**Attachment no 2**

# AUTOREFERAT

Information about scientific interests and achievements

## Application of the otolith microstructure analysis in the research on fish biology and ecology

**dr Dariusz P. Fey**

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Gdynia, May 2012

## 1. Full name

Dariusz Piotr Fey

## 2. Education and Scientific degrees

**Master's degree**

1993 University of Gdansk, Department of Biology, Geography and Oceanography (specialization: biological oceanography).

**Ph.D.**

2002; Sea Fisheries Institute.

(discipline: fisheries; specialization: ecology of early life stages of fish). Title: Otolith microstructure analysis of larval herring in the Vistula Lagoon (*Clupea harengus* L.) – recruitment investigation (supervisor: prof. Tomasz B. Linkowski); The thesis has been awarded by the Scientific Council on a proposal of the reviewers.

## 3. Employment

2003 - present

**National Marine Fisheries Research Institutey,**
**Dept of Fisheries Oceanography and Marine Ecology**

81-332 Gdynia, ul. Kołłątaja 1

Research scientist

2002 - 2003

**NOAA National Ocean Service, Beaufort Laboratory**

28-516 Beaufort, NC 101 Pivers Island Road, USA

Post-doc (National Research Council)

1996 - 2002

**Sea Fisheries Institute, Oceanography Department**

81-332 Gdynia, ul. Kołłątaja 1

Scientist

1994 - 1996

**School of Ocean and Earth Sciences and Technology, University of Hawaii**

96-822 Honolulu, HI 1680 East West Road, USA

Visiting scientist

1992 - 1994

**Sea Fisheries Institute, Oceanography Department**

81-332 Gdynia, ul. Kołłątaja 1

Oceanographer

# 4. Scientific achievements in agreement with „art. 16 ust. 2 ustawy z dnia 14 marca 2003 r. o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki (Dz. U. nr 65, poz. 595 ze zm.)"

## 4.1. Title of the scientific achievement

A series of publications from years 2002-2010, under common title „Application of the otolith microstructure analysis in the research on fish biology and ecology".

## 4.2. List of publications contributing to the scientific achievement

1) Hüssy, K., Hinrichsen, H.-H., **Fey, D. P.**, Walther, Y., Velasco, A. (2010). The use of otolith microstructure to estimate age in adult Eastern Baltic cod (*Gadus morhua* L.). Journal of Fish Biology 76: 1640–1654. (IF=1,33; cyt.: 1; 27 pkt)

   Input D.Fey: 30%; Participation in developing concept of this work, preparation of large part of the materials, minor participation in data analysis and text editing.

2) **Fey, D. P.**, Hare J. A., (2008). Fluctuating asymmetry in the otoliths of a larval Atlantic menhaden (*Brevoortia tyrannus*) - a condition indicator? Journal of Fish Biology 72: 121-130. (IF=1,25; cyt.: 4; 27 pkt)

   Input D.Fey: 80%; Idea and concept of work, technical preparation of materials delivered by J.Hare, data analysis, preparation of graphs and tables, writing all text, and corrections after review.

3) **Fey, D. P.**, Linkowski, T. B., (2006). Age prediction from otolith size measurements for juvenile Baltic cod (*Gadus morhua*). ICES Journal of Marine Science 63: 1045-1052. (IF=1,47; cyt.: 2; 32 pkt)

   Input D.Fey: 70%; Co-participation in development of the idea and concept of work, co-participation in technical preparation of materials; data analysis preparation of graphs and tables, writing all text, and corrections after review.

4) **Fey, D. P**., (2006). The effect of temperature and somatic growth on otolith growth: the discrepancy between two species from a similar environment. Journal of Fish Biology 69: 794-806. (IF=1,39; cyt.: 13; 27 pkt)

5) **Fey, D. P.**, Bath Martin, G., Morris, J. A., Hare J. A., (2005). Effect of otolith type and preparation technique on age estimation of larval and juvenile spot (*Leiostomus xanthurus*). Fishery Bulletin 103:544-552. (IF=1,58; cyt.: 1; 32 pkt)

   Input D.Fey: 80%, Idea and concept of work, technical preparation of materials delivered by G.Bath-Martin and J.Morris, data analysis, preparation of graphs and tables, writing all text, and corrections after review.

6) **Fey, D.P.** (2002) Formation of daily increments in otoliths of larval and juvenile herring (Clupea harengus L.) and early juvenile smelt (*Osmerus eperlanus* L.) in low food conditions. Archive of Fishery and Marine Research 49(3): 189-197. (IF=0,38; cyt.: 5; 13 pkt)

## 4.3. Description of the scientific goals and results of the listed publications

### 4.3.1. Introduction

Processes occurring in fish early life stages, especially those in the larval period, can impact year class fecundity even when spawning stocks are very large since mass larval mortality can result in weak adult fish generations. This is why the larval stage is often referred to as the critical period. Studies that permit identifying the survival mechanisms of early life stages of fish are exceedingly important, but they also require the application of appropriate tools that facilitate obtaining essential information. One such tool is otolith micro-structure analysis. (Fot. 1-4).

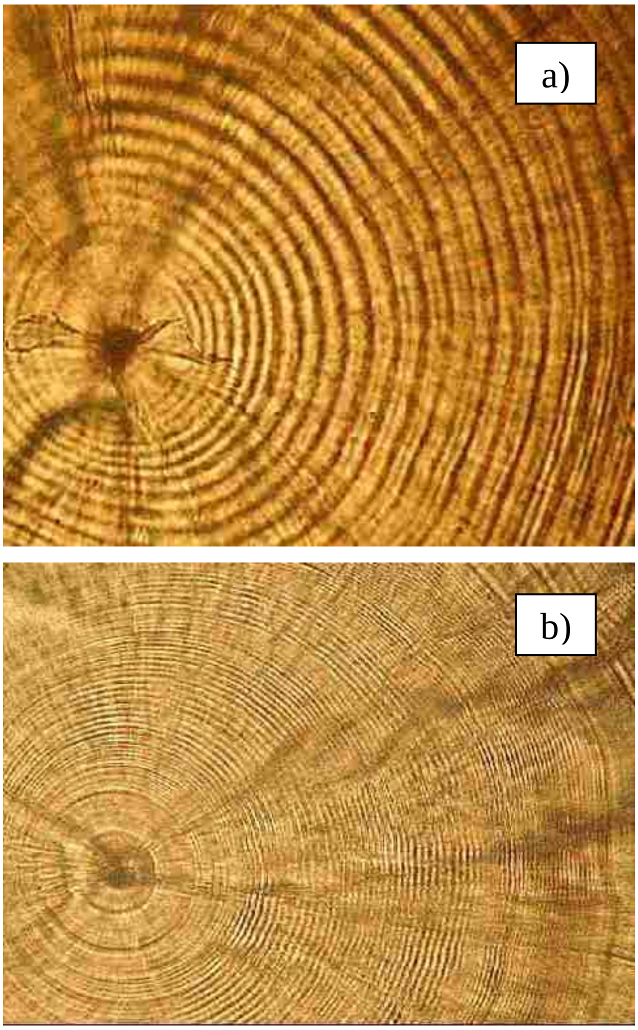
The possibility that growth increments on fish otoliths could be deposited with daily periodicity was first reported in 1971. The term growth increment (daily ring) refers to a structure comprising two zones that are visible in transmitted light under a microscope: they are a narrow dark strip known as the discontinuous zone and a wider, lighter strip known as the incremental zone. The differences in light permeability between these two zones results from the mutual proportions of calcium carbonate and proteins in the otoliths, which are linked to cyclical, daily changes in the metabolic activity of a given individual. Before the discovery of daily growth increments on otoliths, field studies of the ecology of larval fish did little more than determine the distribution and abundance of larvae in a given basin. Using the information recorded in otolith size and micro-structures, including the width of growth increments, facilitates obtaining information for both populations and individuals regarding age, hatch date, growth rate, condition, mortality, and changes in environments inhabited, among other aspects of fish ecology.

The mechanism of daily increment deposition is not as simple as it might initially seem. Identifying and, as far as is possible, explaining, the numerous, detailed issues encountered when using otoliths to study the ecology of early life stages of fish has been the focus of a significant portion of the research work I have pursued.

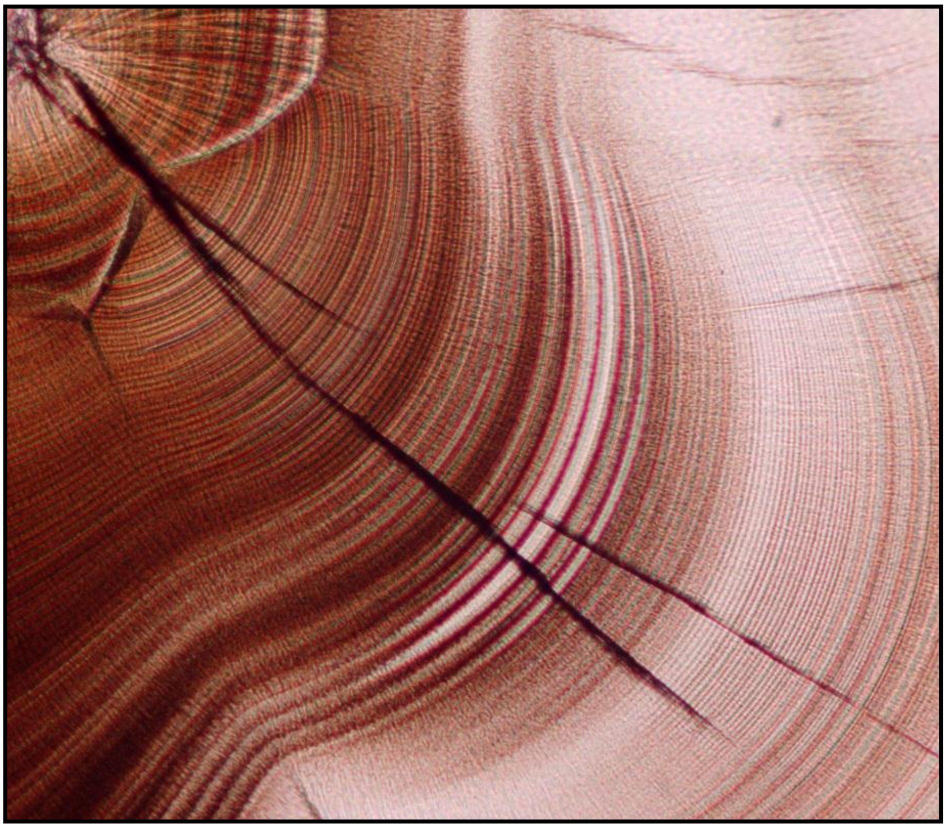
Fot. 1. Otoliths of 8 mm herring larva (fot. K. Horbowa).

The work listed as main scientific achievement was published after my Ph.D., but the beginning of my experience is related to two years (1994-95) during which I was participating in a scientific exchange program at the University of Hawaii (UH). I was working at that time in the laboratory of Prof. Richard Radtke, one of the pioneers of otolith research. The main areas of my research were: 1) verification of deposition rate and widths of daily increments on the otoliths of larval Arctic char (*Salvelinus alpinus*) held in various thermal and feeding conditions (experimental work); 2) comparing spawning time, growth rate and length of developmental stages of two populations of dolly varden (*Salvelinus malma*) based on information from otolith micro-structure analysis; 3) reconstruction of the migratory history of diadromous fish (e.g., *Salvelinus alpinus*) by analyzing the otolith Sr/Ca ratio; 4) research on the ecology of Hawaiian gobies (*Lentipis concollor*) using both otolith microstructure and otolith chemistry 5) Determining the content of elements such as Mg, Zn, Sr, and Ca in cross-sections of the fin rays of juvenile Atlantic cod reared at different temperatures. My involvement with these studies permitted me to gain, among others, hands-on experience with various techniques such as marking otoliths with tetracycline and alizarin, SEM analysis, and X-ray analysis of chemical composition of otoliths.

Following my return from the internship at the University of Hawaii, I began studies in the Vistula Lagoon, which goal was to identify the impact of environmental factors on the abundance, distribution, and growth rates of larval herring. In year 2002 I defended my doctoral dissertation, in which I presented characteristics of early life stages of herring that include, among others, hatch period, the impact of environmental factors such as temperature and food supply at the beginning and end of spawning and growth rate; the impact of the environment on changes in larval abundance within a single season and among years. This type of data for herring from the Baltic region are not readily available, while for the Vistula Lagoon they are the only data available.



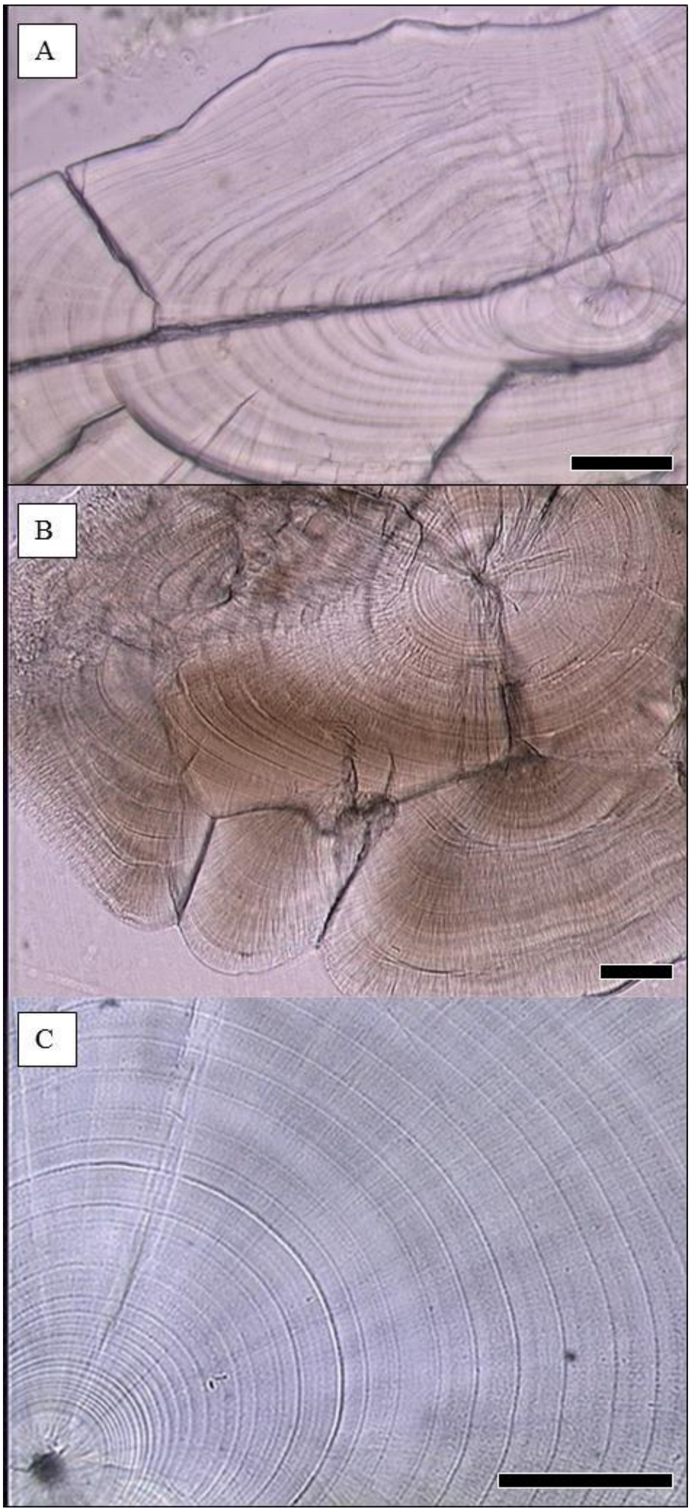

Fot. 2. Otolith microstructure of herring larvae hatched: a) spring, and b) autumn. Differences in increment widths indicate differences in experienced feeding and temperature conditions within few weeks after hatch.



Fot. 3. Daily increments in the otolith of juvenile cod. Increment width ca. 1 to 9 µm. The otolith has benn prepared by cutting and polishing the transverse section from both sides.

During the period when I was preparing my doctoral thesis, I also participated in the development of methods for verifying the effectiveness of the classification of adult herring into spring or fall spawning groups and determining the degree to which these two groups mixed during spawning time.

A substantial portion of the research that was conducted after I finished my doctorate, continues now and the results have yet to be published. However, work that has been published and that I have determined to be of particular scientific achievement is summarized in chronological order in the subsequent sub-chapter (4.3.2). The common goal of this was to verify the accuracy of the principles for effectively applying the possibilities presented by fish otolith analyses. We are potentially able to recreate the life histories of individual specimens beginning with




Fot. 4. Mikrostruktura otolitów *Leiostomus xanthurus:* a) strzałka - wycięty skrawek szlifowany z obu stron; b) strzałka – cały otolit szlifowany z obu stron; c) kamyczek, szlifowany z jednej strony.

determining the precise date of birth to the analysis of growth rate and condition and then migration history. Unfortunately, even the most precise analysis based on rich, long-term material will be worthless if the underlying principles are erroneous. For example, we can determine the number of increments on otoliths, but does the number of these actually reflect age? We can determine the growth curve of a particular individual based on the width of increments, but is otolith width actually correlated with fish growth rate? We can perform analyses using sagittae (one of the three otolith types), but is it not possible to obtain more precise results using lapilli? We can prepare otoliths for analysis by polishing, but perhaps the results would be more precise if we used transverse sections? We can, with a certain degree of precision, determine fish age without time-consuming otolith cutting and polishing if we apply age prediction models, but which parameters should be used in such equations? Will the analysis of fluctuating asymmetry, which performs well as an indicator of fish condition when the size of different body parts is compared, be as effective in comparisons of left and right otolith sizes? The answers to these and other questions regarding the methodological principles used in analyses of the microstructures of otoliths in biological and ecological studies of fish are presented in the summarized cycle of publications that follows. These publications not only provide verification of the methodological principles, but they also include concrete information on the biology and ecology of various fish species.

### 4.3.2. Short description of the results obtained in the publications described as “main scientific achievement”

**Fey, D.P. (2002). Formation of daily increments in otoliths of larval and juvenile herring (Clupea harengus L.) and early juvenile smelt (*Osmerus eperlanus* L.) in low food conditions. Archive of Fishery and Marine Research 49(3): 189-197.**

The goal was to verify the frequency at which increments were deposited on the otoliths of smelt and herring by 1) analyzing the marginal increments of herring and smelt caught in daily cycles in natural conditions, and 2) analyzing marked with tetraciclice otoliths of smelt kept in laboratory. In both cases, the fish experienced low food conditions. Results of these field and laboratory experiments not only permitted confirming the daily formation cycle of increments in both smelt and herring, but they also permitted determining the hour at which the two components of the daily ring are deposited (visible in transmitted light as dark and light rings). Interestingly, it was noted that the daily formation of the night increment takes a similar amount of time as does the deposition of the day-time ring despite it having a roughly ten-fold thinner width. Verification of the rate of increment deposition in the otoliths is essential if otoliths are to be used in other studies on age, growth and survival of fish early life stages.

**Fey, D. P., Bath Martin, G., Morris, J. A., Hare J. A. (2005). Effect of otolith type and preparation technique on age estimation of larval and juvenile spot (*Leiostomus xanthurus*). Fishery Bulletin 103:544-552.0**

The goal of this work was to verify experimentally the frequency of increment deposition on otoliths of larval *Leiostomus xanthurus*, and then determine the advantages and disadvantages of various age-determination methods. The results I obtained indicated that assumptions that had been applied to this species up to that point regarding the deposition of the first increment on the sagitta during the first exogenous feeding (which was at approximately 8 days post hatch) was in fact erroneous. This assumption was based on an experiment in which the authors determined the number of increments on the otoliths of larvae of a known age, but they failed to prepare the otoliths properly by filing and polishing, and this likely meant that fewer increments were visible than there actually were. The results of my analysis indicate that the first increment is deposited in larval *Leiostomus xanthurus* immediately after birth. Simultaneously, I also reported information regarding the possibility of reading the age of larval *Leiostomus xanthurus* based on lapillus analysis. This was the first report made regarding the use of lapilli for age determinations in the larvae of this species. I also compared the precision and reliability of age determinations from both types of otoliths. In brief, if we want to calculate age, it is better to use sagitta, but if we want to back-calculate growth rates, it is preferable to use lapilli. While the choice of the appropriate otolith is one question, how the sample is prepared is another. Either the whole otolith or a section of it can be filed on either  or both sides; I compared the advantages and benefits of applying these various methods. While the paper published in 2005 has several co-authors, I was responsible for developing the concept for the study, the technical analysis of the materials, processing the results, and writing the first draft of the manuscript. Poster presenting results of this study won the Best Poster Award during the Larval Fish Conference in Santa Cruz, CA (USA).

**Fey, D. P. (2006). The effect of temperature and somatic growth on otolith growth: the discrepancy between two species from a similar environment. Journal of Fish Biology 69: 794-806.**

Measurements of increments from the center to the edge permit making back calculations of growth rates, and as such reconstruct the life history of a given individual. The width of marginal increments permit determining the momentary condition and growth rate of a given individual in the period before catch. While valuable information is obtained with both of these analysis variants, the actual value of information depends on whether certain assumptions are fulfilled infallibly.

The most important is that there is a strong link between the growth rate of the fish larva and the growth rate of its otolith. While this assumption has been accepted for many years, my research has indicated that under certain conditions it might not be fulfilled, and this can lead to significant discrepancies in the results obtained during growth rate analysis. I have demonstrated that the reaction of otoliths to changes in larval growth rates is dependent on both environmental conditions such as high temperatures, which if they are often above the optimum, can cause otolith growth that is disproportional to larval growth rate, as well as fish species since the impact of temperature on the deregulation of the dependency described was noted among herring, but not smelt. The results of this study are cited as the only ones that take into consideration inter-specific differences among larvae inhabiting the same environment, and significantly, under natural conditions. The results presented in this publication provide a good example of certain mechanisms, which have long been considered to be straightforward and obvious (e.g., faster larval growth rate = wider increments on the otolith), are actually far more complex and do require appropriate verification.

**Fey, D. P., Linkowski, T. B. (2006). Age prediction from otolith size measurements for juvenile Baltic cod (*Gadus morhua*). ICES Journal of Marine Science 63: 1045-1052.**

Analyzing age by analyzing the daily increments on otoliths is labor intensive, which means it is also costly, especially when it is necessary to prepare the otoliths by cutting, filing, and polishing. One example is juvenile cod; the age of this species can be determined by counting the number of micro-increments on otoliths even in year-old specimens; reliable age determinations at the daily level in many species are only possible until the second or third month of life. This method is, however, hugely labor intensive, and only about 20% of the otoliths analyzed provide information about age since they are often either destroyed during filing or else the micro-structures are rendered illegible. One way of replacing this labor-intensive, inefficient method for reading age by analyzing otolith micro-structures could be an appropriate age prediction model that permits determining the age of individuals based on a range of variable such as fish weight and length, otolith sizes (length, diameter, surface area, and circumference), time of catch (day and year) and catch area. I presented such a model in an article published in the *ICES Journal of Marine Science*. While age prediction was the main theme of the paper as was reflected in the title, the paper also presents information regarding the period when the larval cod hatched in given years, and, thus, also information regarding the spawning period of the adult fish, and differences in larval growth rates in given years. The analysis performed for this paper also indicated the occurrence of the uncoupling phenomenon in cod, in which the otoliths of more slowly growing individuals are relatively larger. This can result in significant error in the results of back calculations of growth rates, which imposes the necessity of applying suitable parameterization in models used for back calculations. It must be underscored that this study was based on very extensive materials.

**Fey, D. P., Hare J. A. (2008). Fluctuating asymmetry in the otoliths of a larval Atlantic menhaden (*Brevoortia tyrannus*) - a condition indicator? Journal of Fish Biology 72: 121-130.**

This publication focuses on one of the methods for determining the condition/growth rate of larval and juvenile fish. Information about how fast a particular individual grew and in what kind of condition it was in can be obtained in several different ways such as body length/weight measurements, analysis of body lipids, RNA/DNA analysis, and the analysis of otolith micro-structures. Each of these methods has its peculiarities, advantages, and disadvantages. One method not mentioned above for studying the condition of living organisms, including fish, is the analysis of asymmetries in body parts, for example asymmetry in otolith size. Although this idea appeared some time ago, it has yet to be verified unambiguously. Therefore, I decided to attempt to confirm this theory using the very ample material I collected during my postdoctoral associateship at the Beaufort Laboratory. From among several thousand larval Atlantic menhaden (*Brevoortia tyrannus*), which represented widely varied growth rate values, and thus the average condition of life (fish size at a given age), I selected specimens with the highest and lowest conditions, and then I analyzed the degree of symmetry of their otoliths. Although the values of the growth rates were extremely different in the two groups compared, I was unable to detect statistically significant differences in otolith asymmetry. It follows that the hypothesis regarding the analysis of otolith asymmetry in ecology studies was not proven.

**Hüssy, K., Hinrichsen, H.-H., Fey, D. P., Walther, Y., Velasco, A. (2010). The use of otolith microstructure to estimate age in adult Eastern Baltic cod (*Gadus morhua* L.). Journal of Fish Biology 76: 1640–1654.**

The aim of the project, within which the publication was prepared, was to develop new methods for determining the age of individuals and the age structure of individual populations of Baltic cod. The age determination method proposed within the framework of the project is based on using otolith size measurements, information regarding the place and date of catch as well as biological information such as sex, length, or weight of the fish. The results presented in this publication indicated that age determinations from cod otoliths (annual increments) are not as reliable as it is considered - the zones of quick and slow otolith growth may be linked more to the temperature experienced by the fish, than to the age. The age of individuals can be estimated by enumeration of daily increments. Although this method is too laborious for routine cod-age analysis, it may be used to verify the results obtained with traditional methods.

### 4.3.3. Summary – for the publications listed as the main scientific achievement

In the majority of studies described, I have personally collected samples, performed the technical processing of the materials, processed the data, and written the text of the publications. I am also aware that this versatility, which was one a great burden, has permitted me to gain wide-ranging experience. This is especially true since the projects I have realized have focused on many different fish species and geographical areas.

Since the completion of my doctorate, the projects I have realized and the resulting publications can be classified into a few thematic categories (listed below) that contribute to realizing the main goal – to verify methodological assumptions and to provide tools allowing use of otolith microstructure analysis in the research on biology and ecology of fish.

1) <u>The strategy of choosing otolith type and preparation procedure to obtain expected scientific goal.</u>

Key element, influencing both quality of the obtained results and time (cost) necessary for the analysis.

2) <u>Validation of the daily increment formation rate in the otoliths of larval fish and annual rings in the otoliths of adult fish.</u>

The assumption about daily periodicity of increments deposition is not always fulfilled – that implies the necessity of increment deposition rate validation for different species of fish in different stage of development.

3) <u>The effects of larval fish growth rate and water temperature on the otolith growth rate and the relationship between fish and otolith size.</u>

Verification of assumptions related to mechanisms of otolith growth is necessary if trustful results are to be obtained during growth back-calculation.

4) Zastosowanie modelu do predykcji wieku wczesnych stadiów rozwojowych ryb.

Estimation of age of individual larvae with use of age prediction model allows significant reduction of time and cost necessary for analysis.

5) Use of otolith asymmetry analysis (*Fluctuating Asymmetry*) as larval fish condition indicator.

New methods can be applied in the research on larval and juvenile fish growth and condition, but earlier verification is necessary to obtain trustful results.

6) Direct use of otolith microstructure analysis in the research on larval and juvenilefish bioogy and Ecology.

During the research, which main goal was to verify different hypothesis and assumptions, I was also obtaining information like age composition, hatch dates, spawning dates, or growth rates, for different species of fish in different environments.

# 5. Description of other scientific achievements

(*according to §4 Rozporządzenia Ministra Nauki i Szkolnictwa Wyższego z dnia 1 września 2011 r. w sprawie kryteriów oceny osiągnięć osoby ubiegającej się o nadanie stopnia doktora habilitowanego*)

## 5.1. Publications after the Ph.D., (not included on the list in chapter 4 )

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5.1.1. **Fey, D. P.** (2012). Length adjustment of larval and early-juvenile cod (*Gadus morhua*) after up to three years of preservation in ethanol. Journal of Applied Ichthyology 1-2. doi: 10.1111/j.1439-0426.2011.01929.x

5.1.2. Sokołowska E. and **Fey, D. P.*** (2011). Age and growth of the round goby, *Neogobius melanostomus*, in the Gulf of Gdańsk several years after invasion: Is the Baltic Sea a new Promised Land? Journal of Fish Biology 78: 1993-2009. *corresponding author

5.1.3. Hernandez, F. J. Jr., Hare, J. A., **Fey, D. P.** (2009). Evaluating diel, ontogenetic and environmental effects on larval fish vertical distribution using generalized additive models for location, scale and shape (GAMLSS). Fisheries Oceanography 18, 4, 224–236.

5.1.4. **Fey, D. P.** (2005). Is the marginal otolith increment width a reliable recent growth index for larval and juvenile herring? Journal of Fish Biology 66:1692-1703.

5.1.5. **Fey, D. P.,** Hare, J. A. (2005). Length correction of larval and early-juvenile Atlantic menhaden (*Brevoortia tyrannus*) after preservation in alcohol. Fishery Bulletin 103:725-727.

5.1.6. Opaliński, K., Maciejewska, K., Krajewska-Sołtys, A. and **Fey, D.P.** (2004). Production and oxygen consumption in the early life stages of herring and smelt in the Vistula Lagoon (Baltic Sea). Bulletin of the Sea Fisheries Institute 2(162): 13-22.

5.1.7. **Fey, D. P.** (2002). Length correction of larval and early-juvenile herring (*Clupea harengus* L.) and smelt (*Osmerus eperlanus* L.) after preservation in formalin and alcohol. Bulletin of the Sea Fisheries Institute 1(155): 47-51.

## 5.2. Summary of the results obtained in the listed above publications

**Fey, D. P. (2002). Length correction of larval and early-juvenile herring (*Clupea harengus* L.) and smelt (*Osmerus eperlanus* L.) after preservation in formalin and alcohol. Bulletin of the Sea Fisheries Institute 1(155): 47-51.**

One of the most frequently used measurements conducted during studies on the ecology and biology of larval fish is body length of analysed individuals. The precision and accuracy of that measurement is crucial for example for the analysis of growth rate. Unfortunately, storing materials in formalin or alcohol cause changes in body size of larval fish. Those changes are especially significant in case of small specimens. The goal of this work was to analyze the shrinkage of larval smelt and herring preserved in alcohol and formalin. The publication included a mathematical formula to calculate the length of the larvae prior to preservation.

**Opaliński, K., Maciejewska, K., Krajewska-Sołtys, A. and Fey, D.P. (2004). Production and oxygen consumption in the early life stages of herring and smelt in the Vistula Lagoon (Baltic Sea). Bulletin of the Sea Fisheries Institute 2(162): 13-22.**

The goal was to evaluate and compare in experimental conditions the growth rate (production) and energetic expense (oxygen consumption) of two pelagic species co-occurring in the Vistula Lagoon – herring and smelt. The results showed that the production for these two species was similar but the oxygen consumption for herring was twice that of smelt. That indicates that body mass production is much more effective for smelt comparing to herring. Such information is especially valuable if possible food competition between these two species – occurring at the same time in the same environment – is considered.

**Fey, D. P., Hare, J. A. (2005). Length correction of larval and early-juvenile Atlantic menhaden (*Brevoortia tyrannus*) after preservation in alcohol. Fishery Bulletin 103:725-727.**

The goal of this work was to analyze the magnitude of shrinkage of larval menhaden preserved in alcohol. The importance of this results was described already in the summary of publication on shrinkage of herring and smelt. Also for menhaden formula allowing fresh length calculation has been presented.

**Fey, D. P. (2005). Is the marginal otolith increment width a reliable recent growth index for larval and juvenile herring? Journal of Fish Biology 66:1692-1703.**

The choice of the type of otolith and the method of its preparation are the first steps to take towards further analysis, during which we can obtain a variety of information. One of such analysis can be, described in this publication, analysis of the width of marginal increments - permit determining the momentary condition and growth rate of a given individual in the period before catch. It is important, however, so the assumption about link between fish growth rate and otolith growth rate is fulfilled. Results obtained in this work indicated that widths of increments formed on otoliths of herring larvae collected during three years were dependent first of all on temperature. Feeding conditions didn't play a significant role.

**Hernandez, F. J. Jr., Hare, J. A., Fey, D. P. (2009). Evaluating diel, ontogenetic and environmental effects on larval fish vertical distribution using generalized additive models for location, scale and shape (GAMLSS). Fisheries Oceanography 18, 4, 224–236**

In 2008, a research project was initiated in the Department of Oceanography entitled "Polish-American co-operation for plankton studies – implementing the ecosystem approach in fisheries management". A joint paper was published in 2009 regarding the application of the GAMLSS (Generalized Additive Models for Location, Scale, and Shape) and AIC (Akaike Information Criteria) models for analyzing the vertical distribution of *Urophycis regia* larvae collected in daily cycles in the area of Western Atlantic. Significant differences in distribution of preflexion and postflexion larvae were obtained. Additionally, the effect of different factors – e.g., time of day, wind strength, current strength, water stratification – on the larvae distribution has been described. Presented results provided not only specific information for *Urophycis regia* larvae, but also showed the usefulness of using GAMLSS model for the research on larval fish distribution.

**Sokołowska E. and Fey, D. P. (2011). Age and growth of the round goby, *Neogobius melanostomus*, in the Gulf of Gdańsk several years after invasion: Is the Baltic Sea a new Promised Land? Journal of Fish Biology 78: 1993-2009.**

Round goby (*Neogobius melanostomus*) i san invasive species noted in Polish waters for the first time in 1990. jest gatunkiem inwazyjnym, po raz pierwszy zaobserwowanym w wodach polskich w roku 1991. The main goal of this work was to provide biological characteristics (age, size, sex, growth rate, condition, etc.) of this species in the Gdańsk Bay. Additionally, we analyzed the suitability of using round goby otoliths for back calculations of growth rate, which is the first report of this type for this species. We also verified the frequency of the deposition on otoliths of annual increments. One of the results of this work was the confirmed occurrence of a round goby specimen older than 6+; this is the first report of this kind in Polish waters. Results presented in this publication clearly indicated that round goby found in the Baltic Sea advantageous for growth and survival condition.

**Fey, D. P. (2012). Length adjustment of larval and early-juvenile cod (*Gadus morhua* L.) after up to three years of preservation in ethanol. Journal of Applied Ichthyology 1-2.**

Presented in this publication shrinkage correction formula is the only available for cod from the size range covering larvae and juveniles (4-40 mm). Additionally, the results base on three-year storage period.

## 5.2.1. Summary of the research activities of Dr. Dariusz Fey (based on work already published in reviewed journals)

### Otolith microstructure research

#### Supporting information

- Korekta kurczliwości larw
  *Fey 1999, 2002, 2012; Fey i Hare 2005.*
- Wybór otolitu oraz metody przygotowania
  *Fey i inni 2005.*

#### Verification of methods

- Validation of increment deposition
  *Radtke i Fey 1996; Fey 2002; Fey i inni 2005; Hüssy i inni 2010.*
- Otolith and larvae growth rate relationship
  *Fey 2005, 2006; Radtke i Fey 1996; Hüssy i inni 2010.*
- „Fluctuating Asymmetry" in condition research
  *Fey i Hare 2008.*
- Age prediction – best model
  *Fey i Linkowski 2006.*
- Otolith chemistry and fish migrations
  *Radtke i inni 1999a, 1999b.*

#### Providing biological data

- Age, growth, spawning and hatching time
  *Radtke i Fey 1996; Radtke i inni 1996a, 1996b; Fey 1999; 2001; Fey i Linkowski 2006; Fey i Hare 2008.*

### Other research

- Bioenergetics of larval fish
  *Opaliński i inni 2002.*
- Larval fish distribution
  *Hernandez i inni 2009.*
- Biology of adult fish
  *Radtke i inni 1996; Hüssy i inni 2010; Sokołowska i Fey 2011.*

## 5.3. Leading of international and national projects or participation in them

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**Projects of Ministry of Science and Higher Education**

- Oct 2010 – Apr 2013; N N304 03 1239, regular project, **project leader**. Environmental effects on the abundance, distribution, and growth of larval herring in the Pomeranian Bay in years 1992-98 and 2007-10.

- Oct 2009 – May 2012; N N304 16 1937, regular project, **project leader**. Effect of feeding and hydrological conditions on the growth rate of larval sprat (*Sprattus sprattus*) in southern Baltic.

  May 2008 – Dec 2010; N N304 26 5234; MIR, habilitation project, **project leader**. Otolith microstructure and size analysis in the research on the ecology of larval and juvenile fish.

- Apr 2006 – Nov 2007; 2 P04F 060 30; MIR, regular project, **project leader**. The mechanism of fish early life stages survival on the example of smelt (*Osmerus eperlanus* L.).

- Nov 2004 – Oct 2005; 2 P04F 009 27; MIR, regular project, **project leader**. The influance of fish growth rate on the survival of larval Atlantic menhaden (*Brevoortia tyrannus*) – otolith microstructure analysis.

- Apr 2001 – Mar 2002; 6 P04F 053 20; MIR, supervisor's project, **main participant**. Daily otolith increments analysis of early life history stages of herring (*Clupea harengus*) in the Vistula Lagoon

**UE Projects**

- 2012 – 2014; HERRING, Joint cross-border actions for the sustainable management of a natural resource (**leader of the Polish part);**
- 2010 – 2015; Euro-BASIN, European Union Basin-scale Analysis, Synthesis and Integration **(participant)**;
- 2007 – 2009; DECODE, Improved methodology for cod age estimation (**leader of the Polish part**);
- 2006 – 2010; UNCOVER, Understanding the Mechanisms of Stock Recovery (**main participant on the Polish side**);
- 2006 – 2008; EuroOcean, European network of excellence for ocean ecosystems analysis (**participant**).

**Leading of the projects supported by the Ministry of Science and Higher Education – statutory activities of the SFI**

- 2012 – present, PBI MIR-PIB; Ecology of coastal ecosystems (large project involving different Departments).
- 2007 – present, SFI/0-153; Polish-American cooperaton n the ichthioplanktop research – implementation of the ecosystem approach to fisheries management.
- 2006 – present, SFI/0-151; Ecology of early life history stages of herring and smelt in the Vistula Lagoon and Pomeranian Bay.
- 2004 – 2005, SFI/0-145; Otolith research application in the research on the ecology of early life history of fish.

**Other**

- Cruse leader on r/v Baltica (2005 – present)

## 5.4. International and national awards for scientific activities

- **Best Poster Award**; 27th Annual Larval Fish Conference, Santa Cruz, USA; 2003.
- **National Research Council (NRC) Associateship Award –** prestigious, one-year stipend; Washington, USA; 2002-2003.
- **Ph.D. Thesis distinction** awarded by the Scientific Council of the SFI on the proposal of reviewers; Gdynia; 2002.
- **SFI Director award** for scientific activity; 1996, 1999, 2001, 2002, 2004, 2005 and 2006.
- **One-year salary bonus** for scientific activity awarded by the SFI Director; 2009, 2011.
- **Foundation for Polish Science –** prestigious stipend for young scientists; 1999.
- **Dean's Award** for the best students of the department of Biology, Geography and Oceanology, Gdańsk University; 1992.

## 5.5. Oral presentations at international conferences

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- **Fey, D. P** (2007). 31th Annual Larval Fish Conference. St. John's, Canada, 9 - 12 July.
- **Fey, D. P.**, Hare, J. A, Laban, E. (2004). Queensland, Australia,11-16 July 2004.
- **Fey, D. P.**, Hare, J. A, Laban, E. (2004). ICES Annual Science Conference. Vigo, Spain. 22-25 September.
- **Fey, D. P.** (2001). 25th Annual Larval Fish Conference. Sandy Hook, New Jersey, USA, 8-13 August 2001.
- **Fey, D. P.** (2001). Variability of the Baltic Sea environment and living resources: Responses to climate change and anthropogenic pressure. Gdynia, Poland, 22-23 June 2001.
- **Fey, D. P.** (2000). An International Symposium on Expectations for a New Millenium. Anchorage, Alaska, USA, February 23-26, 2000. Book of abstracts p. 11.
- **Fey, D. P.** (2000). ICES CM 2000/Z:02., pp. 10 Brugge, Belgium.
- **Fey, D. P.** (1999). ICES Young Scientist Conference on Marine Ecosystem Perspectives. Gilleleje, Denmark, November 20-24, 1999. Book of Abstracts p. 15.
- **Fey, D. P.** (1999). Twenty Fifth Anniversary U.S. – Poland Joint Agreement, Gdynia, Poland, 5-6 July 1999. Book of Abstracts p. 5.
- **Fey, D. P.** (1998). Symposium of Freshwater Fish and the Herring Population in the Baltic Coastal Lagoons - Environment and Fisheries. Gdynia, Poland, 5-6 May 1998. Book of Abstracts p. 6.
- **Fey, D. P.** and Margoński, P. (1998). Symposium of Freshwater Fish and the Herring Population in the Baltic Coastal Lagoons - Environment and Fisheries. Gdynia, Poland, 5-6 May 1998. Book of Abstracts p. 6.

## 5.6. Poster presentation at international conferences

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- Pawełczyk A., **Fey D.P.**, Woźniczka A. (2011). ICES Annual Science Conference, 19-23 September 2011, Gdańsk, Poland.

- Pawełczyk A., **Fey D.**, Woźniczka A. (2009). XXI Zjazd Hydrobiologów Polskich, 9-12 września, Lublin.

- **Fey D. P.** (2009). Symposium on Fish Otolith Research and Application. Monterey, USA, 22-30 August. **P**

- **Fey D. P.** (2008). 32nd Annual Larval Fish Conference, 9-12 July 2007, Kiel, Germany

- **Fey, D. P.** (2005). 29th Annual Larval Fish Conference. Barcelona, Spain, 11 - 14 July.

- **Fey, D. P**, Bath Martin, G, Morris, J. A., Hare, J. A. (2004). Third International Symposium on Fish Otolith Research and Application, Queensland, Australia,11-16 July 2004.

- Hare, J. A, **Fey, D. P.**, Bath Martin, G., Morris, J. A (2004). Third International Symposium on Fish Otolith Research and Application, Queensland, Australia,11-16 July 2004.

- **Fey, D. P**., Bath-Martin, G., Hare, J. A., Morris, J. A. (2003). 27th Annual Larval Fish Conference. Santa Cruz, California, USA, 20-23 August 2003.

- **Fey, D. P**. (1998). Second International Symposium on Fish Otolith Research and Aplication. Bergen, Norway, 20-25 June 1998. Book of Abstracts p. 124.

## 5.7. Participation in international conferences because of administration-related activities (e.g., ICES Science Committee, Publication Committee, Award Committee)

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- 2011 r. - ICES Annual Science Conference. Poland, 23-27 September.
- 2010 r. - ICES Annual Science Conference. France, 21-25 September.
- 2009 r. - ICES Annual Science Conference. Berlin, Germany, 21-25 September.
- 2004 r. - 28th Annual Larval Fish Conference. Clemson, SC, USA, 23-26 May.
- 2004 r. - 5-th EFARO Workshop: How can otolith research contribute at improving fisheries sciences? Brest, France, 2-4 December.

## 5.8. Bibliometric information

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**Hirsch Index (WoS)**

H = 7

**Cumulative Impact Factor for publications ( JCR, for the year of publication)**

| | |
|---|---|
| Main scientific achievement: | IF = 7,4 |
| Other after Ph.D.: | IF = 7,58 |
| Before Ph.D.: | IF = 6,96 |
| Sume: | IF = 21,94 |

**Number of points MNiSW (according to the MNiSW list of 08.08.2011 r. ; only Philadelphic list)**

| | |
|---|---|
| Main scientific achievement: | 158 pts |
| Other after Ph.D.: | 148 pts |
| Before Ph.D.: | 158 pts |
| Sume: | 464 pts |

**Number of citations (WoS)**

| | |
|---|---|
| Main scientific achievement: | 26 cit. |
| Other after Ph.D.: | 20 cit. |
| Before Ph.D.: | 106 cit. |
| Sume: | 152 cit. |

The citations appeared mostly in the following journals:

| | |
|---|---|
| - Journal of Fish Biology | (5-year IF=1,52) |
| - Fisheries Research | (5-year IF=1,76) |
| - Marine Ecology Progress Series | (5-year IF=2,99) |
| - Fisheries Oceanography | (5-year IF=2,59) |