# Journal of Interdisciplinary Science Topics

## Can Hiccup Supply Enough Fish to Maintain a Dragon's Diet?

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31/03/2017

### Abstract

Toothless is a Night Fury dragon who appears in the *How to Train Your Dragon* (HTTYD) franchise, and is said to be the rarest, fastest, and most intelligent of the dragon species. In the 2010 film, Toothless is struck down during a dragon raid and loses his left tail-fin, leaving him trapped in a sunken area. This paper investigates the feasibility of Hiccup, a teenage boy, being able to supply enough fish to maintain the dragon's diet by catching and bringing fish to him. It was found that in the twelve days that Toothless was trapped, he would have required 13 Icelandic cod and 56 Atlantic salmon every day, which totalled 716 kg. Hiccup would have had to carry 828 fish weighing at total of 8592 kg over the twelve days, which is unrealistic since he struggles to lift a shield in combat.

### Introduction

The *How to Train Your Dragon* franchise is loosely based on the popular book series by Cressida Cowell [1]. The events take place in Viking Scotland, in the small village of Berk which is repeatedly attacked by dragons. One of the deadliest dragon species is the Night Fury, which was previously unseen by any living person. It is described as the "unholy offspring of lightning and death itself" due to its speed and camouflage abilities [2]. Toothless is the only known Night Fury, and is shown to be intelligent and playful while also deadly.

Hiccup Horrendous Haddock III, the main protagonist, is a small teenage boy eager to prove himself as a Viking. Using an invention which closely resembles a net gun, Hiccup strikes down Toothless during a dragon raid. Toothless' left caudal fin is severed, rendering him unable to fly out of the sunken area, known as The Cove [3]. Fish are a large component of a dragon's diet, and Toothless is exclusively dependent on fish for nutrition [4]. This paper investigates whether Hiccup is able to maintain Toothless' feeding habits while he is trapped in The Cove.

### Assumptions

Several assumptions and simplifications must be made to calculate the required values. During the time lapse montages in the film, it is taken that Toothless is in The Cove for a total of twelve days [5]. It is assumed that Hiccup visited once a day for the duration of Toothless' stay.

On the third day, Hiccup brings a sack of fish, and mentions that it contains Icelandic cod and salmon. There is also a pond in the clearing, and one scene shows Toothless hunting for fish. However, in this paper, it is assumed that Toothless relies solely on Hiccup for nutrition. During his time in The Cove, it is assumed that his diet consists of only salmon and cod. It is also assumed that each sack contained the same amount of fish, and that he received the same amount every day for twelve days.

The sack is modelled as a cylinder, while the fish have been modelled as prolate spheroids (see Appendix for visual aids).



Figure 1 – Comparison of size of Hiccup to bag [5].

### Size of the bag

Hiccup is said to be 1.625 m tall [6], and using average male proportions, the bag appears to be 3/8 of his height [7]. Therefore, the height of the bag, $H_{bag}$:

$$H_{bag} \approx \frac{3}{8}(1.625\ m) \approx 0.6094\ m \quad (1)$$

The bag appears to have the same height as the diameter; the diameter is taken to be 0.6094 m. Hence the radius, $r$:

$$r = \frac{1}{2}(0.6094) = 0.3047\ m \quad (2)$$

So, the volume of the bag, $V_{bag}$ is:

$$V_{bag} = \pi r^2 h \quad (3)$$

$$V_{bag} = \pi \times (0.3047\ m)^2 \times (0.6094\ m)$$

$$\therefore V_{bag} = 0.1777\ m^3 \quad (4)$$

Therefore, the bag has a capacity of 0.1777 m³.

**Fish sizes**
The fish considered in Toothless' diet are Atlantic salmon, *Salmo salar* [8], and Icelandic cod, *Gadus morhua* [9]. The average dimensions are summarised in Table 1.

| Species | Length (m) | Mass (kg) |
|---|---|---|
| Atlantic salmon | 0.70 – 0.75 [8] | 3.5 – 13.5 [8] |
| Icelandic cod | 0.55 – 0.90 [9] | 40.0 – 96.0 [9, 10] |

Table 1 – Dimensions of fish

The length of salmon was calculated by comparing to Hiccup's height [7]; the salmon was determined to be 1/4 of his height. The width was then established by tracing the image and comparing the ratio of the length to width. This was replicated for cod. The values were close to the lower estimates in Table 1; the final values used are summarised in Table 2.

| Species | Length (m) | Width (m) | Mass (kg) |
|---|---|---|---|
| Atlantic salmon | 0.4063 | 0.0864 | 3.5 |
| Icelandic cod | 0.5500 | 0.1567 | 40.0 |

Table 2 – Dimensions of fish used for calculations

The volume of a prolate spheroid, $V_{ps}$:

$$V_{ps} = \frac{4}{3}\pi a^2 c \quad (5)$$

Where $a = 1/2$ width, $c = 1/2$ length and $a < c$; $a$ is the radius and $c$ half the head-to-tail length. Therefore, for salmon $a = 0.043$ and $c = 0.203$, and for cod $a = 0.078$ and $c = 0.275$. Using Eq. (5) the volumes of the salmon, $V_S$, and cod, $V_C$, are hence:

$$V_S = \frac{4}{3}\pi (0.043)^2 (0.203) = 0.0016\ m^3 \quad (6)$$

$$V_C = \frac{4}{3}\pi (0.078)^2 (0.275) = 0.0071\ m^3 \quad (7)$$

Therefore, the volumes of each salmon and cod are 0.0016 and 0.0071 m³ respectively.

**Portion size**
The number of each fish, $N_S$ and $N_C$, is multiplied by the volumes from Eq. (6) and (7) respectively. This is equal to the total volume of the bag from Eq. (4):

$$0.1777 = 0.0016 N_S + 0.0071 N_C \quad (8)$$

It is assumed that the salmon and cod occupy the same volumes in the bag, and that they are efficiently packed so the entire sack is occupied. Therefore;

$$0.0889 = 0.0016 N_S$$
$$\therefore N_S = 56 \quad (9)$$

$$0.0889 = 0.0071 N_C$$
$$\therefore N_C = 13 \quad (10)$$

The masses of the fishes are:

$$M_S = 56(3.5\ kg) = 196.0\ kg \quad (11)$$

$$M_C = 25(40\ kg) = 520.0\ kg \quad (12)$$

Therefore, in one day the bag contains 56 salmon and 13 cod, with a total weight of 716.0 kg.

**Conclusion**
In the film, it appears that Toothless was in The Cove for twelve days and it was assumed that he was solely dependent on Hiccup for nutrition. The bag used to provide food was calculated as having a capacity of 0.1777 m³, and could hold 56 Atlantic salmon and 13 Icelandic cod. Hiccup would have to carry 716 kg of fish to The Cove every day, a total of 8592 kg over the period of twelve days. Hiccup is depicted as physically weak, and is unable to even hold up a shield for a prolonged time. It is therefore concluded that Hiccup would be unable to carry the bag and could not feed Toothless for the duration of his time in The Cove, unless he made several trips, used less heavy fish, or didn't fully fill the sack.

**References**

[1]  How to Train Your Dragon Wikia (2017) *Toothless (Franchise)*, 8 March 2017. [Online]. Available at: http://howtotrainyourdragon.wikia.com/wiki/Toothless_(Franchise). [Accessed 10 March 2017].

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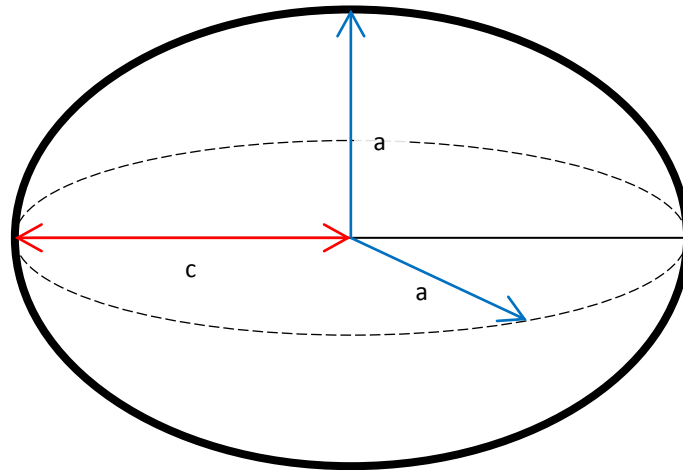
## Appendix

**Prolate spheroid:**

Figure A – Prolate spheroid where $a = 1/2$ width, $c = 1/2$ length and $a < c$; $a$ is the radius and $c$ is the head-to-tail length
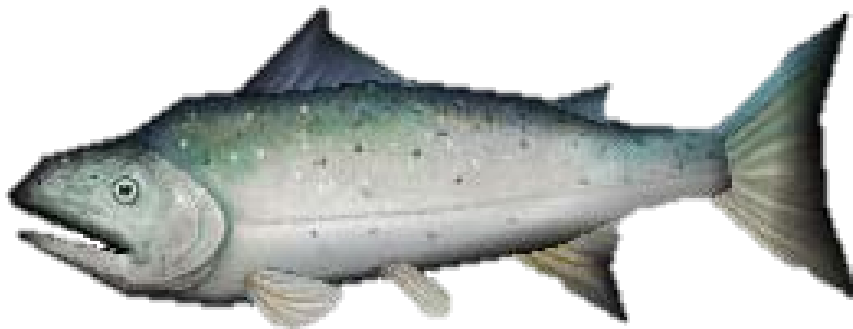
**Atlantic salmon:**

Figure B – Atlantic salmon from HTTYD TV series [A1]
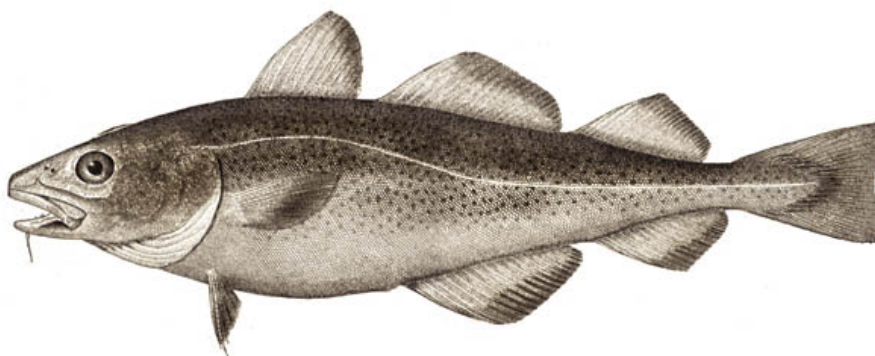
# Icelandic cod

Figure C – Icelandic cod [A2]

**Hiccup holding salmon:**



Figure D – Hiccup holding Atlantic salmon [A3]

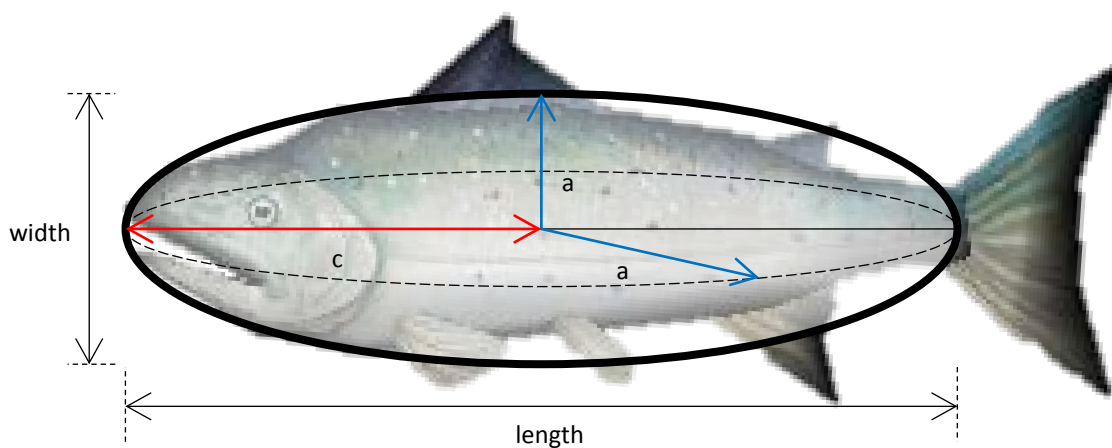**Salmon with prolate spheroid overlaid:**



Figure E – Atlantic salmon with prolate spheroid overlaid

Using average male proportions [A4], the salmon is considered to be 1/4 of Hiccup's height (Figure D). Therefore, the length is calculated to be 0.4063 m with a width of 0.0864 m. Since this was around the lower estimate of Table 1, the mass was taken as 3.5 kg.
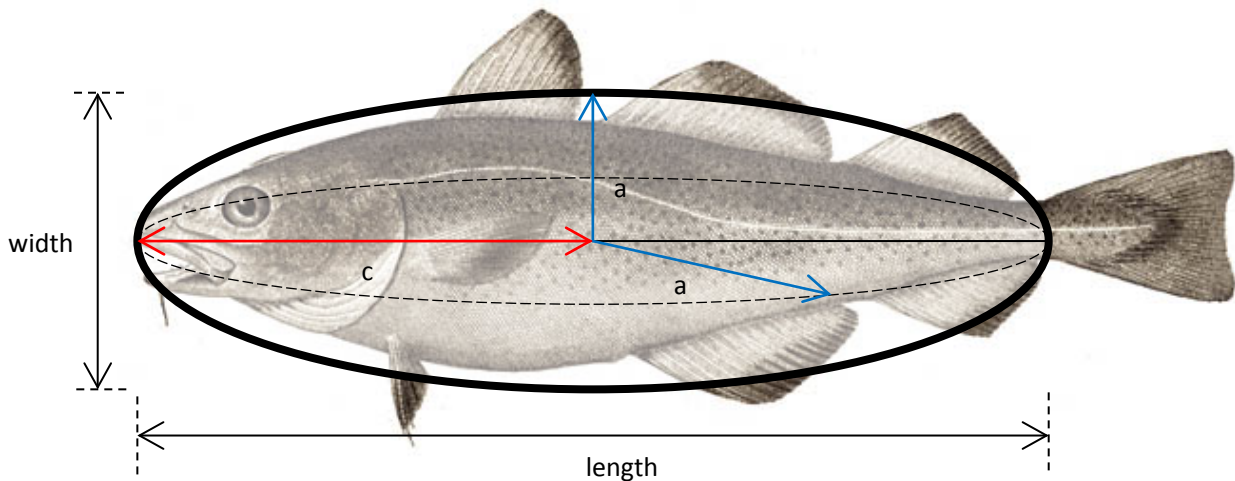
**Cod with prolate spheroid overlaid:**



Figure F – Icelandic cod with prolate spheroid overlaid

Since the salmon length was on the lower scale of the estimates in Table 1, the lower estimate of length for cod was used. Length was hence taken as being 0.5500 m and the width was calculated to be 0.1567 m. The lower mass estimate was taken as 40 kg.

**Appendix Additional References**

[A1]   How to Train Your Dragon Wikia (2016) *Fish*, 11 December 2016. [Online]. Available at: http://howtotrainyourdragon.wikia.com/wiki/Fish. [Accessed 16 March 2017].

[A2]   Wikipedia (2017) *Cod*, 15 February 2017. [Online]. Available at: https://en.wikipedia.org/wiki/Cod. [Accessed 17 March 2017].

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[A4]   idrawdigital (2009) *Drawing Tutorial: Anatomy and Proportion #1*, 14 January 2009. [Online]. Available at: http://www.idrawdigital.com/2009/01/drawing-tutorial-anatomy-and-proportion-1/. [Accessed 17 March 2017].

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[1] How to Train Your Dragon Wikia, "Fish," 11 December 2016. [Online]. Available: http://howtotrainyourdragon.wikia.com/wiki/Fish. [Accessed 16 March 2017].

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[3] C. Sanders and B. DeBlois, Directors, *How To Train Your Dragon.* [Film]. United States of America: DreamWorks Animation, 2010.

[4] idrawdigital, "Drawing Tutorial: Anatomy and Proportion #1," 14 January 2009. [Online]. Available: http://www.idrawdigital.com/2009/01/drawing-tutorial-anatomy-and-proportion-1/. [Accessed 17 March 2017].