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P3_1 Just keep swimming!

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Abstract

This paper investigates the plausibility of the scene in the film "Finding Nemo", in which a school of grouper fish avoid being lifted out of the sea. In the scene the countering force generated by the fish causes the beam to snap however, our results show the total force acting on the beam is 5.8×10^{3}N, which is less than the maximum force of 4×10^{5}N which can be applied to the beam, therefore indicating the fish would not have escaped.

Introduction

The scene in the film "Finding Nemo" shows a school of fish trapped in a fishing net, which swim in unison to exert enough force to break the wooden beam supporting the net's weight, in order to escape. This paper discusses whether the amount of fish and resultant force created by them swimming, is enough to overcome the maximum tensile strength of the wooden beam.

Theory

Due to the lack of information in the scene, the following estimations have been made.

1. The material, from which the beam is made, is assumed to be wood of a tensile strength of 40MPa [1].
2. The net enclosing the fish is considered to be a cylindrical volume, with a radius of 1.25m and a height of 2m.
3. The volume of each fish is estimated by a cylindrical volume, with a radius 0.15m, and length of 0.7m. Each fish has a mass of 20kg and can swim at a maximum speed of $1.5ms^{-1}$ [2].
4. The time over which the fish exert the downwards force by swimming is estimated to be 1 minute.

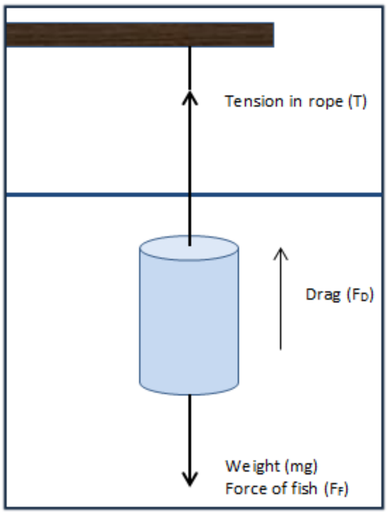

Figure 1: Diagram of force acting on net

In order to obtain the total force acting on the beam, we calculate the forces acting individually on the net. Firstly the force exerted by a fish swimming downwards is calculated as follows, where v denotes the final velocity, u the initial velocity and t the time over which the force occurs [3].

$$F_F = \frac{mv - mu}{t} \quad (1)$$

The weight of the fish in the net is also supported by the tension in the rope which connects the net to the beam. The tension in the rope supports the weight of the fish, accounting for the buoyancy force (the upwards force exerted by a fluid which opposes the weight of an immersed object) and is given by the equation which follows,

$$T = mg - F_B \quad (2)$$

Where mg denotes the total weight of the fish and F_B is the buoyancy force given by $F_B = \rho V$ where ρ is the density of the fluid, and V is the volume (in this case approximated by a cylinder).

As well as the fluid medium causing the buoyancy force, there is also the drag force to take into account, which acts to oppose the motion of the fish. Though fish are generally streamlined, moving in a bulk mass causes a large drag force calculated by the equation below, where ρ is the density of the fluid, v is the velocity, c_d is the drag coefficient, and A is the frontal area of the body.

$$F_D = \frac{1}{2}\rho v^2 c_d A \quad (3)$$

Therefore accounting for all the forces acting on the net and the direction in which they are acting, the force on the beam is can be calculated from the following equation, where mg is the total weight of the fish, $F_F$is the force generated by the fish, F_D is the drag force and T is the tension in the rope,

$$F = mg + F_F - F_D - T \quad (4)$$

In order for the beam holding the rope that supports the net to snap, the force of the fish swimming down plus the total weight of the fishes must be greater than the tensile strength of the wood per cross sectional area of the beam. The tensile strength of a material is given by equation below, where A is the cross sectional area [3],

$$UTS = \frac{F}{A} \quad (5)$$

Since wood is an inelastic material it is assumed that it will snap immediately on application of the maximum force that can be applied.

Discussion

By calculating the volume of the net (given by $= \pi r^2 h$) and dividing by the volume of one fish (also approximated here as a cylinder) yields a value of 200 fish. Equation 1 is used to calculate the force exerted by the 200 fish to obtain a net force of 100N. The tension in the rope (calculated from equation 2) produces a value of $2.9\text{x}10^4$N and the drag force (equation 3) using the value of c_d=0.82 for a cylinder [4], calculates to $4.5\text{x}10^3$N giving a total force on the beam $5.8\text{x}10^3$N. For a cross sectional beam area of 0.1m^2 the maximum force is $4\text{x}10^5$N which is more than enough to accommodate the total force on the beam suggesting it would not snap.

Conclusion

In conclusion the force generated by the fish swimming downwards is very small, almost negligible in comparison to the other forces such as the weight and drag acting on the net. The tensile strength of the wood was calculated to be more than enough to support the total force acting on the beam, so would not cause it to snap. Therefore we conclude in this case the feat is not possible and the fish would have been caught.

References

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