DECADAL VARIATION IN EGG ABUNDANCE OF A MESOPELAGIC FISH, MAUROLICUS JAPONICUS, IN THE JAPAN SEA DURING 1981-2005

Tadanori Fujino
Japan Sea National Fisheries Research Institute, Niigata Prefecture, Japan, fnori159@hotmail.com

Tsuneo Goto
Japan Sea National Fisheries Research Institute, Niigata Prefecture, Japan.

Tsuyoshi Shimura
Tottori Prefectural Fisheries Experimental Station, Tottori Prefecture, Japan

Hiroki Yasuma
Field Science Center for Northern Biosphere, Hokkaido University, Hokkaido, Japan

Yongjun Tian
Japan Sea National Fisheries Research Institute, Niigata Prefecture, Japan

See next page for additional authors

Follow this and additional works at: https://jmstt.ntou.edu.tw/journal

Part of the Aquaculture and Fisheries Commons

Recommended Citation
Fujino, Tadanori; Goto, Tsuneo; Shimura, Tsuyoshi; Yasuma, Hiroki; Tian, Yongjun; Kidokoro, Hideaki; Masuda, Shinya; and Miyashita, Kazushi (2013) "DECADAL VARIATION IN EGG ABUNDANCE OF A MESOPELAGIC FISH, MAUROLICUS JAPONICUS, IN THE JAPAN SEA DURING 1981-2005," Journal of Marine Science and Technology: Vol. 21 : Iss. 1 , Article 8.
DOI: 10.6119/JMST-011-0919-1
Available at: https://jmstt.ntou.edu.tw/journal/vol21/iss1/8

This Research Article is brought to you for free and open access by Journal of Marine Science and Technology. It has been accepted for inclusion in Journal of Marine Science and Technology by an authorized editor of Journal of Marine Science and Technology.
DECADAL VARIATION IN EGG ABUNDANCE OF A MESOPELAGIC FISH, MAUROLICUS JAPONICUS, IN THE JAPAN SEA DURING 1981-2005

Acknowledgements
We thank the Japan Sea National Fisheries Research Institute and Dr. Osamu Katoh for providing biological and oceanographic data sets. We also thank Dr. John Bower and the anonymous referees for their comments. Finally, this paper would not have been possible without the work and dedication of the research-vessel crew members and the researchers who sorted the net samples.

Authors
Tadanori Fujino, Tsuneo Goto, Tsuyoshi Shimura, Hiroki Yasuma, Yongjun Tian, Hideaki Kidokoro, Shinya Masuda, and Kazushi Miyashita

This research article is available in Journal of Marine Science and Technology: https://jmstt.ntou.edu.tw/journal/vol21/iss1/8
DECADAL VARIATION IN EGG ABUNDANCE OF A MESOPELAGIC FISH, MAUROLICUS JAPONICUS, IN THE JAPAN SEA DURING 1981-2005

Tadanori Fujino¹, Tsuneo Goto¹, Tsuyoshi Shimura², Hiroki Yasuma³, Yongjun Tian¹, Hideaki Kidokoro¹, Shinya Masuda², and Kazushi Miyashita³

Key words: regime shift, mesopelagic fish, Maurolicus japonicus, Japan Sea.

ABSTRACT

Egg abundance of Maurolicus japonicus, a dominant mesopelagic fish in the Japan Sea, was analyzed during 1981-2005 as an index of the spawning-adult abundance. There was a major change in egg abundance around 1988/1989, with negative anomalies occurring during 1981-1988 and positive anomalies occurring from 1989. At about the same time (1986/1987), the Tsushima Current shifted from cold to warm conditions. Environmental indices were found to be positively correlated with egg abundance two years later. Our results suggest that the abundance of M. japonicus is affected by climatic regime shifts, and that it could be used as an indicator species.

I. INTRODUCTION

Decadal variability in the climate affects various marine organisms including phytoplankton, zooplankton and fish through changes in environmental conditions, such as water temperature and mixed layer depth [1, 3, 4, 8, 16, 25, 29]. Such decadal variability in marine ecosystems is commonly called a “regime shift” [2, 25], and there have been many documented cases in pelagic waters, but relatively few in the mesopelagic zone [10, 15].

The mesopelagic zone is inhabited by many organisms such as crustaceans, cephalopods and micronektonic fishes, which form a substantial biomass [6]. Their interaction with the pelagic zone is important and indispensable for understanding marine ecosystems, as many pelagic organisms feed on mesopelagic micronektonic species [20, 30]. Moreover, mesopelagic species play an important role in transporting organic material between the productive pelagic zone and less productive mesopelagic zone through diurnal vertical migration [9, 27].

In the Japan sea Maurolicus japonicus (North Pacific lightfish, Family Sternoptychidae) is a dominant mesopelagic micronektonic species with a huge biomass and is recognized as a key species in the marine ecosystem [12, 19]. Egg surveys for Japanese sardine (Sardinops melanostictus) have been conducted since 1978, and during these surveys, M. japonicus eggs have also been collected. The data were collected in the upper 150 m depth by deep vertical net hauls conducted from the shore to oceanic areas in spring (described in MATERIAL AND METHODS section) [7]. M. japonicus occurs along the continental shelf and spawns throughout the year, except during the severe winter season (i.e., February) [11]. Its eggs are negatively buoyant, abundant below 100 m depth and hatch approximately six days after they are spawned [13, 18]. Its egg shell is unique, so it can easily be distinguished from those of other species [17]. Hence, although the surveys were designed for Japanese sardine, they can provide information on the annual egg abundance of M. japonicus throughout the Japan Sea.

In this study we examined the long-term variability of M. japonicus egg in relation to the marine environment in the Japan Sea, assuming that the egg abundance would reveal the spawning adult abundance. We also discuss how ecosystem regime shifts might affect this species.

II. MATERIAL AND METHODS

Egg abundance data have been collected in April, May and June since 1978 by the Japan Sea National Fisheries Research Institute.
Institute and the prefectural experimental stations from the Japan Sea. Fig. 1 shows the locations of the survey stations in May 2005 as an example. The survey stations were located within approximately 185 km from shore at 129°30’ E - 140°30’ E and 34°27’ N - 41°10’ N with an approximately consistent effort. The number of tows and area coverage have fluctuated over the years, however a large area has been sampled annually in May throughout the Japan Sea, with more than 224 stations conducted since 1981 (Table 1).

During the survey period, a conical or cylindrical-conical plankton net with a mouth opening ring diameter of 45 cm and a mesh size of 330, 335 or 345 µm was towed from 150 m or just above the seafloor (if the bottom depth was <150 m) to the surface to collect eggs and larvaives (Table 1). A calibrated flow meter was mounted on the mouth of the net to measure the filtered volume. We estimated egg density per 1 m² sampled for each station during 1981-2005 in May, calculated the average egg density of the whole sampling area, and used the value as an index of the adult M. japonicus abundance for each year.

To investigate environmental change, we used two indices of the Tsushima Current, a warm current in the Japan Sea that is affected by climate regime shifts and affects various marine organisms [25, 31]. The first index was area-averaged 50 m depth water temperature, which is commonly used as an indicator of the Tsushima current [14]. Temperature data were collected during monthly oceanographic monitoring observations conducted by Japanese governmental organizations [28]. We used the average temperature along the entire coast of the Japan Sea in spring (April-June). The second index was the Tsushima Current Index (TCI) provided by the Japan Meteorological Agency. The TCI is the monthly anomaly of the area warmer than 10°C at 100 m depth over the whole Japan Sea (the anomaly was calculated using the average of 1971-2000, represented by percentage) and reveals the fluctuation of the warm water area in the Japan Sea. We calculated the average 12-month value centering on May to obtain the annual value of the TCI. Area-averaged 50 m water temperature and TCI data from 1981 to 2005 were compared with the egg abundance data.

To determine if any major shifts occurred in the time series data, we applied a sequential t-test analysis of regime shift (STARS) developed by Rodionov [22]. STARS uses a t-test analysis to determine whether sequential observations in a time series represent statistically significant departures from mean values observed during the preceding period of a predetermined duration. Because of the presence of autocorrelation in the time series, we used a “preshrining” procedure before applying the STARS algorithm (ver.3) [23]. The change in the confidence of a regime shift is reflected in the value of the regime shift index (RSI), which represents the cumulative sum of the normalized anomalies. The STARS results are determined by the cut-off length for proposed regimes (L), and the Huber weight parameters (H), which define the range of departure from the observed mean, beyond which observations are considered outliers. Based on exploratory analyses with STARS, L was set at 5, and H at 1. STARS is written in Visual Basic for Application (VBA) for Microsoft

![Fig. 1. Location of the survey points in May 2005. Bold line indicates 200 m isobaths, dash line indicates 1000 m isobaths.](image)

Table 1. Details of the NORPAC net surveys conducted in the Japan Sea in May, 1981-2005.

<table>
<thead>
<tr>
<th>Year</th>
<th>Egg abundance (per m²)</th>
<th>Num. of tows</th>
<th>Mesh-size</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>26.1 749 286</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>17.6 709 257</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>0.8 72 262</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>4.1 552 224</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>4.1 309 257</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>17.1 974 270</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>18.7 1307 329</td>
<td>330 µm</td>
<td>NGG54</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>4.3 539 332</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>27.2 903 306</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>33.5 798 333</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>37.4 1621 310</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>24.5 1494 354</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>21.8 982 407</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>43.6 2228 391</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>27.5 1785 300</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>24.0 1096 295</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>32.8 1825 296</td>
<td>345 µm</td>
<td>NIP60</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>44.6 2778 305</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>30.6 1729 271</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>43.1 1404 291</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>38.4 2581 289</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>80.9 4017 281</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>41.6 2082 282</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>63.5 2313 297</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>20.0 722 293</td>
<td>335 µm</td>
<td>Nytal52GG</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 2. Annual change of anomalies in area-averaged 50 m seawater temperature (a), Tsushima current index (b), Egg abundance of Maurolicus japonicus (c) during 1981-2005. The grey (white) bar represents positive (negative) anomalies. The step changes detected by STARS ($P = 0.1, L = 5, H = 1$) are shown in solid lines.

Excel and is available at www.beringclimate.noaa.gov [22-24].

III. RESULTS

The area-averaged 50-m water temperature showed negative anomalies during 1981-1986 (-0.83°C) and positive anomalies during 1987-2005 (0.26°C) (Fig. 2(a)). The TCI showed a similar fluctuation pattern with negative anomalies during 1981-1986 (-112.0) and positive anomalies during 1987-2005 (78.8) (Fig. 2(b)). There was no evident autocorrelation and no significant linear trend, but the STARS analysis indicated that a shift occurred from negative to positive anomalies for both the area-averaged 50 m water temperature and TCI in 1986/1987 (Fig. 2(a), (b)).

The average egg abundance ranged from 0.8 to 80.9 per m² during 1981-2005 (Table 1). There was a large interannual fluctuation, but it seems to show a decadal-scale variation pattern. Egg abundance showed negative anomalies during 1981-1988 (-17.5) and positive anomalies during 1989-2005 (1998-2001 = 3.9, 2002-2005 = 22.4) (Fig. 2(c)). Again, there was no evident autocorrelation and no significant linear trend, but the STARS analysis indicated two major shifts: one from negative to positive anomalies in 1988/1989, and another from low positive to high positive anomalies in 2001/2002 (Fig. 2(c)).

Fig. 3 shows the egg distribution before and after the first shift. Before the shift, eggs occurred mainly in the southwest part of the Japan Sea, however after the shift, eggs started to occur in the northern area, and the egg density increased; the maximum egg number was less than 1307 in 1987, but regularly over 1000 after 1989, reaching 4017 in 2002 (Table 1). Area-averaged 50 m water temperature and TCI were both positively correlated with egg abundance two years later (Spearman’s rank correlation test, $P < 0.01$).
IV. DISCUSSION

In the Japan Sea, temperature and TCI data indicated there was an environmental shift from negative to positive anomalies in 1986/1987 (Fig. 2(a), (b)). Two years following this change, fluctuations in egg abundance showed a clear shift from negative to positive anomalies (Fig. 2(c)). Using the same STARS test, Tian et al. [25] reported a similar shift in abundance following environment change that occurred in the late 1980s in the Japan Sea. The authors indicated that commercially important pelagic warm-water species such as yellowtail (Seriola spp.), Japanese common squid (Todarodes pacificus) and Japanese anchovy (Engraulis japonicus) also showed abundance increases in 1988/1989 (for yellowtail) and 1990/1991 (for Japanese common squid and Japanese anchovy) after a shift from cold to warm temperatures. The close agreement between the abundance of M. japonicus and changing environmental conditions found in the present study suggest that the regime shift also affected the mesopelagic ecosystem.

The coincidence in the timing of the shift in abundance of M. japonicus and the commercially important species suggest that M. japonicus might be useful as a biological indicator of the ecosystem. Biological indicators such as the abundance of zooplankton, which have a rapid response to environment change and are unaffected by fishing, would be useful to detect the occurrence of ecosystem regime shifts [29]. M. japonicus is also unaffected by fishing as it is not fished commercially or caught as bycatch. Hence it should be useful for detecting ecosystem regime shifts at mid-trophic levels.

It is unclear why M. japonicus increased in abundance during a warm regime, however prey conditions may have been a factor. M. japonicus occurs near the pelagic zone; 100-250 m during the day and shallower depths at night [5]. In relation to the prey organism, Ikeda et al. [12] reported that M. japonicus in Toyama Bay, on the central coast of Japan, feeds mainly on epipelagic warm water copepods such as Calanus sinicus, Onccea media, O. mediterranea and O. venusta. Warm water copepods such as C. sinicus are sensitive to temperature during their reproduction process [26], and several studies have indicated that some warm water copepods increase in abundance during warm regime through an increase of their habitat area [3, 21]. In the Japan Sea, no species specific zooplankton data are available, however Tian et al. [25] reported that the total zooplankton biomass increased in the late 1980s. M. japonicus has a 20-22 month life span and is considered to require approximately 12 months to mature [11]. As Tian et al. [25] proposed, bottom up processes following an ecosystem regime shift from cold to warm conditions in the Japan Sea may have benefited M. japonicus by increasing the abundance of its prey organisms.

In future studies, regional abundance of adults should be investigated together with studies on the feeding ecology of M. japonicus related to dominant zooplankton species fluctuations. The present study observed a spread of the distribution and an increase of egg density mainly in the southwestern area during the shift in the late 1980s (Table 1, Fig. 3). The abundance of adults in the southwestern area is presumably significant, however their density and contribution to the total biomass is unknown. Recently acoustic means have been shown useful in monitoring the adult biomass in the Japan Sea [5]. Comparing the egg abundance with the adult abundance derived from the acoustic results may verify the quantitative interpretation of the egg data and help explain how abundance has shifted in the past.

ACKNOWLEDGMENTS

We thank the Japan Sea National Fisheries Research Institute and Dr. Osamu Katoh for providing biological and oceanographic data sets. We also thank Dr. John Bower and the anonymous referees for their comments. Finally, this paper would not have been possible without the work and dedication of the research-vessel crew members and the researchers who sorted the net samples.

REFERENCES


