Course title
Dynamical Systems Theory in Biology and Oceanography

ECTS code

Name of unit administrating study
Department of Physical Oceanography

Studies

Field of study	Type	Form	Specialization
Oceanography	Bachelor's degree studies	Full-time studies	all
Oceanography	Master's degree studies	Full-time studies	all

Teaching staff
prof. UG dr hab. Witold Cieślikiewicz

Forms of classes, the realization and number of hours

A. **Forms of classes**
Lecture
Practical classes/ classes

B. **The realization of activities**
Lectures in the classroom
Interactive work with computers

C. **Number of hours**
45 lectures
35 exercises

ECTS credits
7

The academic cycle
summer 2014/15

Type of course
elective

Language of instruction
English

Teaching methods
Lecture:
- Lecture with multimedia presentation
- Analysis of source materials (publications, Internet resource, specialised software operator manual)
- Discussions

Classes:
- Computer computation and simulation
- Problem solving
- Brain storming in group
- Discussions and debates
- Analysis of source materials (specialized software operator manual, data)

Form and method of assessment and basic criteria for evaluation or examination requirements

A. Final evaluation
graded credit

B. Assessment methods
Lecture:
- midterm test/exam which is a written exam
- final exam which consists of a written and an oral part

Exercises:
- homework sets – homework will generally be due a week after it is assigned, no late homework will be accepted.

C. The basic criteria for evaluation
homework sets (30%),
midterm test/exam (30%),
final exam (40%),

Required courses and introductory requirements
A. Formal requirements: Mathematics for oceanographers, Physics for oceanographers.
B. Prerequisites: Computer. Ability to use Windows to the extent of editing a text file and installing a software package throughout the Internet

Aims of education

Students will learn in a clear and accessible way many concepts from contemporary dynamics that have applications in biology and oceanography, in particular in such areas as biological oceanography, ecology, geophysical fluid dynamics, coastal hydrodynamics, and marine geology. The concepts studied include stability, periodic and chaotic behaviours of nonlinear systems, fractals, cycles, and complex dynamical systems. Students will learn on how to extract information about dynamics form data and will study time-series analysis techniques that allow one to investigate chaotic behaviour of a system.

The course is meant to attract a wider range of students of oceanography, not only those interested in strict physical oceanography. I hope to demonstrate with this course the beauty and power of mathematics in general, and its practical applications in biology and oceanography as well as the excitement of dynamical systems in particular. However, the mathematical prerequisites for this course are very modest. The actual course will start with a reminder of important background mathematical material from calculus, linear algebra, and complex numbers. This mathematical background to the course will also give a gentle introduction to differential equations.

The computer is an extraordinary visual and numerical exploration tool for dynamical systems. The computer programming language used in this course is *Mathematica,* which is a very powerful high-level programming language. *Mathematica* is used for the following reasons: computations are written in a *Mathematica* program in almost exactly the same way as the user would express them; the *Mathematica* language is very simple and easy to understand; *Mathematica* allows for a symbolic programming, on one hand, and has extensive numeric capabilities, on the other hand; *Mathematica* has extensive and easy-to-use graphics capabilities which make it possible to use scientific visualisation to analyse computer computation and simulation results; *Mathematica* is actually an integrated computing environment with an extremely well designed user interface called *a notebook* that allows one to use the computing system in an interactive way. The course will start with introduction on *Mathematica* programming for writing symbolic and numerical computation and simulation programs with emphasis given to functional style of programing, i.e. (i) looping is mostly avoided, (ii) conditional branching is minimised (iii) lists being the general data structures are manipulated in their entirety rather than in a piecemeal fashion, (iv) built-in *Mathematica* functions are utilised whenever possible, and (v) *anonymous* functions and *nested* function calls are used extensively.

Course contents

I. Elements of *Mathematica* programming

1. Symbolic programming.
2. Lists.
3. *Mathematica* functions and functional programming.
4. Graphics and animations in *Mathematica*.
5. Illustrative short programs and examples.

II. Mathematical background

1. Complex numbers.
2. Mathematical sequences.
3. Functions.
4. Derivatives.
5. Indefinite and definite integrals.
6. Basics of ordinary differential equations.
7. Nonlinearity and nonlinear differential equations.
8. Matrices and elements of linear algebra.
9. Basics of vector calculus.

III. Basics and selected general problems of Dynamical Systems Theory

1. Concept of a dynamical system: state vectors, phase space, attractors, discrete time and continuous time, examples.
2. Maps and flows, Poincaré map.
3. Reconstructing the dynamics of the system: return maps, reconstructing the phase plane.
4. Linear systems in one and more dimensions: Markov chains.
5. Nonlinear systems: fixed points, stability, Lyapunov functions, periodicity in a two-dimensional dynamical system
   i. continuous time: Lorentz system and chaos
   ii. discrete time: stability of periodic points, bifurcation and computer-generated bifurcation diagrams.
6. Boolean networks and cellular automata.
7. Fractals: Cantor set, Sierpiński triangle, Koch's snowflake, fractal dimension, fractals in nature and dimension of physical fractals, examples.
8. Complex dynamical systems: Julia sets, the Mandelbrot set.
9. Strange attractors.
10. Characterising chaos.

IV. Specific topics in biology and oceanography

<u>Biology</u>

1. Model of fly population: nonlinear finite-difference equations, cycles and their stability, chaos and the period-doubling route to chaos; bifurcation diagram and Feigenbaum's number; Nicholson's blowflies differential equations with inputs.
2. Chaos in periodically stimulated heart cells.
3. Locomotion in salamanders: Boolean networks and cellular automata.
4. Game of "Life": cellular automata with a rule inspired by interactions of living organisms with one another.
5. Brownian motion and Lévy walks: fractals and nonlinear dynamical systems, random walks with self-similar dynamics and power-law scaling.
6. Growth in an *E.coli* colony: the Eden model for growth.
7. Predator and prey biological system: a classical model of an ecological Lotka and Volterra system.

<u>Oceanography</u>

1. Diffusion limited aggregation (DLA) and models of coral reef growth as an example of fractal growth.
2. Why it may be so hard to predict weather: dynamics in three dimensions; Lorentz equations, butterfly effects and chaos.
3. Lagrangian chaos: chaotic mixing of fluids, Stokes flow in a circular container.
4. Vortex movement.
5. Chaos in the North Pacific SST.

Bibliography of literature

1. Gaylord, R. J. and Wellin, P. R. (1995). *Computer Simulations with Mathematica.* Springer-Verlag, New York.
2. Hazrat, R. (2010). *Mathematica: A Problem Centered Approach.* Springer-Verlag, London.
3. Hearn, C. J. (2008). *The Dynamics of Coastal Models.* Cambridge University Press, New York.
4. Kaplan, D. and Glass, L. (1995). *Understanding Nonlinear Dynamics.* Springer-Verlag, New York.
5. Maeder, R. E. (1997). *Programming in Mathematica (3rd Edition).* Addison Wesley Longman, USA.
6. McWilliams, J. C. (2006). *Fundamentals of Geophysical Fluid Dynamics.* Cambridge University Press, New York.
7. Moon, F. C. (1992). *Chaotic and fractal dynamics.* John Wiley & Sons, New York.
8. Overland, J. E., Adams, J. M. and Mofjeld, H. O. (2000). Chaos in the North Pacific: spatial modes and temporal irregularity. *Progress in Oceanography,* **47**, 337–354.

9. Scheinerman, E. R. (1996). *Invitation to Dynamical Systems.* Prentice-Hall, New Jersey.
10. Wellin, P. R. (2013). *Programming with Mathematica*. Cambridge University Press, New York.

The learning outcomes	**Knowledge** • Graduates will have the basic knowledge of the Dynamical Systems Theory and its applications in biology and oceanography.
	Skills • Graduates will be able to effectively use the scientific method and scientific reasoning both qualitatively and quantitatively including manipulation and analysis of numerical data or observable facts resulting in informed conclusions. • Graduates will have computational and programming skills common to modern applications in natural sciences. • Graduates will be able to effectively communicate scientific information in writing, oral, and visual presentations. • Graduates will be able to carry out independent project-based activity involving creative thinking, innovation, inquiry, analysis, and synthesis of information.
	Social competence • Graduates will be able to work effectively with others within teams to support a shared purpose or goal and to consider different points of view.

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Course title Fish Biology	**ECTS code**

Name of unit administrating study
Department of Marine Biology and Ecology

Studies

Field of study	Type	Form	Specialization
Oceanography, Biology	Bachelor's degree studies	Full-time studies	
Oceanography	Master's degree studies	Full-time studies	

Teaching staff
prof. UG dr hab. Mariusz Sapota, prof. UG dr hab. Konrad Ocalewicz, dr Anna Pawelec

Forms of classes, the realization and number of hours

A. Forms of classes
lectures
laboratory

B. The realization of activities
classrooms of Institute of Oceanography

C. Number of hours
75 (lectures 30 h, laboratory 45 h)

ECTS credits: 5
Classes demanding of direct participation the teacher 3 ECTS / 80 hours
- participation in lectures and exercises :75 hours
- participation in consultation: 5 hours

Student's own work
2 ECTS / 50 hours
- literature reading
- laboratory reports prepared for each block of exercises (reports are group and individual)
- final presentation
- preparing to final test
- preparing for final exam

The academic cycle
summer semester 2014/2015

Type of course
elective

Language of instruction
English

Teaching methods
Lecture with multimedia presentation
Labs
- Practical analysis of fish material (anatomy, reproduction, behaviour, genetics)
- Basic elaboration of obtained data (population structure, age, rate of growth)
- Discussion

Form and method of assessment and basic criteria for evaluation or examination requirements

A. Final evaluation
graded credit

B. Assessment methods
Grades will be determined according to:
Labs:
attendance control, continuous assessment, lab reports, final written assessment (test)
Lectures:
final written (test) and oral assessment

D. The basic criteria for evaluation
Labs:
final grade based on partial marks received during the course:
10% activity
15% lab reports
75% final test
Lectures:
80% test
20% oral exam

Required courses and introductory requirements
A. Formal requirements none
B. Prerequisites basic knowledge of zoology

Aims of education
This course gives a knowledge of the basic fish biology and ecology with special emphasis to marine fishes. Basic methods of ichthyological investigations will be presented and practice.

Course contents
1. Fish Biology Investigation Principles
2. Fish Anatomy
3. Fish Reproduction
4. Fish Growth
5. Fish Behaviour
6. Fish Ecology
7. Fish Genetics

Bibliography of literature

Bone Q.M.A., Marshall N.B., 1982, Biology of fishes, Blackie, Glasgow and London
Brown T. A. , 2006, Genomes., Garland Science;
Cailliet G.M., Love M.S., Ebeling A.W., 1986, Fishes, Wadsworth Publishing Company, Belmont, California
Campana, S. E., and J. D. Neilson. 1985. Microstructure of fish otoliths. Can. J. Fish. Aquat. Sci. 42:1014-1032
Emery W.J, Thomson R.E., Data analysis methods in physical oceanography. Elsevier 1997
Fletcher H., Hickey I., Winter P., 2007, Genetics, Taylor & Francis,
Hartl D.L., Clark A.G., 2007, Principles of population genetics, Sinauer Associates, Sunderland
Hoar W.S. & D.J. Randall, Fish physiology, 2011
Holt G. J., Larval fish nutrition, Wiley Blackwell, 2011
Huet M., 1994. Textbook of Fish Culture. Breedimg and Cultivation of Fish. Fishing New Books, Blaxwell Stientific Publ., Ltd., Oxford.
Lagler K.F., Bardach J.E., Miller R.R., May Passino D.R., 1997, Ichtyology, Wyd. John Willey & Sons, New York, Chichester, Brisbane, Toronto
Lagler K.F., Bardach J.E., Miller R.R., May Passino D.R., 1997, Ichtyology, Wyd. John Willey & Sons, New York, Chichester, Brisbane, Toronto
M. Landau, Introduction to Aquaculture, Wiley, 1991
Richmond, Handbook of Microalgal culture, Blackwell, 2003
Ricker W.E., 1975, Computation and Interpretation of Biological Statistics of Fish Populations, Department of the Environment Fisheries and Marine Service, Ottawa 1975, p:382
Schreck C.B., Mole P. B., 1990, Methods for Fish Biology American Fisheries Society, Bethesda, Maryland
Sloman K., Balshine S.,Wilson R. (eds), Fish Physiology: Behaviour and Physiology of Fish, ELSEVIER, Academic Rress, 2005, pp. 504
Smith L.S.. 1982. Introduction to Fish Physiology- T.F.H. Publication, Inc.
Wotton R. J., 1992, Fish Ecology, Springer; ISBN-10: 0216931525

Extracurricular readings
Baldisserotto Bernardo, J.M. Mancera Romero, B.G. Kapoor (Eds) 2007. Fish Osmoregulation. Science Publishers
Campana, S. E., and J. D. Neilson. 1985. Microstructure of fish otoliths. Can. J. Fish. Aquat. Sci. 42:1014-1032
David H. Evans, James B. Claiborne (Eds). 2005. The Physiology of Fishes, Third Edition. Hardback CRC Press
Harden Jones F. R., 1970, Fish migrations Edward Arnold Ltd. London

Hoar W.S., D.J. Randall. 1971. Fish Physiology (I-V). Academic Press Inc
Roderick Nigel Finn, B.G. Kapoor (Eds). 2008. Fish Larval Physiology. Science Publishers.
Schreck C.B., Mole P. B., 1990, Methods for Fish Biology American Fisheries Society, Bethesda, Maryland
Secor, D .H., J. M. Dean, and E. H. Laban. 1992. Otolith Removal and Preparation for Microstructural Examination: A User's Manual. The Electronic Power Research Institute and the Bell W. Baruch Institute for Marine Biology and Coastal Research

The learning outcomes	**Knowledge** [K_1, K_K02, K_K08] Students correctly describe the fish role in water ecosystems functioning [K_2, K_K07] Students understand how to draw conclusions and make inferences based on basic parameters of fish populations [K_3, K_K09] Students understand and can describe basic concepts in the field of fish biology [K_4, K_K10] Students describe basic concepts related to the fish ecology, particularly in the Baltic Sea [K_5, K_K11] Students are familiar with conceptual categories and ichthyological terminology in Latin language [K_6, K_K14] Students know the basic techniques, research methods and tools that are used on the job by a fish biologist [K_7, K_K15] Students distinguish specific tools that are proper for basic ichthyological investigation and can explain the rules of their application [K_8, K_K16] Students recognize potential threats to fish communities structure resulting from the development of civilization, in particular from intense human impact in the Baltic Sea [K_9, K_K17, K_K18] Students describe the basic role of fish as marine resources [K_10, K_K20] Students define the basic rules of safety in ichthyological laboratory
	Skills [S_1, K_S01] Students independently search for and comprehend English literature in the field of fish biology [S_2, K_S04] Students use the available sources of ichthyological information, including multimedia and internet resources [S_3, K_S05] Students evaluate and elaborate the used resources of fish biology knowledge [S_4, K_S06] Students choose and apply the basic research techniques and tools in the field of fish biology that are adequate for the considered research problem [S_5, K_S12] Students conduct observations and the laboratory- and field-based basic ichthyological measurements [S_6, K_S07] Under the supervision of academic advisor, students perform the basic scientific tasks related to the fish analysis by using the appropriate descriptive and identification methods [S_7, K_S15] Students prepare a documented elaboration or multimedia presentation poster on the selected problem in fish biology
	Social competence [C_1, K_C01, K_C10] Students know the limitations of their own ichthyological knowledge, understand the necessity of life-long learning and professional training [C_2, K_C03] Students can cooperate and work as an fish biology research team by assuming different roles in [C_3, K_C05, K_C09] Students are aware of the importance of professionalism in ichthyological work They critically evaluate the level of their progression [C_4, K_C06] Students show activity, persistence and promptness during the

	realization of individual and team-based fish biology tasks [C_5, K_C11] Students are responsible for their own and others' safety at work [C_6, K_C12] Students are aware of the risks and threats associated with working as a fish biologist in the laboratory, at sea and on land [C_7, K_C13] Students are responsible for the specialized ichthyological and fishery equipment for the laboratory and field research, which had been entrusted to them [C_8, K_C15] Students understand the necessity of posing questions and problems in order to broaden their knowledge in the field of fish biology

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