Growth of larval and early juvenile sardine (Sardinops spp.) and anchovy (Engraulis spp.) in the eastern and western North Pacific Ocean

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Change in fishery catch for *Sardinops* and *Engraulis* and sea surface temperature in the 20th century

**Kuroshio/Oyashio region**
- *S. melanostictus*
- *E. japonicus*

**California Current region**
- *S. sagax*
- *E. mordax*

Change in fishery catch for *Sardinops* and *Engraulis* and sea surface temperature in the 20th century
Studies on growth rate-dependent recruitment for *Sardinops* and *Engraulis*

Growth rates after metamorphosis were positive function of recruitment abundance in *S. melanostictus*.

(Takahashi et al. in preparation)

Late larvae with faster growth rates had greater probability of successful recruitment to the adult population than those with slower growth rates in *E. japonicus*.

(Takahashi and Watanabe 2004)

Growth rates during larval stage are critical determinant of population growth in *S. sagax* and *E. mordax*.

(Lo et al. 1995)

We hypothesize that differential growth due to different environmental conditions causes the out-of-phase population dynamics between the eastern and western N Pacific Ocean.
Objectives

Effects of temperature and food on growth rates during late larval and early juvenile stages of sardine (*Sardinops*) and anchovy (*Engraulis*) in the eastern and western North Pacific Ocean

- Somatic and otolith growth
- Growth standardization
- Growth variations in relation to SST and prey density
- Conclusions
Occurrence of sardine and anchovy in Kuroshio-Oyashio transitional waters

S. melanostictus  E. japonicus

1996-2003, May-Jun., FRA cruise, Trawl
Occurrence of sardine and anchovy in the California Current region

*S. sagax*

2005 Aug.-Sep. BPA, Trawl

2004 Apr. CalCOFI, Bongo

2004 Nov. Beach seine

*E. mordax*

2005 Aug.-Sep. BPA, Trawl

2006 May-Jun. Rockfish, Trawl

2005 Oct. PaCOOS, Trawl
Frequency distribution of SL

- **S. melanostictus**
  - Frequency: %
  - Sample size: N=871

- **E. japonicus**
  - Frequency: %
  - Sample size: N=3057

<table>
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<th>Standard length; SL (mm)</th>
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<th>20</th>
<th>30</th>
<th>40</th>
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<td>0</td>
<td>4</td>
<td>0</td>
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<td>0</td>
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</tbody>
</table>

![Histogram showing frequency distribution of SL for S. melanostictus and E. japonicus](image)
Frequency distribution of SL

- **S. melanostictus** (N=871)
- **S. sagax** (N=232)
- **E. japonicus** (N=3057)
- **E. mordax** (N=216)

Standard length; SL (mm)

Frequency (%)
Otolith of juvenile *S. sagax* (65.8 mm SL, 150 days after hatching)

**Measuring**

Number of increments (N)

Width of increments (IW)

Otolith radius (OR)

**Age in days**

N + 2 (*S. melanostictus*)

N + 3 (*E. japonicus*)

N + 3 (*S. sagax*)

N + 4 (*E. mordax*)

Otolith measurement system

(Ratoc System Engineering Co., Ltd.)

Yokohama  
La Jolla
Frequency distribution of hatch dates

- S. melanostictus (N=883)
- E. japonicus (N=2909)
Frequency distribution of hatch dates

- **S. melanostictus (N=883)**
- **E. japonicus (N=2909)**
- **S. sagax (N=232)**
- **E. mordax (N=216)**

Graph showing the distribution of hatch dates for different species and locations.
SL at age

- **S. melanostictus**
- **S. sagax**
- **E. japonicus**
- **E. mordax**
Increment width (IW) at age of 60-80 mm SL fish

**E. japonicus**

**S. melanostictus**

**S. sagax**

**E. mordax**
Otolith radius (OR) and SL

- **S. melanostictus**
- **E. japonicus**
- **S. sagax**
- **E. mordax**

**Metamorphosis**
- Larva
- Juvenile

**Watanabe and Kuroki (1997)**

**Linear**

**Non linear**
How to backcalculate growth

Biological Intercept Method (Campana 1990)

\[ SRGR = \frac{\ln(BL_{last}) - \ln(BL_{last-5})}{5} \]

\( BL_{last} \): Backcalculated SL at deposition of the last increment

\( BL_{last-5} \): Backcalculated SL at 5 days before the last deposition

Standardized recent growth rate (SRGR, d\(^{-1}\))

(Jones 2002)
SRGR and SST for *Sardinops*

**Late larva**

- **SRGR (d⁻¹)**
- **SST (°C)**

**Early juvenile**

- **S. melanostictus**
- **S. sagax**
  - California
  - Oregon/Washington

Graph showing SRGR and SST for *Sardinops* species.
SRGR and available prey density for *Engraulis*

**Available copepod size**
- Anchovy larva
- Prosome width: 200-600 μm
  (Uotani 1985)

**Zooplankton collection**
- KOTW
  - Mesh: 335 μm
  - Depth: 150 m
- OR/WA
  - Mesh: 200, 335 μm
  - Depth: 100 m

**Late larva**
- SRGR (d⁻¹)
- Available prey density (mg DW m⁻³)

**Early juvenile**
- SRGR (d⁻¹)
- Available prey density (mg DW m⁻³)

- *E. japonicus* (green circles)
- *E. mordax* (black circles)

**Mean ± SD**
Increment width (IW) at age of 60-80 mm SL fish

- **E. japonicus**
- **S. melanostictus**
- **S. sagax**
- **E. mordax**
Conclusions

- Somatic and otolith growth rates of *Sardinops* and *Engraulis* were faster in the KOTW than in the CCT
- We were unable to separate temperature and food effects on *Sardinops* growth rates
- SRGR of *E. japonicus* was faster than *E. mordax* in the SST range for 13-21°C
- Slower SRGR of *E. mordax* off Oregon/Washington was caused by lower concentration of available copepod
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