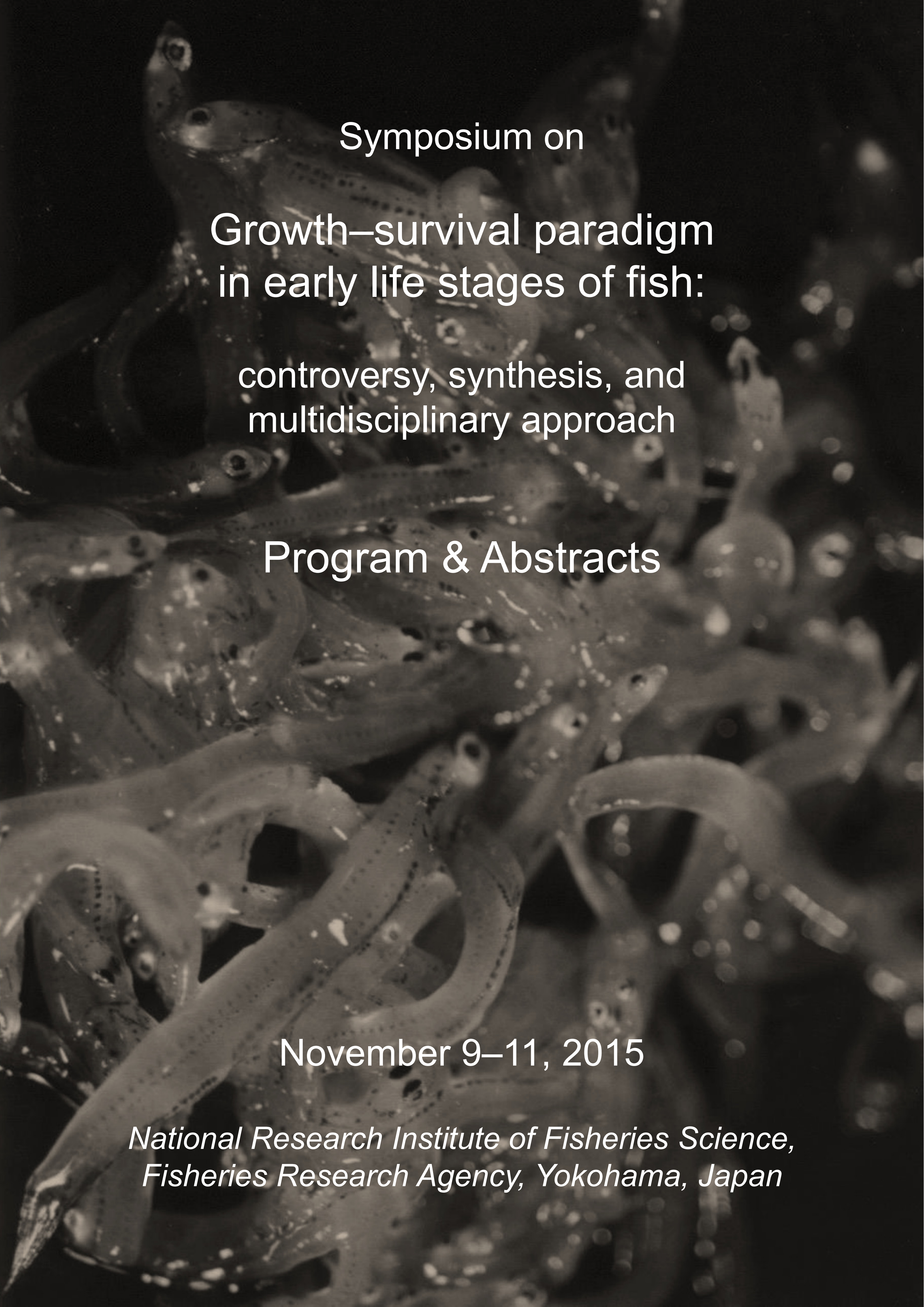


Symposium on

Growth–survival paradigm in early life stages of fish:

controversy, synthesis, and multidisciplinary approach

Program & Abstracts

November 9–11, 2015

National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan

PROGRAM

Symposium on

Growth–survival paradigm in early life stages of fish: controversy, synthesis, and multidisciplinary approach

November 9–11, 2015

National Research Institute of Fisheries Science,
Fisheries Research Agency, Yokohama, Japan

Organizers:

Akinori Takasuka, Dominique Robert, Jun Shoji, Pascal Sirois

Welcome

Welcome to the symposium on "Growth–survival paradigm in early life stages of fish: controversy, synthesis, and multidisciplinary approach" in Yokohama, Japan. We appreciate your interest and participation in this event. We wish that the symposium will produce new ideas on the paradigm, provide a networking environment for future collaborations, and contribute to the progress of studies on early life biology of fish.

Summary

An open-style symposium is held to challenge fundamental issues on the "growth–survival" paradigm in early life stages of fish, which postulates that larger and/or faster-growing individuals are more likely to survive than smaller and/or slower-growing conspecifics. The "growth–survival" paradigm has been given much attention in studies on recruitment dynamics of fish. Indeed, numerous studies have tested the paradigm during the last quarter-century. However, that growing body of literature has revealed contradictory evidence from field, laboratory, and modeling studies across systems and taxa. The objectives of the present symposium/workshop are (1) extracting controversial issues on the paradigm (**controversy**), (2) proposing ideas for synthesizing and reconciling contradictory results based on different perspectives from different study groups (**synthesis**), and (3) promoting a collaborative framework for field, laboratory, and modeling studies (**multidisciplinary approach**). Overall, we aim to improve our understanding of growth–survival relationships in order to facilitate the prediction of recruitment dynamics through numerical modeling.

Dates and venue

November 9 (Monday) to November 11 (Wednesday), 2015

National Research Institute of Fisheries Science, Fisheries Research Agency
2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan
Oral sessions: Large Conference Hall (3F)
Poster session: Meeting Rooms 1 and 2 (3F)

Website

http://cse.fra.affrc.go.jp/takasuka/gsp

Organizers

	Akinori Takasuka (Japan)	National Research Institute of Fisheries Science, Fisheries Research Agency E-mail: takasuka@affrc.go.jp
	Dominique Robert (Canada)	Centre for Fisheries Ecosystems Research, Fisheries and Marine Institute, Memorial University of Newfoundland E-mail: dominique.robert@mi.mun.ca
	Jun Shoji (Japan)	Field Science Education and Research Center, Hiroshima University E-mail: jshoji@hiroshima-u.ac.jp
	Pascal Sirois (Canada)	Research Chair on Exploited Aquatic Species, Department of Fundamental Sciences, University of Quebec at Chicoutimi E-mail: pascal_sirois@uqac.ca

Advisers

The organizers asked two scientists to review progresses of the activities as advisers.

	Louis Fortier (Canada)	Québec-Océan, Département de Biologie, Université Laval E-mail: Louis.Fortier@bio.ulaval.ca
	Yoshioki Oozeki (Japan)	Headquarters, Fisheries Research Agency E-mail: oozeki@affrc.go.jp

Funding Agencies

Japan Society for the Promotion of Science (JSPS) (http://www.jsps.go.jp/english/index.html)
Fisheries Research Agency (FRA) (http://www.fra.affrc.go.jp/english/eindex.html)

Research projects

Grant-in-Aid for Scientific Research (A) Takasuka, A. (PI), Oozeki, Y., Kuroda, H., Okunishi, T. KAKENHI No. 26252031 (April 2014 to March 2019) (http://kaken.nii.ac.jp/d/p/26252031.en.html)
Grant-in-Aid for Scientific Research (B) Shoji, J. (PI), Mitamura, H., Takasuka, A. KAKENHI No. 24380107 (April 2012 to March 2016) (http://kaken.nii.ac.jp/d/p/24380107.en.html)
Grant-in-Aid for Scientific Research (C) Oozeki, Y. (PI), Okamura, H., Takasuka, A. KAKENHI No. 26450275 (April 2014 to March 2017) (http://kaken.nii.ac.jp/d/p/26450275.en.html)

Background

The year 2014 marked the 100th anniversary of contemporary science on fish population dynamics, after Johan Hjort proposed that fish populations are controlled through survival success during the first few days of life (Hjort 1914). Growth and survival dynamics during early life stages has been a focal point in studies on recruitment dynamics of fish for a long time.

Larger and/or faster-growing individuals are more likely to survive than smaller and/or slower-growing conspecifics. This “growth–survival” paradigm originates from the “growth–mortality” hypothesis (Anderson 1988). Anderson (1988) concluded that this concept provides a rational theoretical framework for future studies. Indeed, the “growth–survival” paradigm has been given much attention in studies on recruitment dynamics of fish, with the leitmotiv of predicting recruitment dynamics. However, attempts of predicting recruitment from early growth dynamics has revealed difficult so far.

Numerous field, laboratory, and modeling studies have tested the paradigm, contributing to early life biology and recruitment studies during the last quarter-century. In general, previous field studies tended to support the paradigm. On the contrary, some laboratory experiments provided evidence contrary to the paradigm. Moreover, recent studies revealed the variable nature of selective survival. Hence, the actual relationship between growth and survival appears to be much more variable and dynamic than previously recognized. More than 25 years after the publication of Anderson (1988), our objective is to review recent progress and expand the current paradigm in an attempt to reconcile contradictory results.

Anderson, J. T. (1988) A review of size dependent survival during pre-recruit stages of fishes in relation to recruitment. *Journal of Northwest Atlantic Fishery Science*, 8: 55–66.

Hjort J (1914) Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. *Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer*, 20: 1–228.

Objectives

An open-style symposium is held to challenge fundamental issues on the "growth–survival" paradigm. The objectives of the present symposium are:

(1) "**Controversy**": Extracting controversial issues on the paradigm.

Contradictory results have been generated from field, laboratory, and modeling studies across systems and taxa. Moreover, results obtained from testing the paradigm tend to differ among study groups. We will extract controversial issues on the paradigm from previous studies by collecting a variety of perspectives. Key missing elements in previous and current studies will also be identified.

(2) "**Synthesis**": Proposing ideas for reconciling and synthesizing contradictory results based on different perspectives from different study groups.

A major goal of the present symposium is to figure out how to reconcile and synthesize contradictory evidence from field, laboratory, and modeling studies across systems and taxa. To achieve this goal, we will discuss the possibilities of producing literature reviews, comparative approaches, meta-analyses, and conceptual frameworks based on different perspectives from different study groups.

(3) "**Multidisciplinary approach**": Promoting a collaborative framework for field, laboratory, and modeling studies.

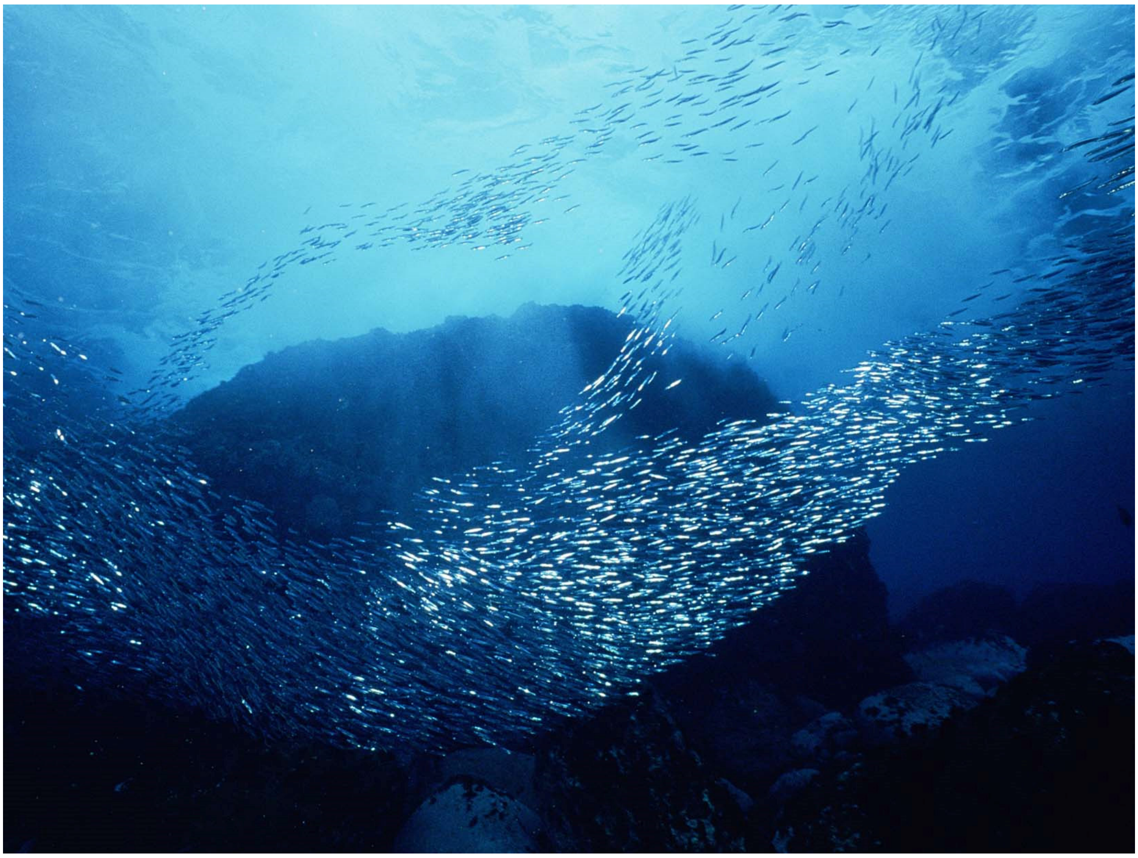
A collaborative framework for field, laboratory, and modeling studies will be needed to achieve the synthesis. In particular, this collaborative framework will incorporate results from field and laboratory studies into predictive models of recruitment dynamics.

In addition to these major objectives, we will propose recommendations for future studies through discussion.

Overall, we aim to improve our understanding of growth–survival relationships in order to facilitate the prediction of recruitment dynamics through numerical modeling.

Keynote speakers

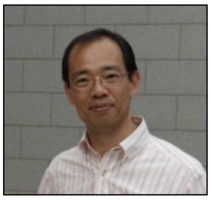
	Pierre Pepin (Canada)	Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada E-mail: pierre.pepin@dfo-mpo.gc.ca
	Arild Folkvord (Norway)	Department of Biology, University of Bergen and the Hjort Centre for Marine Ecosystem Dynamics E-mail: arild.folkvord@uib.no
	Myron A. Peck (Germany)	Institute of Hydrobiology and Fisheries Science, University of Hamburg E-mail: myron.peck@uni-hamburg.de



Invited speakers

	Ignacio A. Catalán (Spain)	Instituto Mediterráneo de Estudios Avanzados (IMEDEA)- Consejo Superior de Investigaciones Científicas / Universitat de les Illes Balears E-mail: ignacio@imedea.uib-csic.es
	Alberto G. García (Spain)	Coordinator of the Mediterranean Fisheries Program of the Spanish Institute of Oceanography (IEO) E-mail: agarcia@ma.ieo.es
	Marc Hufnagl (Germany)	Institute of Hydrobiology and Fisheries Science, University of Hamburg E-mail: marc.hufnagl@uni-hamburg.de
	Klaus B. Huebert (Germany / USA)	Institute of Hydrobiology and Fisheries Science, University of Hamburg E-mail: klaus.huebert@uni-hamburg.de
	Louis Fortier (Canada)	Québec-Océan, Département de Biologie, Université Laval E-mail: Louis.Fortier@bio.ulaval.ca
	John F. Dower (Canada)	Department of Biology and School of Earth & Ocean Sciences, University of Victoria E-mail: dower@uvic.ca
	Su Sponaugle (USA)	Department of Integrative Biology, Oregon State University E-mail: Su.sponaugle@oregonstate.edu

	Evan K. D’Alessandro (USA)	Rosenstiel School of Marine and Atmospheric Science, University of Miami E-mail: edalessa@rsmas.miami.edu
	Richard D. Brodeur (USA)	Northwest Fisheries Science Center, NOAA Fisheries E-mail: Rick.Brodeur@noaa.gov
	Stuart A. Ludsin (USA)	Department of Evolution, Ecology, and Organismal Biology, The Ohio State University E-mail: ludsin.1@osu.edu
	Guido Plaza (Chile)	Escuela de Ciencias del Mar, Facultad de Recursos Naturales, Pontifiica Universidad Católica de Valparaíso E-mail: guido.plaza@ucv.cl
	Patricia M. Ayón (Perú)	Instituto del Mar del Perú E-mail: payon@imarpe.gob.pe
	Naoki Tojo (Japan)	International Education Office, Faculty of Fisheries Sciences, Hokkaido University E-mail: n.tojo.raven@fish.hokudai.ac.jp
	Yoshioki Oozeki (Japan)	Headquarters, Fisheries Research Agency E-mail: oozeki@affrc.go.jp

	Shin-ichi Ito (Japan)	Atmosphere and Ocean Research Institute, The University of Tokyo E-mail: goito@aori.u-tokyo.ac.jp
	Mikimasa Joh (Japan)	Mariculture Fisheries Research Institute, Hokkaido Research Organization E-mail: joh-mikimasa@hro.or.jp
	Yosuke Tanaka (Japan)	Seikai National Fisheries Research Institute, Fisheries Research Agency E-mail: yosuket@affrc.go.jp
	Motomitsu Takahashi (Japan)	Seikai National Fisheries Research Institute, Fisheries Research Agency E-mail: takahamt@fra.affrc.go.jp

General schedule

Monday, November 9		
11:30	Registration opens	
13:30	Opening	
14:00	Session 1: Introduction	5 presentations
16:10	Coffee break	
16:30	Session 2: Field studies	3 presentations
18:20	End	
Tuesday, November 10		
9:30	Session 2: Field studies	4 presentations
11:50	Lunch break	
13:10	Session 2: Field studies	3 presentations
14:35	Coffee break	
14:55	Session 2: Field studies	4 presentations
16:45	Session 3: Seeds of early life biology	2 presentations
18:00	Poster Session	16 presentations
20:00	End	
Wednesday, November 11		
9:30	Session 4: Laboratory studies	3 presentations
11:10	Session 5: Modelling studies	2 presentations
12:25	Lunch break	
13:45	Session 5: Modelling studies	3 presentations
15:20	Coffee break	
15:40	Wrap-up	
16:50	Closing	
17:00	End	
18:30	Symposium dinner	
21:00	End	
Thursday, November 12 – Friday, November 13		
	Workshop	

Workshop

Following the symposium, a 2-day workshop (invited participants only) will be held at the same venue in a practical style (discussion and writing only) during November 12 (Thursday) to November 13 (Friday).

The objectives of the workshop are:

(1) Providing a networking environment for future collaborations among the participants to resolve some important issues identified during the workshop.

(2) Publishing a "perspective" paper co-authored by all workshop participants to identify what is needed for breakthroughs in the study of recruitment dynamics. The paper will provide concrete study designs to improve our understanding of the growth–survival relationships during early life stages of fish.

Presentation guidelines

Oral presentation

Time slots for oral presentations are variable. Each slot includes time for questions, answers, and discussion. Please allow at least 5 minutes for questions/discussion for a 25 min presentation and 8–10 minutes for a 35–40 min presentation. A PC laptop (OS: Windows 7) equipped with Microsoft PowerPoint 2010 will be prepared on the platform for presenters, along with a laser pointer. If you want to use a Macintosh computer, you will have to bring yours. Please bring your USB memory stick including your presentation in PowerPoint format to the conference room at latest 30 minutes before the session on the day of your talk.

Poster presentation

The recommended poster size is A0 (height: 1,189 mm; width: 841 mm). A board and pins will be prepared for each poster. You may display your poster on the board at any time before the Poster Session (Tuesday evening).

Access

National Research Institute of Fisheries Science (NRIFS),
Fisheries Research Agency (FRA)
2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan
Tel: +81-45-788-7615; Fax: +81-45-788-5001
Access: http://nrifs.fra.affrc.go.jp/intro/access_e.htm

Airport

Narita International Airport (NRT) is the most popular international airport in Japan. But you may also find some flights to Haneda Airport (HND), which is more convenient for transportation to Yokohama.
Narita International Airport (NRT) website: http://www.narita-airport.jp/en/index.html
Haneda Airport (HND) website: http://www.tokyo-airport-bldg.co.jp/en

From NRT to Yokohama

Airport Limousine Bus is strongly recommended for transportation from NRT to Yokohama unless you are very familiar with Japanese train system.

(1) Find the counter of Airport Limousine Bus after passing the arrival exit at the airport.
(2) Buy the tickets to Yokohama City Airterminal (YCAT). Frequency is every 15 or 20 minutes. Approximately 90 minutes from NRT to YCAT.
(3) One way: 3,600 JPN; Return: 6,000 JPN (recommended)

Yokohama City Airterminal (YCAT) website: http://ycat.co.jp/en

From HND to Yokohama

Airport Limousine Bus or train (Keikyu Line) is recommended for transportation from HND to Yokohama.

From YCAT to the recommended accommodation area (see “Accommodation”)

If you are familiar with Japanese train system, you can simply use trains from YCAT to closest stations to your hotel. Otherwise, it is better to take a taxi at YCAT.

From your hotels to the venue

If you stay in our recommended accommodation area (see “Accommodation”), you can use “JR Negishi” Line and change to “Kanazawa Seaside” Line at the “Shinsugita” station. “Shidai-igakubu” station of the Kanazawa Seaside Line is the closest station. Then, you can walk to the institute in 5 minutes. It takes approximately 45–50 minutes from the recommended accommodation area to the venue.
Access to the venue: http://nrifs.fra.affrc.go.jp/intro/access_e.htm

Accommodation

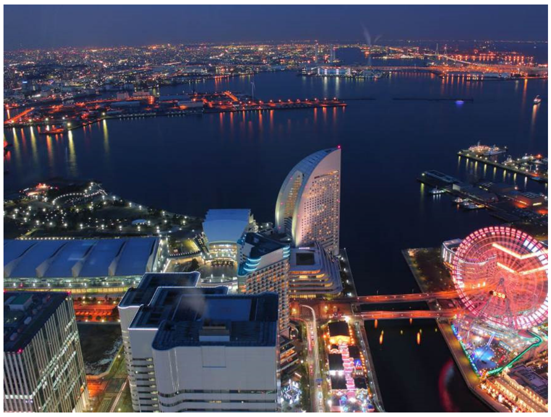
Our institute is located in an industrial area. We do not recommend staying around this inconvenient area.

Area recommended

We recommend you to book any hotel in the seaside area around the "Kannai" or "Sakuragicho" station of "JR" Line. See the map below. This area includes "Minatomirai", "Sakuragi-cho", "Bashamichi", "Kannai", and "Yamashita" and is very convenient for your short stay in Yokohama.
Yokohama Bay City Map: http://www.baycitymap.jp/top.html

Hotels recommended

These two hotels have been used for our guests in the previous workshop activities. Both are recommended in terms of access, quality, and cost performance.
Richmond Hotel Yokohama Bashamichi
Sumiyoshi-cho, Naka-ku, Yokohama, Kanagawa 231-0013, Japan
Tel: +81-45-228-6655
Website: http://richmondhotel.jp/en/yokohama
Hotel JAL City Kannai Yokohama
72 Yamashita-cho, Naka-ku, Yokohama, Kanagawa 231-0023, Japan
Tel: +81-45-661-2580
Website: http://www.kannai-yokohama.jalcity.co.jp/en/index.html



Social events

Poster Session

The poster session is intended to be a place for scientific communication and networking.

Symposium dinner

A formal symposium dinner will take place in Minatomirai or Kannai area on the evening of November 11. Registration for the dinner was requested on the symposium registration form. If you registered the symposium dinner, a ticket will be given to you at the time of registration. More details on the symposium dinner will be provided on site.

Communication and networking

We will propose informal dinners that will take place around the recommended accommodation area every evening.

Miscellaneous

Internet connection

Wi-Fi internet is available in the conference room only. More details on the ID & PW for the Wi-Fi connection will be provided on site.

Lunch

Lunch is not provided at the symposium venue. As our institute is located in an industrial area, there are only a few small restaurants and cafes around the monorail station (a couple of minutes' walk from the institute). There are also two convenience stores located within a couple of minutes' walk from the institute. While there are such options for lunch, we recommend you to carry a lunch from the hotel or to buy a lunch box on your way to the institute.

Our previous activities — What the organizers will propose as an introduction at the symposium

The present symposium was designed based on our previous activities through Japan–Canada collaboration workshops. At the symposium, we will propose a starting point for discussion. Here is a brief introduction of previous research activities.

Stage-I (Japan–Canada collaboration workshops)

To tackle the problem of the paradigm (see “Background”), we held Japan–Canada collaboration workshops on “Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future” in October 2011 (Yokohama), May 2012 (Vancouver), and November 2013 (Yokohama). These workshops were designed to produce a review paper in which we expose our ideas and perspectives on the paradigm through synoptic reviews. Our review comprises 4 sections, as follows.

(1) “Theory”: Summarizing a theoretical framework of the current "growth–survival" paradigm and its functional mechanisms.

(2) "Advance": Reviewing recent advances in studies on the paradigm.
(3) "Synthesis": Proposing a conceptual framework of growth–survival relationship which potentially reconciles contradictory evidence from field, laboratory, and modeling studies across systems and taxa.
(4) "Future": Presenting recommendations for future study directions.

A major result from the previous workshops (hereafter "Stage-I") was a conceptual framework of growth–survival relationship. The original paradigm has inherently assumed a linear growth–survival relationship, but we believe that this assumption is a possible reason for failures of prediction. We concluded that the growth–survival relationship can be nonlinear and vary with predator types. The conceptual framework was constructed based on the optimal foraging theory on the side of predators separately for three functional mechanisms for different predator types.

However, the ideas and perspectives in this review are not necessarily objective. Accordingly, we wish to collect a variety of ideas and perspectives broadly from different study groups for further progresses.

Stage-II (present symposium/workshop)

As the next step (hereafter "Stage-II"), we aim to hold an international symposium/workshop by inviting experts from different countries to cover different ecosystems, taxonomies, approaches, etc. First, an open style symposium is held with presentations by invited speakers mainly. Different ideas and perspectives will be exchanged through this symposium. Then, a practical workshop is held by the organizers, invited speakers, and some collaborators in a closed style, to produce manuscripts for publication.

Proposals for Stage-II

The proposals for a starting point of discussion at the present symposium are:
(1) Extracting controversial issues on the review paper from Stage-I, in particular the proposed conceptual framework of growth–survival relationship (controversy).
(2) Synthesizing contradictory evidence with different perspectives from different study groups (synthesis).
(3) Revising the conceptual framework through the processes of (1) controversy and (2) synthesis.

(4) Incorporating the revised framework into predictive models of fish growth and survival for future simulation analyses under different conditions (multidisciplinary approach).
(5) Proposing update recommendations for future studies.

Stage-I workshops

Japan–Québec collaboration workshop on "Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future" Yokohama, Japan, October 26 – November 1, 2011.

Japan–Québec collaboration workshop on "Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future" Part II (follow-up workshop) Vancouver, Canada, May 23–26, 2012.

Japan–Canada collaboration workshop on "Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future" Part III (follow-up workshop) Yokohama, Japan, November 8–15, 2013.

Presentations

Sirois, P., Takasuka, A., Robert, D., Shoji, J., Aoki, I., Fortier, L., Oozeki, Y. (2012) Size- or growth-selective mortality during early life history of fishes: publication bias and the need for a new conceptual framework. 36th Annual Larval Fish Conference, Bergen, Norway, July 2–6, 2012.

Sirois, P., Takasuka, A., Robert, D., Shoji, J., Aoki, I., Fortier, L., Oozeki, Y. (2012) Publication and citation biases in studies on growth and survival during early life stages of fish. Annual Meeting of Japanese Society of Fisheries Science, Tokyo, Japan, March 26–30, 2013.

Takasuka, A., Robert, D., Shoji, J., Sirois, P., Aoki, I., Fortier, L., Oozeki, Y. (2014) Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future. 38th Annual Larval Fish Conference, Québec City, Canada, August 17–21, 2014 (Keynote Talk).

Takasuka, A., Robert, D., Shoji, J., Sirois, P., Aoki, I., Fortier, L., Oozeki, Y. (2014) Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future. Annual Meeting of the Japanese Society of Fisheries Oceanography 2014, Yokohama, Japan, November 14–17, 2014.

Newsletters

Robert, D., Takasuka, A., Sirois, P., Shoji, J., Oozeki, Y. (2012) In Japan to review the growth–survival paradigm in fisheries oceanography. Québec-Océan Newsletter, 5 (February 2012): 3.

Takasuka, A., Robert, D., Shoji, J., Sirois, P., Aoki, I., Fortier, L., Oozeki, Y. (2012) Workshops on growth–survival paradigm in early life stages of fish: the paradigm needs a synthesis. STAGES, 33 (2) (June 2012): 4–5.

Symposium program

Monday, November 9	
Registration	
11:30	Registration opens
Opening	
13:30	Opening remarks (organizers)
13:35	Welcome remarks Dr. Masaaki Fukuda Executive Director (Vice President), Fisheries Research Agency Dr. Ichiro Nakayama Director – General, National Research Institute of Fisheries Science, Fisheries Research Agency
13:45	Background and objectives (organizers) Announcements (organizers)
Session 1: Introduction	
	This session is intended to introduce the results of the Japan–Canada collaboration workshops, which led to the idea of the present symposium. Moderators: organizers
14:00 S1-1	**Akinori Takasuka**, Dominique Robert, Jun Shoji, Pascal Sirois, Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki (Japan/Canada) "Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future" (Japan–Canada collaboration workshops) Background and theory
14:20 S1-2	**Dominique Robert**, Akinori Takasuka, Jun Shoji, Pascal Sirois, Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki Advance — Spatio-temporal variability and measurement bias in selection for fast growth during the larval stage of fish
14:45 S1-3	**Jun Shoji**, Akinori Takasuka, Dominique Robert, Pascal Sirois, Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki Advance — Complexity in growth–survival mechanisms under variable prey–predator interactions
15:10	Short break

15:20 S1-4	**Pascal Sirois**, Akinori Takasuka, Dominique Robert, Jun Shoji, Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki Synthesis — Publication and citation biases in the growth–survival paradigm
15:45 S1-5	**Akinori Takasuka**, Dominique Robert, Jun Shoji, Pascal Sirois, Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki Synthesis — Conceptual framework and future
16:10	Coffee break
Session 2: Field studies	
	In this session, presenters introduce field studies which tested the paradigm. The session highlights a variability of the results of the paradigm test in various ecosystems and taxa. Moderators: Pierre Pepin and Dominique Robert
16:30 S2-1	***Keynote*** **Pierre Pepin** (Canada) The growth–survival paradigm: the view from a probabilistic framework
17:10 S2-2	**John Dower** and Pierre Pepin (Canada) Interacting effects of prey availability, temperature, and predation on larval fish growth: Possible implications for exploring the “growth–survival” paradigm in the field
17:35 S2-3	**Louis Fortier**, Maxime Geoffroy, Andrew Majewski, Stéphane Gauthier, Yvan Simard, Mathieu LeBlanc, Wojciech Walkusz, and James D. Reist (Canada) Could ice cover duration dictate polar cod (*Boreogadus saida*) growth and recruitment?
18:00	Discussion
18:20	End
Tuesday, November 10	
Session 2: Field studies (continued)	
	Moderators: Pierre Pepin and Dominique Robert
09:30 S2-4	**Su Sponaugle**, Kathryn Shulzitski, Tauna Rankin, and Kirsten Grorud-Colvert (USA) Selective mortality and linkages across life stages in coral reef fishes

10:05 S2-5	**<u>Evan K. D'Alessandro</u>**, Su Sponaugle, and Robert K. Cowen (USA) Tracking larval reef fish survivorship to shore and beyond
10:30	Short break
10:40 S2-6	**<u>Stuart A. Ludsin</u>**, Cassandra J. May, Kevin L. Pangle, and Elizabeth A. Marschall (USA) Does fast early life growth confer a recruitment advantage in freshwater fish populations?
11:15 S2-7	**<u>Alberto García</u>**, Raul Laiz-Carrión, Amaya Uriarte, and Jose Quintanilla (Spain) Trophic ecology and the growth paradigm in oligotrophic and productive ecosystems: stable isotopes studies in the early life stages of fish larvae
11:50	Lunch break
	Moderators: <u>Arild Folkvord</u> and <u>Jun Shoji</u>
13:10 S2-8	**<u>Guido Plaza</u>**, Francisco Cerna, and Mauricio F. Landaeta (Chile) Otolith-based field studies linked to the bigger-is-better and growth rate mechanisms in teleost fishes: A review of methods used and its perspectives
13:45 S2-9	**<u>Richard D. Brodeur</u>**, Jamal Moss, and Elizabeth A. Daly (USA) Predation impact by salmon on early life stages of focal piscine prey in the eastern North Pacific Ocean
14:10 S2-10	**<u>Yoshioki Oozeki</u>**, Akinori Takasuka, and Hiroshi Okamura (Japan) *In situ* estimation of mortality rate of pelagic fish larvae: Differences among methodological approaches
14:35	Coffee break
14:55 S2-11	**<u>Mikimasa Joh</u>** (Japan) Growth selective mortality of flatfish throughout its pelagic and demersal life
15:20 S2-12	**<u>Yosuke Tanaka</u>** (Japan) Growth and survival of Pacific bluefin tuna in the early life history
15:45 S2-13	**<u>Motomitsu Takahashi</u>**, Chiyuki Sassa, Youichi Tsukamoto, and Yoshiro Watanabe (Japan) Growth-selective survival during late larval and early juvenile stages of forage fishes in the western North Pacific
16:10 S2-14	**<u>Emily Campbell</u>**, Jason Dunham, Gordon Reeves, and Steve Wondzell (USA)

	Salmon phenology and growth in streams with variable thermal regimes in Alaska
16:35	Short break
Session 3: Seeds of early life biology	
	This special session aims to support launching and developing early life biology in some ecosystems. Moderators: Akinori Takasuka and Dominique Robert
16:45 S3-1	**Patricia Ayón** (Perú) Early life biology in the northern Humboldt Current system
17:20 S3-2	**Naoki Tojo** and Azeddine Ramzi (Japan/Morocco) Exploring for research frontiers from the spawning environment and early-life habitat off the North Atlantic African Coast: synthesis from analyses in ecology, understandings in atmospheric teleconnection and cooperative capacity enhancement
17:45	Discussion
Poster Session	
18:00	Poster presentations (see below)
20:00	End
Wednesday, November 11	
Session 4: Laboratory experiments	
	In this session, presenters introduce laboratory experiments which tested the paradigm or are potentially relevant to the paradigm test. The session highlights any difference from field studies and considers future study designs of laboratory experiments for the paradigm test. Moderator: Arild Folkvord and Pascal Sirois
09:30 S4-1	***Keynote*** **Arild Folkvord** (Norway) Experiments with closed populations in the laboratory and mesocosms – how can they provide insights about vital rates in the field?
10:10 S4-2	**Francis Juanes** and David G. Stormer (Canada) A year in the (early marine) life of Chinook Salmon: effects of variable water temperature and food availability on seasonal growth, condition and mortality
10:35	**Patricia Reglero** and collaborators (Spain)

S4-3	Understanding the mechanisms underlying observed correlations between the environment and the distribution and abundance of tuna species: laboratory, field data and models on tuna larvae
11:00	Short break
Session 5: Modelling studies	
	In this session, presenters introduce progresses in modeling studies. The session highlights any strategy of linking field and laboratory results to predictive models of fish growth and survival in the context of the paradigm test. Moderators: Myron A. Peck and Pascal Sirois
11:10 S5-1	***Keynote*** **Myron A. Peck**, Marc Hufnagl, Klaus Huebert, and Marta Moyano (Germany) Spatially-explicit biophysical models of the growth and survival of early life stages of fish: A synthesis with recommendations
11:50 S5-2	**Marc Hufnagl**, Myron A. Peck, and Ken Haste Andersen (Germany) When and how do growth paradigms evolve from IBMs and size structured models?
12:25	Lunch break
13:45 S5-3	**Klaus B. Huebert**, Johannes Pätsch, Marc Hufnagl, Markus Kreus, and Myron A. Peck (Germany) Modeling larval fish growth using Quirks
14:10 S5-4	**Shin-ichi Ito**, Tatsuya Sakamoto, Takeshi Okunishi, Akinori Takasuka, Michio Yoneda, Sachihiko Itoh, and Kosei Komatsu (Japan) Growth–survival problems in a coupled model between fish growth and environments
14:45 S5-5	**Ignacio A. Catalán** (Spain) Are management goals impeding or fostering the scientific progress of the growth–survival paradigm?
15:20	Coffee break
Wrap-up	
	Moderators: organizers
15:40	Free discussion
16:10	Wrap-up discussion
16:40	Conclusions
Closing	

16:50	Closing messages Dr. Tokio Wada Executive Director (Vice President), Fisheries Research Agency
16:55	Closing remarks (organizers)
17:00	End
18:30	Symposium dinner
21:00	End

Poster Session

P-1	**<u>Dariusz. P. Fey</u>** and Lena Szymanek (Poland) Temperature and zooplankton effect on the growth rate of larval and early-juvenile sprat (*Sprattus sprattus*) in the South Baltic Sea
P-2	**<u>Hwa Hyun Lee</u>**, Sukyung Kang, Kyungmi Jung, Suam Kim, and Sukgeun Jung (Korea) Buoyancy and vertical distribution of Pacific mackerel eggs and larvae and its climate change implication for the temporal variability of recruitment
P-3	**<u>Yoichi Miyake</u>**, Shingo Kimura, Sachihiko Itoh, Seinen Chow, Keisuke Murakami, Satoshi Katayama, Aigo Takeshige, and Hideaki Nakata (Japan) Does vertical migratory behavior of spiny lobster larvae influence their open-ocean migration?
P-4	**<u>Aigo Takeshige</u>**, Yoichi Miyake, Hideaki Nakata, Takashi Kitagawa, and Shingo Kimura (Japan) Impact of climate change on the egg and larval transport of Japanese anchovy off Kyushu Island, the western coast of Japan
P-5	**<u>Naotaka Yasue</u>**, Shigeo Harada, and Akinori Takasuka (Japan) Seasonal variability in development of Japanese anchovy *Engraulis japonicus* during the transition from larval to juvenile stages in the Kii Channel
P-6	**<u>Masayuki Chimura</u>**, Hiroshige Tanaka, and Yuuho Yamashita (Japan) Effects of body size and growth rate in larval and early juvenile stages on the year class strength of walleye pollock in the Sea of Japan
P-7	**<u>Shingo Watari</u>**, Hideo Sakaji, and Tatsuya Kaji (Japan) Annual variation of growth of juvenile yellowtail *Seriola quinqueradiata* in Tosa Bay, off the Pacific coast of Japan
P-8	**<u>Kiyoshi Kasugai</u>**, Hayato Saneyoshi, Hajime Oomori, Mitsuru Torao, Tomoya Aoyama, Yoshihito Shinriki, Anai Iijima, Yasuyuki Miyakoshi, and Mitsuhiro Nagata (Japan) What drives migration of chum salmon fry in the rivers and coastal waters in eastern Hokkaido?
P-9	**<u>Tatsuya Kawakami</u>**, Yuichi Shimizu, Gen Ogawa, Toshihiko Saito, Masaya Iida, Naoko Sugihara, Kotaro Shirai, Shunpei Sato, Hiroshi Ueda, and Tsuguo Otake (Japan) Otolith stable isotope and trace element analyses to reconstruct migration history of chum salmon *Oncorhynchus keta*

P-10	**Chiyuki Sassa** and Motomitsu Takahashi (Japan) Growth, mortality, and prey consumption of three numerically dominant mesopelagic fish larvae in the Kuroshio waters during late winter
P-11	**Kirara Nishikawa**, Akinori Takasuka, Hiroshi Kuroda, Takeshi Okunishi, Yugo Shimizu, Hideo Sakaji, Tadashi Tokai, and Yoshioki Oozeki (Japan) Geographical variability in larval growth of Pacific saury *Cololabis saira* in the Kuroshio Current system
P-12	**Yuanyuan Zhu**, Tadashi Tokai, Fuxiang Hu, Yoshiaki Fukuda, Koki Abe, and Tomohiko Matsuura (Japan/China) Sampling results of multiple layer opening/closing MOHT in Sagami Bay, Pacific coast of Japan — Effect of towing speed and fish body size on net avoidance of myctophid fishes
P-13	**Masaki Hata** and Jun Shoji (Japan) Occurrence, distribution and prey items of juvenile marbled sole *Pseudopleuronectes yokohamae* around submarine groundwater seepages on a tidal flat in southwestern Japan
P-14	**Hiroki Tanaka**, Hikari Kinoshita, and Jun Shoji (Japan) Daytime predation refuge for juveniles or nighttime foraging ground for predators? Two contribution pathways of vegetated habitats to production of coastal fishery resources in southwestern Japan
P-15	**Tatsuya Utsunomiya** and Jun Shoji (Japan) Increase in species richness and abundance of juvenile and small-sized fishes around submarine groundwater seepage
P-16	**Masayuki Yamamoto** and Jun Shoji (Japan) Relationship between hatch-date and recruitment of Japanese anchovy in central Seto Inland Sea, Japan

ABSTRACTS

S1-1–5

Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future

Akinori Takasuka[1,*], Dominique Robert[2], Jun Shoji[3], Pascal Sirois[4],
Ichiro Aoki[5], Louis Fortier[6], and Yoshioki Oozeki[7]

[1]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*
[2]*Centre for Fisheries Ecosystems Research, Fisheries and Marine Institute, Memorial University of Newfoundland, St. John's, Canada*
[3]*Field Science Education and Research Center, Hiroshima University, Hiroshima, Japan*
[4]*Research Chair on Exploited Aquatic Species, Laboratoire des sciences aquatiques, Université du Québec à Chicoutimi, Chicoutimi, Canada*
[5]*Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan*
[6]*Département de Biologie, Québec-Océan, Université Laval, Québec, Canada*
[7]*Headquarters, Fisheries Research Agency, Yokohama, Japan*
*takasuka@affrc.go.jp

General abstract

Growth and survival are tightly coupled in early life stages of fish. Larger and/or faster growing individuals (or populations) are more likely to survive than smaller and/or slower growing conspecifics. This “growth–survival” paradigm was given much attention in studies on recruitment dynamics of fish. However, predicting year-class strength from early growth dynamics has revealed difficult. Moreover, there have been contradictory results between field and laboratory studies and among different ecosystems, taxonomic groups, and study groups. We believe that a synthesis of the recent literature is needed. Here we present our ideas and perspectives on the “growth–survival” paradigm through synoptic reviews from Japan–Canada collaboration workshops. First, we summarize the theoretical framework of the current paradigm and its functional mechanisms (theory). Second, we review recent advances in studies on the paradigm (advance). Subsequently, we challenge a synthesis of results from field, laboratory, and modeling studies across systems and taxa (synthesis). In particular, a conceptual framework is proposed to potentially reconcile contradictory results. This conceptual framework comprises non-linear larval growth–survival relationships for three functional mechanisms under predation pressure from three predator types in an optimal foraging context. Finally, we propose recommendations for the direction of future studies (future).

S1-1–5

Review of "Growth–survival paradigm in early life stages of fish: theory, advance, synthesis, and future" is introduced by the following 4 talks.

Respective abstracts

Background and theory

Akinori Takasuka*, Dominique Robert, Jun Shoji, Pascal Sirois,
Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki
*takasuka@affrc.go.jp

First of all, we briefly introduce background of our previous activities of the Japan–Canada collaboration workshops, which is also our motivation of planning the present symposium. Then, we summarize the theoretical framework of the current paradigm and its functional mechanisms. To date, three functional mechanisms have been proposed to explain the survival advantages of larger and/or faster growing individuals. The "bigger is better" mechanism states that faster-growing individuals will have a larger somatic size at a given age, which leads to various survival advantages. The "stage duration" mechanism assumes that faster-growing individuals will experience a much lower cumulative mortality rate during the larval stage. The "growth-selective predation" mechanism posits that faster-growing individuals will be less vulnerable to predation mortality than slower-growing conspecifics, even if they are the same size, at a given moment. The operational conditions of these three mechanisms are summarized in conceptual figures.

Advance — Spatio-temporal variability and measurement bias in selection for fast growth during the larval stage of fish

Dominique Robert*, Akinori Takasuka, Jun Shoji, Pascal Sirois,
Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki
*dominique.robert@mi.mun.ca

Mortality during the larval stage of fish is controlled by growth-selective processes including predation pressure from various organisms. While it is commonly considered that fast-growing individuals survive at a higher rate than their slow-growing counterparts, recent field-based and laboratory studies have demonstrated that growth-selective pressure may vary in time and space. In time, the nature of growth-selective pressure can evolve within a given cohort as individuals are facing a suite of predator fields through development. Temporal variability in growth selection can also occur among cohorts at a given larval age or size. Concurrently, the nature of growth-selective pressure can drastically differ among adjacent populations of the same species at a given time. These recent findings have major implications for the current “growth–survival” paradigm, which assumes a positive correlation between larval growth, survival and year-class strength. Field-based and laboratory studies however have their limitations relative to the measurement of growth-selective processes. In particular, the risk of measurement bias in field studies due to gear selectivity and the consideration of processes at the population level, and in laboratory studies due to investigated growth rates that are not always representative of the range achieved in the wild, will be discussed.

Advance — Complexity in growth–survival mechanisms under variable prey–predator interactions

Jun Shoji*, Akinori Takasuka, Dominique Robert, Pascal Sirois, Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki
*jshoji@hiroshima-u.ac.jp

Growth–survival mechanisms during the early life stages of fish are variable under various environmental conditions. Growth and survival rates, as well as the direction of growth/size selective survival are affected by a variety of biotic and abiotic conditions such as temperature, prey availability, and predators that vary with time and space even within a single species. In general, larger and/or faster-growing individuals have more chance to survive since they are better at avoiding predators and vulnerable to predation during a shorter time period. On the other hand, there have been many lines of evidence that larger and/or faster-growing individuals have less chance to survive under natural and laboratory conditions. Prey–predator interactions including size and behavior affect the operations of the growth–survival mechanisms. The characteristics of these mechanisms vary among fish species. In addition, the growth–survival mechanisms for a species that is distributed over a large spatial scale can differ among climate regimes, ecosystems, habitats, and predator communities even within the same species. This talk reviews previous field, laboratory, and modelling studies to highlight complexity in the growth–survival mechanisms during the early life stages of fish.

S1-1–5

Synthesis — Publication and citation biases in the growth–survival paradigm

Pascal Sirois*, Akinori Takasuka, Dominique Robert, Jun Shoji,
Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki
*Pascal_Sirois@uqac.ca

During the last 25 years, the “growth–survival” paradigm constituted a central theoretical framework in fisheries science to predict recruitment fluctuations in fish. However, evidences contrary to the paradigm also emerged from several field, laboratory, and modelling studies. We reviewed the literature presenting fish size- and/or growth-selective mortality data during the larval stage and we synthesized the results published to date to assess the paradigm as a central theoretical framework in fisheries science. We found various types of selective mortality results: selection for larger or faster growing larvae that supports the paradigm, selection for smaller of slower growing individuals that goes against the paradigm, no selection (random mortality), and mixed selection during the larval stage. We argue that publication and citation biases favored the diffusion of results supporting the paradigm. We believe that random mortality results were likely not published and that papers that did not support the paradigm were less cited. Finally, we conclude that there is a need for a new conceptual framework reconciling variable results of size- and/or growth-selective mortality reported in the literature.

Synthesis — Conceptual framework and future

Akinori Takasuka*, Dominique Robert, Jun Shoji, Pascal Sirois,
Ichiro Aoki, Louis Fortier, and Yoshioki Oozeki
*takasuka@affrc.go.jp

A conceptual framework of growth–survival relationship is proposed to potentially reconcile contradictory results from field, laboratory, and modeling studies across systems and taxa. This conceptual framework comprises non-linear larval growth–survival relationships for three functional mechanisms under predation pressure from three predator types in an optimal foraging context. The proposed framework is testable and integrates the following components: (1) a predation-based model, (2) the three functional predation mechanisms, and (3) optimal foraging theory. The essential assumptions are: (1) probability of survival throughout the larval stage in a given

individual, (2) predation as the main direct source of mortality, (3) gape-size-limited predation, (4) different feeding strategies among three predator types, and (5) that the framework is dimensionless (non-comparable among curves in absolute values). The start point is a dome-shaped curve for the relationship of larval activity to growth rate in consideration of energy trade-off between growth and physiological performance. Then, the non-linear growth–survival relationships are constructed for three types of predators (filter/particulate feeding predator, raptorial feeding predator, and ambush predator) for growth-, size-, and stage-selective predation, respectively. An advantage of this conceptual framework is a possible theoretical solution to apparently contradictory evidence between field and laboratory studies. Finally, we propose recommendations for the direction of future studies. A multidisciplinary approach of incorporating the conceptual framework of growth–survival relationship into biophysical individual-based models (IBMs) is proposed as a possible collaboration framework among field, laboratory, and modelling studies.

S2-1

The growth–survival paradigm: the view from a probabilistic framework

Pierre Pepin*

Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada, St. John's, Canada

* Pierre.pepin@dfo-mpo.gc.ca

Survival through the larval phase (e.g. from hatch to metamorphosis) is predicated on the probabilities of successful feeding, which dictates growth rates, the probabilities of encountering (or not) predators, and the likelihood that currents will carry an individual to a suitable habitat for further development. The growth-survival paradigm (GSP) centers on the concept that an individual with a high growth rate is expected, on average, to have a greater likelihood of surviving than another larva with a slower growth rate. In this presentation I will focus on how to take a probabilistic approach to the investigation of early life dynamics to assess how changes in the distribution of growth histories and mortality rates inform us of the processes that affect survival. I will attempt to determine if measurements of growth and mortality can be linked to relatively high density observations of prey and predators, and how these gives insights about the processes that govern these interactions. I will investigate how spatial or temporal changes in the distributions of growth and mortality can affect expectations of the GSP and the interpretation of field observations of growth-selective patterns of loss.

S2-2

Interacting effects of prey availability, temperature, and predation on larval fish growth: Possible implications for exploring the "growth–survival" paradigm in the field

John Dower[1,*] and Pierre Pepin[2]

[1]*University of Victoria, Victoria BC, Canada*
[2]*Fisheries and Oceans Canada, St. John's NL, Canada*
*dower@uvic.ca

The "growth–survival" paradigm is approaching dogmatic status in the fisheries oceanographic literature. However, for any given cohort of larval fish the potential for growth-survival effects to come into play is highly situational. For example, with faster larval growth (particularly as temperature increases) comes a higher weight-specific energy demand; thereby increasing the need to forage and possibly increasing the rate of predator encounters. Thus, in situations where (i) food is limiting and/or (ii) temperatures are high, or (iii) predators are particularly abundant, could faster growth actually be a disadvantage?

Within this context we present results from a field study in coastal Newfoundland in which we tracked the growth and mortality of five species of larval fish over five surveys during a single summer. We expected that larval growth rates would increase with temperature and decline with decreasing prey abundance. We also expected larval mortality to increase with both temperature and predator abundance. Instead, we found: (i) species-specific growth rates remained constant or decreased as temperature increased, (ii) species-specific growth rates did not correlate with changes in prey availability, and (iii) species-specific mortality rates decreased with increasing temperature and were uncorrelated with the abundance of pelagic fish.

Our observations suggest that variations in (and interactions among) prey availability, temperature, and predation may be sufficiently complex to limit the value of the growth-survival paradigm in teasing out the drivers of larval fish dynamics in the field.

Could ice cover duration dictate polar cod (*Boreogadus saida*) growth and recruitment?

Louis Fortier[1,*], Maxime Geoffroy[1], Andrew Majewski[2], Stéphane Gauthier[3], Yvan Simard[4], Mathieu LeBlanc[1], Wojciech Walkusz[2], and James D. Reist[2]

[1]*Québec-Océan, Université Laval, Québec, Canada*

[2]*Fisheries and Oceans Canada, Freshwater Institute, Winnipeg, Canada*

[3]*Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, Canada*

[4]*Pêches et Océans Canada, Institut Maurice-Lamontagne, Mont-Joli, Canada*

*Louis.Fortier@bio.ulaval.ca

In Arctic seas, polar cod (*Boreogadus saida*) typically make up 95% of the pelagic fish assemblage and could effect up to 75% of the energy transfer between the plankton and higher trophic levels. Year-class strength and recruitment variability remain undocumented. Hydroacoustic surveys from 2010 to 2014 assessed inter-annual variations in the distribution, size, abundance, and biomass of epipelagic juveniles and mesopelagic age-1+ polar cod in the Beaufort Sea. To test the hypothesis that longer ice-free seasons and higher SST in spring increase growth and recruitment of epipelagic age 0, mean annual abundance and biomass (estimated by kriging) were correlated to the date of ice breakup and to mean sea-surface temperature (SST) measured by remote-sensing. Mean standard length of age-0 polar cod at the end of August was positively correlated to mean SST in spring. The abundance and biomass of age-0 were significantly higher in years of early ice breakup and higher spring SST. These preliminary results stress the importance of pursuing annual acoustic surveys in the Beaufort Sea so as to lengthen the time series and validate the relationships reported here.

Selective mortality and linkages across life stages in coral reef fishes

Su Sponaugle[1,*], Kathryn Shulzitski[2], Tauna Rankin[3], Kirsten Grorud-Colvert[4]

[1]*Department of Integrative Biology, Oregon State University, HMSC, Newport, OR, USA*

[2]*Department of Marine Biology and Ecology, RSMAS, University of Miami, Miami, FL, USA*

[3]*Coral Reef Conservation Program, NOAA NMFS, Silver Spring, MD, USA*

[4]*Department of Integrative Biology, Oregon State University, Corvallis, OR, USA*

*su.sponaugle@oregonstate.edu

Mortality of larval fishes in the plankton is typically high and often selective as predators remove prey with particular early life history traits. Although the trait composition of surviving larvae can play an important role in recruitment and population dynamics, the processes influencing selective survival in the plankton can be challenging to measure. We have used the analysis of otolith microstructure to examine patterns of selective mortality of larval and juvenile cohorts of coral reef fishes tracked over time. Environmentally induced natural variation in larval traits sets the stage for differential trait-based survival. As predators remove larvae with particular traits from the population, the distribution of traits of survivors changes over time. Directional shifts in the traits of surviving pelagic larvae can propagate through to settlement and beyond into juvenile life. Settlement from the plankton to a markedly different habitat involves settler encounter with new selective pressures, which can lead to a switch in the direction of selective mortality. Such variation in the strength or direction of selective mortality occurs over time and space as well as between species as traits are translated into particular behaviors that make individuals more or less vulnerable to predation. Some seemingly conflicting results in the literature may be due to the sampling of different life stages, at different times or in different habitats, or alternatively, by using different methods. Tracking and sampling cohorts over time can be a powerful approach, but requires multiple gears and is often labor intensive and costly. However, such detailed sampling and analysis of a diversity of fish species will ultimately contribute to refining our understanding of the growth-survival paradigm.

S2-5

Tracking larval reef fish survivorship to shore and beyond

Evan K. D'Alessandro[1,*], Su Sponaugle[2], and Robert K. Cowen[2]

[1]*Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida, USA*
[2]*Hatfield Marine Science Center, Oregon State University, Newport, Oregon, USA*
* edalessa@rsmas.miami.edu

It is widely accepted that small changes in growth and mortality during the early life stages in marine fishes can have important effects on the magnitude and composition of recruitment, and that frequently large or faster growing fishes preferentially survive. Testing this Growth-Survival Paradigm in tropical fishes is challenging due to diffuse populations spread over vast areas of inaccessible ocean and shifts in behavior and habitat utilization with development. This difficulty is compounded by the fact that selection is often not static and important patterns can be missed by examining only the beginning and end of life stages. We sought to overcome these challenges by repeatedly sampling multiple cohorts of three lutjanid (*Ocyurus chrysurus*, *Lutjanus synagris*, and *Lutjanus griseus*) and one sphyraenid (*Sphyraena barracuda*) species in the Florida Keys utilizing four different stage-specific sampling techniques: ship-board plankton tows to collect young and older larvae, light traps to sample settlers, diver-based surveys of new recruits, and seines targeting older juveniles. Daily growth and size-at-age trajectories were then reconstructed from otolith microstructure analysis. Our results revealed differences in selective mortality between closely related species and over short time periods within the same species. These findings highlight the need to sample repeatedly over short time and age intervals and illustrate the potential pitfall of generalizing patterns of selective mortality to unstudied species.

S2-6

Does fast early life growth confer a recruitment advantage in freshwater fish populations?

Stuart A. Ludsin[1,*], Cassandra J. May[1], Kevin L. Pangle[1,2], and Elizabeth A. Marschall[1]

[1]*Aquatic Ecology Laboratory, Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus, Ohio, USA*
[2]*Current Address: Department of Biology, Central Michigan University, Mt. Pleasant, Michigan, USA*
*ludsin.1@osu.edu

Our general understanding of the fish recruitment process has mostly derived from a large and continually growing number of early life-stage investigations conducted in marine ecosystems. Because fewer early life-stage investigations have been conducted in freshwater ecosystems, an understanding of whether common marine recruitment hypotheses are applicable to freshwater ecosystems remains largely speculative. Towards filling this information gap, we summarized the small but growing body of research from freshwater ecosystems that has explored the relevance of the "growth-survival" hypothesis to understanding the fish recruitment process. This hypothesis posits that fast growth during early (pre-recruited) life stages benefits survival to older (recruited) life stages. As in marine ecosystems, support for the growth-survival hypothesis has been mixed in freshwater ecosystems. For example, while our research has shown consistent support for the growth-mortality hypothesis as a determinant of recruitment in some populations (e.g., Lake Erie yellow perch, *Perca flavescens*), support for it has been mixed in others (e.g., Lake Erie walleye, *Sander vitreus*). Collectively, these and other findings from the freshwater literature highlight the need to consider the environmental context (e.g., other recruitment drivers) when attempting to rectify the importance of fast early life growth to recruitment success. Given that the importance fast early life growth to future recruitment appears to vary similarly in freshwater and marine ecosystems, we strongly encourage continued investigation of marine hypothesis in freshwater ecosystems and a continued erosion of barriers between marine and freshwater recruitment science.

Trophic ecology and the growth paradigm in oligotrophic and productive ecosystems: stable isotopes studies in the early life stages of fish larvae

Alberto García*, Raul Laiz-Carrión, Amaya Uriarte, and Jose Quintanilla

[1]*Instituto Español de Oceanografía, Centro Oceanográfico de Málaga, Málaga, Spain*
*agarcia@ma.ieo.es

Stable isotope analyses of nitrogen and carbon are widely being applied for verifying trophic food web relationships between species in marine ecosystems. Nonetheless, few examples of their use are found in examining the trophodynamics at early life stages of fish species in relation to the planktonic components that comprise their feeding resources. The differential fractionation resulting from the assimilation of food gives way to the enrichment of the heavy isotope of nitrogen(N15)is enriched over the lighter nitrogen isotope (N14) such that the ratio increases with each trophic level. The appropriate baselines of lower trophic levels, as size-fractionated plankton samples which originate the energy resources for fish larvae allow determining the trophic levels of early life stages during ontogenic development.

The trophic food web is size-structured by successive increasing trophic levels that can relate to the growth potential that a determined species may develop till reaching maturity. To understand the relationships that trophic levels may have during larval development the comparative approach has been applied with the aim of assessing larval growth relationships with the trophic environment. The comparative approach has been used across species inhabiting a varied suite of environments ranging from productive to oligotrophic marine ecosystems that include coastal and oceanic environments. This approach enabled to reasonably interpret the trophic nature that can relate to larval growth, but also opening new questions and conundrums to resolve.

S2-8

Otolith-based field studies linked to the bigger-is-better and growth rate mechanisms in teleost fishes: A review of methods used and its perspectives

Guido Plaza[1,*], Francisco Cerna[2], and Mauricio F. Landaeta[3]

[1]*Escuela de Ciencias del Mar, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile*
[2]*Instituto de Fomento Pesquero, Valparaíso, Chile*
[3]*Facultad de Ciencias del Mar, Universidad de Valparaíso, Valparaíso, Chile*
*guido.plaza@pucv.cl

In the last three decades otolith-based methods have emerged as cost-effective tools to supply information to test the growth-survival relationship in different species. In the current study, forty otolith-based field studies were revised so as to obtain some qualitative characteristics associated to the bigger-is-better (BiB) and growth-rate (GR) mechanisms. In 90% of cases BiB was operating, either positive (82%) or negatively (8%) and in the remaining studies BiB was not evaluated. GR mechanism was less frequently evaluated [64%; 56%(+); 8%(-)]. The traditional approach where growth traits were compared between survivors and members of an original population was the most used approach, although in most cases survivors corresponded to late larval stages instead of young-of-the year fish (YOY). When YOY were used as survivors BiB and GR mechanisms operated positively. To what extent these evidences are purely coincidental? Or alternatively growth and survival relationship would more reliable evaluated when YOY fishes are included in the analyses? It is reasonable to expect a link between the magnitude of early growth and subsequent survival under the action of BiB and GR mechanisms, and such a relationship would be more reliably tested when several years are compared (i.e., long time series). Such an approach can be achieved in commercial fishes because estimations of biomass can be available as part of stock assessment process and because YOY can also be collected through hydroacoustic surveys on an annual basis. As part of this process otoliths of YOY fishes can remains stored and available for otolith micro-structure analysis so as early growth traits are revealed. Although almost all otolith-based studies have been carried out in commercial fishes (92%) only in a few cases the relationship between early growth and year-class strength was tested using short time series. It is important to underline that early fish growth can also vary across seasons; hence, it must be quantified at least at a monthly cohort level before being compared with the subsequent year-class strength. Hence, it seems necessary to perform studies on large-temporal and spatial scales in some commercial species to contribute to understating the BiB and GR mechanisms in fishes.

S2-9

Predation impact by salmon on early life stages of focal piscine prey in the eastern North Pacific Ocean

Richard D. Brodeur[1,*], Jamal Moss[2], and Elizabeth A. Daly[3]

[1] *Northwest Fisheries Science Center, NOAA Fisheries, Newport, OR, USA*

[2] *Alaska Fisheries Science Center, NOAA Fisheries, Auke Bay, AK, USA*

[3] *Cooperative Institute for Marine Resources Studies, Oregon State University, Newport, OR, USA*

* rick.brodeur@noaa.gov

Although predation is thought to be the major limiting factor in fish recruitment, there have been few studies examining the effects of predators on prey populations. Juvenile Chinook and coho salmon are highly piscivorous (60-90% of their diets by weight) in their first summer at sea and are likely to be one of the most important fish predators on larval and juvenile fishes in coastal waters. The aim of this study is to examine focal juvenile fish prey of Chinook and coho salmon in coastal regions of both the Northern California Current (Oregon and Washington) and Eastern Gulf of Alaska (off Southeast Alaska) to examine: 1) proportions of the major fish prey in the diets of each predator by season and year and compare these to available prey fishes from contemporary trawl sampling, 2) sizes of fish prey consumed compared to available sizes, and 3) overall prey consumption using bioenergetics modeling and estimates of salmon present in coastal waters. For the NCC, juvenile sandlance, rockfishes and anchovies were the dominant prey in late spring, summer and fall, respectively, over a 15 year period (1998-2012) although other taxa (i.e. smelt or flatfishes) can be important in other years. For the EGOA, juvenile rockfish, capelin, and in some years sand lance and walleye pollock are important prey over the 3 summers (2011-2013) of data examined. Prey fish sizes range from <10 mm to >100 mm which represents a challenge to getting estimates of prey availability and may require multiple gears types (plankton to small-mesh trawls) to get quantitative measures of prey selection. The consumption rates show coherence to time series estimates of available prey in both regions.

S2-10

In situ estimation of mortality rate of pelagic fish larvae: Differences among methodological approaches

Yoshioki Oozeki[1,*], Akinori Takasuka[2], and Hiroshi Okamura[2]

[1]*Headquarters, Fisheries Research Agency, Yokohama, Japan*
[2]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*
*oozeki@affrc.go.jp

Natural mortality rate during the early life stages of fishes has been difficult to estimate accurately, despite its being a critical parameter in understanding the growth–survival relationship quantitatively. This talk reviews differences in estimates of mortality rate of fish larvae among methodological approaches. Eulerian approach, sampling of fish larvae at certain time intervals in an area broad enough to estimate the population size and mortality rate, has been mainly adopted for fish species spawning demersal eggs or forming dense aggregations in the spawning ground. This approach has been developed with the aid of otolith analysis technique providing the hatching date and cohort discrimination. Lagrangian approach, detecting the decrease of the abundance on the same larval aggregation, has been developed drifting buoys equipped with the global positioning system for tracking the same water mass. Lagrangian approach is appropriate for estimating the mortality rate of small pelagic fishes, since the possibility of small-scale observations compared to the Eulerian approach. These two approaches indicated considerable difference on the estimates of larval mortality rate from the analyses of previous studies, although the Lagrangian approach provides more accurate values on a short-term scale and the Eulerian approach does so on a long-term scale. The Eulerian approach tended to provide lower mortality rates, whereas the Lagrangian approach tended to provide higher mortality rates. The scale-dependent estimation of the advective loss might be one reason in relation to the scale difference of the study area. Under estimates of the recruitment of newly hatched larvae might be another reason. We will provide materials for discussion on these issues, aiming at improving estimation of natural mortality rate during the early life stages of fishes.

S2-11

Growth selective mortality of flatfish throughout its pelagic and demersal life

Mikimasa Joh*

Mariculture Fisheries Research Institute, Hokkaido, Japan
*joh-mikimasa@hro.or.jp

Flatfishes drastically change their habitat, body form, and feeding during metamorphosis; thus, the early juvenile stage is also viewed as being critical for early survival. We examined growth-selective survival for both larval and juvenile stages of marbled flounder *Pseudopleuronectes yokohamae* in Hakodate Bay, Japan from 2001 to 2003. During the pelagic larval stage, growth-selective survival was not detected in any of the 3 yr. Marbled flounder spawns adhesive eggs on sea floor and planktonic larval life is shorter than other flatfish species. Due to those features, larval survival may not be growth selective. During the early juvenile stage, fast-growing individuals survived selectively in the year when water temperature was low. In low water temperature environment, juvenile growth was slow and juveniles required time to pass the size spectrum that is vulnerable to shrimp predation. Our results show the importance of the early juvenile stage for the survival of flatfishes. Hakodate Bay is northernmost habitat, thus juvenile growth is faster in warmer temperature and growth-selective survival was observed in cold environment. For some flatfishes, the relationship between water temperature and juvenile growth was reported to be dome shape. Therefore, in southern habitat, growth selective mortality may occur at the temperature that is higher than optimum temperature. In future, laboratory study that examines optimum temperature for juvenile growth of marbled flounder is required. Additionally, the investigation of growth selective mortality in southern habitats is required to wholly understand the relationship between early growth and survival of this species.

For flatfishes, secondary growth centers are formed around otolith edge at metamorphosis, and consequently, otolith microstructure cannot be analyzed throughout larval and juvenile stages with sagittae. Thus, for flatfishes, the number of studies that report early life ecology using otolith microstructure is limited. On the other hand, some studies report that there is no secondary growth center on lapillus of flatfishes. However, unfortunately, otolith microstructure analysis using lapillus is not conducted for flatfishes enough. Flatfishes change its morphology and habitat during metamorphosis, and the survival during juvenile stage is possibly growth selective. In future, the progress in early growth study using lapillus are required for many flatfish species.

S2-12

Growth and survival of Pacific bluefin tuna in the early life history

Yosuke Tanaka*

Seikai National Fisheries Research Institute, Fisheries Research Agency,
Setouchi, Kagoshima, Japan
*yosuket@affrc.go.jp

Fast growth plays an important role for the survival processes in the early life stages of Pacific bluefin tuna *Thunnus orientalis*. In order to estimate the survival process of Pacific bluefin tuna during the larval period, otolith microstructure analysis was carried out. Estimated growth histories were compared between the larvae collected in late spring and the juveniles collected in summer 2004, which were considered to be the survivors of the larval cohorts. Back-calculated SLs by the biological intercept method showed the larval tuna in the postflexion phase were larger-at-age than preflexion and flexion larvae, suggesting that only larger and faster growing larvae were able to survive to the postflexion phase. The otolith radii (OR) of the larvae with slower growth and development were smaller than the minimum OR of the surviving juvenile tuna indicating the smallest possible size for larvae to successfully recruit to the fishery. These results indicate that the survival of larvae for Pacific bluefin tuna depends largely on size and growth rate during the early life history.

Secondly, the importance of piscivory for growth of tuna larvae was examined using laboratory-reared fish. The tuna larvae after onset of piscivory showed significantly faster growth than the tuna in zooplanktovious stage. Stable isotope and otolith analysis revealed that small growth variations of tuna larvae in zooplanktovious stage could induce further large growth variations in consequent piscivorous stages. The results of laboratory experiment suggest that piscivory in Pacific bluefin tuna larvae must be a potential key factor for their growth selective survival processes in the field.

S2-13

Growth-selective survival during late larval and early juvenile stages of forage fishes in the western North Pacific

Motomitsu Takahashi[1,*], Chiyuki Sassa[1], Youichi Tsukamoto[2], and Yoshiro Watanabe[3]

[1]*Seikai National Fisheries Research Institute, Fisheries Research Agency, Nagasaki, Japan*
[2]*Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Sapporo, Japan*
[3]*Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan*
*takahamt@fra.affrc.go.jp

Growth trajectories based on otolith daily growth increments of Japanese anchovy *Engraulis japonicus* and Japanese jack mackerel *Trachurus japonicus* were compared between conspecifics in different life stages in the western North Pacific. For Japanese anchovy, recruits collected in 1999 in the northern Kuroshio-Oyashio transitional waters were assumed to originate from pre-recruits collected in 1998 in the entire transitional waters. Widths of otolith growth increments (IW) as a proxy of daily growth rates at 30, 40, 50 and 60 days post hatching (dph) were compared between pre-recruits and recruits. IW at 30 dph of recruits was comparable with that of pre-recruits, meanwhile IWs after 40 dph of recruits were corresponding to wider IWs of pre-recruits. As mean backcalculated standard length (SL) at 30 dph of pre-recruits ranging from 19 to 27 mm was corresponded with the late larval stage, this indicates that late larvae and early juveniles with faster growth rates have higher survival probability up to recruitment than those with slower growth rates. For Japanese jack mackerel, growth trajectories were compared between larvae and pelagic juveniles in April and demersal juveniles collected during May to June in the East China Sea. Mean backcalaculated SL-at-ages of demersal juveniles were significantly larger than those of larvae and pelagic juveniles after 23 dph in 2009. As mean backcalculated SL at 23 dph was approximately 8 mm and corresponded with the late larval stage, this indicates that late larvae with faster growth rates have higher survival probability than those with slower growth rates during the transition from pelagic to demersal habitat. Thus, individuals with faster growth rates during the late larval and early juveniles stages result in higher survival probability during the subsequent life stages than slower growth rates in the nursery grounds.

S2-14

Salmon phenology and growth in streams with variable thermal regimes in Alaska

Emily Campbell[1,*], Jason Dunham[2], Gordon Reeves[3], and Steve Wondzell[3]

[1]*Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA*
[2]*U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon, USA*
[3]*Pacific Northwest Research Station, Corvallis Forestry Sciences Lab, Corvallis, Oregon, USA*
*emily.campbell@oregonstate.edu

Temperature is an important factor influencing the timing of Pacific salmon life history events because it directly affects development and growth rates. Salmon have complex lifecycles and phenology is a crucial determinant of individual fitness because transition timing to new life history stages and habitats will place constraints on subsequent growth opportunities. Although we know that temperature and phenology interact to affect salmon fitness and survival, little work has been done to elucidate these mechanisms empirically. We tested hypotheses relating stream thermal regimes to Coho salmon (*Oncorhynchus kisutch*) hatch timing and subsequent juvenile growth. Hatch timing and growth was measured in five streams with variable thermal regimes on the Copper River Delta, Alaska from April-October in 2013 and 2014. Thermal regimes ranged from groundwater dominated streams with relatively constant annual temperatures (3-5° C), to surface-water dominated streams with much greater thermal variation (0- 17°C). Despite differences in thermal regimes, Coho salmon hatch timing was synchronized (p=0.79) among streams due to an asynchronous (p<0.001) spawn timing and differences in Accumulated Thermal Units (ATU's) accrued during the winter egg incubation period. Subsequent juvenile growth rates were nearly twice as fast in groundwater streams, suggesting that thermal stability offers better growth opportunities for developing salmon. Understanding the interactive effects of thermal variability, salmon phenology, growth and fitness is important as climate change continues to alter thermal regimes worldwide.

S3-1

Early life biology in the northern Humboldt Current system

Patricia Ayón*

Instituto del Mar del Perú, Lima, Perú

*payon@imarpe.gob.pe

This talk presents the current status of early life biology of main commercial fish species (anchovy, sardine, jack mackerel, horse mackerel, and others) in the Peruvian Upwelling System or the northern Humboldt Current System and introduces our current projects. Studies have focused on spatial distribution and abundance in relation to seasonal, inter-annual, and decadal variability. It has been clearly observed that warm events like El Niño are the main factors driving changes in distribution and abundance patterns with opposite effects especially in anchovy (negative effect) and sardine (positive effect). We also noticed changes at decadal scales, associated with changes in optimal habitat availability for anchovy and sardine (species alternation hypothesis).

Anchovy is the most studied species in this system; however, little studies have been done for early life biology (larval growth and feeding), and even less has been formally published. Some studies have used models to infer the growth rates, but those results have not been tested experimentally. In 2012, the IMARPE exchanged a memorandum of understanding of collaboration with National Research Institute of Fisheries Science, Fisheries Research Agency, Japan. The collaboration project “Comparative study on biological processes of species alternations in the Kuroshio and Humboldt Current systems” is now ongoing to elucidate the biological mechanisms of species alternations based on comparative analyses of the spawning habitat, spawning biology, and population dynamics of small pelagic fish in relation to environmental factors in the Humboldt and Kuroshio Current systems. Since 2014, the IMARPE has implemented a scientific program to monitor and understand the processes related with the survival success of larvae, with implications for recruitment studies. Some studies on otolith analysis of anchovy larvae showed a great variability of growth rates at the same somatic size, which could be even twice. We also need to improve the sampling methodology to proceed with growth analysis of anchovy larvae.

S3-2

Exploring for research frontiers from the spawning environment and early-life habitat off the North Atlantic African Coast: synthesis from analyses in ecology, understandings in atmospheric teleconnection and cooperative capacity enhancement

Naoki Tojo[1,*] and Azeddine Ramzi[2]

[1]*International Education Office, Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan*

[2]*Institut National de Recherche Halieutique, Laboratoires Centraux de Casablanca, Casablanca, MOROCCO*

*n.tojo.raven@fish.hokudai.ac.jp

Since the significant works by Hjort (1914) and others, scientific investigations in the early life history have been made and dynamics in the recruitment of fishes have been explained based on the results of the investigations. Variability of the recruitment is often under the influence of the environmental variability, and the recruitment dynamics has strongly impacted to local fisheries as the cases of the Japanese sardine (*Sardinops melanostictus*). Apparently, many ecological monitoring and integrative analyses have been carried out to understand the mechanisms of the recruitment variability and contributing to the small pelagic fisheries management in our countries including Japan. On the other hand, advanced surveys and cutting-edge analysis are not always the available options in fisheries circumstances over the world, and the networking among the research is often not sufficient for various cases. Since 2010, a cooperative research was made between Morocco and Japan to synthesize information in early life of small pelagic fishes for sustainable resource assessment. Time series analyses with cumulated observations in the cooperative research suggested the spatio-temporal variabilities in the retention patterns and spawning grounds of the small pelagic fishes. The synthesized explanations were begun to be incorporated to the assessment process for management measures of Morocco. Comparable biological research has also been suggested among different ecosystems including the western African coast and Japan through the cooperation. Corroborative research in the early life biology of fishes allows us to explore a new frontier for significant research with the context of the climate teleconnection as well as to find a countermeasure for the sustainable fisheries in the study area. Early life biology studies and analyses could find scientific frontier with societal contributions for our next generation.

S4-1

Experiments with closed populations in the laboratory and mesocosms – how can they provide insights about vital rates in the field?

Arild Folkvord*

Department of Biology, University of Bergen and the Hjort Centre for Marine Ecosystem Dynamics, Bergen, Norway

*arild.folkvord@uib.no

Documentation of the growth and mortality dynamics during the early life stages of fish is of key importance for our understanding of fluctuations in fish recruitment in natural populations. Detailed quantification of vital rates in natural populations in the field is often challenging due to logistic and economic constraints imposed by extended spatial and temporal scales. Experimental studies may represent a supplement to field studies in obtaining high resolution growth and mortality estimates. In general experimental studies offer advantages in terms of control, experimental design and interpretation. One of the major advantages of experimental studies on early life stages of fish involves the use of closed populations where lack of advective losses and inputs makes the inferences from sequential samplings more straightforward and potentially more revealing. However, the downscaled size and the artificial settings imposed by an experimental setup limit the general validity and transferability of the obtained findings relative to natural settings. In this presentation, I will discuss how some of the disadvantages of the experimental conditions can be reduced, and how estimates of vital rates in the early life stages of fish from these systems can be relevant for our understanding of these processes under natural conditions. Examples will mainly be provided from laboratory and mesocosm studies on cod and herring, where sampling of closed populations over time have provided high resolution estimates of growth and mortality rates under different environmental conditions. The estimation of accurate and temporally resolved mortality rates is often more difficult than the estimation of corresponding growth rates, both in the field and under experimental settings. Still, a close multidisciplinary collaboration between modellers and colleagues working on field and experimental studies is expected to be the way forward to provide new important insights about the early life history dynamics of fish.

S4-2

A year in the (early marine) life of Chinook Salmon: effects of variable water temperature and food availability on seasonal growth, condition and mortality

Francis Juanes* and David G. Stormer

Department of Biology, University of Victoria, Victoria, British Columbia, Canada
*juanes@uvic.ca

Rising temperatures in the Northeast Pacific Ocean over the past 30+ years have been associated with declines in the early marine survival of many southern British Columbia populations of Chinook salmon, but the mechanisms are unclear. Our objectives were to experimentally evaluate how juvenile ocean-type Chinook responded to temperature and food variability during their first summer, autumn and winter. Water temperature had a greater effect on growth than energetics, such that the growth potential of fish was maximized in the lowest water temperature during summer and highest temperature during winter, while lipid content was primarily influenced by ration in all seasons except for summer. Seasonal mortality was greatest during summer, particularly at the highest water temperature (45%). Only 20% of fish died during winter, even when completely deprived of food. Summer ocean temperatures approaching those simulated in the highest temperature here could negatively affect natural populations of Chinook salmon resulting from stunted growth, poor condition and increased temperature-induced acute mortality even when food is abundant. The compensatory growth response and energy maintenance during winter by fish that survived the highest summer temperature suggests that the effects of climate change on juvenile Chinook salmon physiology may only be critical during summer.

S4-3

Understanding the mechanisms underlying observed correlations between the environment and the distribution and abundance of tuna species: laboratory, field data and models on tuna larvae

Patricia Reglero*
on behalf of collaborators working with bluefin tuna in the Mediterranean Sea

Instituto Español de Oceanografía, Centro Oceanográfico de las Islas Baleares,
Palma de Mallorca, Spain
*patricia.reglero@ba.ieo.es

Evidence from field sampling suggests strong correlations between tuna distributions and abundance and environmental variables, mainly temperature, frontal structures and chlorophyll. Such relationships had lead to two main general hypotheses on where tuna reproduces: -The temperature hypotheses that reproduction is restricted to areas above 20ºC and -the ocean triad hypothesis that spawning occurs in oligotrophic areas with mesoscale oceanographic features such as fronts and eddies. During the last five years we have focused on understanding the mechanisms underlying the observed significant correlations between tuna species and environmental variability combining laboratory and field data on tuna larvae of Atlantic bluefin tuna and bonito. Based on experimental results, we have investigated the survival and development of eggs and larvae with temperature and food conditions emphasizing the existence of a “second” critical window in tuna larvae: the switch from planktivory to piscivory. Size-dependent mortality patterns in the laboratory challenge the growth-survival paradigm in these species. Besides, a model of larval foraging and bioenergetics shows the predator-prey size distribution and the relative densities of larvae may produce overcompensation in recruitment under some environmental conditions. In this talk we will summarize the identification of key environmental variables in field research and the mechanistic process behind paying special attention to tuna larval growth and survival as main topic of the symposium.

S5-1

Spatially-explicit biophysical models of the growth and survival of early life stages of fish: A synthesis with recommendations

Myron A. Peck*, Marc Hufnagl, Klaus Huebert, and Marta Moyano

Institute of Hydrobiology and Fisheries Science, University of Hamburg, Hamburg, Germany

*myron.peck@uni-hamburg.de

We review how biophysical models have been used to understand environmental regulation of growth and survival in marine fish early life stages. Emphasis is placed on critically reviewing the literature and critiquing the state-of-the-art in spatially-explicit models. The review spans modeling studies targeting different species and contrasting ecosystems (marine, estuarine, freshwater) thereby attempting a synthesis of (the vast) literature. The review highlights efforts to incorporate biological realism such as key trophic interactions and elements of the ecophysiology of larval stages within spatially-explicit, biophysical models. A review of the key (sensitive) physiological parameters is provided. Advances in how models depict physical processes are still greatly outpacing those in biological processes such as larval growth energetics and prey overlap (needed to examine bottom-up drivers) and predator fields (needed to estimate the strength and variability in top-down processes). Individual-based models most often simulate what happens when larvae with average traits experience different environments instead of what happens when larvae with different traits experience average environments. We argue that some combination of the two approaches is needed to adequately explore and use biophysical models to understand the link between growth and survival of marine fish early life stages across different cohorts, species and habitats.

S5-2

When and how do growth paradigms evolve from IBMs and size structured models?

Marc Hufnagl*, Myron A. Peck, and Ken Haste Andersen

Institute of Hydrobiology and Fisheries Science, University of Hamburg, Hamburg, Germany
*marc.hufnagl@uni-hamburg.de

We used models of different complexity and with different degrees of trophic interaction to identify situations in which slower growth was expected to lead to higher survival. The first study focused on larval herring feeding on variable size-structured zooplankton prey fields including seasonal dynamics but no dynamic link between larvae and their prey. It can be expected that faster growing larvae outgrow their suitable prey range and suffer from food limitation in simulations where the main prey biomass shifted from larger to smaller size as observed in spring, however that was not the case. The model was thus further extended and a dynamic link was included allowing larvae to potentially deplete the prey, while the prey feeds on a static resource. This approach was sensitive against the assumed background mortality that zooplankton experiences and only in occasions where zooplankton size decreased rapidly due to predation by larger larvae smaller larvae showed a benefit. The third approach is based on a size structured food web which includes predation pressure which beyond the larvae stage included all life stages feeding on size-structured prey fields and experiencing size-dependent predation mortality. While the first two models were parameterized for larval herring the results are applicable to other species as well. Thus results from all three approaches were summarized to identify species groups and sizes, times in the year and situations where the potential for a growth paradigm is high. All results were then compared to actually reported and available growth rates and life cycles.

S5-3

Modeling larval fish growth using Quirks

Klaus B. Huebert*, Johannes Pätsch, Marc Hufnagl,
Markus Kreus, and Myron A. Peck

University of Hamburg, Hamburg, Germany
*klaus.huebert@uni-hamburg.de

Ecological modeling of fish larvae is a useful tool for the critical evaluation of the "growth-survival paradigm." Our model Quirks uses mechanistic rules to simulate the foraging behavior and growth physiology of fish larvae, as a function of their biological traits (e.g., swimming speed and metabolic rate) and environment (e.g., temperature and prey field). Quirks performed very well in validation experiments, predicting over half of the variability in published growth rates among larvae of four species and across a wide range of environmental conditions (e.g., <3 to >24 °C and starvation to unlimited prey). Over a 40-year period between 1970 and 2010, North Sea modeled median growth of larval Atlantic cod in February and European anchovy in August explained 22% and 35% of juvenile recruitment variability in the following year, respectively. This is consistent with the "growth-survival paradigm" but suggests that the coupling between growth and mortality is likely more complex. In its current form, the model does not consider predation – only mortality from insufficient prey or intolerable temperature is included. Quirks is open source software, and could be expanded to simulate growth- and size-dependent predation.

S5-4

Growth–survival problems in a coupled model between fish growth and environments

Shin-ichi Ito[1,*], Tatsuya Sakamoto[1], Takeshi Okunishi[2], Akinori Takasuka[3], Michio Yoneda[4], Sachihiko Itoh[1], and Kosei Komatsu[1]

[1]*Atromosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan*
[2]*Tohoku National Fisheries Research Institute, Fisheries Research Agency, Shiogama, Japan*
[3]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*
[4]*National Research Institute of Fisheries and Environment of Inland Sea, Fisheries Research Agency, Imabari, Japan*
*goito@aori.u-tokyo.ac.jp

As a coupled model between fish growth and lower-trophic-level ecosystem, NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography. For including Saury and Herring) has been developed. Prey plankton density estimated by NEMURO is used to drive a bioenergetics model for growth of the model fish. The prey preference is defined based on life stages of the model fish. NEMURO.FISH type models are effective tools to investigate fish responses to climate change and variability. However, to simulate the fish abundance, survival process of the model fish is essential and it is still our big challenges to define the relationship between the fish growth and survival. In addition, as always, it is very hard to estimate all model parameters. Field observations and laboratory experiments have been conducted to estimate bioenergetics model parameters, however, some parameters are based on previous studies. In the worst cases, some parameters are based on parameters estimated for other species or are tuned as adjusted parameters to reproduce reasonable growth of the model fish. To improve the models, laboratory experiments are essential to fill the parameter gaps. In addition, field experiment to trace larval schools using a drifter buoy array and monitor the larval feeding, growth and survival will bring breakthrough knowledges to improve our understandings. Otolith chemical analysis such as stable oxygen isotopes will add new insights to investigate larvae experienced circumstances and relation to survival conditions. Combination of NEMURO.FISH type models with otolith chemical analysis may be another breakthrough which will bring better understandings of survival processes.

S5-5

Are management goals impeding or fostering the scientific progress of the growth–survival paradigm?

Ignacio A. Catalán*

Mediterranean Institute for Advanced Studies, Spanish National Research Council-University of the Balearic Islands (IMEDEA, CSIC-UIB), Esporles, Spain

*ignacio@imedea.uib-csic.es

Hundreds of papers have emanated from the growth–survival paradigm (GSP) in early life of fish, either directly or indirectly. Evidence for direct relationships between G and S exist, but results are far from conclusive. In the first part of the talk I will review my own work in the light of the GSP. In many works, including some of my own, a dangerous mantra is assuming that positive direct G-S relationships do exist when, in fact, these relationships may only occur (or be relevant) under some circumstances, and even inverse relationships may be the rule. The scientific community caring about the GSP, and other potential mechanisms explaining recruitment variability, are longing for general rules that can be used independently of the species/stock/region, but this may be impossible to attain in the desired form. Deepening on general mechanisms governing early life survival has been proven feasible, and unifying theoretical background exists. In my view, one key factor that can affect the speed at which hypotheses such as GSP are refined or abandoned have to do with the source of funding (basic research or more applied resource management), and how honest scientists are with respect to the foreseen project outputs vs the allocated money. In data-poor regions, the potential incorporation of early life research into assessment models is usually an indirect (and appealing) objective in research projects. Usually, projects dealing with commercial stocks (particularly during economical crisis) will be favored by funding bodies, but these projects (usually expensive) may not necessarily do a favor to the best science trying to solve the recruitment problem. In this context, I will comment on my perspective about the opposing forces, including geographical differences, governing the research on issues such as the GSP.

P-1

Temperature and zooplankton effect on the growth rate of larval and early-juvenile sprat (*Sprattus sprattus*) in the South Baltic Sea

Dariusz. P. Fey* and Lena Szymanek

Department of Fisheries Oceanography and Marine Ecology,

National Marine Fisheries Research Institute, Gdynia, Poland

*dfey@mir.gdynia.pl

The mean growth rate of larval sprat (*Sprattus sprattus*) (n=996, SL range: 9.0-35.0 mm, Mean SL= 21.5 mm) collected in the south region of the Baltic Sea between June and August 2006-2010 was 0.54 mm/d. For larvae collected in August, the highest growth rate was observed in 2006 (0.53 mm/d) and 2010 (0.53 mm/d), and the lowest in 2008 (0.42 mm/d) and 2009 (0.39 mm/d). The growth rate of sprat collected in June were 0.63 mm/d in 2006 and 0.59 mm/d in 2007. Thus, larvae growing in May-June were characterized by faster growth rate than those growing in July-August. That was despite the fact that temperature was higher during July-August. The differences in growth rate between the two time periods can be explained by zooplankton biomass, which was higher in May-June than in July-August. Thus, food availability was more important for fast growth than high temperature. In all years and months, except June 2006, larvae form the Gdansk Basin had faster growth than larvae from Bornholm Basin. Those differences were related to temperature differences – faster growth of larvae in the Gdansk Basin was related to higher temperature in that area. The only season (May-June 2007) when temperature in Gdansk Basin was lower, was also the only season when no differences in growth rate between Bornholm Basin and Gdansk Basin were observed. Because of low number of zooplankton stations, it was not possible to do similar comparison of the possible differences in zooplankton biomass between the two geographical areas.

P-2

Buoyancy and vertical distribution of Pacific mackerel eggs and larvae and its climate change implication for the temporal variability of recruitment

Hwa Hyun Lee[1,*], Sukyung Kang[2], Kyungmi Jung[2], Suam Kim[1], and Sukgeun Jung[3]

[1]*Pukyong National University, Busan, Korea*
[2]*National Fisheries Research & Development Institute, Busan, Korea*
[3]*Jeju National University, Jeju, Korea*
* proxima07@hanamil.net

Vertical distribution of fish eggs and larvae is a crucial component for determining advection and recruitment variability. Little has been reported about the vertical location of Pacific mackerel *Scomber japonicus* eggs and larvae in Korean waters. Therefore, we measured the specific gravity of eggs and larvae using artificially fertilized eggs, and then simulated its vertical distribution to understand the distribution patterns in the spawning area around Jeju Island, Korea. All eggs from broodfish (May-June 2014 and 2015) were spawned, in rearing tank, and the specific gravity of fertilized eggs and larvae was measured by density-gradient column (Martin In. Co. LTD). The egg specific gravity during the early stage ranged from 1.203-1.0211. In general, the fertilized egg showed a gradual decline in specified gravity until full development of the main organs, with a sudden increase just before hatching. However, specific gravity of larvae tended to increases with diel pattern from 4 to 16 days after hatching. Due to the different salinity in spawning area, the vertical location of eggs and larvae should be different interannually, which determines the various levels of advection as well as recruitment success.

P-3

Does vertical migratory behavior of spiny lobster larvae influence their open-ocean migration?

Yoichi Miyake[1,2,*], Shingo Kimura[1,2], Sachihiko Itoh[2],
Seinen Chow[3], Keisuke Murakami[4], Satoshi Katayama[5],
Aigo Takeshige[2], and Hideaki Nakata[6]

[1]*Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan*
[2]*Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan*
[3]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*
[4]*Fisheries Research Agency, Yokohama, Japan*
[5]*Graduate School of Agriculture Science/Faculty of Agriculture, Tohoku University, Sendai, Japan*
[6] *Faculty of Fisheries, Nagasaki University, Nagasaki, Japan*
*miyakey@aori.u-tokyo.ac.jp

A growing number of studies suggest that vertical migratory behavior of planktonic larvae can affect their dispersal scale. The effect of this behavior has been extensively studied for species that disperse during their early life stages in coastal regions. However, little is known about its effect on migration in the open ocean. Spiny lobsters have planktonic larvae called phyllosomas, which have a long pelagic duration (ca. 1 year). We aimed to determine if vertical migratory behavior of phyllosomas influences their open-ocean migration by simulating larval transport of two spiny lobster species (*Panulirus japonicus* and *P. penicillatus*) in the Pacific Ocean using individual-based models in which particles (i.e. simulated larvae) can temporally change their vertical distribution. For *P. japonicus*, vertical migratory behavior of phyllosomas was found to facilitate detrainment from the Kuroshio Extension (KE) and southwestward transport (toward adult habitats) in the recirculation regions of the Kuroshio and KE, which both likely resulted in increased transport success. For *P. penicillatus*, vertical migratory behavior was found to prevent larval exchange across the East Pacific Barrier (EPB), which is consistent with genetic isolation between populations that are located on either side of the EPB. These findings suggest that vertical migratory behavior of phyllosomas influences their open-ocean migration. This behavior may be important not only for spiny lobsters but also for other species that have teleplanic larvae that migrate in the open ocean.

Impact of climate change on the egg and larval transport of Japanese anchovy off Kyushu Island, the western coast of Japan

Aigo Takeshige[1*], Yoichi Miyake[2], Hideaki Nakata[3], Takashi Kitagawa[1], and Shingo Kimura[2]

[1]*Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan*

[2]*Graduate School of Frontier Sciences/Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan*

[3]*Faculty of Fisheries, Nagasaki University, Nagasaki, Japan*

*a-takeshige@aori.u-tokyo.ac.jp

To investigate the impact of climate change on egg and larval transport of Japanese anchovy (*Engraulis japonicus*) off Kyushu Island, the western coast of Japan, particle-tracking simulations on transport success/failure to fishing grounds during 1960–2007 was conducted. The modeled transport success since the mid-1990s increased and decreased in the offshore and coastal zones, respectively, compared with the 1960s and 1970s. The estimated northward shift of the spawning ground and weakened Tsushima Warm Current contributed to the increase in modeled transport success to the offshore zone. Conversely, the weakening trend of the modeled onshore current in the Goto-Nada Sea combined with the northward shift of the spawning ground resulted in unsuccessful larval transport. These results suggest that fluctuations in juvenile and sub-adult anchovy catch in this area may be attributable to changes in the physical environment. Effects of global warming on larval distribution were also investigated based on the global warming scenario. The results showed that the main larval distribution shifts northward, and the transport success to the offshore fishing zone would decrease after global warming, compared with that of the average of the 1950s–1990s. It was also suggested that the intensified Tsushima Warm Current transports larvae outside the offshore fishing zone, and the northward shift of the spawning ground weakens the larval supply connection with the offshore fishing zone. Larval growth rate was estimated to be accelerated due to higher temperature, while the strengthened thermal stratification seems to lower primary production during spring bloom by limiting nutrient supply, and it may restrict the food availability for the larval anchovy.

P-5

Seasonal variability in development of Japanese anchovy *Engraulis japonicus* during the transition from larval to juvenile stages in the Kii Channel

Naotaka Yasue[1,*], Shigeo Harada[2], and Akinori Takasuka[3]

[1]*Agriculture, Forestry, and Fisheries General Affairs Division, Wakayama Prefectural Government, Wakayama, Japan*

[2]*Wakayama Prefectural Fisheries Experimental Station, Kushimoto, Japan*

[3]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*

* yasue_n0001@pref.wakayama.lg.jp

Seasonal (inter-cohort) variability in development of Japanese anchovy *Engraulis japonicus* during the transition from larval to juvenile stages was examined based on the change in head size, degree of guanine deposition, and the ossification in the Kii Channel. The sea temperature influence on their development was examined. Head length at standard length of 20 mm, 25 mm, and 30 mm was all positively related to temperature. In addition, both standard length right before the start of guanine deposition and standard length immediately after the start of guanine deposition were negatively related to temperature. Moreover, the development of the caudal fin supports and pectoral fin rays tended to be fast at higher temperature at the same standard length. Thus, the morphology of fish differed between seasons in the same standard length. A parallel development of the external morphology and the internal morphology was observed. The energy use for development of some characteristics did not result in delayed development of other characteristics. Larvae were considered to have a higher avoidance ability from predators and prey capture ability at higher temperature. Therefore, the larvae living at higher temperature were expected to have a higher survival potential. The present results would contribute to understanding mechanistic processes linking environmental conditions to survival probability through the environmental effects on development during early life stages of fish.

P-6

Effects of body size and growth rate in larval and early juvenile stages on the year class strength of walleye pollock in the Sea of Japan

Masayuki Chimura[1,*], Hiroshige Tanaka[1], and Yuuho Yamashita[1]

[1]*Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Japan*
*chimchim@affrc.go.jp

For the walleye pollock stock distributing in the Sea of Japan off Hokkaido Island, the recruitment, defined as the number of age-2 fish, positively correlates with the abundance of pelagic larvae and juveniles estimated by acoustic surveys after 2006 year-class. Year class strength of this stock will be determined within a few months from spawning, and be influenced mainly by the transport success of eggs to nursery ground, feeding condition during first feeding period, and size and/or growth rate dependent predation mortality. Hatch dates and growth rates of pelagic juveniles were estimated through otolith analysis. The juveniles in 2006 and 2012 year-class with high-abundance originated from eggs spawned in the latter half of the spawning season, and their body size at capture were smaller than that of the early-hatched juveniles in 2008, 2010 and 2013 year-class with low- or middle-abundance. Among the late-hatched fish, the juveniles of high-abundance year classes grew slower than the fish in the low-abundance 2008 year-class. Contrastively, for the walleye pollock stock in the Pacific coast off Hokkaido, fish hatched early and had larger body size on a given date are thought to be advantageous to the survival by age-0 epibenthic juvenile stage. For the walleye pollock stock in the Sea of Japan, the effect of size and growth rate dependent predation mortality on the year class strength may be smaller than other factors (e.g. failure in egg transport).

P-7

Annual variation of growth of juvenile yellowtail *Seriola quinqueradiata* in Tosa Bay, off the Pacific coast of Japan

Shingo Watari[1,*], Hideo Sakaji[2], and Tatsuya Kaji[3]

[1]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*
[2]*National Research Institute of Fisheries and Environment of Inland Sea, Fisheries Research Agency, Hatsukaichi, Japan*
[3]*Kochi Prefectural Fisheries Experimental Station, Susaki, Kochi, Japan*
*swatari@affrc.go.jp

Landings of Japanese stock of yellowtail *Seriola quinqueradiata* reached highest level during the last 50 years. The estimated stock abundance in 2014 was almost twofold higher than that in 2005. The latest stock assessment also indicated that both spawning stock abundance and amount of recruitment have been at high level since 2011. Hence, it is considered that some environmental factors had positive effects on the survival during the early life stages of yellowtail. In this study, we focused on growth of juvenile yellowtail and discussed the early life stage in response to changes in the stock status. Juvenile samples were collected in Tosa Bay, off the Pacific coast of Japan, in March, April and May since 2005. The mean fork length showed an increasing trend during recent years. The estimated daily growth rate thorough otolith microstructure analysis showed a trend of fast growth during recent years. We also discuss relationship of growth during the early life stages and the stock status.

P-8

What drives migration of chum salmon fry in the rivers and coastal waters in eastern Hokkaido?

Kiyoshi Kasugai[1,*], Hayato Saneyoshi[2], Hajime Oomori[2], Mitsuru Torao[2], Tomoya Aoyama[3], Yoshihito Shinriki[3], Anai Iijima[1], Yasuyuki Miyakoshi[1], and Mitsuhiro Nagata[1]

[1]*Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization, Eniwa, Japan*

[2]*Doto Research Branch, Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization, Nakashibetsu, Japan*

[3]*Donan Research Branch, Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization, Yakumo, Japan*

*kasugai-kiyoshi@hro.or.jp

Chum salmon (*Oncorhynchus keta*) fry originated in Japan migrate from the rivers to the ocean in the spring and from the coastal waters to the offshore of the Okhotsk Sea in the first summer. Abundance of juvenile chum salmon was high at sea surface temperatures (SSTs) between 8°C and 13°C in the nearshore areas of Nemuro Bay and Kushiro area, eastern Hokkaido, northern Japan. In Nemuro Bay, catch per unit effort (CPUE) in the littoral zone was higher in the years when SST increased slowly in the nearshore areas, and CPUE in the nearshore area was lower in the years when SST increased faster outside of Nemuro Bay. These results suggest that SST influences the migration of juvenile chum salmon in the coastal waters. In both areas, chum salmon fry were stocked in the upper reach of rivers. Between the upper and lower reaches of both rivers, periods when the catch of salmon fry began to increase were different, although periods of low catch of salmon fry were similar. Water temperatures in the upper reaches were between 8°C and 13°C, and were favorable for salmon fry. Timing of migration and breeding is influenced by photoperiod among Pacific salmon *Oncorhynchus* spp.; therefore, it is likely that downstream migration of salmon fry in the rivers is driven by photoperiod finally.

Otolith stable isotope and trace element analyses to reconstruct migration history of chum salmon *Oncorhynchus keta*

Tatsuya Kawakami[1,*], Yuichi Shimizu[2], Gen Ogawa[2], Toshihiko Saito[3], Masaya Iida[4], Naoko Sugihara[5], Kotaro Shirai[5], Shunpei Sato[3], Hiroshi Ueda[6], and Tsuguo Otake[1]

[1]*Department of Aquatic Bioscience, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan*

[2]*Iwate Fisheries Technology Center, Iwate, Japan*

[3]*Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Hokkaido, Japan*

[4]*Japan Sea National Fisheries Research Institute, Fisheries Research Agency, Niigata, Japan*

[5]*Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan*

[6]*Field Science Center for Northern Biosphere, Hokkaido University, Hokkaido, Japan*

*kawakami@aqua.fs.a.u-tokyo.ac.jp

Reconstructing migration history of chum salmon *Oncorhynchus keta* is essential to reveal their growth pattern, survival process and the population dynamics. In this study, the otolith stable isotope and trace element was analyzed to evaluate its potential for reconstructing migration history of chum salmon. To assess its usefulness as natal tags, otolith stable isotope ratios ($\delta^{13}C$, $\delta^{18}O$) and elemental ratios (K/Ca, Na/Ca, Mg/Ca, Zn/Ca, Mn/Ca, Sr/Ca, Ba/Ca, Sr/Ba) were analyzed for artificially produced juveniles collected at 23 hatcheries from three regions in Japan (Hokkaido, Iwate and along the Japan Sea). Discriminant analysis showed that both the stable isotope ratios and the elemental ratios could discriminate the juveniles from different hatcheries within the same region, with high level of accuracy. To obtain otolith elemental profile through the life, the elemental ratios mentioned above were analyzed for adults caught at Hokkaido coast and immature fishes caught at the Bering Sea. Among the elemental ratios, Sr/Ba periodically fluctuated along the analysis line, so it was a possible indicator to divide the migration phase. First abrupt increase in Sr/Ba was found at the analytical point located at around 20% of analysis line. This increase probably corresponded to juvenile downstream migration. Furthermore, consecutive peaks and troughs corresponded to opaque zones and transparent zones, respectively, likely indicated seasonal migration across the sea. These results suggest that analyses of otolith stable isotopes and trace elements are promising way to reconstruct the migration history of chum salmon.

P-10

Growth, mortality, and prey consumption of three numerically dominant mesopelagic fish larvae in the Kuroshio waters during late winter

Chiyuki Sassa* and Motomitsu Takahashi

Seikai National Fisheries Research Institute, Fisheries Research Agency, Nagasaki, Japan

*csassa@fra.affrc.go.jp

The larvae of mesopelagic fish have been described as the dominant ichthyoplankton in the Kuroshio waters during late winter off southwestern Kyushu Island, Japan where spawning grounds of several commercial pelagic fishes are formed. Here, we examined the growth, mortality, and prey consumption of three numerically dominant mesopelagic fish larvae: *Myctophum asperum*, *Notoscopelus japonicus* (Myctophidae), and *Sigmops gracilis* (Gonostomatidae). Larvae of the three species occurred mainly on the offshore side of the Kuroshio axis, with a habitat temperature of 18–22°C. The absolute growth rates of all species increased with age, and ranged 0.09–0.23 mm day^{-1} in *M. asperum*, 0.09–0.20 mm day^{-1} in *N. japonicus*, and 0.09–0.26 mm day^{-1} in *S. gracilis*. The weight-specific instantaneous growth coefficient (G_W) was highest in *M. asperum* (0.150 day^{-1}) and lowest in *S. gracilis* (0.077 day^{-1}). The daily instantaneous mortality coefficient (Z) of *S. gracilis* (0.067 day^{-1}) was significantly lower than the values of the other two species (0.143 day^{-1} for both species). The ratio G_W/Z, an index of stage-specific survival of the larvae, was from 0.90 (*N. japonicus*) to 1.15 (*S. gracilis*), without a significant difference from a value of 1 in all species. Based on the reported relationship between G_W and ingestion rate of the marine fish larvae, the daily ration of each species was calculated to be from 28.9 to 42.3% body dry weight day^{-1}. The daily consumption of prey by the three species was estimated to be 0.95 mg dry weight day^{-1} m^{-2} on the offshore side of the Kuroshio axis, and the larval feeding pressure on zooplankton production was estimated to be approximately 0.7% per day. However, considering that the larvae feed mainly on copepod nauplii and early-stage copepodites, the feeding pressure on only these prey items would be markedly higher than the above estimation.

P-11

Geographical variability in larval growth of Pacific saury *Cololabis saira* in the Kuroshio Current system

Kirara Nishikawa[1], Akinori Takasuka[2], Hiroshi Kuroda[3], Takeshi Okunishi[4], Yugo Shimizu[2], Hideo Sakaji[5], Tadashi Tokai[6], Yoshioki Oozeki[7]

[1]*National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Shizuoka, Japan*
[2]*National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Japan*
[3]*Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Japan*
[4]*Tohoku National Fisheries Research Institute, Fisheries Research Agency, Shiogama, Japan*
[5]*National Research Institute of Fisheries and Environment of Inland Sea, Fisheries Research Agency, Hiroshima, Japan*
[6]*Tokyo University of Marine Science and Technology, Tokyo, Japan*
[7]*Headquarters, Fisheries Research Agency, Yokohama, Japan*
*kiraranishi@affrc.go.jp

Geographical variability in larval growth of Pacific saury *Cololabis saira* was examined in relation to environmental factors off the Pacific coast of Japan during the winter spawning season in 2014. Based on measurements of knob length and otolith increment widths, marginal 3-day mean increment widths for each of three size-classes (5–10, 10–15, and 15–20 mm) of larvae were compared among the areas around the Kuroshio axis and on the inshore and offshore sides of the Kuroshio axis in terms of environmental factors: sea surface temperature (SST), sea surface salinity (SSS), and sea surface chlorophyll-*a* concentration (CHL). The larvae were more densely distributed in the Kuroshio axis and offshore areas (higher SST and lower CHL) than in the inshore area (lower SST and higher CHL). For the smaller size classes, there were significant differences between the areas. However, differences of mean increment widths were small relative to the range of variation. No clear relationship was found between the marginal 3-day mean increment widths and any of SST, SSS, and CHL, probably because effects of these factors compensated with each other. The survival potential of the minorities of the larvae in the inshore area was considered comparable with that of the majorities of the larvae in the Kuroshio axis and offshore areas.

P-12

Sampling results of multiple layer opening/closing MOHT in Sagami Bay, Pacific coast of Japan — Effect of towing speed and fish body size on net avoidance of myctophid fishes

Yuanyuan Zhu[1,*], Tadashi Tokai[1], Fuxiang Hu[1],
Yoshiaki Fukuda[2], Koki Abe[2], and Tomohiko Matsuura[2]

[1]*Graduate Scholl of Marine Science and Technology, Tokyo University of Marine Science and Technology, Tokyo, Japan*

[2]*National Research Institute of Fisheries Engineering, Fisheries Research Agency, Kamisu, Japan*

*zhuyuanyuan8812@yahoo.co.jp

A new multiple layer sampling trawl, MOC-MOHT (Multiple layer Opening/Closing Matsuda-Oozeki-Hu trawl) has been developed to sample the pelagic larval and juvenile fish in target water depth quantitatively. Sea trials with using MOC-MOHT with five codend nets were carried out in Sagami Bay, Pacific during night time on 4, 5, and 6 October 2013. Three types of tows were tested in the sea trials: oblique tow, step-oblique tow and stable tow. In the oblique tow with a constant towing speed of 3 kt, each of five codend nets were opened in water depth from 0 to 200m, from 200 to 150m, from 150 to 100m, from 100 to 50m, and from 50 to 0m. Step-oblique tows were around 50 m and 100 m water depths, and the towing speeds of each tow were 4, 3, and 2 kt. Stable tows were conducted in 50m water depth with the towing speed down in the three stages of 4, 3, and 2 kt in this order. Larvae and juveniles of myctophids were sorted out from the caught samples and were grouped into 5mm-class intervals of body length. Especially, body length data of *Diaphus theta* was utilized for analyzing effect of towing speed on net avoidance. In oblique tows, the catch number of the myctophids juvenile was the largest at the depth range of 100-50 m, while the average body length of the juvenile was the largest at 200-150 m depth. In step-oblique tows, the collected samples were obviously different in species composition and fish size between 50 m and 100 m water depths. In stable tows, *Diaphus theta* of large size were not caught when the towing speed was slower, and it suggested net avoidance of the juvenile at slow towing speed.

Occurrence, distribution and prey items of juvenile marbled sole *Pseudopleuronectes yokohamae* around submarine groundwater seepages on a tidal flat in southwestern Japan

Masaki Hata and Jun Shoji*

Field Science Education and Research Center, Hiroshima University, Hiroshima, Japan

*jshoji@hiroshima-u.ac.jp

Occurrence, distribution and prey items of juvenile marbled sole *Pseudopleuronectes yokohamae* were investigated around submarine groundwater seepages on a tidal flat in southwestern Japan. Spatial distribution of radon-222 (^{222}Rn) concentration in water showed more submarine groundwater seepage at offshore area within the survey site. Salinity gradient between nearshore to -offshore stations with lower values at offshore sampling stations corresponded with the spatial gradient of ^{222}Rn concentration. Juvenile marbled sole were collected from March through June with seasonal peak in April in 2013 and 2014. Mean juvenile abundance was highest at the second most offshore station where high submarine groundwater seepage was indicated. Major prey items of the marbled sole were small crustaceans such as cumaceans and gammarids at the post-settlement stage (10-40 mm) and were replaced with polychaetes in larger juveniles (40-50 mm). Abundance of these major prey items was also relatively higher at offshore stations. A significant negative correlation between gammarid abundance and salinity indicated a higher concentration of gammarids around the area of high submarine groundwater seepage than for the other major prey organisms. Stable isotope analysis showed greater dependence of juvenile marbled sole during the post-settlement stage on prey items with low δ^{13}C indicating a terrestrial origin through feeding on crustaceans on the tidal flat.

P-14

Daytime predation refuge for juveniles or nighttime foraging ground for predators? Two contribution pathways of vegetated habitats to production of coastal fishery resources in southwestern Japan

Hiroki Tanaka, Hikari Kinoshita, and Jun Shoji*

Field Science Education and Research Center, Hiroshima University, Hiroshima, Japan
*jshoji@hiroshima-u.ac.jp

An increase in nocturnal predation risk was demonstrated in a seagrass *Zostera marina* bed which has previously been considered as a predation refuge for small fishes. Seasonal and day-night changes in fish community structures and predation rate on juvenile and small-sized fishes were examined in the seagrass bed in temperate waters of the Seto Inland Sea. The number of piscivorous fish species, and their abundance and biomass during nighttime were significantly higher than in daytime in all seasons (October 2009, January, April and July 2010). Analysis of stomach contents of 182 piscivorous fishes showed no predation during daytime in all seasons while predation rate during nighttime ranged between 0 and 0.5±0.6 fish 100 m^{-2}. Since the piscivorous fishes which visit the seagrass bed during nighttime include important fisheries resource species, the evidence of nighttime predation indicates hat these piscivorous fishes obtain energy in the seagrass bed through predation on small fishes. Therefore, the function of seagrass beds as fish habitats should be evaluated considering two possible pathways in which seagrass beds contribute to fishery production: daytime predation refuge for juvenile fishes while as nighttime foraging ground for piscivorous fish.

P-15

Increase in species richness and abundance of juvenile and small-sized fishes around submarine groundwater seepage

Tatsuya Utsunomiya and Jun Shoji*

Field Science Education and Research Center, Hiroshima University, Hiroshima, Japan
*jshoji@hiroshima-u.ac.jp

There have been far more studies on how the variability in surface water discharge affects production of animal communities in aquatic ecosystems while less information has been accumulated on the mechanisms of how the groundwater supply works. Physical and biological surveys were conducted to test the hypothesis that high level of submarine ground water seepage enhances species richness, abundance and biomass of fishes and invertebrates in coastal waters of Obama Bay, Japan, where a high contribution of nutrients (ca. 65% of phosphorus) to total provided through all freshwater has been reported. Survey for horizontal distribution of radon-222 (^{222}Rn) concentration showed high levels of submarine groundwater seepage in the west part of survey area. Fish and invertebrate communities were compared within a relatively small spatial scale (ca. 100 m) in relation to level of submarine groundwater seepage. Species richness, abundance and biomass of fishes and abundance and biomass of turban snail and hermit crab were significantly higher in the area with high ^{222}Rn concentration. Abundance of gammarids, the most major prey item of the fishes, was 18 times higher in the area with high ^{222}Rn concentration. Since the turban snail, hermit crab and gammarids feed on producers (phytoplankton and benthic microalgae), submarine groundwater are concluded to increase species richness and production of fishes and invertebrates through providing nutrients and enhancing primary production.

Relationship between hatch-date and recruitment of Japanese anchovy in central Seto Inland Sea, Japan

Masayuki Yamamoto[1,*] and Jun Shoji[2]

[1]*Kagawa Prefectural Fisheries Experimental Station, Takamatsu, Japan*
[2]*Field Science Education and Research Center, Hiroshima University, Hiroshima, Japan*
*ky0554@pref.kagawa.lg.jp

Japanese anchovy *Engraulis japonicus* is an important commercial species in Japan. Late larval and early juvenile anchovy (20-50 mm) called *"chirimen"* and/or *"kaeri"* are caught with boat seine-nets in Hiuchi-nada, central Seto Inland Sea. Spawning area approximately coincides with fishing ground in this area, which is a semi-narrow sea. The forecast of recruitment populations is required for efficient exploitation. However, we don't sufficiently understand which cohorts contribute greatly to recruitment, since the species spawns mainly from spring to autumn and catch is composed of several cohorts. The present study aims to understand how the survival probability differs among the cohorts. We examined the catch in number of semimonthly cohort in Hiuchi-nada off Kagawa Prefecture from late April to late July in 2010-2012, based on catch, length distribution and age-length key. Survival index was calculated for each cohort as the ratio of catch in number to egg production. Japanese anchovy spawned after late April or early May and main spawning period was between May and June. The catch (billion individuals) of Japanese anchovy < 50 mm was 8.9 in 2010, 2.5 in 2011 and 4.9 in 2012. The cohort in late May was abundant in 2010 and 2011, whereas the cohort in late May was a little and that in early July was abundant in 2010. Otolith analysis showed ages of Japanese anchovy (20-50 mm) ranged between 22 and 63 days. The catch in number and the survival indexes of the cohorts in June were relatively stable, whereas the values of the cohorts in May varied greatly. In 2010 and 2012 where the values of the cohorts in May were high, the recruitment was high in this area. We conclude that variability in survival probability of late larval and early juvenile Japanese anchovy cohorts in May affects recruitment abundance in Hiuchi-nada.

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

Memorandum

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

Memorandum

MEMORANDUM

Memorandum

MEMORANDUM

科研費 KAKENHI

FRA Fisheries Research Agency

http://cse.fra.affrc.go.jp/takasuka/gsp