Jumping fish and swimming speed

Many koi owners have experienced a fish flapping on the lawn because it jumped out of the water. Many have spent fruitless hours trying to revive these suffering fish in the hope of a miracle happening. We want to blame someone for this mishap and are quick to find the culprit, usually a protection net that was carelessly closed over the tank, or worse, failure to use the net at all. They call that negligence.

There may be other reasons for fish jumping. Rushing, bubbling water is one. A waterfall, or water rushing from air stones or return pipes dangling near the pond edge may be the common reason. A full moon may trigger such behavior. Newly bought fish may find their new pond environment unsettling. An itch from parasites like anchor worms or fish lice is also a known reason why fish get uneasy and jumpy. Unfavorable water quality, especially low oxygen levels or toxins, will prompt fish to jump. Who knows, even a psychological feeling of "not belonging" can trigger these suicidal tendencies. For the more esoteric minded, who says they may not jump for joy? [1]

If ever you witness such an act, you will always be surprised at the height and distance a koi can travel through the air. Even if you are on the scene to save the fish immediately, such koi may often not survive the fall if the head is the first point of contact on a hard surface. If it does survive, it can be overcome by the stressful situation and be a ready target for parasites and fungi. Preventative treatment is essential or you risk further complications.

It is best to put such koi in the hospital tank immediately, in a 0.3-0.5% salt solution and some wide spectrum treatment[2]. Inspect the fish to assess the damage at the point of contact and treat the bruise topically. In a severe case, where the fish is near death and inverted, breathing irregularly or stiff, or even dry from being out in the sun, an injection of a steroid like dexamethasone can be a lifesaver. The intra-venous or intra-peritoneal route is advised.[3]

Studies by researchers Katopodis and Gervais[4] and others have illustrated that swimming speed of fish are directly related to body length and that this relationship can be represented mathematically across a wide spectrum of fish body conformations. Analysis of the maximum swimming speeds for 80 species in 255 data records by Froese and his co-workers in 2008[5] confirmed this relationship and showed that variations between species are limited. Although the burst speed may vary greatly among species, the length-speed relation remains the same.

Experimental values for common carp *Cyprinus carpio* and the crucian carp, *Carassius auratus* had some close coexistence and were pooled for best-fit regression analysis from data we extracted from the FishBase database and other sources[6]. Table 1 presents the results.

Table 1. Estimated burst speeds for common carp of various sizes, vertical height and distance attained.

Total length cm	Burst speed m/sec	Vertical height m	Vertical height body lengths	Distance at 45° m	Distance at 45° body lengths
2	0.23	0.003	0.13	0.005	0.27
3	0.33	0.005	0.18	0.011	0.37
4	0.42	0.009	0.23	0.018	0.45
5	0.51	0.013	0.27	0.027	0.54
10	0.94	0.045	0.45	0.090	0.90
13	1.18	0.071	0.55	0.143	1.10
15	1.34	0.092	0.61	0.183	1.22
20	1.72	0.152	0.76	0.303	1.52
30	2.46	0.308	1.03	0.617	2.06
40	3.16	0.510	1.28	1.020	2.55
50	3.85	0.754	1.51	1.508	3.02

(Derived from the relation Log10 (Vb) = a Log10 (TL) + b, where a = 0.8752, b = 1.0981, Vb is the burst speed attainable at the start, in cm/sec and TL is the total length in cm)

A burst speed of 3.85 meter per second means that a 50 cm carp can reach a speed of about 14 km per hour initially. The sustainable speed for fish is normally about 5 to 10 times less. An 11 cm common carp was found to sustain a speed of 0.59 meter per sec (Bainbridge, 1958 as quoted by Froese, 2008) that will translate to a cruising speed of just over 2 km per hour. A healthy 50 cm koi will probably be able to cruise continuously at 2-5 km per hour.

Compare that with a tuna *Thunnus albacares* with a burst speed measured at 20.4 m/s (73 km/h) or a black marlin *Istiompax indica* measured at 36.1 m/s, a staggering 129 km/h.

Using this data and simple mechanics it can be calculated that a 30 cm young koi, breaking the water vertically at his maximum speed, could reach a height of 0.31 meter and if it should break the water at an angle of 45 degrees it could reach an apex height of 0.15 m and a distance of 0.77m. This may be realistic, as anyone with experience of working with fish will attest to.

Performing the same calculations on smaller fish the values in Table 1 do not seem to hold. Our experience with small fish is that they can quite easily clear two or three times their body length when they feel the need to. Similarly, large 60 cm females will hardly muster the speed to clear a vertical 1.1m as the data suggests. The mathematical model clearly breaks down at these far extrapolated points probably due to the paucity of data. Individual variation might also play a roll. More work on this subject is clearly needed.

An interesting fact is that koi can perform a 90º turn with a body and caudal fin maneuver at high speeds, and the turning radius is not related to the swimming speed. In 2007, Wu and co workers[7] also found that except in very fast turns, the turning radius is not affected by the turning rate which was recorded to be as high as 1050 degrees per second. These are spontaneous turns performed routinely during normal activity, but may serve the koi well during prey evasion.

It may be speculated that by instinctively "practicing" the evasion maneuver, the koi becomes more proficient in its survival skills. We know that if you want to be a gymnast, you must

practice in order for the central nervous system to coordinate your movements more effectively. The natural tendency of young animals to jump, play and frolic, seemingly endlessly, can be traced to practicing for future danger evasion. When however, the koi end up on dry land, it surely is a move gone wrong.

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1 Animal Suicide. In 1845, the Illustrated London News reported that a Newfoundland dog had been acting less lively over a period of days before being seen "to throw himself in the water and endeavour to sink by preserving perfect stillness of the legs and feet". Every time he was rescued, he attempted to do this again before he finally held his head underwater until death. Other dogs, as well as ducks, have also drowned themselves. One duck did so after the death of its mate. Wikipedia. https://en.wikipedia.org/wiki/Animal_suicide accessed 2 August 2016

2 Antibacterial and antiparasitic treatment like Elbazui, Pafurajin F, Koi M+F (malachite and formalin mixture)

3 Johnson, Dr Erik J. Koi Health and Disease.1997

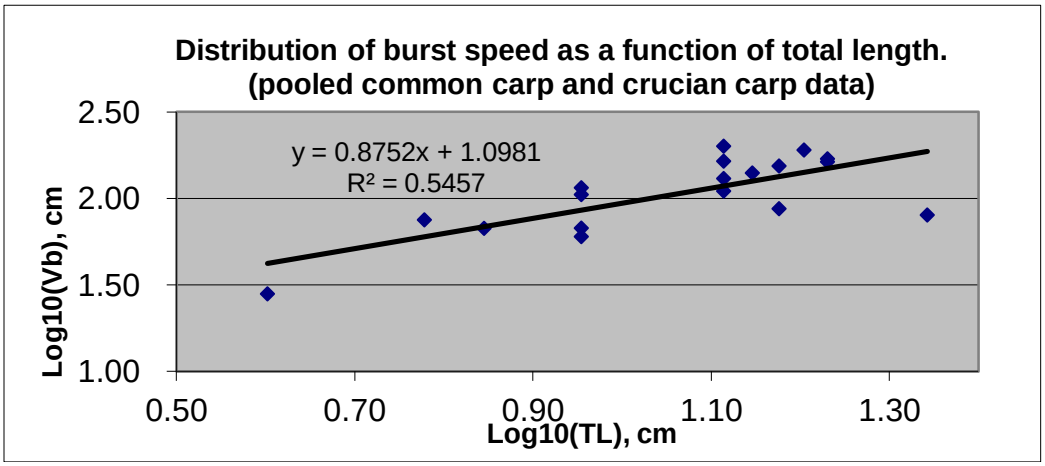
4 Katopodis, C., and R. Gervais. 1991. Ichthyomechanics. Freshwater Institute. Central and Arctic Region. Department of Fisheries and Oceans, Canada.

Anonymous 2006. Fish Swimming Speeds. Section 6 Appendix 6_B Environmental Guide for Fish and Fish Habitat. Ministry of Transportation, Canada

Sambilay, V.C., Jr. 1990. Interrelationships between swimming speed, caudal fin aspect ratio and body length of fishes. Fishbyte 8(3):16-20.

5 Froese R, Torres, A. Binohlan C and D Pauly. 2008. Internet database. www.fishbase.org,

6 Figure 1 The distribution of the burst speed of a data sample that was analyzed.



7 Wu, G., Yang, Y. and L Zeng. 2007. Routine turning maneuvers of koi carp Cyprinus carpio koi: effects of turning rate on kinematics and hydrodynamics. J. Exp. Biology 210, 4379-4389