfoil Barb (*Barbus schwanenfeldii*)	75
Black Neon Tetra (*Hyphessobrycon herbertaxelrodi*)	171
Peppered Corydoras (*Corydoras paleatus*)	208
Scissortail (*Rasbora trilineata*)	132
Pictus catfish (*Pimelodus pictus*)	141
Midas cichlid (*Cichlosoma citrinellum*)	78
Angelfish (*Pterophyllum scalare*)	57
Black Widow Tetra (*Gymnocorymbus melanistius*)	116
Oranda Goldfish (*Carassius auratus*)	90
Common Goldfish (*C. auratus*) [2]	
At 10°C	56
At 16°C	94
At 22°C	100
Large Goldfish[3] (*C. auratus*)	59

[1] SGR = 100 × (ln. w2 − ln. w1)/trial d;, where ln is the natural log, w1 is the weight of a fish on d 0, and w2 is the weight of a fish on the last trial day.
[2] Common Goldfish between 1.5 and 60 g BW.
[3] Large Common Goldfish between 150 and 450 g BW.

Food requirements

The food used was AQUARIAN Flakes (goldfish or tropical, as appropriate for the species), (manufactured by Masterfoods Complimentary Petcare). Food requirements were calculated using the following equation:

$$\text{Food requirement (mg)} = [\text{Predicted weight (g)} \times \text{energy requirement at } 0.1\%\ \text{SGR (J/g BW/d)}]/\text{Estimated metabolizable energy (J/mg)};$$

where SGR is specific growth rate, calculated using the following equation:

$$\text{SGR} = 100 \times (\text{ln. final wt of fish} - \text{ln. intial wt of fish})/\text{trial d};$$

where ln is the natural log, J = joules, and BW= body weight in g.
Estimated metabolizable energy = (4 × protein + 9 × fat + 4 × NFE) × 4.186, where NFE is nitrogen free extract (6).

RESULTS

Weight prediction models

Separate models were produced for each group of goldfish and for each of the 15 species of tropical fish. Some of the equations fitted required the Y_0 term, which indicates that they do not pass through the origin. For these species a restricted weight range is provided (**Table 1**) insofar as it is not possible for a fish of zero length to have a positive BW, or for a short fish to have negative BW.

Bodyweight was predicted with a sufficient degree of accuracy ($R^2 \geq 0.80$) in 12 tropical species and the small Common Goldfish (BW 1.5–60 g). The BW of Large Goldfish (BW 150–450 g), Oranda Goldfish and 3 tropical species could not be predicted with sufficient accuracy.

Energy requirements

Energy requirements were determined for Oranda Goldfish, Common Goldfish, and 8 tropical fish species (Table 1). The energy requirements of Common Goldfish were examined at 3 different temperatures to replicate the yearly cycle of a pond in temperate climates. Energy requirements have yet to be determined for the other 7 species mentioned in **Table 2**.

Food requirements

The food requirement is determined from the BW (g) (predicted from measured body length), the energy needed to

TABLE 2

Relation between body length and BW in 16 species of ornamental fish species[1]

Common name (species)	Y_0	a	b	Length range, mm	Restricted weight range, g[2]	Adjusted R^2	N
Common Goldfish[3] (*C. auratus*)	—	0.0000757	2.80139	37–110	N/A	0.922	2594
Oranda Goldfish (*C. auratus*)	—	0.00007965	3.0425	33–60	N/A	0.691	472
Large Common Goldfish[4] (*C. auratus*)	—	0.000093417	2.82921	160–225	N/A	0.567	18
Black Spotted Corydoras(*Corydoras melanistius*)	−2.2514	0.0022	2.0462	37–60	1–8	0.925	227
Black Widow Tetra (*Gymnocorymbus ternetzi*)	−3.9364	0.4238	0.7121	27–38	0.5–2.0	0.800	535
Angelfish (*Pterophyllum scalare*)	−0.4680	0.00006909	2.904	30–64	1–20	0.967	477
Midas Cichlid (*Cichlasoma citrinellum*)	−87.4036	0.2051	1.3838	98–155	30–150	0.966	69
Pictus Catfish (*Pimelodus pictus*)	—	0.0000011	3.6077	65–90	N/A	0.896	358
Scissortail (*Rasbora trilineata*)	−2.3087	0.3077	0.6392	26–38	0.2–1.0	0.815	179
Tiger Barb (*Barbus tetrazona tetrazona*)	—	0.0000051	3.58641	30–36	N/A	0.957	1694
Golden Barb (*Puntius sachsi*)	0.0282191	0.00000125	3.25027	17–60	0.1–5.0	0.948	984
Red Zebra (*Pseudotropheus zebra*)	—	0.000001919	3.25767	45–87	N/A	0.973	629
Peppered Corydoras (*Corydoras paleatus*)	−2.4125	0.3924	0.6329	23–31	0.4–1.2	0.713	355
Black Neon Tetra (*Hyphessobrycon herbertaxelrodi*)	—	0.00000327	3.54811	20–30	N/A	0.814	521
Tinfoil Barb (*Barbus schwanenfeldii*)	—	0.00000493	3.3411	123–176	N/A	0.889	97
Black Barb (*Barbus nigrofasciatus*)	—	0.00004995	2.93536	40–48	N/A	0.646	10
Rosey Barb (*Barbus conchonius*)	−7.6075	0.5244	0.7961	40–48	2.5–4.5	0.555	13
Opaline Gourami (*Trichogaster opaline*)	—	0.0000493	2.84116	57–82	N/A	0.906	14

[1] Equation is of the form Y (BW in g) = Y_o + a(length in mm)^b.
[2] Restricted weight range provided for fish species fitted with an equation containing Y_0 term.
[3] Common Goldfish between 1.5 and 60 g BW.
[4] Large Common Goldfish between 150 and 450 g BW.

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promote 0.1% specific growth rate (J/g BW/d), and the predicted metabolizable energy of food (J/mg).

For example, for a Tinfoil Barb, with a predicted BW of 78 g, and an energy requirement of 75 J/g BW/d, fed tropical flakes containing a predicted metabolizable energy of 16.7 J/mg, the food requirement would be:

$$\text{Food requirement (mg)} = (78 \times 75)/16.7$$
$$= 350\,\text{mg food required/d.}$$

DISCUSSION

This research demonstrates that it is possible to fit regression equations that have a high R^2 for the ornamental fish populations used, as previously found in many aquaculture species (1–5). Regression equations with an R^2 of <0.8 were found for 5 groups of fish, probably because of either small sample size or large BW variability within the group. To fully complete the validation of the predicted equation, further work should be conducted using the equation in fish populations not used to derive the equation.

This research also shows that ornamental species have different energy requirements and that further research is warranted to provide the species with optimal nutrition. There are several factors that may influence energy requirements in fish. Fish species can vary in their energy requirement depending on their natural behavior. Data in this study demonstrates that highly active shoaling fish, such as the Black Widow Tetra, tend to expend more energy than sedentary species, such as the Common Goldfish and the highly territorial, solitary Midas Cichlid. Body weight may also influence energy requirements. A very small fish species, such as the Black Neon Barb and Peppered Corydoras, has a relatively high requirement compared with larger fish species, like the Tinfoil Barb and Midas Cichlid. This study also demonstrates that water temperature influences energy requirements, at least in the Common Goldfish, with increasing water temperature resulting in increased energy requirements. It is likely that fish activity level increases as water temperature rises, which results in higher energy requirements.

For foods with a known energy content, it is possible to calculate accurate species-specific food requirements for adult fish by combining the predicted BW with energy requirement to achieve 0.1% SGR. Feeding optimal amounts of food to aquarium fish will enable an owner to ensure that fish receive enough food for healthy growth while minimizing the risk of overfeeding and subsequent tank pollution.

Conclusion

It is possible to predict the BW of a range of ornamental fish species from body length. Thus, together with energy requirement data and food energy density data, it is possible to develop accurate feeding guides for aquarium fish that enable fish to grow at a healthy rate while reducing the risk of overfeeding and subsequent tank pollution. Energy requirements varied between fish species and a number of possible reasons for this were discussed including body size, natural behavior, and water temperature.

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