Effect of temperature and amount of food on the growth rate/aerobic scope of juvenile chum salmon

Yuki Iino
Takashi Kitagawa, Takaaki Abe, Tsuyoshi Nagasaka, Yuichi Shimizu, Katsuhiko Ota, Takuya Kawashima, and Tomohiko Kawamura
International Coastal Research Center,
The Atmosphere and Ocean Research Institute, The University of Tokyo
Japanese chum salmon (Oncorhynchus keta) after 3 years, migrate into fresh water Aug.–Nov. (adapted Urawa, 2000)
Intro. Chum salmon catch and hatchery production

Year


No. catch (ten million)

0 0.5 1.0 1.5 2.0 2.5

No. hatchery release (billion)

0 0.5 1.0 1.5 2.0 2.5

hatchery release
catch

Japan

Russia

(NPAFC 2018)
Intro. Chum salmon catch and hatchery production

No. catch (ten million)

No. hatchery release (billion)

Year

Japan

Russia

(hatchery release)

(catch)

(NPAFC 2018)
Intro. Chum salmon catch and hatchery production

Hatchery production + Environmental condition (after ocean entry) → Variation of catch

No. catch (ten million)

No. hatchery release (billion)

Year


Japan
Russia

(NPAFC 2018)
Intro. Low growth rate may cause high mortality in the Okhotsk Sea.
Intro. Low growth rate may cause high mortality

the Okhotsk Sea

Low growth

High mortality

(Kitagawa, 2017)
(Honda et al., 2017)
Environmental condition

**Temperature**

**Prey abundance**

Body size

Small

Large

Survived

Intro. Temp. & food levels affect growth rate

Temperature & Prey abundance

How affect ??

Growth rate

(Ogawa & Shimizu 2012, Tucker et al., 2016)
Intro. Growth & Fish bioenegetics

Fish bioenegetics (Ricker, 1971)

Temperature

Food

intake

Respiration

Growth

Excretion

Locomotion

*Allocate energy to locomotion and growth

* The amount of allocation differ from temp. & food levels

(Elliott 1976, Kurita 2010)
Intro. How to evaluate energy allocation of fish

Swim tunnel respirometer (Blazka-type)

▶ measurement content

Oxygen consumption during swimming
Intro. Swim tunnel in the study of Salmonids

✓ Measured: Pacific bluefin tuna, Sockeye salmon etc...

Including Adult chum salmon

(Brett 1964, Brill 1979, Lee et al. 2003, Blank et al. 2007, Abe et al. 2019)

Little is known in the study of chum salmon juveniles
The aim of our study is ...

To determine how the metabolic performance of juvenile chum salmon under different food levels and temperatures affects their growth rates.
Method: Fish collection and rearing

Jan.–Mar. 2018

✓ Food level  4 % (=surplus level) & 1 % of body mass  
(Leitritz & Lewis, 1976)

✓ Temp( °C )

8.0 (1%)
6.0-8.1 (4%)
10
12
14 °C  
(n=100 / tank)

1st day

15th day

Measured fork length & metabolic rate
Measurement of metabolic rate of juvenile
Measurement of metabolic rate of juvenile
Method: Measuring contents

Mean daily growth rate (mm \cdot day^{-1})

Metabolic rate (mg \text{O}_2 \cdot kg^{-1} \cdot min^{-1})

1. Maximum metabolic rate (MMR)

2. Resting MR (RMR)

Aerobic Scope = 1 - 2

capacity of aerobic metabolism
linked to swimming performance, growth rate and digestion
Results: High growth at High food level & Temp.

4% of Body mass

Reported growth rate in wild (Honda et al. 2017)

Mean daily growth rate (mm day$^{-1}$)

<table>
<thead>
<tr>
<th>Temperature (℃)</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0-8.1</td>
<td>0.68</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

$n=8$ / each Temp.
Results: **Low** growth at **Low** food level

Mean daily growth rate (mm・day\(^{-1}\))

1 % of Body mass

\[ \text{Temperature (°C)} \]

\[ n = 8 / \text{each Temp.} \]
Results: High metabolic rate at High Temp.

4 % of Body mass

Metabolic rate (mg O₂ · kg⁻¹ · min⁻¹)

Temperature (°C)

MMR

RMR
Results: High metabolic rate at High Temp.

Metabolic rate (mg O\(_2\) \cdot kg\(^{-1}\) \cdot min\(^{-1}\))

Temperature (°C)

4 % of Body mass

Aerobic Scope

MMR

RMR
Results: **High aerobic scope at High Temp.**

4 % of Body mass

![Graph showing the relationship between Aerobic Scope (mg O₂ · kg⁻¹ · min⁻¹) and Temperature (°C). The graph indicates an increasing trend with temperature.]
Results: Low aerobic scope at High Temp.
Discussion: Multiple effect on growth of juvenile

**High food level**

**Low food level**

Food levels → **Multiple effect** → Growth rate

Temperature

Growth rate
Discussion: Multiple effect on growth of juvenile

**High food level**

**Low food level**

**Growth rate**

Temperature

**Maximum growth rate** (Kaeriyama 1986)

**Food levels** → **Multiple effect** → **Growth rate**

Temperature
Recent trend

Discussion: Water properties may affect adult catch

✓ The ratio of Warm water mass increasing (Wagawa et al., 2016)

Water properties

- Low prey abundance
- Low metabolic capacity
- Low growth
- Low catch

Tsugaru warm water current

Kuroshio Extension (Warm water current)
Summary

➢ Multiple effect on growth

Food levels ➞ Multiple effect ➞ Growth rate

➢ First measurement of metabolic capacity in juvenile chum

➢ Decreasing trend of adult catch

Increasing ratio of Warm water mass may cause low growth & High mortality