Modeling Phytoplankton Movement and Fitness in Lakes

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CCS CONCEPTS

• **Computing methodologies → Modeling and simulation**; •
Applied computing → Computational biology.

KEYWORDS

lake ecology, phytoplankton, fitness, movement

1 INTRODUCTION

The majority of organisms on Earth are ectothermic, and their body
temperatures largely depend on the surrounding environmental
conditions. Body temperature strongly affects fitness [2]. In a spa-
tially variable environment, movement can allow an ectothermic
organism to change their body temperature. This project explores
body temperature and movement in the context of phytoplank-
ton fitness within lake environments. By modelling movement
strategies using lake thermal profile data, we infer the range of
temperatures phytoplankton experience and the resulting effect on
fitness.

2 METHODS

Temperature data was collected from Sparkling Lake in Vilas County,
Wisconsin at intervals from .5 to 3m throughout the lake at a fre-
quency of one minute over a period of 26 years [1]. Phytoplankton
fitness w is a function of water temperature T:

$$w(T) = b_1 e^{b_2 T} - (d_0 + \frac{b_1 b_2}{d_2} e^{(b_2 - d_2)T_{opt}} e^{d_2 T}) \qquad (1)$$

where b_1 represents birth rates at $0°C$, b_2 represents the exponential
change in birth rate due to increased temperature, d_0 represents a
temperature-independent mortality constant, d_1 and d_2 represent
exponential changes to mortality rates due to increased tempera-
ture, and T_{opt} represents the temperature at which growth rate is
maximized [2]. We designed three movement algorithms to simulate
patterns of phytoplankton movement across lake depths. **Diel Ver-
tical Migration (DVM)** represents the daily pattern of movement
observed in certain species of phytoplankton. Phytoplankton move
upwards during the day and downwards at night. Two phytoplank-
ton speeds were implemented. **Random Walk (RW)** randomly
samples depths independent of the distance traveled. **Directional
Random Walk (DRW)** randomly samples depths confined to the
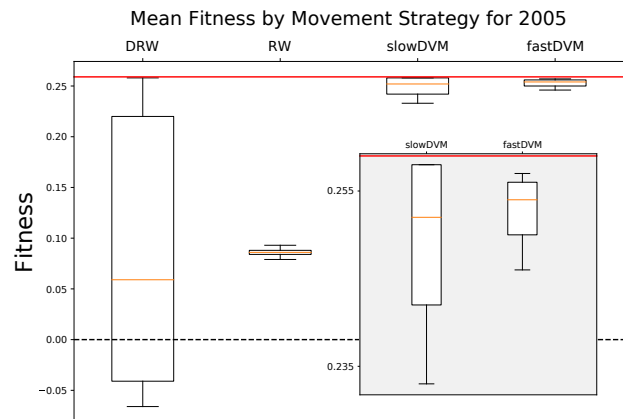local neighborhood.

**Figure 1: Mean body fitness across 1000 runs of all five move-
ment strategies over the 2005 warm season. The solid red
line indicates the highest possible mean fitness. The inset
shows two DVM speeds.**

3 RESULTS AND DISCUSSION

The two speeds of diel vertical migration both achieve mean fitness
nearly as high as the maximum fitness (Figure 1). During the sum-
mer, the day period is longer than the night period. This means that
the phytoplankton can swim further upwards than they are able to
swim downwards in the night. Regardless of starting position, phy-
toplankton will eventually reach the warmer temperatures at the
lake's surface and achieve higher fitness. However, slower phyto-
plankton have a greater variance in fitness because they take longer
to reach the surface (figure inset). The random walk movement pat-
tern demonstrates the average body temperature experienced over
space and time. The large variance seen in the directional random
walk demonstrates the wide spread of fitness achieved at varying
depths in the lake. Together, these movement patterns allow us
to quantify potential thermal fluctuations phytoplankton experi-
ence as they move throughout their environment, and identify how
different patterns of movement influence fitness over time.

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