ARCHIVUM SOCIETATIS ZOOLOGORUM POLONIAE

ZOOLOGICA POLONIAE

2016 **VOL. 61** **FASC. 1-1**

LUBLIN 2016

ZOOLOGICA POLONIAE

ARCHIVUM SOCIETATIS ZOOLOGORUM POLONIAE

VOL. 61 FASC. 1-1
2016

LUBLIN 2016 POLAND

Zoologica Poloniae
in open access
http://www.degruyter.com/view/j/zoop
http://www.umcs.pl/pl/zoologica-poloniae,11696.htm

International scientific journal founded by
Jarosław Wiącek Zakład Ochrony Przyrody
Dept. of Biology and Biotechnology
UMCS Lublin

ISSN 0044-510X

PRINTED IN POLAND

Opracowanie do druku:
True Colours s.c., ul. I Armii WP 5/2, 20-078 Lublin, www.tcolours.com

Nakład
200

INDEX

Wojciech Kudła, Łukasz Dawidowicz

CHRYSOCRAMBUS LINETELLA (FABRICIUS, 1781) AND ANOTHER RARELY AND LOCALLY ENCOUNTERED PYRALOIDEA (LEPIDOPTERA) IN POLAND FROM THE SCIENTIFIC COLLECTION OF THE NATURE EDUCATION CENTRE OF THE JAGIELLONIAN UNIVERSITY IN KRAKOW 5

Zbigniew Wojciechowski, Jacek J. Nowakowski

DYNAMICS OF ARRIVAL OF COMMON STARLINGS *STURNUS VULGARIS* ON COMMUNAL ROOST IN POST-BREEDING PERIOD 21

Alexander Čanády, Ladislav Mošanský and Peter Krišovský

CRANIOMETRIC ANALYSIS OF THE FAT DORMOUSE ***GLIS GLIS*** FROM SLOVAKIA 41

Marek Nieoczym

NEW BREEDING LOCALITY OF FERRUGINOUS DUCK *AYTHYA NYROCA* (GÜLDENSTÄDT, 1770) IN LUBLIN REGION 53

Kaveri Purandhar, Nivedita Pareek, Disha Patell, Bhavin Patel And Sriram Seshadri

STUDY OF THE HISTOARCHITECHTURAL AND BIOCHEMICAL CHANGES WITH PROGRESSION OF AGE IN MALE MICE 59

Sebastian Mertowski, Paweł Buczyński, Edyta Buczyńska

SHORT REPORT. UNTYPICAL COLOURATION OF THE JACKDAW *CORVUS MONEDULA* AS THE EXAMPLE OF THE PLUMAGE ABERRATIONS IN BIRDS 85

Zoologica Poloniae (2016) 61/1. 5-19

CHRYSOCRAMBUS LINETELLA (FABRICIUS, 1781) AND ANOTHER RARELY AND LOCALLY ENCOUNTERED PYRALOIDEA (LEPIDOPTERA) IN POLAND FROM THE SCIENTIFIC COLLECTION OF THE NATURE EDUCATION CENTRE OF THE JAGIELLONIAN UNIVERSITY IN KRAKOW

Wojciech Kudła[1], Łukasz Dawidowicz[2]

[1] Zoological Division, Nature Education Centre, Jagiellonian University, Krakow, Poland
Email: wojciech.kudla@uj.edu.pl
[2] Department of Zoology, Maria Curie-Skłodowska University, Lublin, Poland
E-mail: mori666@o2.pl

Abstract: This study presents the records of 30 locally or rarely encountered species of Pyraloidea in Poland deriving from the scientific collection of the Nature Education Centre of the Jagiellonian University in Krakow. The most interesting records concern: *Chrysocrambus linetella, Anania luctualis, Parapoynx nivalis, Acrobasis legatea, Uresiphita gilvata* and *Scoparia ingratella*. This paper shows the second record of *C. linetella* after more than 100 years since it's last observation and the only known contemporary record of *A. luctualis* within Poland.

Key words: Pyralidae, Crambidae, distribution, checklist, faunistics, Lesser Poland

INTRODUCTION

Natural history museum collections are a very important source of information, such as changes in species distributions over the decades. At present, many of them are being re-examined in detail for the purpose of providing information for biodiversity databases (for example GBIF or KSIB) and making scientific data on biodiversity accessible worldwide for anyone via web services. Biodiversity databases gather valuable and often very unique data about species distributions and habitat changes (GBIF 2011; Tykarski 2015). Published records are preferred as they are considered more reliable. The authors decided to collect and publish this information on rarely and locally encountered species within Poland of Pyraloidea stored in the scientific collection of the Nature Education Centre of the Jagiellonian Univer-

sity in order to provide trustworthy records to the KSIB project and widen the knowledge about Lepidoptera occurrence in the country. Material in this paper, in most cases, was chosen to fill the gaps in the distribution of many species appertaining to the Pyraloidea superfamily in Poland (Buszko & Nowacki 2000). On account of the objectives of the KSIB project, some specimens were listed even if the species was already found within the boundaries of a particular voivodeship.

Chrysocrambus linetella (Fabricius, 1781) was identified for the second time in Poland and this is the only preserved specimen stored in a collection located in Poland (Fig.1).

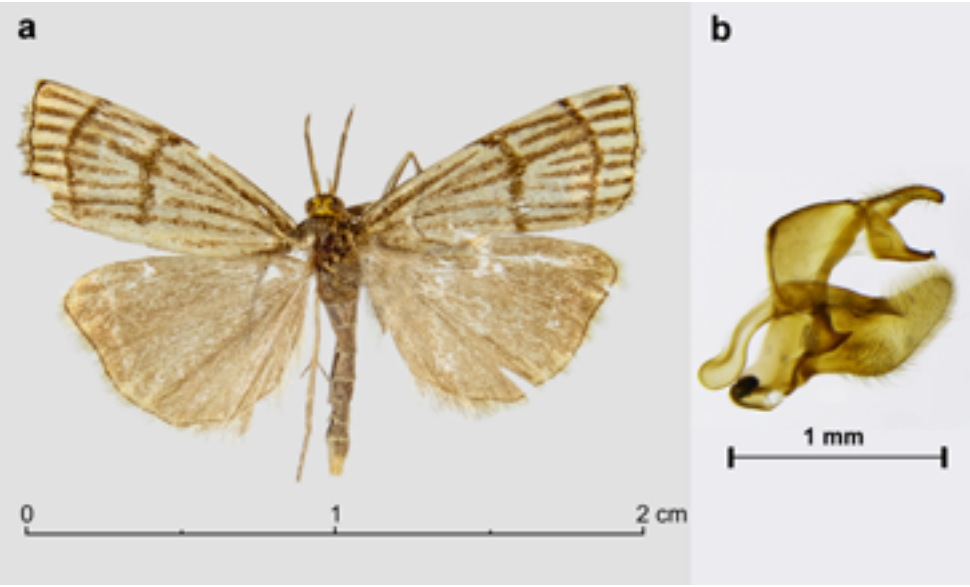


Fig. 1. *Chrysocrambus linetella (Fabricius, 1781); UTM: EV97, Łubne, VIII 1988, leg. A. Gruszka; a – general specimen's view; b – male genital structure.*

The species list is as follows:

Aphomia sociella (Linnaeus, 1758)

Material examined

UTM: DA14, Krakow, 18.06.1967 (1 ex.), 28.06.1967 (1 ex.), leg. W. Węglarski
UTM: DV26, Tatry [Zakopane], Bystre, 10.07.1971 (1 ex.), leg. W. Węglarski

The species is an occasional synanthrope. Larva feed on cells and honeycombs in the nests of wasps (*Vespula* spp.) and bees, including the honey bee (*Apis mellifera* L.) (Slamka 2006). The species is native to Europe (Karsholt & Razowski 1996), but

it is also known from North Africa, Asia and North America. Practically known from the all territory of Poland. So far, the species has not been noted from Lesser Poland after 1960 (Buszko & Nowacki 2000).

***Aglossa pinguinalis* (Linnaeus, 1758)**

Material examined
UTM: CA97, Klucze [village], 10.07.2012 (1 ex.), leg. W. Kudła
UTM: CA97, Klucze [village], 29.06.1995 (1 ex.), leg. W. Kudła

The species occurs in many synanthropic habitats, especially in barns and basements. Larva feed on various dry plant and animal remnants, foodstuffs and sometimes also on paper. Distributed throughout the whole Holarctic as well as India and China (Slamka 2006). Historically recorded from the entirety of Poland, but has become less abundant over the past few decades due to the abandonment of livestock farming. At present, the species has not been noted from Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Etiella zinckenella* (Treitschke, 1832)**

Material examined
UTM: DV26, Tatry, [Zakopane] Gubałówka, 30.08.1963 (1 ex.), leg. W. Węglarski

The species prefers hot, dry and open habitats. Larva feed mostly inside the pods of Fabaceae Lindl. Widely distributed: Europe, N America, China, India but usually not abundant (GBIF 2016). Mostly recorded from the southern part of Poland as a migrant species. All known records of this moth coming from Lesser Poland are dated previous to 1960 (Buszko & Nowacki 2000).

***Rhodophaea formosa* (Haworth, 1811)**

Material examined
UTM: CA97, Hutki [near Olkusz], Dry Biala River Valley, 8.06.2009 (1 ex. ad lucem), mixed forest with heathers, leg. W. Kudła

The species occurs mainly in bushy and sunny habitats. Larva feed on common heather (*Calluna vulgaris* (L.) Hull) and elms (*Ulmus* spp.) but also sometimes on birches (*Betula* spp.) or oaks (*Quercus* spp.) (Romaniszyn & Schille 1930). Known from almost all European countries. In Poland, recorded from the majority of the country. At present, the species has not been noted from Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Dioryctria schuetzeella* Fuchs, 1899**

Material examined
UTM: DV47, Pieniny, Niedzica, 23.07.1969 (1 ex.), leg. W. Węglarski
UTM: DV57, Pieniny, Marcelowa Góra, 22.07.1960 (2 ex.), leg. W. Węglarski
UTM: FD84, Puszcza Białowieska, Czerlonka, 14.08.1987 (1 ex. ad lucem), leg. A. Gruszka

The species occurs in wooded areas, mostly in spruce forests. In Europe, it is distributed throughout suitable habitats, mostly in central, northern and eastern parts of the continent (Karsholt & Razowski 1996). Known also from the South Siberia. In Poland, occurs primarily in the eastern and southern parts in spruce-dominant areas. At present, the species has not been recorded in Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Acrobasis legatea* (Haworth, 1811)**

Material examined
UTM: DV57, Pieniny, Kąty, 23.07.1957 (1 ex.), leg. W. Węglarski

Known from scattered localities throughout South and Central Europe, Asia Minor, the western part of Russia, Kazakhstan and Kyrgyzstan as well. It was only reported in Poland once over a half century ago in the Pieniny Mts. UTM: DV57, Macelowa Góra, 26.06.1959, in bushy habitats on rocks (limestone slopes), one pair (as *Eurhodope legatella* (Hbn.)) (Błeszyński et al. 1965).

***Homoeosoma nimbella* (Duponchel, 1837)**

Material examined
UTM: DV15, Tatry, Nędzówka, 20.07.1968 (2 ex.), leg. W. Węglarski
UTM: DV57, Pieniny, Marcelowa Góra, 16.07.1968 (1 ex.), leg. W. Węglarski

The species is known from all of Europe with the exception of the northernmost regions (Karsholt & Razowski 1996). Mostly observed within sandy areas. Larva feed on various representatives of Asteraceae family (Wagner 2011). In Poland, recorded from the majority of the country. All known records of this moth coming from Lesser Poland are dated previous to 1960 (Buszko & Nowacki 2000).

***Phycitodes albatella* (Ragonot, 1887)**

Material examined
UTM: DA43, Puszcza Niepołomicka, Szarów, 6.08.1972 (1 ex.), leg. J. Wojtusiak
UTM: DV26, Tatry, [Zakopane] Gubałówka, 28.08.1963 (1 ex.), leg. W. Węglarski

The species is widely distributed in Europe. Encountered in many open and dry habitats. Larva feed on many plants of the Asteraceae family (Karsholt & Razowski 1996, Schultz 1951). Known from the majority of Poland. The species has not been previously recorded from Lesser Poland (Buszko & Nowacki 2000).

***Phycitodes binaevella* (Hübner, 1813)**

Material examined
UTM: DA14, Krakow (Jadwigi St.), 25.08.1971 (1 ex.), leg. W. Węglarski
UTM: DV57, Pieniny, Zamczysko, 25.07.1959 (1 ex.), leg. W. Węglarski
UTM: DV57, Pieniny, Facimiech, 20.07.1958 (1 ex.), leg. W. Węglarski

Widely distributed species throughout Europe (Karsholt & Razowski 1996). Larva feed on various plants of the Asteraceae family. Known from the majority of Poland. All known records of the species coming from Lesser Poland are previous to 1960 (Buszko & Nowacki 2000).

***Plodia interpunctella* (Hübner, 1813)**

Material examined
UTM: DA24, Krakow (Grodzka St.), 16.06.1979 (2 ex.), 26.06.1979 (1 ex.), 2.09.1979 (1 ex.), 5.03.1980 (1 ex.), leg. W. Węglarski

A cosmopolitan and common lepidopteran pest species. Caterpillars can feed on a wide range of many dry foodstuffs of plant origin, e.g.: cereals, bread or nuts (Geiter et al. 2002). Known almost from the whole area of Poland. At present, the species has not been noted from Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Ephestia elutella* (Hübner, 1796)**

Material examined
UTM: DA24, Krakow (Grodzka St.), 29.06.1952 (1 ex.), leg. W. Węglarski
UTM: DA14, Krakow (Jadwigi St.), 31.05.1971 (1 ex.), leg. W. Węglarsk
UTM: DV26, Tatry, [Zakopane] Gubałówka, 29.07.1970 (1 ex.), leg. W. Węglarski
UTM: DV15, Tatry, Nędzówka, 20.07.1969 (1 ex.), leg. W. Węglarski
UTM: EV48, Dukla, 27.07.1988 (1 ex. ad lucem), leg. A. Gruszka

A cosmopolitan and widespread storage pest species. The larva feed on diverse stored materials, especially cacao, tobacco and cereals (Geiter et al. 2002). Known from the majority of the country. The species has never been recorded in the Subcarpathian Province or from Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Ephestia kuehniella* Zeller, 1879**

Material examined

UTM: EA31, Jasło, 21.06.1965 (1 ex. ad lucem), leg. A. Gruszka
Poznań, 7.06.1961 (1 ex.), leg. S.A. Szmyt
UTM: DA14, Krakow, 19.06.1971 (1 ex.), leg. W. Węglarski

Another common pest species with cosmopolitan distribution. *E. kuehniella* is mainly encountered in flour mills and bakeries. Larva feed on many dry foodstuffs of plant origin, especially wheat products (grain and flour) (Geiter et al. 2002). Known from a majority of Poland. The species has not been recorded in Greater Poland or the Subcarpathian Province and from Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Cadra cautella* (Walker, 1863)**

Material examined

Poznań, 13.09.1970 (1 ex.), 23.09.1970 (3 exx.), 30.09.1970 (1 ex.), 6.10.1970 (1 ex.), leg. S.A. Szmyt

A pest of stored food products, and originates from tropical and subtropical regions. Adventive in temperate zones where it can overwinter only in heated areas and warehouses. The larva feed on many stored foodstuffs such as cereals, flour and dry fruits (CABI 2007, Geiter et al. 2002). Reported from almost all European countries (Karsholt & Razowski 1996). In Poland, historically known from five provinces but contemporarily only recorded in two. The species has not been recorded from Greater Poland since 1960 (Buszko & Nowacki 2000).

***Pyrausta falcatalis* Guenée, 1854**

Material examined

UTM: DV57, Pieniny, Cisowiec, 3.07.1957 (1 ex.), leg. W. Węglarski
UTM: EV87, Liszna ad Sanok, 11.07.1968 (1 ex.), on flower, mountain mixed forest, leg. A. Gruszka
UTM: EV48, Dukla, Krzemienie, 19.07.1967 (1 ex.), wet meadow on northern slope, leg. A. Gruszka
UTM: FA20, Pogórze Przemyskie, Makowa, 300 m a.s.l., 22.07.2009 (1 ex.), leg. J. Wojtusiak

The species inhabits fresh and damp mixed forest clearings, it is predominantly observed in the montane regions of Central and Eastern Europe (Slamka 2013, Slamka 2010). Recorded mainly from the SE part of Poland, most records are dated from several decades ago (Buszko & Nowacki 2000; Romaniszyn & Schille 1930).

In the last few years, confirmed from a few localities in SE Poland: UTM: FA10, Rybotycze 26.07.2012 (1 ex.) (Kudła unpublished); UTM: FV33, Bukowiec, 13.08.2014, 3 exx. (Dawidowicz unpublished); UTM: EV98, Góra Sobień 20.07.2008 (Dawidowicz 2011); UTM: FA25, Łapajówka, 07.2001; UTM: EV97, Łączki, 18.07.2012; UTM: EV89, Liszna, 20.07.2012; UTM: EV98, Łukawica, 18.07.2012 (Bury & Buga 2014).

***Pyrausta ostrinalis* (Hübner, 1796)**

Material examined

UTM: XU20, Poznań, Marcelin, 10.05.1958 (1 ex.), leg. M.R. Lewandowski
UTM: XU20, Poznań, Edwardowo, 22.05.1963 (1 ex.), leg. M.R. Lewandowski
UTM: DA14, Krakow (Jadwigi St.), 7.08.1972 (1 ex.), leg. W. Węglarski

The species occurs in open and dry habitats (e.g. sandy areas or heathlands). Distributed throughout Europe except the northern part, less abundant in the east part. In Poland, found mostly in the eastern part of the country (Buszko & Nowacki 2000). In Greater Poland, reported only once in 2000 (Bąkowski et al. 2011).

***Pyrausta porphyralis* (Denis & Schiffermüller, 1775)**

Material examined

- UTM: DA10/DV19, Jordanów, 11.07.1951 (1 ex.), leg. W. Węglarski
- UTM: DV25, Tatry, Dolina Ku Dziurze, 16.05.1934 (1 ex.), leg. A. Rudkowski

The species generally inhabits dry and open places. In Europe, more frequently observed in the north, absent in most of the southern parts of the continent. Distributed also throughout Central Asia. In Poland, known mostly from the northern and eastern parts of the country. At present, the species has not been recorded from Lesser Poland (Buszko & Nowacki 2000).

***Uresiphita gilvata* (Fabricius, 1794)**

Material examined

UTM: DA14, Krakow, Tyniec, Podgórki (Skołczanka): 31.05.1945 (5 exx.), 27.05.1947 (1 ex.), leg. R. Wojtusiak; 19.05.1953 (1 ex.), leg. W. Węglarski; 21.05.1945 (1 ex.), 22.05.1946 (1 ex.), 28.05.1944 (1 ex.), leg. S. Błeszyński; 22.05.1950 (1 ex.), 19.08.1956 (1 ex.), leg. J. Razowski

The species of xerothermic habitats. In Europe, known mostly from the eastern and southern part of the continent (Slamka 2013, Slamka 2010). In Poland, it has been mostly recorded from Lower Silesia and Lesser Poland. In some places like Skołczanka Reserve in Krakow, the species was abundant (Razowski & Palik 1969).

However, all of these observations are dated to the mid-1900s or earlier (Buszko & Nowacki 2000; Stach, 1938; Romaniszyn & Schille 1930; Żebrawski, 1860). *U. gilvata* has not been observed in Krakow since the 1960s. In older Polish literature, it was mentioned as *Mecyna polygonalis* Hübner.

***Anania lancealis* (Denis & Schiffermüller, 1775)**

Material examined
UTM: DA08, Złożeniec ad Pilica, 19.06.2006 (1 ex.), leg. W. Kudła

The species inhabits fresh and damp habitats mostly in river valleys, floodplains, wet woodlands and forest edges. Observed in most of parts of Europe, but more frequently in the west and central part of the continent. Known also from Central and East Asia (Slamka 2013). Distributed throughout Poland but locally and usually not abundant. The species has not been recorded from Lesser Poland since 1960 (Buszko & Nowacki 2000). There are no specimens coming from Lesser Poland dated after 1960 in the scientific collection of the Nature Education Centre. The specimen listed above was collected within Silesia province. Nevertheless, authors decided to include the one into the list because the locality where the material was gathered is placed only 800 meters from the boundary of the Lesser Poland Voivodeship. Furthermore, the species was observed less than two kilometres from place where the listed specimen was captured, within the boundaries of Lesser Poland: UTM: DA08, Góry Bydlińskie 20.06.2002 (Kudła unpublished).

***Anania luctualis* (Hübner, 1793)**

Material examined
UTM: DA28, Tunel [pow. miechowski], 15.06.1988 (1 ex.), leg. J. Wojtusiak

The species is probably associated with thermophilous, deciduous forests and their edges. At present, it has only been recorded from Lesser Poland and Lower Silesia. Some records are even known from the Krakow's territory (regions: Łuczanowice (Żebrawski, 1860) and Olsza (Stach, 1938)). All of the above-mentioned records are dated prior to 1960 (Slamka 2013, Slamka 2010, Buszko & Nowacki 2000; Razowski & Palik 1969; Romaniszyn & Schille 1930). The presented information constitutes the only known contemporary record of the species in Poland.

***Anania perlucidalis* (Hübner, 1809)**

Material examined
UTM: DA10/DV19, Jordanów, VII 1950 (1 ex.), leg. W. Węglarski

The species generally occurs in wet meadows, floodplains and other damp habitats. Known mostly from Central Europe, the species does not occur in the southern part of the continent. In Poland, known from the whole territory of the country. Encountered locally. At present the species has not been recorded from Lesser Poland (Buszko & Nowacki 2000).

***Paratalanta pandalis* (Hübner, 1825)**

Material examined

UTM: CV99, Babia Góra, 1600 m a.s.l., 25.06.1969 (1 ex.), leg. J. Wojtusiak

The species inhabits various open habitats both dry and damp. Encountered throughout Europe, also known from scattered localities in Turkey, southern Siberia and Japan (Slamka 2013). Recorded from the majority of Poland. All known records of this moth coming from Lesser Poland are dated prior to 1960 (Buszko & Nowacki 2000).

***Udea ferrugalis* (Hübner, 1796)**

Material examined

UTM: DV26, Tatry, [Zakopane] Gubałówka, 31.08.1963 (2 exx.), leg. W. Węglarski

UTM: CA97, Klucze, Góra Jałowce [Czubatka], 360m, 31.10.2001 (1 ex. ad lucem), deciduous forest with sycamore (*Acer pseudoplatanus* L.), leg. W. Kudła

Inhabits fresh and damp habitats, especially tall herb fringe communities in river valleys and forest edges. Occurs throughout Europe, but in the northern part of the continent as a migrant species, occasionally as far as Scandinavia and Iceland (Slamka 2013). The species also occurs in Asia Minor, Azerbaijan, North Africa, and the Canary Islands. In Poland, mostly known from the southern part of the country. At present, the species has not been noted from Lesser Poland since 1960 (Buszko & Nowacki 2000).

***Udea fulvalis* (Hübner, 1809)**

Material examined

UTM: DV25, Zakopane, Kuźnice, 9.08.1964 (1 ex.), leg. A. Gruszka

UTM: EA23, Pilzno, pow. Dębica, VII 1964 (1 ex.), VII 1965 (2 exx.), VII 1966 (1 ex.), leg. A. Gruszka

The species occurs in fresh and damp habitats, forest edges and clearings. Distributed throughout Europe except the northernmost parts. Known from the entire territory of Poland (Slamka 2013). All known records of the species coming from Lesser Poland are prior to 1960 (Buszko & Nowacki 2000).

***Cydalima perspectalis* (Walker, 1859)**

Material examined

UTM: DA24, Krakow:

Old Town, Ogród Kołłątajowski, 26.08.2016 (2 exx.), 1.09.2016 (1 ex.), 2.09.2016 (1 ex.); Old Town, Wiślna St., Planty, 2.09.2016 (1 ex.); Stradom, Saint Agnieszka St., 2.09.2016 (1 ex.); Stradom, St. Agnieszka Church, 2.09.2016 (1 ex.); Ludwinów, Dworska St., 6.09.2016 (1 ex.); 19.06.2016 (ex. l.), larva: Cmentarz Rakowicki, 4.06.2016 (1 ex.); 21.06.2016 (ex larvae), larva: Cmentarz Rakowicki, 4.06.2016 (1 ex.); 19.08.2016 (ex. l.), larva: Cmentarz Rakowicki, 22.07.2016 (1 ex.); 20.08.2016 (ex. l.), larva: Cmentarz Rakowicki, 22.07.2016 (ex. l.); 30.07.2016 (exx. l.), larva: Old Town, Ogród Profesorski, 8.07.2016 (2 exx.); 3.08.2016 (ex. l.), larva: Wesoła, Park Strzelecki, 8.07.2016 (1 ex.), leg. W. Kudła

The species is native to East Asia. In Europe, occurs in habitats with boxtrees (*Buxus* spp.), typically in parks, gardens and cemeteries (Slamka 2013). Since the last decade, it has been more and more frequently observed in Europe. It is assumed that the species was introduced into the European continent with its host plant. One of the earliest observations in Europe comes from south-west Germany in 2007 (Krüger 2008). In Poland, it was found for the first time in 2012 and 2013 in Michałkowa in the Owl Mountains, Lower Silesia. In 2015 some individuals were also observed in Opole and Krakow (Blaik et al. 2016). In 2016 all developmental stages, in total number of over 1000 (mostly caterpillars), were found in many parts of Krakow (Old Town, Grzegórzki, Krowordza, Dębniki, Osiedle Podwawelskie). In some places (e.g. Ogród Profesorski in the Old Town), the complete defoliation of boxtrees has been observed (Kudła, own observation).

***Scoparia ingratella* (Zeller, 1846)**

Material examined

UTM: DA14, Krakow (Jadwigi St.), 15.06.1968 (1 ex.), leg. W. Węglarski

The species is known from many countries of Central and Southern Europe (Karsholt & Razowski 1996). Hitherto recorded merely from Silesia and Lesser Poland before 1960 (Buszko & Nowacki 2000; Romaniszyn & Schille 1930).

***Euchromius ocellea* (Haworth, 1811)**

Material examined

UTM: DA14, Krakow (Jadwigi St.), 5.08.1968 (1 ex.), 5.10.1967 (1 ex.), leg. W. Węglarski

A cosmopolitan species widely distributed in the tropical and subtropical regions of the world. Recorded from almost all European countries, mainly as a migrant

species (Slamka 2008, Karsholt & Razowski 1996). Also in Poland observed several times. At present, the species has not been recorded from Lesser Poland (Buszko & Nowacki 2000).

***Friedlanderia cicatricella* (Hübner, 1824)**

Material examined

UTM: XS35, Wrocław, Klecina, 9.08.1970 (1 ex. ad lucem), leg. A. Kokot
UTM: DA68, Krzyżanowice, 5.07.1958 (1 ex.), leg. W. Węglarski
UTM: DA14, Krakow, Podgórki [Skołczanka], 10.08.1941 (1 ex.), leg. R. Wojtusiak

A hygrophilous species occurring in marshes and wet meadows, especially around lakes and river banks. Known throughout Central Europe, but it is usually local and rare (Slamka 2008, Karsholt & Razowski 1996). Observed mainly in the southern and western regions of Poland (Buszko & Nowacki 2000, Romaniszyn & Schille 1930).

***Chrysocrambus linetella* (Fabricius, 1781) (= *Crambus cassentiniellus* (Herrich-Schäffer, 1848))**

Material examined

UTM: EV97, Łubne [pow. leski], VIII 1988 (1 ex.), dead specimen in a lamp case, leg. A. Gruszka (male, prep. genit. nr 1/10.02.16) (Fig.)

This is the second record of the species within the current Polish boundaries after more than 100 years of no observations. *C. linetella* was previously recorded only in the Sudetes: UTM: XR36, Śnieżnik Mountain, 6.07.1874, one large male from a meadow in the forest. This specimen was identified as *Crambus craterellus* f. cassentiniellus (Wocke 1874). In the past, the species in question was treated as a form of the sister species *C. craterella* which can be easily confused with each other. The main difference lies in the external appearance of the wings apex pattern. In the case of worn specimens, examination of the genital structure is required (Błeszyński 1965). The latter species has also been formerly recorded in Poland but only a few times and all of these records are dated prior to 1960 (Błeszyński 1956). *C. linetella* is a quite common and abundant species in many south-European regions, especially within warm, dry, grassy and open habitats. The species sometimes has a tendency to take migratory flights. The nearest localities of common occurrence to Poland are from Slovakia and the Czech Republic (Slamka 2010; Slamka 2008, Karsholt & Razowski 1996). *Crambus cassentiniellus* (Herrich-Schäffer, 1848) is the synonym of the discussed species mentioned in older literature (Błeszyński 1957, Błeszyński 1958).

***Scirpophaga praelata* (Scopoli, 1763)**

Material examined

UTM: FD94, Grudki [formerly Gródki, pow. hajnowski], 20.07.1985 (1 ex. ad lucem), the old and humid mixed forest, leg. A. Kokot

The species is strictly connected with wetland habitats, predominantly with *Scirpus* spp. assemblages. In Poland, the species is currently known only from Polesie. Formerly, it was also recorded in the Pieniny Mts. and Rytro but only as an accidental migrant (Buszko & Nowacki 2000; Błeszyński et al. 1965; Romaniszyn & Schille 1930). The moth is more abundant in the southern part of Europe (Slamka 2010, Slamka 2008). This is the only known record for the Podlasie region (Buszko & Nowacki 2000).

***Parapoynx nivalis* (Denis & Schiffermüller, 1775)**

Material examined

UTM: FD94, Grudki [formerly Gródki, pow. hajnowski], 30.07.1985 (1 ex. ad lucem), the old and humid mixed forest, leg. A. Kokot,

UTM: DA14, [Krakow], Przegorzały, 24.06.1935 (1 ex.), leg. R. Wojtusiak

The species is associated with wetland habitats. This is probably a migrant species with the main distribution area located further east than Poland. At present, it has only been recorded from Podlasie, Mazovia, Lublin Province and Lesser Poland (Slamka 2010; Buszko & Nowacki 2000; Razowski & Palik 1969; Romaniszyn & Schille 1930). The species is included in the Red List of threatened animals in Poland with VU category (Buszko & Nowacki 2002).

ACKNOWLEDGMENTS

The authors would like to thank Professor Jarosław Buszko from Nicolaus Copernicus University and Professor Józef Razowski from the Institute of Systematics and Evolution of Animals for donation of Microlepidoptera specimens to the former Zoological Museum of Jagiellonian University.

CHRYSOCRAMBUS LINETELLA (FABRICIUS, 1781) I INNE RZADKO ORAZ LOKALNIE SPOTYKANE PYRALOIDEA (LEPIDOPTERA) W POLSCE W ZBIORACH NAUKOWYCH CENTRUM EDUKACJI PRZYRODNICZEJ UNIWERSYTETU JAGIELLOŃSKIEGO W KRAKOWIE

STRESZCZENIE

Niniejsza praca przedstawia dane na temat 30 lokalnie lub rzadko spotykanych gatunków motyli należących do nadrodziny *Pyraloidea* w Polsce. Prezentowane informacje opierają się na zbiorach naukowych należących do Centrum Edukacji Przyrodniczej Uniwersytetu Jagiellońskiego w Krakowie. Najbardziej interesujące rekordy dotyczą, m.ni.: *Chrysocrambus linetella, Anania luctualis, Parapoynx nivalis, Acrobasis legatea, Uresiphita gilvata* oraz *Scoparia ingratella*. Praca przedstawia przypadek drugiego stwierdzenia *C. linetella* w Polsce po ponad 100 latach braku jakichkolwiek informacji na temat występowania tego gatunku w kraju oraz jedyny współczesny rekord *A. luctualis*.

REFERENCES

Bąkowski M., Słodzinka R. & Żurawlew P. 2011: New and rare Crambidae (Lepidoptera) from Wielkopolska region. Entomological News, **30**(3): 191-192.

Blaik T., Hebda G. & Masłowski J. 2016: *Cydalima perspectalis* (Walker, 1859) – inwazyjny gatunek motyla w faunie Polski. Przyroda Sudetów. **19**: 121-124.

Błeszyński S. 1956: Omacnicowate – Pyralidae, Wachlarzykowate – Crambinae. Klucze do oznaczania owadów Polski, **XXVII**(45b): 1-87.

Błeszyński S. 1957: Studies on the Crambidae (Lepidoptera). Part XIV. Revision of the European species of the generic group *Crambus* F. s. l. Acta Zoologica Cracoviensia, 1: 161–622, pls 27–92.

Błeszyński S. 1958: Studies on the Crambidae (Lepidoptera). Part XVIII. Revision of the genus *Chrysocrambus* Blesz. Acta Zoologica Cracoviensia, **2**(34): 845-885.

Błeszyński S. 1965: Crambinae. [in:] Amsel H.G., Gregor F. & Reisser H. (eds.), Microlepidoptera Palaearctica 1 (1-2). Georg Fromme & Co., Wien, Pp. I–L, 1–553, pls. 1–133.

Błeszyński S., Razowski J. & Żukowski R. 1965: Fauna motyli Pienin. Acta Zoologica Cracoviensia, **10**(5): 375-493.

Bury J. & Buga E. 2014: New records of *Pyrausta falcatalis* Guenée, 1854 (Lepidoptera: Crambidae) from south-eastern Poland. Entomological News, **33**(3): 220.

Buszko J. & Nowacki J. 2000: The Lepidoptera of Poland. A Distributional Checklist. Polish Entomological Monographs, Polskie Towarzystwo Entomologiczne, Poznań-Toruń, 1-178.

Buszko J. & Nowacki J. 2002: Lepidoptera Butterflies, [in:] Głowaciński Z. (ed.), Czerwona Lista Zwierząt Ginących i Zagrożonych w Polsce. IOP PAN, Krakow, 80-87.

CABI 2007: *Ephestia cautella* (Walker) Tropical warehouse moth datasheet. Crop Protection Compendium, 2007 Edition. CAB International Publishing. Wallingford, UK.

Dawidowicz Ł. 2011: A new record of *Pyrausta falcatalis* Guenée, 1854 (Lepidoptera: Crambidae) in Poland. Entomological News, **30**(2): 124.

GBIF 2011: Publishing and Registering Data with GBIF, version 1.0, released on 11 April 2011, (contributed by Remsen D., Hahn A., Ko B., Chavan V., Raymond M.), Copenhagen: Global Biodiversity Information Facility, 9 pp. Accessible at: http://links.gbif.org/dwc-a_publishing_guide_en_v1.pdf.

GBIF 2016: *Etiella zinckenella* Treitschke, 1832 (GBIF ID 1870450), released on 10 October 2016. Accessible at: http://data.gbif.org.

Geiter O., Homma S. & Kinzelbach R. 2002: Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit. Forschungsbericht 296 89 901/01. UBA-FB 000215: Bestandsaufnahme und Bewertung von Neozoen in Deutschland Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potenziellen Effekten gentechnisch veränderter Organismen.

Karsholt O & Razowski J. 1996: The Lepidoptera of Europe. A distributional checklist. Apollo Books, Stenstrup, 1-380.

Krüger E.O. 2008: *Glyphodes perspectalis* (Walker , 1859) – neu für die Fauna Europas (Lepidoptera: Crambidae). Entomologische Zeitschrift, 118: 81-83.

Razowski J. & Palik E. 1969: Fauna motyli okolic Krakowa. Acta Zoologica Cracoviensia, 4: 217-310.

Romaniszyn J. & Schille F. 1930: Fauna motyli Polski. T. II. Prace monograficzne komisji fizjograficznej, **7**: 1-358.

SCHULTZ V.G.M. 1951: Neue Beiträge zur Schmetterlingskunde. Nr. 10. Über *Homoeosoma pseudonimbellum* Bentinck (erste Stände und Generationenfolge) (Lep. Pyralididae). Zeitschrift der Wiener Entomologischen Gesellschaft, **36**: 55-59.

Slamka F. 2006: Pyraloidea of Europe (Lepidoptera). Vol. 1. Bratislava, 138 pp.

Slamka F. 2008: Pyraloidea of Europe (Lepidoptera). Vol. 2. Bratislava, 223 pp.

Slamka F. 2010: Pyraloidea (Lepidoptera) of Central Europe, Bratislava, 176 pp.

Slamka F. 2013: Pyraloidea of Europe (Lepidoptera). Vol. 3. Bratislava, 357 pp.

Stach S. 1938: Motyle drobne okolic Krakowa. cz. I: Pyralidae. Sprawozdanie komisji fizjograficznej, 72: 433-452.

Tykarski P. 2015: Polish biodiversity information network (KSIB), its resources and web application. [in:] Nowak M. (ed.), The scientific, technological and legal background in the creating integrated databases of biotic elements. UAM Pulisher, Poznań, 53-66.

Wagner H. 2011: Die Kleinschmetterlings-Fauna ausgewählter Biotope auf der nordfriesischen Insel Sylt (Lepidoptera). Drosera, **2010**: 1-44.

Wocke M.F. 1874: Verzeichniss der Falter Schlesiens II. Microlepidoptera. Zeitschrift für Entomologie, 4: 1-107.

Żebrawski T. 1860: Owady łuskoskrzydłe czyli motylowate okolic Krakowa. Krakow, 354 pp.

Zoologica Poloniae (2016) 61/1. 21-39

DYNAMICS OF ARRIVAL OF COMMON STARLINGS *STURNUS VULGARIS* ON COMMUNAL ROOST IN POST-BREEDING PERIOD

Zbigniew Wojciechowski[1], Jacek J. Nowakowski[2]

[1] Department of Biodiversity Research, Dydactic and Bioeducation, Lodz University, 90-237 Łódź, Banacha 1/3, Poland, e-mail: zbig@biol.uni.lodz.pl
[2] Department of Ecology and Environmental Protection, University of Warmia and Mazury in Olsztyn, 10-727 Olsztyn, Plac Łódzki 3, Poland; e-mail: jacek.nowakowski@uwm.edu.pl

Corresponding author: e-mail: jacek.nowakowski@uwm.edu.pl

Abstract: The aim of this paper was to provide a statistical description of the arrival of starling flocks to communal roost at the Okręt fishpond (Central Poland), distinguish different migratory periods on the basis of the characteristics of bird arrival (timing, flock size, and arrival direction), and assess the impact of weather conditions on starling flock size. Analysis of 3,520 arrival flocks indicated the „wave" dynamics in the numbers of starlings at the roost, which was associated with non-homogeneous structures in terms of bird behavior. The most pronounced and regular cyclicity was variability of information entropy measured by H' index, which counted the proportion of flocks arriving with 8 compass directions. An increase in entropy was always associated with an arrival of new flocks to the roost, and thus the migration of birds. Weather conditions (strong wind, precipitation, fog) only slightly modified the distribution of flock size of starlings arriving to the roost.

Key words: birds, communal roosts, weather, migration, birds behavior

INTRODUCTION

Research on the arrival of Common Starlings *Sturnus vulgaris* to communal roosts has mostly focused on an inventory and classification of roosts (especially in winter), an estimation of bird numbers at the roosts (Fitter 1942; Jumber 1956; Delvingt 1961; Potts 1967; Lyon and Caccamise 1981; Caccamise et al. 1983; Zając and Tranda 1987), and also on the methods of deterring birds from unusually large roosts (Keil 1965; Gramet and Davoust 1973; Gramet 1976; Zając

1979, 1983; Zając and Tranda 1987). The relationships between the time of sunset, light intensity and the time of arrival of starling flocks to roosts were initially studied by Nice (1935) and Górska (1991, 1992). Hypotheses on the general causes of roosting were discussed by Lack (1966, 1968), Siegfried (1971), Ward and Zahavi (1973), Francis (1976), Weatherhead (1983), and Richner and Heeb (1996).

At present, an accurate statistical description of starling arrival at roosting sites is lacking, which is a description of the materials collected would be daily. There also undertaken analysis of numbers dynamics and changes of migratory behaviour in post-breeding period based on data of birds behaviour on communal roosting. Distinction of starling migratory periods was made based on the observations of bird flight behavior in the Curonian Spit (Russia) by Bielopol'skij and Odincova (1971) and in Żuławy (North-Poland) by Gromadzki (1980). The authors identified two migratory periods: summer migration – from late June to mid-July, and autumn migration, sometimes preceded by a stabilization in bird numbers, from mid-September to late October. Payevsky (1971) also distinguished two migratory periods in the Common Starling, mainly on the basis of ringing data. The first period lasted from early July to late September when birds performed increasingly directed movements mostly at low altitudes. The second period lasted through October and November and was characterized by very fast, long-distance movements, often at a very high altitude.

The aim of this study was to provide a statistical description of the arrival of starling flocks to the communal roost, distinguish different migratory periods on the basis of the characteristics of bird arrival, and assess an impact of weather conditions on the starling flock size.

STUDY AREA

The research was conducted at the Okręt fishpond (52°02'N, 19°51'E) located ca. 10 km south-west of the town of Lowicz(Central Poland). The pond lies within the Warsaw-Berlin glacial valleys at an altitude of 95-97 meters a.s.l., in a swampy valley of the Bobrówka River. Bobrówka Valley is surrounded from the north and south by kames of the Domaniewickie Hills, which forms an accumulation landform (Dylikowa and Olaczek 1982). These areas are mainly covered with pine forests. Okręt pond is supplied with water from the Bobrówka River, its total surface area is 160.0 hectares and its average depth is 1.3 m. The littoral zone of the pond isabout 20% covered with rush vegetation dominated by *Phragmites australis*, *Typha latifolia, Glyceria aquatica* and *Scirpus lacustris*. Reed beds in the eastern and southern parts of the pond were the main communal roosts of starlings. The climate of this area is characteristic for a large part of Poland and is recognized as the Great Valleys climate district based on the Romer classification (Dylikowa and Olaczek 1982). This region has one of the highest annual sums of solar radiation (86.3 kcal / cm^2)

in Poland. Annual precipitation average is approx. 550 mm. Average temperatures during the period of May-September range from 12.5 to 18.0°C, with July being the warmest month of the year. Westerly winds dominate throughout the year and their share is highest in July (28%) (Dylikowa and Olaczek 1982).

METHODS

Field methods

Data on 3,520 arriving flocks of starlings were collected during 88 days of fieldwork. Observations of starling flocks arrival to the roost were carried out every day during the period from 3 July to 27 September 1979, and in addition, twice in October (15 and 22 Oct. 1979). Observations started before the arrival of the first birds and continued until the end of arrival of birds to the roost. During the observations, we noted the timing and direction of arrival, as well as the size of each flock. To assess the size of the flocks, we used a five-class logarithmic scale (class1 – from 1 to 10 individuals, class 2 – from 11 to 100 ind., class 3 – from 101 to 1,000 ind., class 4 – from 1,001 to 10,000 ind., class 5 > 10,000 ind.). During the fieldwork, flock size estimation was based on the half-intervals of distinguished classes, forcing the observers to count the number of birds in a relatively accurate way. Directions of flock arrival at the roost were assigned to the eight directions of the compass. During the fieldwork, weather conditions (temperature, wind speed based on the Beaufort scale, degree of cloudiness on a scale of 0 to 10, and precipitation with distinctions for fog, drizzle and rain) were also noted.

Statistical methods

Distribution of starling flock size was log-normal on each study day, which was tested using the chi square goodness-of fit test. Estimation of the number of roosting birds on each day was based on the assumption of a log-normal distribution, which was calculated as the mean of log-normal distribution using the following formula:

$$\overline{\mu}_x = e^{\mu+\frac{1}{2}S^2}$$

where: $\overline{\mu}$ – theoretical mean of log-normal distribution of starling flocks, e – base of natural logarithms, S^2 – variance of the upper levels of the different categories of flocks size expressed in natural logarithms, which follows from the definition of a log-normal distribution (Krzysztofiak and Urbanek 1975).

Statistical analyzes were based on the division of a year into pentads, 72 units composed of 5 consecutive days each, proposed by Busse (1973). The relationship

between the number of flocks arriving from different directions in adjacent pentads was described using the Spearman correlation coefficient for the wind rose to counted starting from the N and ending at the N-W (n = 8 directions x 5 days). Correlation coefficient values were used as a measure of stability of starling arrival to the communal roost and does not have a statistical relationship that can be directly attributed with significance. It was assumed that any change in the roosting behavior of starlings would have an effect on the arrival of birds to the roost and, thus, could be expected to decrease the correlation coefficient. The same was also expected for any change in the number of flocks, total number of birds at the roost, or flock size. An initial separation of periods of different starling behavior were made based on changes in total bird numbers, flock size, the number of flocks and Spearman correlation coefficient values between the arrivals of flocks from different directions in adjacent pentads. The cluster analysis with Ward's method for grouping of objects and the distance referred to complement the Pearson correlation coefficient to unity (*1-r*) was used. Featured variables were analyzed in logarithmic transformations, and the first Spearman correlation coefficient value was assigned to 38 pentad, which was combined with an incomplete 37 pentad (spanning only 2 days). The results of clustering were checked using discriminant analysis (StatSoft 2013). Variability of an average flock size in the succeeding pentads was described using the quadratic polynomial regression model. The data was subject to quotient transformation prior to analysis, the relationship shows the degree of concentration of birds in the flock. The values of entropy were calculated according to the formula (Pielou 1974):

$$H' = -\Sigma(n_i/N)\ log(n_i/N),$$

where: n_i is the number of flocks arriving to the roost from the i-th direction in the pentad, and N is the number of all arriving flocks to the roost in the pentad. All statistical analyses were conducted using statistical packages „Statistica" and „SPSS".

RESULTS

Changes in dynamics of birds numbers, number of flocks, and mean flock size

The dynamics of starling arrival at the roost showed two distinct periods of gradual increase and two periods of rapid decline in bird numbers (Figure 1). The numbers of birds gathering at the communal roost increased from the beginning of July to 25 August (from 38 to 48 pentad) and from 2 to 19 September (from 50 to 53 pentad), reaching a maximum on 25 August (approx. 300,000 individuals). The declines in bird numbers occurred from 25 August (48 pentad) to the beginning of September (50 pentad) and between 19 September (53 pentad) and the end of the study period. The periods of contrasting dynamics in bird numbers (increase vs. de-

crease) showed differences in the mean flock size of starlings (Figure 2). In the first period of increase (3 July-25 August, 38-48 pentad) changes in the mean flock size were strongly correlated with changes in bird numbers ($r=0.93$, $n=56$; $p<0.0001$), whereas after 26 August the correlation of these variables was lower ($r=0.72$, $n=32$; $p<0.0001$). The difference between the two correlation coefficients was significant ($p=0.0016$) and reflected the relative and absolute decrease in flock size, as well as an increasing number of flocks (Figure 3).

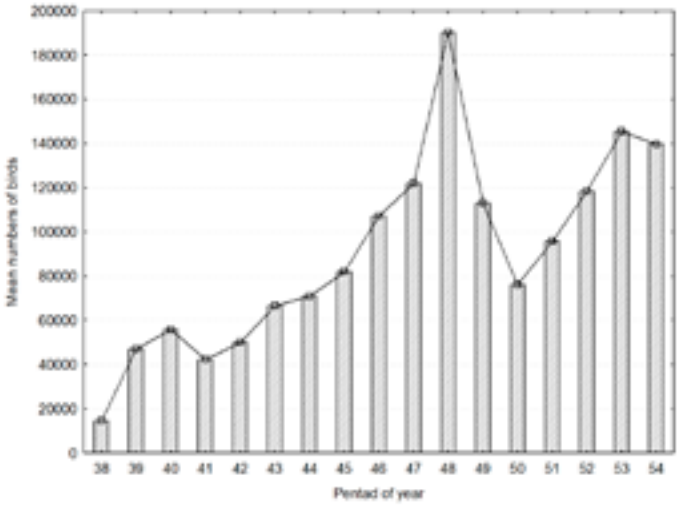


Fig. 1. *Dynamics of the total numbers of starlings at roost*

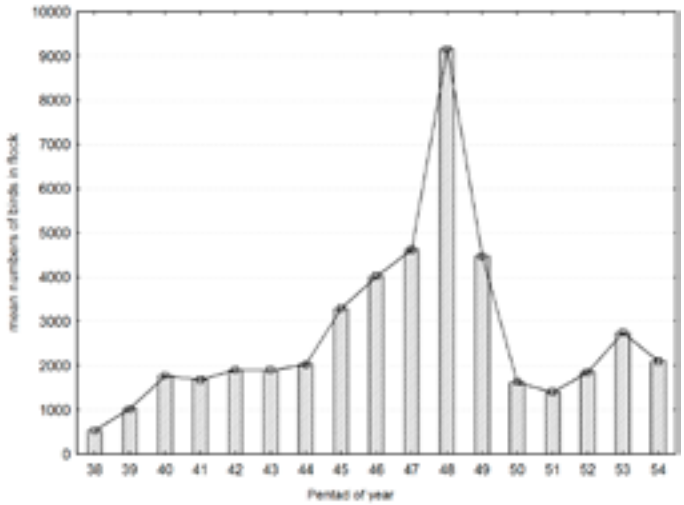


Fig. 2. *Dynamics of mean flock size of roosting starlings*

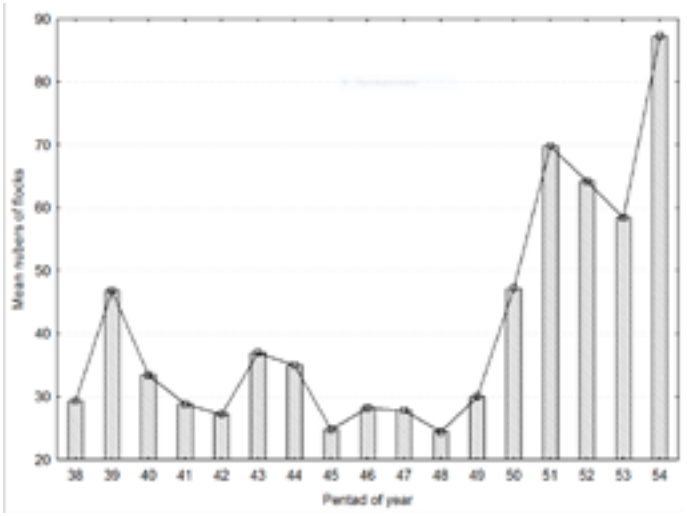


Fig. 3. *Dynamics of the number flock of starlings at roost*

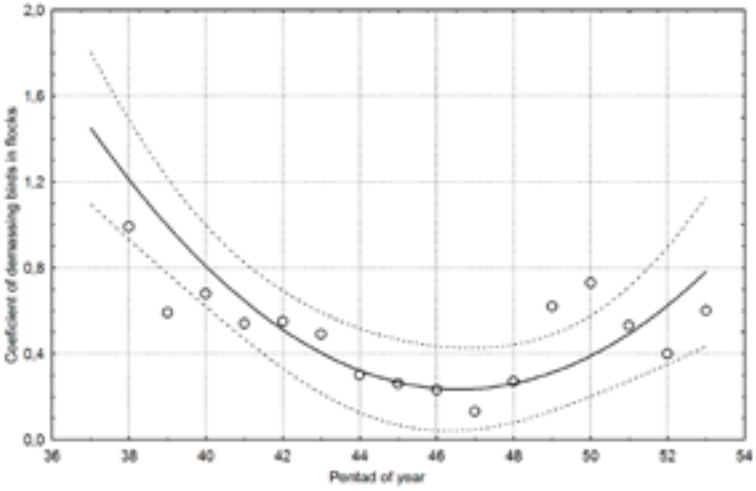


Fig. 4. *Regression of mean flock size in the quotient transformation with respect to subsequent pentads of year; date show ends of selected pentad*

From July to the first days of September, the number of arriving flocks slightly changed and fluctuated at around 30, while in September, and especially at the end of this month, the number of arriving flocks significantly increased (up to 60-160). A significant decrease in flock size occurred during the 48 pentad (Figure 4), when there was a decline in the total number of roosting birds (Figure 1) along with an increase in the number of flocks (Figure 3). Changes in the absolute concentration

of individuals in a flock can be described by the following equation of quadratic regression of the mean flock size in the quotient transformation in relation to the pentad of the year: $y=30.262 - 1.235x + 0.013x^2 + eps$ ($R^2=0.697$, df=2 and 14, p=0.0002; all regression parameters p<0.0004). The equation implies a gradual decline in concentration of birds in the flocks from the beginning of the study period to 57 pentad, and then another increase in concentration (Figure 4).

Characteristics of the dynamics in flock arrival to the roost, as described by the changes in the total bird numbers and the number of flocks (Figure 1 and 3; $r_{Spear}=-0.60$, n=17; p=0.011), as well as by the Spearman correlation coefficient between the number of arrival flocks from following directions in adjacent pentads (Figure 5) suggest significant changes in birds roosting behavior during the post breeding season.

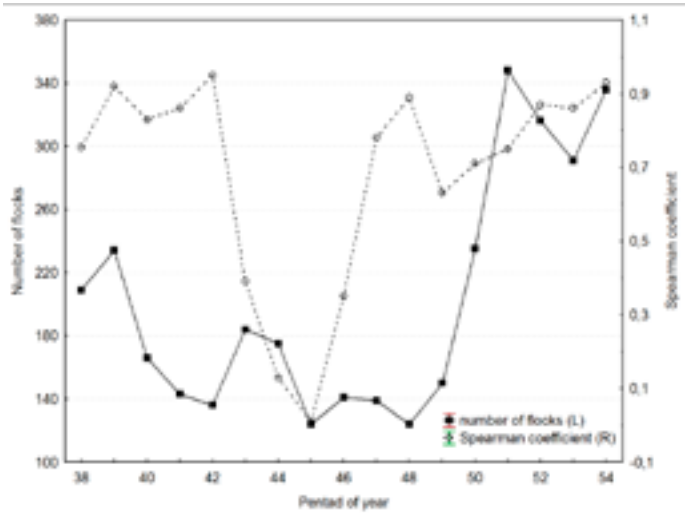


Fig. 5. *Changes of the Spearman correlation coefficient values calculated for the number of arrived flocks from 8 directions between two adjacent pentads and the total number of flocks arriving to roost in the pentads; correlation coefficient values have been assigned to next pentad*

During the period from 3 July to 3 August (pentad 38-42), we did not observe significant changes in the dynamics of bird numbers or the number of flocks, while high values of Spearman correlation coefficients provided evidence for the arrival of birds from similar directions (Figure 5). The period from 4 to 23 August (43-46 pentad) was associated with an increase in the total number of birds at the roost (Figure 1). At the same time, flock size increased (Figure 2, 4) and correlation coefficients decreased, suggesting that starling flocks arrived from different directions (Figure 5). The next short period from the 24 August to 2 September (pentad 47-48) was characterized by the highest bird numbers (Figure 1) and a strong concentra-

tion of birds in flocks (a small number of flocks with many individuals) accompanied with a stabilization of arrival to the roost from similar directions (high value of Spearman correlation coefficient) (Figure 5). The last period from 3 to 27 September (pentad 49-54) was characterized by a gradual increase in the Spearman correlation coefficient value indicating a progressive directing of arrival of flocks to the roost (Figure 5). During this period, there was also a strong increase in the number of flocks with a weaker increase in the total number of birds at the roost (Figure 1, 5).

Separation of periods with different post-breeding behaviors

Separation of periods with similar characteristics of starling arrival to the communal roost was based on hierarchical clustering method, while taking into account: the number of starlings at the roost, number of flocks (both variables in the logarithmic transformation), and the Spearman correlation coefficient between the number of arriving flocks from different directions in adjacent pentads. A dendrogram of a distance between the pentads made on the basis of all these variables indicated the presence of four post-breeding stages (Figure 6).

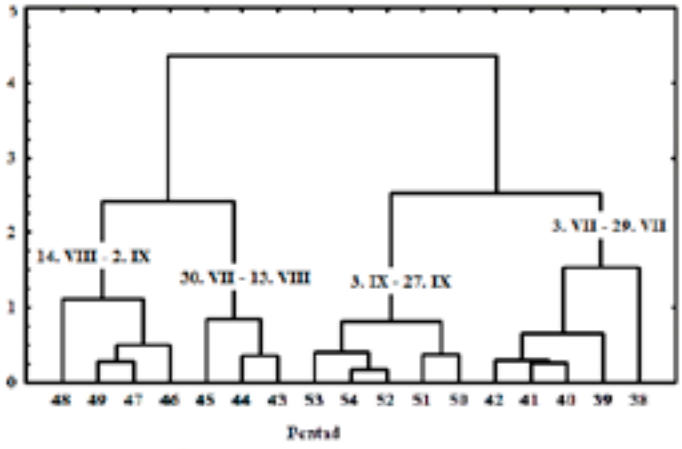


Fig 6. *The results of the separation of the pentads using the hierarchical clustering methods with respect to: the number of starlings at roosting, number of flocks (both variables in the logarithmic transformation) and Spearman correlation coefficient between the number of arriving flocks of following directs in adjacent pentads*

Statistical validity of this separation was confirmed using discriminant analysis (Figure 7, Table 1-3). Based on the position of factor loadings in the dimension of the first two functions, we could divide the first period (3-29 July) into two distinct periods of 3-19 July and 20-29 July (Figure 7).

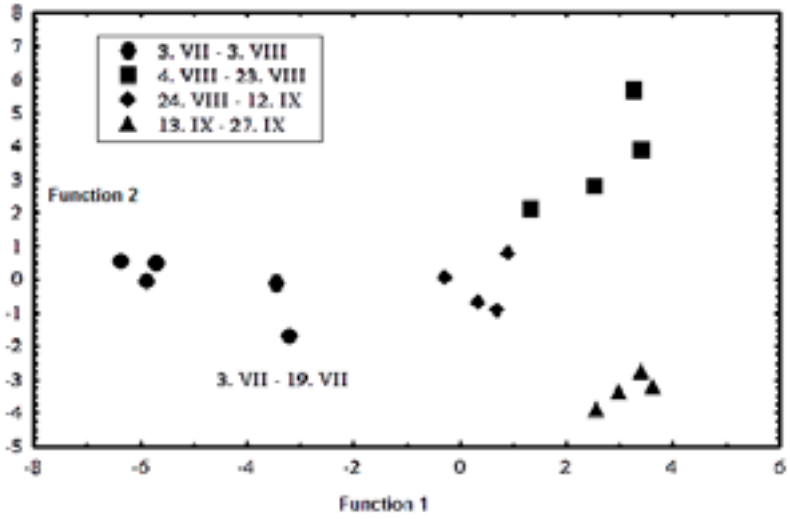


Figure 7. *Scatter of the canonical loadings factors for the first two functions*

Table 1. *Variables, they tolerance and canonical loadings factors between distinguished variables and functions used in the discriminant analysis*

Variable	λ Wilks'	λ partial	Fo(3,11)	p	tolerance	Func. 1	Func. 2	Func. 3
Spearman correlation coefficient	0.0438	0.1077	30.38	0.00001	0.712	-0.320	-0.817	-0.480
Log of flocks number	0.0286	0.1646	18.61	0.0001	0.506	0.158	-0.482	0.862
Log of total bird numbers	0.0424	0.1112	29.30	0.00002	0.407	0.369	-0.155	-0.917

Table 2. *The results of the testing of canonical functions*

Number of deleted function	Eigenvalue	R canonical	λ Wilks'	χ2	df	p
0	14.579	0.967	0.005	66.967	9	<0.00001
1	7.419	0.939	0.073	32.643	4	<0.00001
2	0.618	0.618	0.618	6.013	1	0.01421

Table 3. *Standardized coefficients of following functions*

Variable	Func. 1	Func. 2	Func. 3
Spearman correlation coefficient	-0.904	-0.728	-0.241
Log of flocks number	1.060	-0.740	0.552
Log of total bird numbers	1.470	-0.314	-0.446
Eigenvalue	14.579	7.419	0.618
Cumulative share of eigenvalues	0.645	0.973	1.000

The impact of weather conditions on the dynamics of birds arrival on the roost

Changes in the mean flock size of starlings arriving to the roost depended on wind strength ($F_{2, 3249}$ =7.235; p=0.0007) and type of precipitation ($F_{3, 3317}$ =3.006; p=0.029). Strong winds (>5°Bf) increased flock size, and an average wind speed of 2-5°Bf induced a modest decrease in the flock size in comparison with near windless conditions (Figure 8). Among the three categories of precipitation (fog, drizzle and rain) only fog induced an effect of increasing flock size (Figure 9). The fog was associated with an increased the proportion of the largest flocks (from the fourth and fifth size categories), while the drizzle and rain significantly increased the proportion of flocks from the third size category (Table 4).

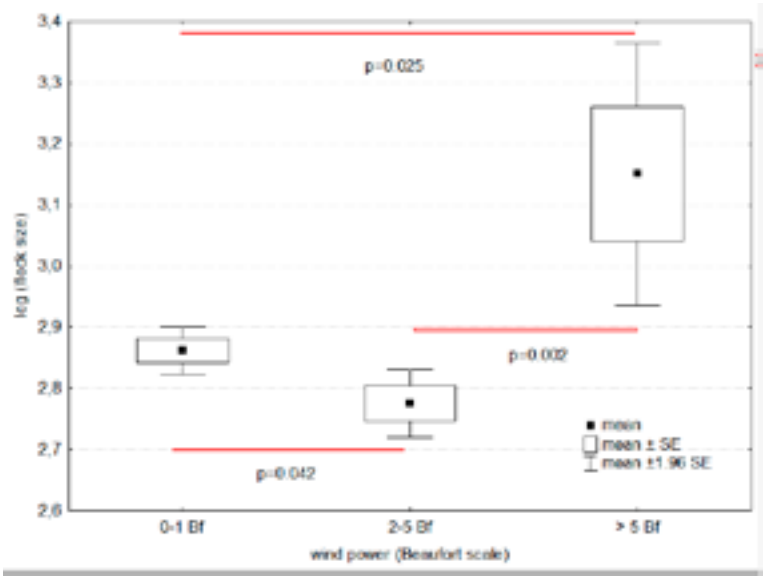


Fig. 8. *Mean flock size in the logarithmic transformation depending on the wind speed; shown the significant statistic relevance of post hoc Bonferonni test*

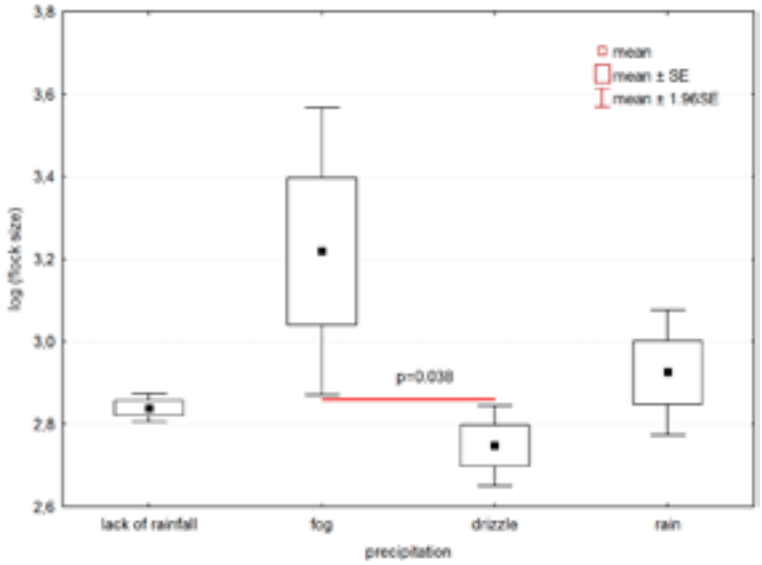


Fig. 9. *Mean flock size in the logarithmic transformation depending on the precipitation type; shown the significant statistic relevance of post hoc Bonferonni test*

Table 4. *Distribution of starling flock sizes depending on the type of precipitation (2 =38.15; df=12; p<0.001)*

Precipitation type		Flock size category					Total
		1	2	3	4	5	
lack of precipitation	N (%)	122 (4.3)	1069 (36.8)	979 (33.7)	632 (21.7)	106 (3.6)	2908 (100)
fog	N (%)		9 (28.1)	11 (34.4)	8 (25.0)	4 (12.5)	32 (100)
drizzle	N (%)	12 (4.4)	97 (35.4)	115 (42.0)	48 (17.5)	2 (0.7)	274 (100)
rain	N (%)	1 (0.9)	31 (29.0)	54 (50.5)	17 (15.9)	4 (3.7)	107 (100)
total	N	135	1206	1159	705	116	3321

DISCUSSION

Any division of post-breeding period of the common starling without considering the data from marked individuals is difficult and risky. On the other hand, an analysis of retraps (eg. Payevsky 1971) which is not linked to the aspects of bird behavior may also lead to simplistic conclusions. Our description of the dynamics of the roost size and identification of determinants of changes in the dynamics of bird arrival to the roost perfectly complements knowledge about the post-breeding behavior of this species. The roost clearly demonstrates a „wave" dynamic of bird numbers with two distinct peaks. In our study, wave dynamics of bird numbers did not form a homogeneous structure and the timing of the roosting did not correspond to the previous studies at the Curonian Spit and Zulawy (Bielopol'skij and Odincova 1971; Gromadzki 1980).

Our methods of analysis indicated the presence of 4 or 5 post-breeding periods of starling behavior (Figure 6-7). The two methods yielded similar results, and the differences were only visible in the length of the periods, although they never exceeded two pentads. The periods seem to be best separated with the discriminant analysis method, because the division is made based on the partial contribution of independent variables. During the first period, ie. from early July to 3 August, the roost showed a gradual aggregation of individuals from nearby areas. It was characterized by high stability in the number of arriving flocks and an increase in the total number of starlings at the roost. This means that the influx of birds was slow and small groups of individuals gradually joined the roost. High correlation between the number of flocks arriving from the various directions between pentads also confirmed stability of the phenomenon. This period can be divided into two shorter ones (I – 3-19 July; II – 20 July-3 August), which differed only in the intensity of bird influx. The second period (4-23 August) was characterized by a very rapid increase in total bird numbers with a constant level of arrival flock numbers. As in the earlier period, the mean flock size proportionally increased with the total number of birds at the roost, as shown by the high correlation between these variables ($r=0.93$, $n=56$; $p<0.0001$). While the first period was likely characterized by short-distance movements, the second one must have involved movements of birds from more distant areas. It was a period of very large changes in bird numbers, with the maximum concentration of birds at the roost and a low correlation in the number of arriving flocks from different directions between adjacent pentads. This relationship, in particular, distinguished this period from the previous one. Instability in the number of arriving flocks from different directions indicates that the arrival of birds to the roost was a very dynamic process, and such a behavior might be associated with frequent changes in the points of concentration of birds during this period. Moving birds have the effect of variation in points of concentration and, thus, the directions from which they arrived. Presumably, this may reflect a displacement of birds

from smaller roosts to a larger one, as indeed the disappearance of a small nearby roost was observed at the same time. Alternatively, this pattern might be consistent with a higher intensity of long-distance movements. The third period (24 August-12 September) was characterized by a rapid decline in the total number of starlings at the roost and a decrease in the mean flock sizes. A rapid increase in flock numbers along with a decrease in their size probably indicates the start of the autumn migration phase. We know from field observations that starlings migrate through central Poland in relatively small flocks, usually smaller than 60 individuals (Z. Wojciechowski – pers. obs.). Migrating birds have less time to concentrate in large flocks. Decreasing day length during migration means that birds have less and less time for feeding, so the time available for clustering in large flocks must be limited.The fourth period began on 13 September and, similarly to the previous one, was characterized by an increasing stabilization of the direction from which flocks arrived. This seems to indicate a progressing phase of autumn migration, when roaming flocks are expected to arrive to the roost from feeding grounds without clustering at independent points of concentration. In contrast to the previous period, the number of birds at the roost and the number of flocks increased.

Proportionately fewer flocks arrived from directions from which they could be expected during the migratory period, i.e. from north, north-east, and east (χ^2=76.36, df=17, p<0.001). This means that during migration, starlings do not fly directly to roosts and arrivals are preceded by the penetration of the surrounding areas, most likely associated with the search for food. Thus, arrivals from northern directions (Figure 10) could also be related to the location of favorable feeding grounds and points of bird concentration. Theoretically, it is expected that periods of apparent displacement of starlings should be associated with their weaker recognition of good feeding areas and points of concentration in comparison with periods of greater stability. Under this assumption, we can expect that the proportion of flocks arriving from different directions should become more similar during migration. Hence, it can be assumed that the entropy of information related to the arrival of flocks from different directions should increase during periods when the roosting behavior of the birds is changing. As expected, the proportion of flocks arriving from the north became lower as the season progressed (Figure 10), as well as became negatively related to the H' index (r=-0.898, df=16, p<0.0001). A large number of flocks that arrived from the north were frequently associated with both tall poplar trees *Populus serotina* which serve as points of concentration for birds in large flocks and the border meadows of the Bzura River that are locally very important feeding site for starlings during the post-breeding period.

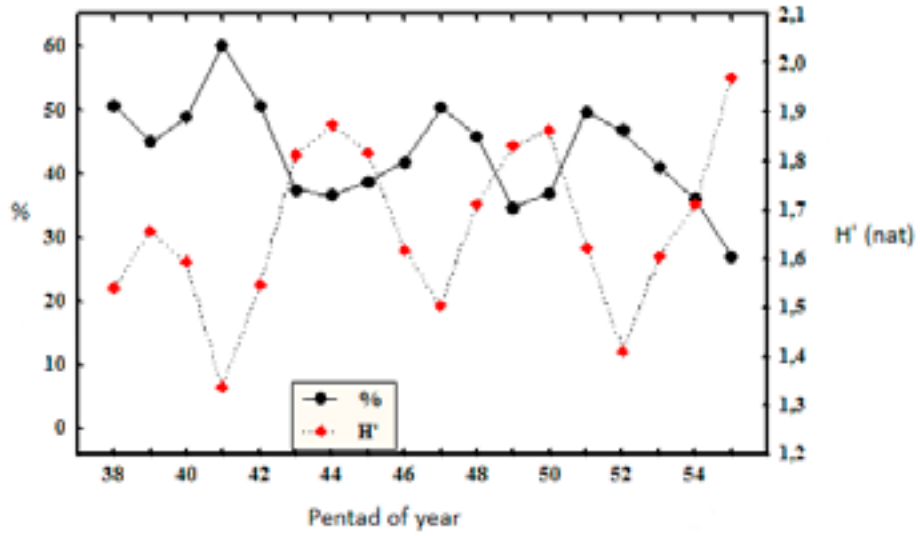


Fig. 10. *Changes in the share of a flock of starlings arriving from the north compared to changes in the Shannon-Wiener functions (variation of entropy of information) calculated from the proportion of flocks arriving from distinguished directions in the next pentads of year; solid lines indicate periods separated using discriminant analysis method*

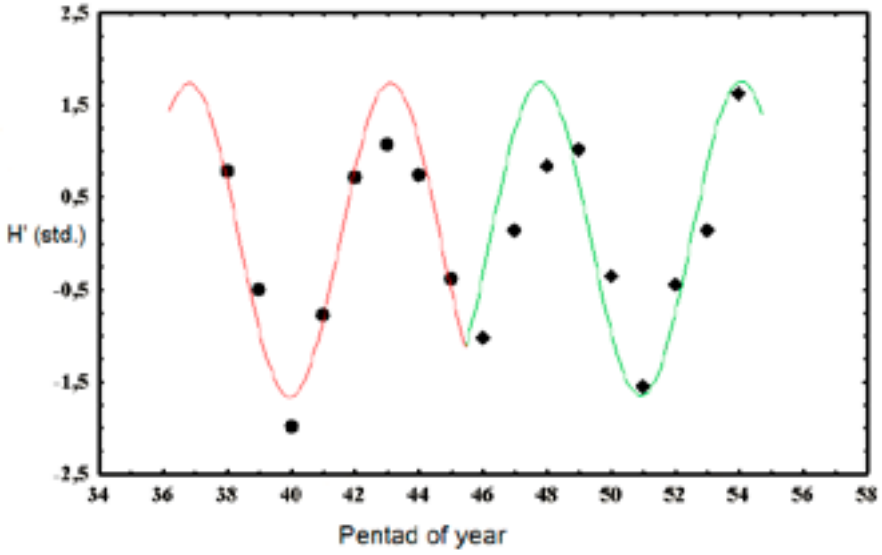


Fig 11. *Variation of entropy of information (H') calculated from the proportion of flocks arriving from distinguished directions in the next pentads of year*

Periods of increasing or decreasing H' index corresponded well to the separation of bird behavior based on the discriminant analysis function. An increase in the

entropy of information indicated a clear advantage of movements in flocks, and its decline was associated with periods of stabilization of bird numbers at the roost, often combined with gradual processes of aggregation and dispersion of individuals. After the departure of several of the flocks, the remaining birds likely continued to become better at finding sites for foraging and concentrating before roosting and thus the H' index decreased. It is difficult to explain the cyclical nature of variation in H' index (Figure 11). The last two cycles continued for more than 1.6 pentads, so this relationship may not be adequately described using a regression. The equation for the first two incomplete cycles takes the form $y=0.001x + 1.7\cos(x-5.4)$, and the two consecutive cycles take the form of $y=0.001x + 1.7\cos(x-3.8)$. It seems that the cyclical rhythm is a reflection of the same migration.

The size of starling flocks arriving to the roost was only slightly affected by weather conditions: wind, precipitation, but mainly fog. Wind blowing at a speed of 2 to 5 degrees on the Beaufort scale resulted in smaller flocks, while stronger winds resulted in an increased concentration of birds in the flocks, probably, the birds have difficulty flying in small groups and thus form large flocks for better stability. By contrast, fog increased the percentage of the largest flocks, despite the fact that such weather conditions usually cause an earlier arrival of birds to the roost, and for this reason, individuals have less time available to aggregate into smaller flocks. It seems likely that birds may feel safer in large flocks during adverse weather. There was a much weaker effect due to rain and drizzle, which increased the proportion of flocks from the third size category, this may be explained by a shortened period of time for the concentration of starlings into flocks due to the reduced light levels, inducing them to return to roost earlier than normal.

CONCLUSIONS

1. Structure of the "wave" dynamic in the number of starlings at the roost does not form a homogeneous structure in terms of birds behavior.
2. Post-breeding period of starlings (from July to the end of September) can be divided into five sub-periods:
   IA – from 3th July to 19th July,
   IB – from 20th July to 3th August,
   II – from 4th August to 23th August,
   III – from 24th August to 12th September,
   IV – from 13th September to the end of the month.
3. The distinguished sub-periods follow each other with a similar rhythm.
   IA – the period is characterized by an increase in the total bird numbers and the number of flocks. This is the beginning of roosting which involves an increasing number of birds after the second brood.

IB – this period is different from the previous one, despite continuing growth in total bird numbers. It is characterized by a decline in the number of flocks and an increase in flock size. It is a stable period of slow accumulation of starlings to the roost.

II – this period is characterized by a rapid growth in the total number of birds with no or a slight decrease in the number of flocks. It is distinguished by a decisive decrease in the value of the correlation coefficient between neighboring pentads, which may be due to the concentration of starlings into large flocks.

III – during this period, birds start to leave the roost, so their number rapidly declines. Correlation between adjacent pentads and the number of flocks increases, while the total number of birds decreases.

IV – the last period was wandering, the number of overnight birds is rapidly increasing, while the number of flocks remained at the same level or increasing. Correlation coefficient of the number of flocks arriving from different directions between adjacent pentads increses.

4. The most pronounced and regular cyclicity is variability of information entropy measure by H' index, which counted was the proportion of flocks arriving with 8 directions of the compass. The increase in entropy was associated with an arrival of new flocks at the roost, and so with migration of birds. In contrast, the periods of a decline in H 'are related to the time of departure stabilization or starlings on roost. The reason for this variation is probably the degree of the feeding grounds, and perhaps accumulation of individuals in the flocks.
5. Weather only slightly changed the size distribution of starling flocks arriving to the roost. Strong winds (>5 on the Beaufort scale) resulted in an increase in the mean flock size and weak winds caused the reduction of flock size. Also, precipitation caused changes in the distribution of flocks size. Fog resulted in the concentration of individuals into larger flocks, while drizzle and rain, rain in particular, increased the proportion of flocks from the third size category.

DYNAMIKA PRZYLOTU SZPAKÓW *STURNUS VULGARIS* NA NOCLEGOWISKO W OKRESIE POLĘGOWYM

STRESZCZENIE

Przedmiotem badań jest statystyczny opis zjawiska przylotu szpaka *Sturnus vulgaris* na noclegowisko, próba wydzielenia okresów wędrówkowych na podstawie charakterystyk przylotów oraz ocena wpływu warunków atmosferycznych na rozkład wielkości stad. Badania były prowadzone na noclegowisku znajdującym się na terenie stawu rybnego Okręt (52°02'N, 19°51'E) leżącego w obrębie pradoliny warszawsko-berlińskiej (Centralna Polska). Ogółem zebrano informacje dotyczące

przylotu 3520 stad szpaków, w ciągu 88 dni badań. Obserwacje przylotu szpaków na noclegowisko prowadzone były codziennie w okresie od 3.VI do 27.IX.1979 roku oraz dodatkowo, dwukrotnie w październiku (15 i 22.X.1979). Liczenia ptaków rozpoczynano przed przylotem pierwszych ptaków i prowadzono do czasu zakończenia zapadania ptaków na noclegowisko. Podczas obserwacji notowano: czas przylotu kolejnych stad szpaków, wielkość każdego stada, kierunek jego przylotu oraz warunki pogodowe (temperatura, siła wiatru w skali Beauforta, stopień zachmurzenia w skali od 0 do 10 oraz opad z wyróżnieniem mgły, mżawki i deszczu). Liczebność gromadzących się na noclegowisku ptaków w kolejnych dniach ustalano w oparciu o założenie log-normalności rozkładów, z których wyliczono średnie rozkładu log-normalnego. Zależność między liczbą nadlatujących stad z poszczególnych kierunków w sąsiadujących pentadach roku opisana została współczynnikiem korelacji Spearmana policzonym dla róży wiatrów zaczynając od kierunku północnego, a kończąc na północno-zachodnim (n = 8 kierunków x 5 dni), a wartości korelacji zostały przyjęte jako miara stałości zjawiska przylotu stad szpaków na noclegowisko. Wydzielenie okresów różnego zachowania się szpaków wykonano w oparciu o zmiany dynamiki liczebności, zmiany wielkości stad, zmiany liczby stad oraz zmiany współczynnika korelacji Spearmana między przylotami stad z wyróżnionych kierunków w kolejnych pentadach przy zastosowaniu metody hierarchicznego grupowania. Otrzymany podział sprawdzony został za pomocą analizy dyskryminacyjnej. Przebieg dynamiki liczebności przylatujących na noclegowisko szpaków wykazuje falową strukturę, z wyraźnymi dwoma okresami stopniowego wzrostu liczebności oraz dwoma szybkiego jej spadku. Liczebność gromadzących się na noclegowisku ptaków wzrastała od początku lipca (38 pentada) do 25 sierpnia (48 pentada) oraz w okresie od 2 do 19 września (od 50 do 53 pentady), osiągając maksimum 25 sierpnia – ok. 300,000 osobników. Spadek liczebności nastąpił dwukrotnie: pierwszy miał miejsce w terminie od 25 sierpnia (48 pentada) do początku września (50 pentada), drugi zaś między 19 września (53 pentada) i końcem okresu badań. Na podstawie analizy dendrogramu podobieństw i położenia ładunków czynnikowych w przestrzeni dwóch pierwszych pierwiastków wyodrębnionych w analizie dyskryminacyjnej wydzielono pięć okresów wędrówkowych związanych z odmiennym zachowaniem się szpaków oraz dynamiką liczebności. Zmiany średniej wielkości stada przylatujących szpaków zależały od siły wiatru oraz opadu mgły.

REFERENCES

Belopolskij L.O., Odincova N. P. 1971: Migracii skvorca, *Sturnus vulgaris* Lna Kurśskoj Kose (1957-1966). Ućen. Zap. Kalingr. Univ., 6: 108-117.

Busse P. 1973: Przedstawienie dynamiki wędrówek ptaków. Not. orn., 14: 68–75.

Caccamise D.F., Lyon L.A., Fischl J. 1983: Seasonal patterns in roosting flocks of Starlings and Common Grackles. Condor, 85: 474–481.

Cramp S., Simmons K.E.L. 1977: The Birds of the Western Palearctic. Vol. 7. Oxford University Press. Oxford.

Delvingt W. 1961: Les dortioirs d'Etourneaux (*Sturnus vulgaris*), de Belgique en 1959-60. Le Gerfaut, 51: 1–27.

Dylikowa A., Olaczek R. (red.). 1982: Środowisko geograficzne i przyrodnicze. [w:] Województwo Skierniewickie. Monografia regionalna. Zarys dziejów, obraz współczesny, perspektywy rozwoju. Gregorowicz J. (red.). UŁ, UW w Skierniewicach, Łódź – Skierniewice, str. 11–82.

FITTER R.S.R. 1942: The Starling roosts of the London Area. London Nat., 1941-1946: 3–23.

Francis W.J. 1976: Micrometeorology of a blackbird roost. J. Wildl. Manage., 40: 131–136.

Górska E. 1991: Roczny cykl rozpoczynania i kończenia aktywności dziennej miejskich populacji sierpówki (*Streptopelia decaocto*), wróbla (*Passer domesticus*), kosa (*Turdus merula*), szpaka (*Sturnus vulgaris*) i kawki (*Corvus monedula*) w Słupsku. Not. orn., 32: 37–54.

Górska E. 1992: Zróżnicowanie czasu rozpoczynania i kończenia aktywności dziennej w miejskich populacjach sierpówki (*Streptopelia decaocto*), wróbla (*Passer domesticus*), kosa (*Turdus merula*), szpaka (*Sturnus vulgaris*) i kawki (*Corvus monedula*) w cyklu rocznym. Not. orn., 33: 67–80.

Gramet P. 1976: Intéret practique de l'utilisation de la méthode d'effarouchement acoustique I.N.R.A. sur dortois d'etourneaux (*Sturnus vulgaris*). Cah. ing. agron., 308: 25–32.

Gramet P., Davoust P. 1973: Dortoir insulaire d'etourneaux (*Sturnus vulgaris*). Comportement naturel. Experience d'effarouchement acoustique. Ann. zool. – Ecol. anim., 5: 491–498.

Gromadzki M. 1980: Dynamika liczebności i siedliska żerowania szpaków *Sturnus vulgaris* na Żuławach Wiślanych. Acta orn., 17: 257–269.

Jumber J. 1956: Roosting behaviour of the Starling in Central Pennsylvania. Auk, 73: 411–426.

Keil W. 1965: Erfahrungen zur phonoakustischen Verbreitung Von Staren – *Sturnus vulgaris* – aus ihren Schlaftplätzen. Luscinia, 38: 78–85.

Krzysztofiak M., Urbanek D. 1975: Metody statystyczne. PWN, Warszawa.

Lack D. 1966: Population studies of birds. Oxford, Clarendon Press.

Lack D. 1968: Ecological adaptations for breeding in birds. London, Methuen.

Lyon L.A., Caccamise D.F. 1981: Habitat selection by roosting blackbird and starlings: management implications. J. Wildl. Manage., 45: 435–443.

Nice M.M. 1935: Some observations on the behaviour of Starling and Grackles in relation to light. Auk, 52: 91–92.

Paevskij V.A. 1971: Atlas migracij ptic po dannym kol 'cevanija na Kurśskoj Kose. Trudy Zool. Inst. Akad. Nauk SSSR, 50: 3–110.

Pielou C. 1974: Population and Community Ecology. Principles and Methods. Gordon and Breach, Science Publishers, Inc. New York.

Potts G.R. 1967: Urban Starling roosts in the British Isles. Bird Study, 14: 25–42.

Richner H., Heeb P. 1996: Communal life: Honest signaling and the recruitment center hypothesis. Behavioral Ecology, 7: 115–118.

Siegfried W.R. 1971: Communal roosting on the Cattle Egret. Trans. Roy. Soc. S. Afr., 39: 419–443.

StatSoft Inc. 2013: Electronic Statistics Textbook. Tulsa, OK: StatSoft. WEB: http://www.statsoft.com/textbook/

Ward P., Zahavi A. 1973: The importance of certain assemblages of birds as 'information centres' for food finding. Ibis, 115: 517–534.

Weatherhead P.J. 1983: Two principal strategies in avian communal roosts. Amer. Nat., 121: 237–243.

Zając R. 1979: Zastosowanie metody bioakustycznej w ochronie czereśni i wiśni przed szpakami. Prace ISK, S.F., 15: 1–7.

Zając R. 1983: Biosonics and piroacoustics as protection means of large cherry orchards against Starlings in Poland. Fruit. Sci. Rep., 10: 113–133.

Zając R.Z., Tranda E. 1987: Problemy związane z gromadnymi noclegowiskami szpaków w Polsce i wyniki prób ich rozwiązania. Prz. Zool., 31: 65–88.

Zar J.H. 1984: Biostatistical analysis. Second Edition. Prenticle-Hall, Inc. Englewood Cliffs, New Jersey.

Zoologica Poloniae (2016) 61/1. 41-52

CRANIOMETRIC ANALYSIS OF THE FAT DORMOUSE *GLIS GLIS* FROM SLOVAKIA

Alexander Čanády[1*], Ladislav Mošanský[2] and Peter Krišovský[3]

[1*] Institute of Biology and Ecology, Faculty of Science, P.J.Šafárik University, Šrobárova 2, SK-041 54 Košice, Slovakia e-mail: alexander.canady@gmail.com
[2] Institute of Parasitology, Slovak Academy of Science, SK-040 01 Košice, Slovakia. e-mail: mosansky@saske.sk
[3] The East Slovak Museum Košice, Námestie Maratónu mieru 2, SK-040 01 Košice, Slovakia. e-mail: peter.krisovsky@vsmuzeum.sk

[*] Corresponding author: alexander.canady@gmail.com

Abstract. A craniometric analysis was conducted on skulls of fat dormice (*Glis glis*) from Slovakia. Eighteen skull and dental variables were measured and evaluated for a sample of 35 adult individuals according to age classes II-IV. Overlap of the values of the measured traits between the age classes was evident, and analysis of the measurements indicated that growth takes place throughout an individual's life. Moreover, this study also shows the importance of collecting large samples of specimens for preservation in museum collections that are currently the subject of species conservation efforts. Comparisons of the literature data with our results showed differences in the measurements between different regions; therefore, we can speak about regional craniometric differentiation. Our population is similar in skull size and falls into the variability range of the subspecies *G. g. germanicus*.

Keywords: dental trait; skull measurement; age class; PCA analysis

INTRODUCTION

The fat dormouse (*Glis glis*) is a widespread species whose range mainly coincides with the deciduous forest zone in the western Palearctic (Kryštufek 2010). This causes large variability in body and cranial characteristics, depending on the distribution area (Miller 1912; Sidorowicz 1958; Storch 1978; Gaisler *et al.* 1977; Homolka 1979; Spitzenberger 1983; Anděra 1986; Doğramaci and Tez 1991; Peshev and Delov 1995; Spitzenberger and Bauer 2001; Potapova, 2001;

Çolak *et al.* 1998, 2003; Grubešić *et al.* 2004; Kryštufek and Vohralík 2005; Kryštufek 2010; Helvaci *et al.* 2012; Markov, 2001, 2014). The mentioned studies showed that the numerical values of most of these measurements overlap between age classes, sexes, populations and subspecies. Both sexes were also found to be the same in size and coloration, and therefore we can consider this species to be monomorphic (Kryštufek 2010; Čanády et al. 2016).

Krištofík (2012) summarized published and unpublished data from Slovakia and showed that the dormice inhabit broadleaved and mixed forests and is represented on approximately 43.9% of Slovak territory. Nevertheless, no analysis of cranial traits of dormice has been adequately performed in Slovakia (see Gaisler *et al.* 1977; Homolka 1979; Anděra 1986). Anděra (1986) evaluated individuals from the territory of the former Czechoslovakia, now the Czech and Slovak Republics. However, the majority of the samples came from the Czech lands (Bohemia and Moravia), and only 14 individuals were from Slovakia. Čanády et al. (2016) conducted a comprehensive analysis of somatic measures from Slovakia.

In this study, we provide morphological analyses of skull and dental sizes of individuals from Slovakia. Accordingly, the main aims of our research were to contribute to the knowledge of quantitative characteristics of measures and describe their variability.

MATERIAL AND METHODS

In Slovakia, the fat dormouse is a species of conservation concern, and the country is a contracting party to the Bern Convention, which lists *G. glis* in Appendix III (Kryštufek 1999; Žiak and Urban 2001). Therefore, the sample size evaluated in this study was restricted only to individuals of older data deposited in museums. The samples analyzed in this study came from 13 localities in eastern Slovakia and were taken from the collections of the Department of Natural History of the Sarisske Museum Bardejov and the East Slovakian Museum in Kosice (see Mošanský 1993; Hromada *et al.* 2015). The material was collected at the following sites: Sarisske Museum Bardejov – (30): Bardejov (13), Zlaté Poľany (4), Vyšná Voľa (3), Lenartov (3), Hertník (3), Lukavica (1), Šiba (1), Livov (1), Cigeľka (1); East Slovakian Museum in Kosice – (5): Košice – Čermeľská dolina (1), Košické Hámre (1), Ružín (1), Rožňava (1), Bardejov (1).

For the purpose of analysis of craniometrical variability within our *G. glis* populations, a total of 35 skulls belonging to age classes II-IV were examined. Age was estimated from the degree of enamel abrasion on the occlusion surface of the molars (Gaisler *et al.* 1977; Homolka 1979). Skull measurements were measured using a digital calliper with an accuracy of 0.01 mm, and dental traits were measured with a stereomicroscope Olympus SZ 400. Moreover, all of the skulls were measured only by one person (L. Mošanský) and only the right side was measured in the paired characteristics.

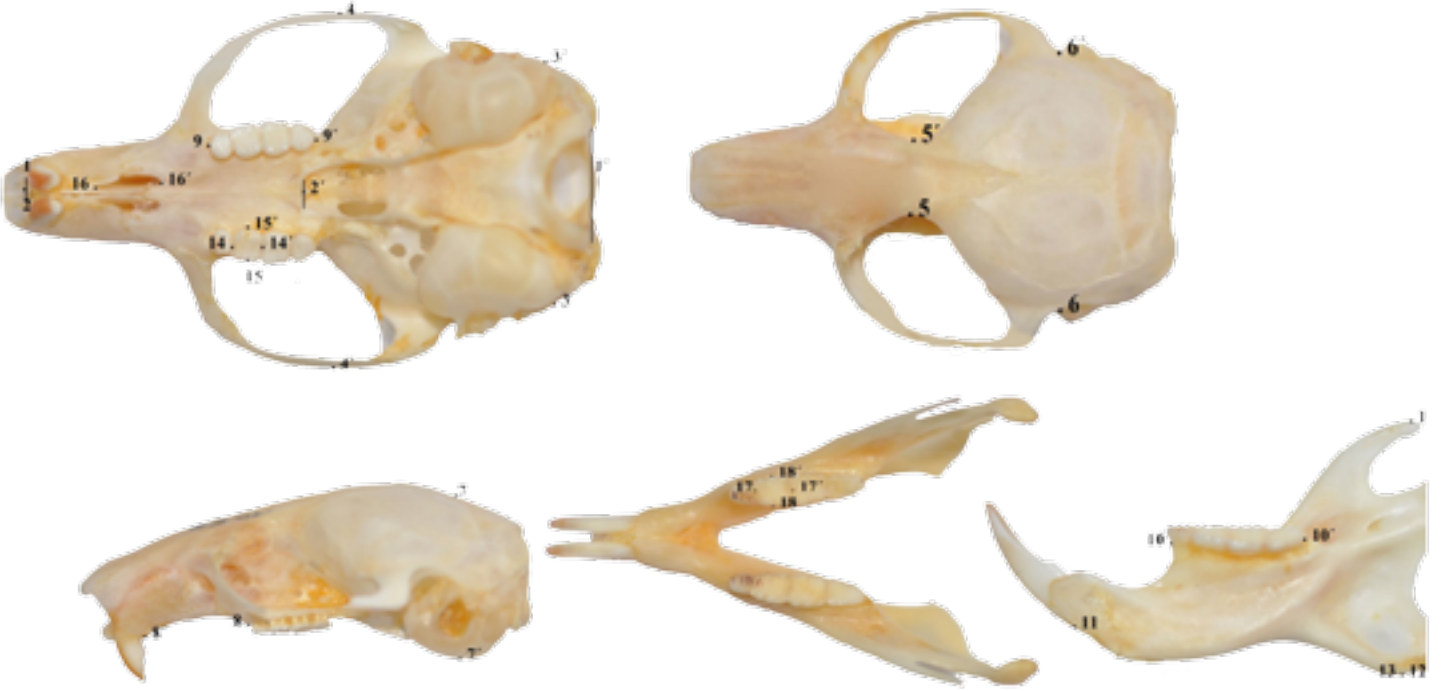


Figure 1. *Skull and dental measures used in the study of Glis glis. Measures: LCb – condylobasal length (1-1´); LPm – median palatal length(2-2´); MW – mastoidal width (3-3´); LaZ – zygomatic breadth (4-4´); Io – postorbital breadth (5-5´); LaN – neurocranium breadth (6-6´); BCH – brain case height per bullae (7-7´); LD – length of the diastema (8-8´), LOSD – length of the tooth row in the maxilla (9-9´); LOID – length of mandibular tooth row (10-10´); LMd – total length of mandible at processus articularis (11-11´); AMdm – maximum height of mandible excluding coronoid process (12-12´); AMd – coronoid height of mandibular (13-13´); LM1 – length of the first upper molar (14-14´); WM1 – breadth of the first upper molar (15-15´); LFI – length of foramen incisivum (16-16´); LM1 – length of the first lower molar (17-17´); WM1 – breadth of the first lower molar (18-18´).*

A preliminary analysis and analysis of body traits (see Kryštufek 2010; Čanády *et al.* 2016) showed an overlap of values in the sexes and confirmed monomorphism; the specimens were therefore pooled. In contrast, a preliminary analysis using the unpaired t-test showed significant differences in the measured traits between the age categories (namely between age category II and age category III, see Table 1).

Table 1. *Results of unpaired t-test between age categories II and III. Explanations: P – P-value (* P<0.05,** P<0.01, *** P<0.001. Abbreviations of measured traits see in Material and methods.*

	t	P
LCb	5.65	<0.0001***
LPm	4.24	0.0002***
MW	4.36	0.0003***
LaZ	4.95	0.0001***
Io	2.49	0.0188*
LaN	3.74	0.0011**
BCH	2.02	0.0554
LD	5.83	<0.0001***
LOSD	1.03	0.3137
LOID	0.45	0.6580
LMd	7.34	<0.0001***
AMdm	4.87	<0.0001***
AMd	5.63	<0.0001***
LM^1	0.92	0.3625
WM^1	0.33	0.7456
LFI	1.12	0.2707
LM_1	0.38	0.7098
WM_1	2.19	0.0370*

The following 18 skull and dental traits (Figure 1) were measured, as recommended by several authors (Storch 1978; Anděra 1986; Baláž *et al.* 2013): LCb – condylobasal length (1-1′); LPm – median palatal length (2-2′); MW – mastoidal width (3-3′); LaZ – zygomatic breadth (4-4′); Io – postorbital breadth (5-5′); LaN – neurocranium breadth (6-6′); BCH – brain case height per bullae (7-7′); LD – length of the diastema (8-8′), LOSD – length of the tooth row in the maxilla (9-9′); LOID – length of mandibular tooth row (10-10′); LMd – total length of mandible at *processus articularis* (11-11′); AMdm – maximum height of mandible excluding coronoid process (12-12′); AMd – coronoid height of mandibular (13-13′); LM^1

– length of the first upper molar (14-14′); WM^1 – breadth of the first upper molar (15-15′); LFI – length of *foramen incisivum* (16-16′); LM_1 – length of the first lower molar (17-17′); WM_1 – breadth of the first lower molar (18-18′).

The obtained untransformed data was evaluated using the following statistical parameters: means (M), standard deviation (SD), standard error of the mean (SE) and coefficient of variance (CV). The D'Agostino-Pearson omnibus K^2 test and the Shapiro-Wilk *W*-test were used to decide whether the values met the conditions of Gaussian distribution. All measurements were also $\log_{10}$ transformed to reduce intra-sample variation and to improve normality. We investigated the relationships among skull and dental traits using principal component analyses (PCA) based on a variance-covariance matrix.

Analyses were made using MS Excel 2003 for Windows XP and the statistical analysis system GraphPad Prism version 5.01 (GraphPad Software, Inc., San Diego, California, USA). Principal component analysis was done using the Statistical Software PAST, version 3.11 (Hammer et al., 2001).

RESULTS

The descriptive statistics of the studied variables for fat dormice of different age categories from Slovakia are reported in Table 1. Although the age category samples were too small, the overlap of the range values of the measured traits in the ages was evident, and analysis of the measurements indicated that growth takes place throughout an individual's life. A very large increase was obtained for all measured traits (with the exception of dental traits, in which a decrease due to the abrasion of teeth enamel was observed) but distinguished according to the growth rates (Table 2). A total increment in the range of 10-19% was observed for traits AMdm, AMd, LaZ and LMd. An intermediate increase with an increment in the range of 6-9% was found for traits LD, LCb, LaN, MW and LFI. Finally, a minimal increase of 2-4% was stated for traits Io, BCH and LPm. Moreover, despite the small sample sizes, which are insufficient to make definitive conclusions, the tests confirmed significant differences in all traits (with the exception of a few traits, see Table 2) between age categories II and III. The results of PCA, as an exploratory technique for discovering structure in data, are given in Table 3. The PCA values showed that the first two principal components (PC1–PC2) explain 73.2% of the variation. The first component (PC1) explained 49.8 of the total variance and was associated mainly with length of the *foramen incisivum* (LFI) and maximum height of the mandible excluding coronoid process (AMdm). A second factor (PC2) accounted for 23.4% and was correlated with maximum height of the mandible (AMdm) and coronoid height of mandibular (AMd). Finally, a third component (PC3) accounted for only 5.5% of overall variation and was highly associated with the length and breadth of the first upper molar (LM^1 and WM^1).

Table 2. *Comparison of cranial measurements (mm) in three age categories of fat dormouse (Glis glis) from Slovakia. Data for females and males were pooled.*

	Age category II					Age category III					Age category IV					Increment (%)
	N	M ±SD	min-max	SE	CV	N	M ±SD	min-max	SE	CV	N	M ±SD	min-max	SE	CV	
LCb	10	33.81±0.65	33.21-34.95	0.21	1.9	17	35.65±0.91	34.22-37.19	0.22	2.6	2	36.40±0.06	36.35-36.44	0.05	0.2	7.7
LPm	13	17.75±0.46	17.05-18.98	0.13	2.6	17	18.54±0.55	17.29-19.43	0.13	3	3	18.37±0.23	18.11-18.52	0.13	1.2	2.0
MW	8	12.67±0.46	11.90-13.32	0.16	3.7	14	13.35±0.26	12.77-13.69	0.07	2	2	13.53±0.08	13.47-13.59	0.06	0.6	6.3
LaZ	7	21.16±0.60	20.38-22.13	0.6	2.9	13	22.60±0.64	21.52-23.61	0.18	2.8	3	23.56±0.47	23.17-24.08	0.27	2	11.3
Io	15	5.02±0.11	4.70-5.16	0.03	2.3	17	5.14±0.17	4.91-5.71	0.04	3.3	3	5.22±0.12	5.10-5.34	0.07	2.3	4.0
LaN	9	15.55±0.37	15.07-16.03	0.12	2.4	16	16.03±0.28	15.64-16.53	0.07	1.8	2	16.58±0.30	16.37-16.79	0.21	1.8	6.6
BCH	9	12.89±0.38	12.30-13.43	0.13	3.0	15	13.22±0.38	12.54-13.88	0.10	2.8	2	13.31±0.03	13.29-13.33	0.02	0.2	3.3
LD	15	8.88±0.28	8.24-9.48	0.07	3.2	17	9.49±0.32	9.13-10.20	0.08	3.3	3	10.02±0.30	9.68-10.25	0.17	3	9.0
LOSD	15	6.63±0.16	6.35-6.92	0.04	2.4	17	6.69±0.19	6.27-6.98	0.05	2.9	3	6.42±0.24	6.23-6.69	0.14	3.7	
LOID	14	7.10±0.20	6.69-7.41	0.05	2.8	17	7.13±0.21	6.69-7.43	0.05	2.9	3	6.94±0.15	6.77-7.05	0.09	2.2	
LMd	14	17.76±0.53	17.11-18.83	0.14	3.0	17	19.01±0.41	18.14-19.80	0.10	2.2	3	19.56±0.68	18.84-20.19	0.39	3.5	10.2
AMdm	13	9.14±0.65	8.26-10.87	0.18	7.1	17	10.21±0.59	9.25-11.32	0.14	5.7	3	10.84±0.15	10.69-10.99	0.09	1.4	18.6
AMd	13	11.94±0.43	11.42-12.57	0.12	3.6	17	13.04±0.60	11.72-13.91	0.14	4.6	3	13.48±0.65	12.73-13.87	0.38	4.8	12.9
LM^1	15	1.88±0.06	1.75-1.95	0.02	3.4	17	1.90±0.08	1.83-2.13	0.02	4.4	3	1.83±0.08	1.75-1.90	0.04	4.1	
WM^1	15	2.01±0.04	1.95-2.08	0.01	1.8	17	2.01±0.10	1.75-2.13	0.02	4.9	3	2.02±0.08	1.95-2.10	0.04	3.8	
LFI	14	3.75±0.16	3.35-4.00	0.04	4.3	17	3.78±0.18	3.55-4.30	0.05	4.8	3	3.98±0.23	3.75-4.20	0.13	5.7	6.1
LM_1	14	1.93±0.06	1.83-2.03	0.02	3.0	17	1.93±0.06	1.83-2.03	0.01	2.9	3	1.89±0.05	1.83-1.93	0.03	2.7	
WM_1	13	1.91±0.05	1.83-2.00	0.01	2.4	17	1.95±0.06	1.85-2.03	0.01	2.8	3	1.93±0.06	1.88-2.00	0.04	3.3	

Explanations: N – number of individuals; M – mean; SD – standard deviation; SE – standard error of the mean; CV – coefficient of variance. Abbreviations of measured traits see in Material and methods.

Table 3. *Loading values of Principal Component Analysis (PCA) for the three main components (PC1–PC3) for G. glis: their eigenvalues and percentage (variability %) expressions. Abbreviations of measured traits see in Material and methods*

	PC 1	PC 2	PC 3
LCb	0.119	0.188	0.016
LPm	0.114	0.189	0.192
MW	0.037	0.138	-0.113
LaZ	0.051	0.169	-0.055
Io	0.034	0.075	-0.078
LaN	0.041	0.130	0.023
BCH	0.029	0.127	-0.051
LD	0.209	0.190	-0.172
LOSD	0.040	0.006	0.339
LOID	0.085	-0.042	0.383
LMd	0.106	0.323	-0.037
AMdm	0.313	0.552	-0.028
AMd	0.224	0.404	-0.011
LM^1	0.026	0.047	0.414
WM^1	0.013	0.006	0.569
LFI	0.865	-0.472	-0.062
LM_1	0.059	0.012	0.303
WM_1	0.037	0.076	0.231
Eigenvalue	0.004	0.002	0.000
Variance (%)	49.8	23.4	5.5

DISCUSSION

Data on the morphology of skull and dental traits of *G. glis* from the European distribution range have been published by several authors: Western Europe by Miller (1912); Poland by Sidorowicz (1958); Central and Eastern Europe by Storch (1978); Austria by Spitzenberger (1983) and Spitzenberger and Bauer (2001); Czech and Slovak Republic by Anděra (1986); Bulgaria by Peshev and Delov (1995) and Markov (2001, 2014); Croatia by Grubešić *et al.* (2004) and the territory of northern Turkey (Doğramaci and Tez 1991; Çolak *et al.* 2003; Kryštufek

and Vohralík 2005; Helvaci *et al.* 2012). Storch (1978) studied the populations of fat dormice from Central and Eastern Europe from a taxonomical point of view, summarizing and comparing older literature data from several European countries. Based on this comparison, he showed differences in size between different populations. The population from southern Europe showed bigger values than specimens from the northern part of the European continent. On the other hand, Peshev and Delov (1995) reported values for specimens of *G. glis* from Bulgaria, but a more detailed comparison with our results is not possible due to the use of a different method of aging their samples belonging to another subspecies. Similarly, Markov (2001) showed low inter-population divergence for non-metrical cranial traits among Bulgarian samples of *G. glis*.

Anděra (1986) presented a morphometric analysis of dormice from the territory of the former Czechoslovakia. Based on the average values and variation ranges, the author showed divergence between the populations. Individuals from northern Moravia (25 individuals) appeared smaller upon comparison with animals from central Bohemia (49 ind.) and the Western Carpathians (i.e. 14 samples from the territory of Slovakia), which were slightly larger. The samples were small, and the author could not conduct further statistical evaluations. Nevertheless, he showed for the index (LD/LCb) that the populations from central Bohemia and northern Moravia had a rostrum relatively longer than those from the Western Carpathians. A comparison of our results with those published by Anděra (1986) showed that dormice from eastern Slovakia had lower mean values than those from the Czech lands (central Bohemia and northern Moravia) and samples from the Western Carpathians (i.e. Slovakia territory). Nevertheless, the comparison proved that the numerical values of most of these measurements overlap between age classes.

Spitzenberger and Bauer (2001) presented skull and dental dimensions of dormice of age category II from Austria. Compared with the results of their study, our samples appeared to be smaller in all common features.

Comprehensive geographical variations on a subspecific level of *G. glis* were also investigated in its distribution area in Turkey (Selçuk *et al.* 2012; Helvaci *et al.* 2012). Based on morphometrical analyses, two subspecies were differentiated: the European population *G. g. pindicus* in Thrace from the Asiatic population *G. g. orientalis* in Anatolia (Doğramaci and Tez 1991). Moreover, the alveolar pattern in the Turkish population does not differ from the condition in Europe (Storch 1978; Çolak *et al.* 2003). On the other hand, Çolak *et al.* (2008 cited by Selçuk *et al.* 2012) showed that an analysis of 28 allozyme loci did not reveal any differentiation between the two subspecies. Similarly, Selçuk *et al.* (2012) showed on the basis of RAPD-PCR analysis (Random amplified polymorphic DNA that both subspecies were not clearly segregated. Based on these analyses, it should be stated that a contradiction exists between genetic and morphological data in distinguishing the subspecies of fat dormouse in Turkey. The reason for this discrepancy among the Glirid species was

due to the ancient origin and separation of its genera (Filippucci and Kotsakis 1995). Moreover, Kryštufek and Vohralík (2005) showed that the distribution range of fat dormice in Turkey had two parts, European and Asiatic. Nevertheless, Selçuk *et al.* (2012) in their study revealed that the population from Anatolia is genetically closer to those in Thrace. This shows that although the Bosporus and Dardanelles straits seem to be a geographic barrier, gene flow continues between the two populations. Similarly, Helvaci *et al.* (2012) investigated variation among the understudied zone of Northern Turkey using the mitochondrial cytochrome b gene for genetic differences and size and shape of the first upper molar for phenotypic differences. They found a conflict between the genetic and morphometric results. A great homogeneity throughout the Eurasian range of the *G. glis* was confirmed by genetic analyses. In contrast, morphometrics pointed to a complex, step-wise differentiation along the Black Sea coast, with differences between the easternmost and westernmost Turkish dormice. According to the authors, the genetic similarity suggests that this phenotypic differentiation is not the residue of glacial refuges, but it was result of a more recent post-glacial isolation.

In conclusion, comparisons of literature data with our results showed differences in characteristics between the different regions; therefore, we can speak about regional craniometric differentiation. Our population is similar in body (Čanády *et al*. 2016) and skull size and falls into the variability range (LCb less than 38.0 mm) stated by Violani and Zava (1995) and Kryštufek (2010) for the subspecies *G. g. germanicus*. This study also shows the importance of collecting large samples of specimens for preservation in museum collections that are currently the subject of species conservation efforts. The comparisons also confirmed larger dimensions for most cranial and dental characteristics in the southern European populations in comparison to the northern European populations, which could indicate a relationship to and the influence of altitude. Nevertheless, to confirm the above statements, more numerous materials from several parts of the distribution range as well from Slovakia, coupled with molecular analyses, will need to be evaluated in the future.

ACKNOWLEDGEMENTS

We would like to thank Mr. David McLean for linguistic revision of the manuscript. Our thanks also include Mr. Tomáš Jászay, a head of the Natural History Department of the Sarisske Museum Bardejov, Slovakia, for access to the collections and for general help. Finally, we would like to thank two anonymous referees for their valuable comments on the manuscript. This work was prepared with the financial help of grant no. VEGA 2/0060/14, 2/0059/15 and APVV – 14-0274.

KRANIOMETRIA POPIELIC *GLIS GLIS* ZE SŁOWACJI

STRESZCZENIE

Wykonano analizę kraniometryczną popielic (*Glis glis*) ze Słowacji. Zmierzono i oceniono osiemnaście punktów pomiarowych czaszek i zębów w próbce 35 dorosłych osobników według klas wiekowych od II do IV. Pokrywanie się wartości mierzonych cech między grupami wiekowymi było ewidentne a analiza pomiarów wykazała, że wzrost odbywa się przez całe życie osobnika. Ponadto, badania wykazały również znaczenie gromadzenia dużych próbek materiałów przechowywanych w zbiorach muzealnych, które są obecnie przedmiotem badań wykorzystywanych na rzecz ochrony gatunku. Porównanie danych literaturowych z naszymi wynikami wykazało różnice w pomiarach pomiędzy różnymi regionami. Dlatego możemy mówić o regionalnym zróżnicowaniu gatunku widocznym w pomiarach kraniometrycznych. Nasza populacja jest podobna w rozmiarze czaszki oraz mieści się w zakresie zmienności obserwowanej u podgatunku *G. g. germanicus*.

REFERENCES

Anděra M. 1986: Dormice (Gliridae) in Czechoslovakia. Part I.: *Glis glis*, *Eliomys quercinus* (Rodentia: Mammalia). Folia Mus Rer Natur Bohem Oxid, Plzeň, Zoologica 24: 3-47.

Baláž I., Ambros M., Tulis F., Veselovský T., Klimant P. and Augustiničová G. 2013: Hlodavce a hmyzožravce Slovenska. Univerzita Konštantina Filozofa v Nitre.

Çolak E., Sozen M., Yiğit N. and Ozkurt Ş. 1998: Hibernation and body weight in dormice, *Glis glis orientalis* (Nehring, 1903) (Rodentia: Gliridae), maintained under uncontrolled conditions. Turk J Zool., **22:** 1-7.

Çolak E., Yiğit N., Sozen M. and Ozkurt Ş. 2003: Data on the cranial and tooth development of *Glis glis orientalis* Nehring, 1903 (Rodentia: Gliridae). Acta Zool Acad Sci Hungaricae., 49(Suppl.): 33-38.

Çolak R., Kankılıç T., Olgun G., Kandemır I., Çolak E. 2008. Türkiye'de Yayılış Gösteren *Glis glis*'te Allozim Varyasyonları 19. National Biology Congress Abstrakt Book, June 2008. Trabzon

Čanády A., Mošanský L. and Krišovský P. 2016: Sexual size monomorphism and body variation in the fat dormouse *Glis glis* in Slovakia. Biologia. 71**:** 1061-1066.

Doğramaci S. and Tez C. 1991. Geographic variations and karyological characteristics of the species *Glis glis* (Mammalia: Rodentia) in Turkey. Turk. J. Zool., 15: 275-288.

Filippucci M.G. and Kotsakis T. 1995: Biochemical systematics and evolution of Myoxidae. Hystrix Ital. J. Mammal., 6: 77-97.

Grubešić M., Krapinec K., Glavaš M. and Margaletić J. 2004: Body measurements and harvesting dynamics of the fat dormouse (*Glis glis* L.) in the mountainous part of Croatia. Acta Zool Acad Sci Hung., 50: 271-282.

Gaisler J., Holas V. and Homolka M. 1977: Ecology and reproduction of Gliridae (Mammalia) in Northern Moravia. Folia Zool., 26: 213-228.

Hammer Ø., Harper D.A.T. and Ryan P.D. 2001: PAST: Paleontological statistics software package for education and data analysis, Palaeontol Electron. 4: 1-9.

Helvaci Z., Renaud S., Ledevin R., Adriaens D., Michaux J., Çolak R., Kankiliç T., Kandemir İ., Yiğit N. and Çolak E. 2012: Morphometric and genetic structure of the edible dormouse (*Glis glis*): a consequence of forest fragmentation in Turkey. Biol J Linn Soc., 107: 611-623.

Homolka M. 1979: A contribution to age determination in Gliridae. Folia Zool., 28: 103-114.

Hromada M., Čanády A., Mikula P., Peterson A.T. and Tryjanowski P. 2015: Old natural history collections for new millennium – Birds and mammals in the collection of PhMr. Tibor Weisz in Sarisske Museum Bardejov, Slovakia. Folia Oecologica, Acta Universitatis Presoviensis. 7: 115-141.

Krištofík J. 2012. Fat dormouse (*Glis glis*). In: Krištofík J. and Danko Š., (editors) Mammals of Slovakia: distribution, bionomy and protection. Veda – Slovak Academy of Sciences (SAS) Publishing House, Bratislava. pp. 76-81.

Kryštufek B. 1999. *Glis glis* (Linnaeus, 1766). In Mitchell-Jones A.J. et al., (editors) The atlas of European mammals. T & AD Poyser Natural History, London, United Kingdom. pp. 294-295.

Kryštufek B. 2010. *Glis glis* (Rodentia: Gliridae). Mamm. Species., 42: 195-206.

Kryštufek B. and Vohralík V. 2005: Mammals of Turkey and Cyprus. Rodentia I: Sciuridae, Dipodidae, Gliridae, Arvicolinae. 1st ed. Univerza na Primorskem, Znanstveno-raziskovalno Središče, Koper, Slovenia. 292 p.

Markov G.G. 2001: Microgeographical non-metrical cranial diversity of the fat dormouse (*Glis glis*). Trakya University Journal of Scientific Research B, **2:** 115-119.

Markov G.G. 2014: Femoral Osteometry of the Edible Dormouse, *Glis glis* (L., 1766): an Indicative Basis for Specificity of Its Sex and Age. Acta Zool Bulg., 66: 25-30.

Miller G.S. 1912: Catalogue of the mammals of Western Europe (Europe exclusive of Russia) in the collection of the British Museum. British Museum (Natural History), London, United Kingdom. 1044 p.

Mošanský A. 1993: The mammalian fauna of East Slovakia and the catalogue of mammaliological collections of Eastslovakian museum. Part V. (Rodentia 2) Acta Musei Slovaciae Regionis *Orientalis,* Kosice. 34: 129-144.

Peshev D. and Delov V. 1995: Craniological study and subspecific status of three species of Dormice from Bulgaria. Hystrix Ital. J. Mammal., 6: 225-230.

Potapova E.G. 2001: Morphological patterns and evolutionary pathways of the middle ear in dormice (Gliridae, Rodentia). Trakya University Journal of Scientific Research B **2:** 159-170.

Selçuk S.E., Çolak R., Karacan G.O. and Çolak E. 2012: Population structure of edible dormouse, *Glis glis* (Linnaeus, 1766) in Turkey, inferred from RAPD-PCR. Acta Zool Bulg., 64**:** 77-83.

Sidorowicz J. 1958: Some notes on the edible dormouse (*Glis glis* L.) in Poland. Acta Theriol., **2:** 292-295.

Spitzenberger F. 1983: Die Schläfer (Gliridae) Österreichs. (Mammalia austriaca 6) (Mammalia, Rodentia). Mitt. Abt. Zool. Landesmus. Joanneum, 10**:** 139-156.

Spitzenberger F. and Bauer K. 2001. Siebenschläfer *Glis glis* (Linnaeus, 1766). In: Spitzenberger F. (editor) Die Säugetierfauna Österreichs. 1st ed. Grüne Reihe des Bundesministeriums für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Band 13, Graz, Austria. pp. 338-344.

Storch G. 1978: *Glis glis* (Linnaeus, 1766) – Siebenschlafer. In: Niethammer J. and Krapp F., (editors). Handbuch der Säugetiere Europas. Bd. 1, Rodentia 1., 1st ed. Akademische Verlagsgesellschaft, Wiesbaden, Germany. pp. 243-258.

Violani C. and Zava B. 1995: Carolus Linnaeus and the edible dormouse. Hystrix Ital J Mammal. 6(1-2): 109-115.

Žiak D. and Urban P. 2001. Red (Ekosozolical) List of Mammals (Mammalia) of Slovakia. In: Baláž D., Marhold K. and Urban P., (editors). Red (Ekosozological) List of Plants and Animals of Slovakia. Ochrana prírody 20 (Suppl.): 154-156.

Zoologica Poloniae (2016) 61/1. 53-57

NEW BREEDING LOCALITY OF FERRUGINOUS DUCK *AYTHYA NYROCA* (GÜLDENSTÄDT, 1770) IN LUBLIN REGION

Marek Nieoczym*

* Department of Zoology, Animal Ecology and Hunting. University of Life Sciences in Lublin, Akademicka 13 Str. 20-033 Lublin. Poland. E-mail: mnieoczy@wp.pl

Abstract: This article presents a new breeding locality of Ferruginous Duck in the Lublin region, located on the fish ponds in Samoklęski. In 2015 the first brood was found. However, single males, females or pairs have been observed during the breeding seasons since 2013. The earlier records were from the period of spring and autumn migration in this site. Records of the new breeding sites of the Ferruginous Duck can indicate positive changes in the distribution of this species and indicate the return of this species to Południowopodlaska Lowland.

Key words: Ferruginous Duck, fishponds, breeding season

INTRODUCTION

Ferruginous Duck *Aythya nyroca* is endangered with extinction in Poland, and is classified as threatened over their entire range (Birdlife International 2017, Głowaciński 2002). The main part of the breeding population occurs in Asia. This species breeds mainly from central and eastern Europe to western Mongolia and China. Isolated breeding populations are found in North Africa and south-western Asia from Algeria to Pakistan and India (BirdLife International 2017, del Hoyo et al. 1992), In Europe, breeding areas of Ferruginous Duck extend from the central part of the continent to Ukraine and Belarus in the east and the region of the Mediterranean Sea and the Caspian-Black Sea in the south and south-east (Bankovics 1997). The largest breeding population in Europe is in Romania (BirdLife International 2017). The species is extremely scarce in Poland, breeding mainly in the southern and eastern parts of the country (Wieloch and Stawarczyk 2007). Historically, this species was one of the most common domestic ducks (Taczanowski 1882). At the beginning of the 1980s, the number of Ferruginous Ducks was

estimated at 400-500 pairs, while in 1995-97 their numbers had declined to about 40 pairs in Poland. After a dramatic decline, a gradual increase in the number of pairs began at the beginning of the twenty-first century (Tomiałojć and Stawarczyk 2003, Wieloch and Stawarczyk 2007). Monitoring carried out in Poland between 2007-2016 showed the presence of 81-129 pairs (http://monitoringptakow.gios.gov.pl). Most of the breeding population of these ducks is concentrated at three sites in Poland: in the Lublin region, in the Barycz Valley and in Buda Stalowska fishponds (94%) (Chodkiewicz *et al.* 2016). The most important breeding habitats are large river deltas and extensive fishponds in Europe (BirdLife International 2017, Petkov 2006). In Poland, the duck inhabits mainly ponds, reservoirs, sometimes eutrophic lakes, shallow flood waters and oxbow lakes (Witkowski and Urban 2015). In the Lublin region, it breeds only at fishponds and reservoirs mainly in the Polesie Lubelskie. Single records also come from the Zamość region: Nielisz Reservoir, Tarnawatka and Dub-Swaryczów fishponds (Stachyra et al. 2011, Komisja Faunistyczna 2011, Komisja Faunistyczna 2013). Begining from the 2013 breeding season, single birds or pairs have been observed on fishponds in the Samoklęski village, located on the southern border of the Południowopodlaska Lowland. Ferruginous Duck also appeared in Południowopodlaska Lowland in the 1980s and 1990s. In 1995, a brood was observed in nearby Kozłowieckie Forest (Tomiałojć and Stawarczyk 2003, Wieloch and Stawarczyk 2007). Currently, the nearest breeding sites are located in the east, in the Polesie Lubelskie at a distance of 40-60 km from Samoklęski.

STUDY AREA AND METHODS

The research was carried out in the fishpond complex in Samoklęski village, located in an agricultural landscape about 30 km north of Lublin, in the Wysoczyzna Lubartowska region. There were 52 farming ponds differing in size from 0.1 to 18 ha (total area of the complex is about 200 ha). Single ponds were eutrophic, shallow (depths ranged from 0.5-2 m), and rich in aquatic plants (emergent aquatic vegetation coverage ranged from 5 – 65%; mainly *Typha* angustifolia and *Phragmites australis*). The fish fauna of the ponds were dominated by farmed carp *Cyprinus carpio*. Most ponds were filled with water between February to April, and drained between September to November. Ponds were supplied with water from the Minina river and rainwater.

Observations were conducted at different times of the day from dawn to dusk during the breeding season and migration period in the years 2000-2002, 2004-2010 and 2013-2016. The round count method of Koskimies and Väisänen (1991) was used, walking around the ponds and observing birds with the use of binoculars and scopes.

RESULTS AND DISCUSSION

The first observation of Ferruginous Duck during the breeding season came from 2013 when there was one pair on 24th June and one female on 28th August at the same pond. In 2014-2015, Ferruginous Ducks were recorded more often. On 18th June and between 24th September and 2nd October 2014 one male was observed. In 2015, one male (single observation) and one female (two records) were observed from 25th April to 25th May. The observation of a female with seven ducklings was on 13th July (M. Gągała – personal communication) and 22nd July. Previous observations that came from the period outside of the breeding season. Two males and one female were spotted during the spring migration on 22nd March 2002 (Nieoczym 2006). One pair was observed on 15th April 2008 and one female on 16th April 2009. The presence of birds on the Samoklęski ponds from 2014-2015 during the breeding season and during migration was also confirmed by data collected in the special avifauna database of the Lublin region (http://www.kartoteka.lto.org.pl).

No birds were observed during the 2016 breeding season by the author. There are noteworthy records from other observers in 2016: 7th April – one male (M. Gałan - personal communication) and 20th May – one female (M. Traciłowska and S. Ligęza - personal communication).

The pond with the brood of Ferruginous Duck was known as the fingerling pond. This pond was preferred by numerous breeding diving ducks such as Pochard *Aythya ferina* and Tufted Duck *Aythya fuligula* and other waterbirds species. Ducks preferred this pond because it was a shallow reservoir with patches of reed providing shelter and food. There were favorable trophic conditions, namely an abundance of submerged plant material, tadpoles, and invertebrates (Kloskowski et al. 2010, Nieoczym and Kloskowski 2015). The diet of this species is dominated by aquatic macrophytes but they also feed on animals like invertebrates and amphibians (del Hoyo et al. 1992). Another important factor is the water turbidity, which was low in this pond due to the abundance of plants and the presence of only small carps, which are not able to destroy the pond bottom as readily (Crivelli 1983, Nieoczym and Kloskowski 2014, Robinson and Hughes 2006).

NOWE STANOWISKO LĘGOWE PODGORZAŁKI AYTHYA NYROCA (GÜLDENSTÄDT, 1770) NA LUBELSZCZYŹNIE

STRESZCZENIE

Artykuł prezentuje nowe stanowisko lęgowe podgorzałki na Lubelszczyźnie, zlokalizowane na stawach rybnych w Samoklęskach. W 2015 roku stwierdzono pierwszą rodzinę podgorzałki. Natomiast pojedyncze samce, samice lub pary obserwowane były w sezonie lęgowym od 2013 roku. Wcześniejsze obserwacje z tego miejsca pochodzą z okresu migracji wiosennej i jesiennej. Stwierdzenie nowego stanowiska lęgowego podgorzałki może świadczyć o zachodzących pozytywnych zmianach w rozpowszechnieniu tego gatunku oraz wskazuje na powrót tego gatunku na Nizinę Południowopodlaską we wschodniej Polsce.

ACKNOWLEDGMENTS

I would like to thank to the fisheries managers Marek and Maria Filipiak for providing access to the ponds. I am grateful to M. Urban who helped me prepare this manuscript and M. Gałan, M. Gągała, M. Traciłowska and S. Ligęza for sharing their observations.

REFERENCES

Bankovics A. 1997. *Aythya nyroca* Ferruginous Duck. W: Hagemeijer W.J.M., Blair M.J. (ed.). The EBCC Atlas of European Breeding Birds: their distribution and abundance. T & A D Poyser, London: 104–105.

BirdLife International. 2017: Species factsheet: *Aythya nyroca*. Downloaded from http://www.birdlife.org on 13/03/2017.

Chodkiewicz T., Meissner W., Chylarecki P., Neubauer G., Sikora A., Pietrasz K., Cenian Z., Betleja J., Kajtoch Ł., Lenkiewicz W., Ławicki Ł., Rohde Z., Rubacha S., Smyk B., Wieloch M., Wylegała P., Zielińska M., Zieliński P. 2016: Monitoring Ptaków Polski w latach 2015–2016. Biuletyn Monitoringu Przyrody 15, 1.

Crivelli A.J. 1983: The destruction of aquatic vegetation by carp. Hydrobiologia, 106: 37-41.

del Hoyo J., Elliott A., Sargatal J. (eds.). 1992: Handbook of the Birds of the World, vol. 1: Ostrich to Ducks. Lynx Edicions, Barcelona, Spain.

Głowaciński Z. (ed.) 2002: Czerwona lista zwierząt ginących i zagrożonych w Polsce. PAN, Instytut Ochrony Przyrody, Kraków.

Kloskowski J., Nieoczym M., Polak M., Pitucha P. 2010: Habitat selection by breeding waterbirds at ponds with size-structured fish populations. Naturwissenschaften, 97: 673–682.

Komisja Faunistyczna 2011. Rzadkie ptaki obserwowane w Polsce w roku 2010. Ornis Pol. 52: 117-149.

Komisja Faunistyczna 2013. Rzadkie ptaki obserwowane w Polsce w roku 2012. Ornis Pol. 54: 109-150.

Koskimies P., Väisänen R.A. 1991: Monitoring bird populations. A manual of methods applied in Finland. Zool. Mus., Finnish Mus. Nat. Hist., Univ. Helsinki, Helsinki.

Nieoczym M. 2006: Rare and endangered species of waterfowl from fishponds in Samoklęski (Lublin region). Teka Commission of Protection and Formation of Natural Environment. Polish Academy of Sciences, Branch in Lublin, Vol. III: 147-152.

Nieoczym M., Kloskowski J. 2014: The role of body size in the impact of common carp Cyprinus carpio on water quality, zooplankton, and macrobenthos in ponds. Int. Rev. Hydrobiol., 99: 212-221.

Nieoczym M, Kloskowski J. 2015: Responses of epibenthic and nektonic macroinvertebrate communities to a gradient of fish size in ponds. J. Limnol., 74(1): 50-62.

Petkov N. 2006: The importance of extensive fishponds for Ferruginous Duck *Aythya nyroca* conservation. In: Boere G.C., Galbraith C.A., Stroud D.A. The Stationery (eds.). Waterbirds around the world. Office, Edinburgh, UK: 733-734.

Robinson, J. A., Hughes B. 2006: International single species action plan for the conservation of the Ferruginous Duck Aythya nyroca. CMS/AEWA, Bonn, Germany.

Stachyra P., Kobylas T., Mazurek P. 2011. Raport z wykonania inwentaryzacji ornitologicznej dla obszaru specjalnej ochrony ptaków sieci Natura 2000 PLB060011 Ostoja Tyszowiecka w roku 2011. Wykonano na zlecenie Generalnej Dyrekcji Ochrony Środowiska w Warszawie. Lubelskie Towarzystwo Ornitologiczne, Zamość.

Taczanowski W. 1882: Ptaki Krajowe. Tom II. Akademia Umiejętności w Krakowie.

Tomiałojć L., Stawarczyk T. 2003: Awifauna Polski. Rozmieszczenie, liczebność i zmiany. PTPP „pro Natura" Wrocław: 162-166.

Wieloch M., Stawarczyk T. 2007: Podgorzałka *Aythya nyroca*. W: Sikora A., Rhode Z.,

Gromadzki M., Neubauer G., Chylarecki P. (red.). Atlas rozmieszczenia ptaków lęgowych Polski 1985–2004. Bogucki Wyd. Nauk., Poznań: 76–77.

Witkowski J., Urban M. 2015: Podgorzałka Aythya nyroca. W: Chylarecki P., Sikora A., Cenian Z., Chodkiewicz T. (red.). Monitoring ptaków lęgowych. Poradnik metodyczny. Wydanie 2. GIOŚ, Warszawa: 134-138.

http://monitoringptakow.gios.gov.pl

http://www.kartoteka.lto.org.pl. Lublin Ornithological Society

Zoologica Poloniae (2016) 61/1. 59-83

STUDY OF THE HISTOARCHITECHTURAL AND BIOCHEMICAL CHANGES WITH PROGRESSION OF AGE IN MALE MICE

Kaveri Purandhar[1], Nivedita Pareek[1], Disha Patell[1], Bhavin Patel[2] And *Sriram Seshadri[1,2]

1 Institute of Science, Nirma University, Ahmedabad, Gujarat, 382481
2 Department of Animal Husbandry. Government of Gujarat, Ahmedabad, Gujarat

* Corresponding Author
dr. Sriram Seshadri
Institute of Science
Nirma University
Sarkhej Gandhinagar Highway, Village – Chharodi
Ahmedabad, Gujarat – 382481
Tel: +91-2717-241901 ext 752
Fax: +91-2717-241916
Email: sriram.seshadri@nirmauni.ac.in, sriramsjpr@gmail.com

Abstract: Our main focus of this study was to understand the functional and morphological changes in reproductive tissues at the somatic tissue level and correlating biochemical changes with respect to progression of age in the male mice.

Blood and Semen samples were collected from Swiss albino male mice from various age groups ranging from 20 weeks to 54 weeks. Basic semen analysis was performed in order to check the normality of the semen samples, seminal fluid biochemistry and serum biochemistry was performed. Both the vital reproductive and vital somatic organs were excised from each group of animal and processed for standard histopathological analysis.

Our data shows a significant deterioration of the semen quality with the progression of age. In case of seminal fluid biochemistry a decreasing trend of superoxide dismutase, reduced glutathione, lipid peroxidation and Catalase was seen with increasing age while no trend is found in lactate dehydrogenase. Organelle markers such as α-glucosidase, fructose and L-carnitine level were decreasing in higher age, there is no significant trend observed in lactate dehydrogenase levels. Serum biochemical analysis also showed similar trend with parameters like superoxide dismutase, reduced glutathione, lipid peroxidation levels and lactate dehydrogenase. With the progression of

age calcium levels were found to decrease. Alteration in histoarchitecture is observed in all the tissues excised with the increase in age. Reproductive tissues were seen with the distortion in the anatomy which can be directly correlated with the low levels of organelle markers secreted. In the histoarchitechture of the somatic tissues was revealed in the case of somatic tissues. Tissues were found to be less organized and functional with the increase in age. Overall, a decreasing trend was observed in most of the vital organs of the reproductive and somatic tissue system.

It can be concluded that with decrease in the biochemical parameters in both serum as well as seminal fluid suggests a decreased organ functioning in higher age groups and thereby leading to impaired organ functioning with progression of age. The alteration in histoarchitechture in the middle aged mice is an indicative of increased oxidative stress in mice specifically in the middle age group.

Keywords: Aging, Male Reproduction, Oxidative stress, Sperm, Seminal fluid

INTRODUCTION

Aging is an extremely complex and multifactorial process that proceeds to the gradual deterioration in functions (Poljsak and Milisav 2013). It involves various biochemical and physiological changes. It is a complex process involving hereditary, environmental and life style factors (Sun and Tower 1999; Vieira *et al.* 2000) According to the free radical theory of aging, lifespan is determined by the ability of organisms to cope with random cellular damage induced by reactive oxygen species (ROS), the natural by-products of energy metabolism (Sohal 2002). Excessive production of free radicals in an organism and the imbalance between the concentrations of these and antioxidant defenses may be related to processes such as aging and several diseases (Kasapoglu and Ozben 2001).

According to our earlier findings (Purandhar *et al.* 2013), aging has been associated with the change in serum testosterone levels and the progressive aggravation of calcium deficiency. The semen parameters have also been shown to demonstrate age related changes. An imbalance in ROS production may lead to potential deterioration in sperm quality and function. In our previous study, we used human and semen samples which gave us the insight to conduct this invivo study so as to have a more clear picture to observe the trend in the physiological and the biochemical changes. The major limitation in our previous report was the limit in the sample size with less varied age groups for sampling and histoarchitechtural studies of vital organs which is required to understand the age related changes.

The serum and semen biochemical analysis and tissue architecture would provide a valuable insight and act as a crucial marker in diagnosis of physiological and functional changes of the organ system during the process of aging. This study focuses mainly on the oxidative stress and determination of any specific trend in the serum biochemical and semen quality parameters with the progression of age in a mouse model.

MATERIALS AND METHODS

Study Subject

A total of 24 Healthy male Swiss albino mice 12 weeks of age were procured from the Animal Vaccine Institute, Gandhinagar, compelling to CPSCEA guidelines. Animals were grown up to 54 weeks. This project (IS/PHD/13-1/032) was approved by the Institutional Animal Ethics Committee (IAEC). The Guidance for Care and Use of Animals for Scientific Research (Indian National Science Academy 2000) was strictly followed. The animals were acclimated for a two months prior to the experiments. The food and water intake of the animals was monitored on a daily basis.

Necropsy Schedule

Four animals of each age group were sacrificed at regular intervals i.e., after they attained the age of 20 weeks, 32 weeks, 48 weeks and 54 weeks for the study using a high concentration of anesthesia (diethylether). Reproductive as well as vital organs were dissected, viz. epididymis, seminal vesicles, testis, prostrate, brain, lung, liver, kidney, and were used for histopathological evaluation. Blood was collected through heart puncture and used for blood profiling and serum biochemical analysis.

Semen Collection and Analysis

The testicular and epididymal sperm were collected by gently shearing the tissues and rupturing the tubules. The seminal fluid with the sperm was suspended in N-saline and further used for semen analysis (Kempinas and Lamana-Carbalho 1988). To check the normality of the sample and functional status of the sperm, basic semen analysis was carried out within an hour of collection of sampling according to the manual by the World Health Organization (WHO, 2010).

Seminal Fluid Biochemistry

Seminal fluid was obtained by centrifugation of the semen sample and was used for different organelle marker assays, i.e. Neutral α-glucosidase as an epididymal marker, fructose as a seminal vesicle marker, lactate dehydrogenase (LDH) as a marker for testicular function (WHO Manual, 2010) and L-carnitine as a epididymal marker (WHO Manual 2010). In addition, seminal fluid Ca^{2+} was assessed using a diagnostic kit (Accucare Diagnostic Kit, Mumbai).

Antioxidants assays were also performed to evaluate oxidative stress with the progression of age. These included superoxide dismutase (SOD) (Kono 1978), reduced glutathione (GSH) (Beutler *et al.* 1963) and Lipid peroxidation (LPO) (Bernheim *et al.* 1948). Catalase (CAT) assay was performed according to AEBI (1984) with modifications.

Blood Collection

The blood samples were collected in non-EDTA coated vials for the separation of serum. The blood serum was separated by centrifugation.

Serum Biochemistry

The serum obtained was used to determine the levels of calcium and for the antioxidant assays as previously mentioned in the seminal fluid biochemistry.

Histopathological Analysis

A small portion of the dissected organs excised from animals of each age group were cleared of any trace residues of visible fat bodies and were fixed in 10% v/v formalin saline and processed for standard histopathological procedures. Shortly after fixation, the tissues were dehydrated and embedded in paraffin sectioned at 5μm. These sections were stained with Harris haematoxylin and eosin.

Statistical Analysis

Data were expressed as mean±sd and the graphical representation of the values was made using Graph Pad Prism, version 6. The statistical analysis was performed using one-way Anova (non-parametric).

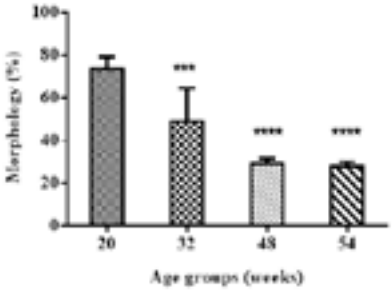
RESULTS

For all of the parameters measured, the values were expressed as mean±sd and n=3; $^{*}p<0.05$, $^{***}p<0.001$, $^{**}p<0.01$

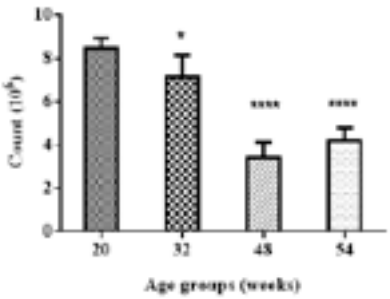
Semen Analysis

To check the normality of the semen samples basic semen analysis was performed. A significant decrease in sperm morphology and sperm count was observed. This indicates a clear deterioration of semen quality with the progression of age (Graph A and Graph B).

Graph A (Morphology)

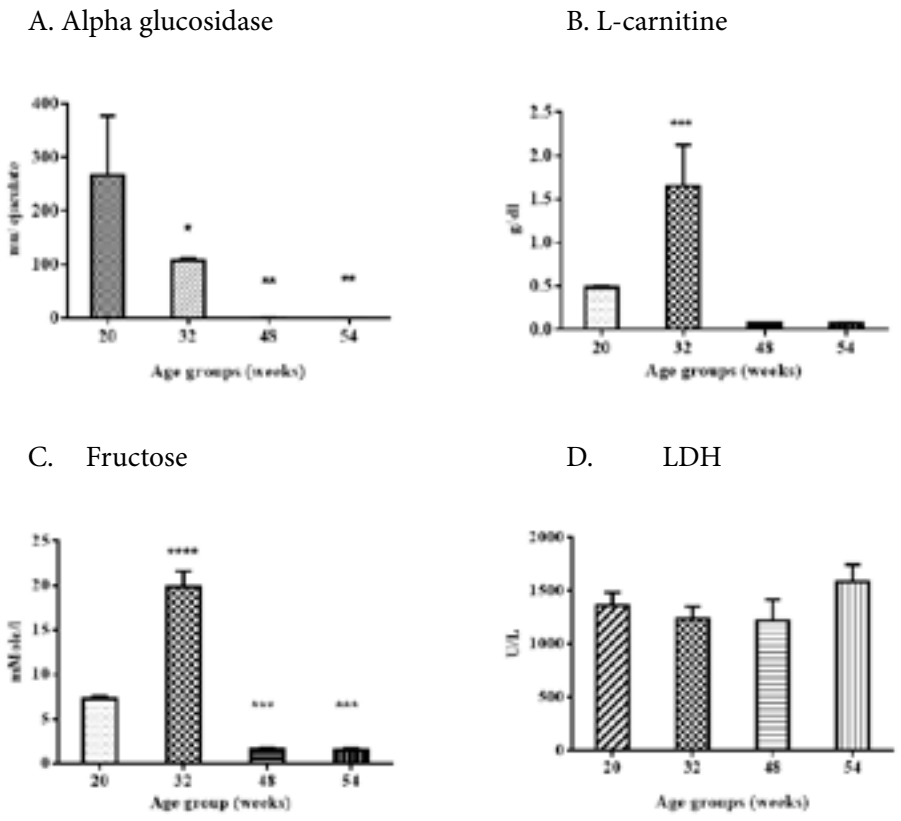


Graph B (Sperm Count)



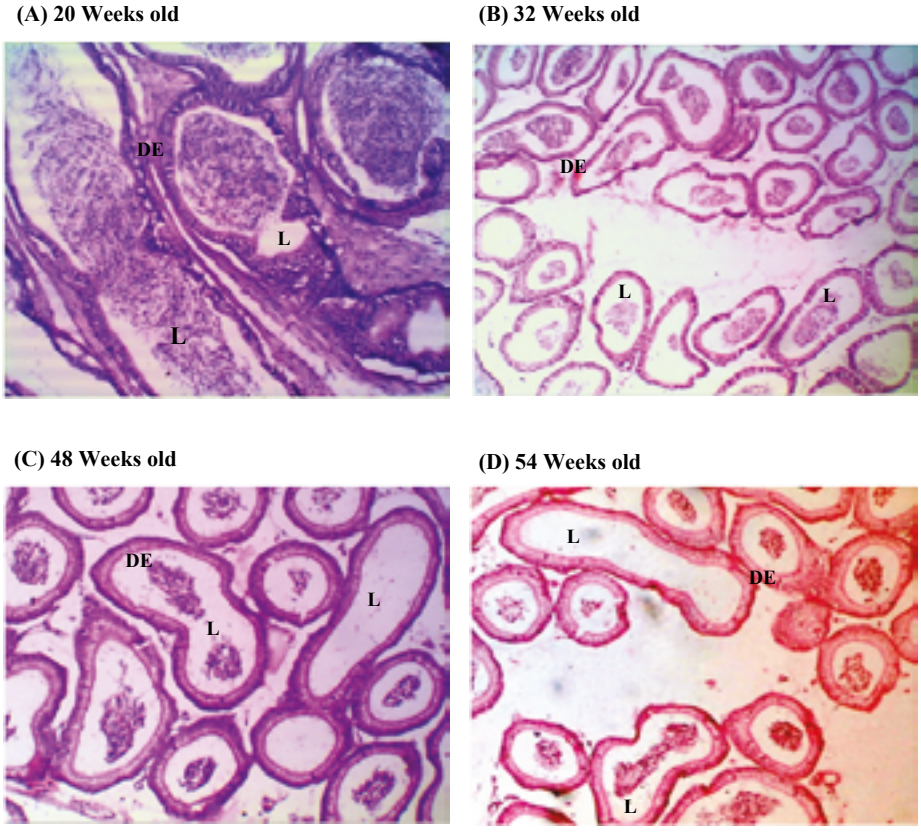
Reproductive Histoarchitechtural and Tissue Biochemical Analysis

The epididymis is an important component of the reproductive organs for the storage and maturation of sperm. The lumen was packed with spermatozoa in 20 weeks old mice. The sperm concentration in the lumen of ductus epididymis appeared to decrease with the progression of age as per the histology micrographs. This observation can be directly correlated with the epididymal secretion of α-glucosidase and L-carnitine. The level of α-glucosidase decreased with the increase in age, a sharp decline was observed in 48 weeks old mice and 54 weeks old mice. A decreasing trend was also seen in L-carnitine levels with a high level in 32 weeks old mice and significantly lower levels in 48 and 54 weeks old mice. A remarkable reduction in the number of spermatozoa was seen in the histoarchitechture of the epididymis which could be due to the decreased secretion of the epididymal markers [Graph 1; Figure 1].



Graph 1. *Showing the levels of organelle marker with the progression of age.*

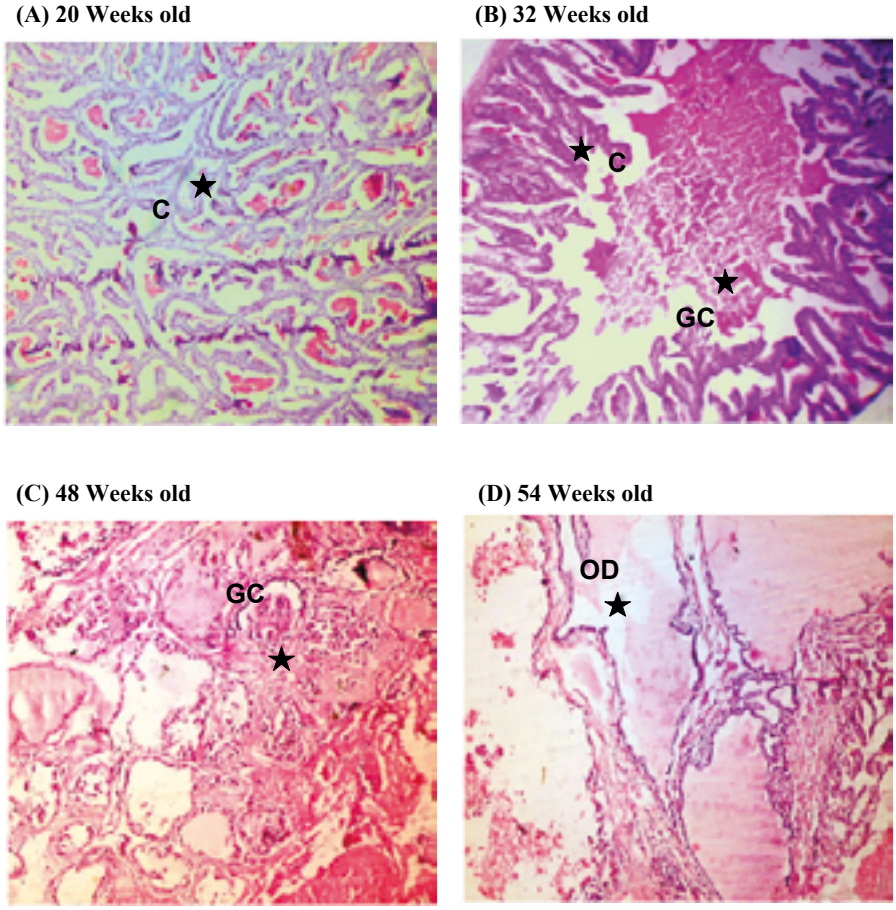
Figure 1. *Histological Observations of of Epididymis in mice at various age groups (10X)*



DE indicates Ductus Epithelium; L indicates Lumen in the figure A, B, C and D.

The seminal vesicle is an accessory sex gland which secretes a significant proportion of the fluid that ultimately becomes semen. In 20 weeks old mice, the seminal vesicle showed a normal histology consisting of cuboidal epithelium thrown into crypts. In 32 weeks old mice, the epithelial crypts were found to be much more compact as compared to 20 weeks old mice. In 48 weeks and 54 weeks old mice, differences were found in coloidal content. Glands were found to be more atrophied and oedematous which can be correlated with the low levels of fructose secretion in older age groups which is a good indicator of the secretion of the seminal vesicle. Simultaneously, in 32 weeks old mice, a sharp increase was observed which can be due to less utilization of fructose by the sperm because of the low count and morphology [Graph 1; Figure 2].

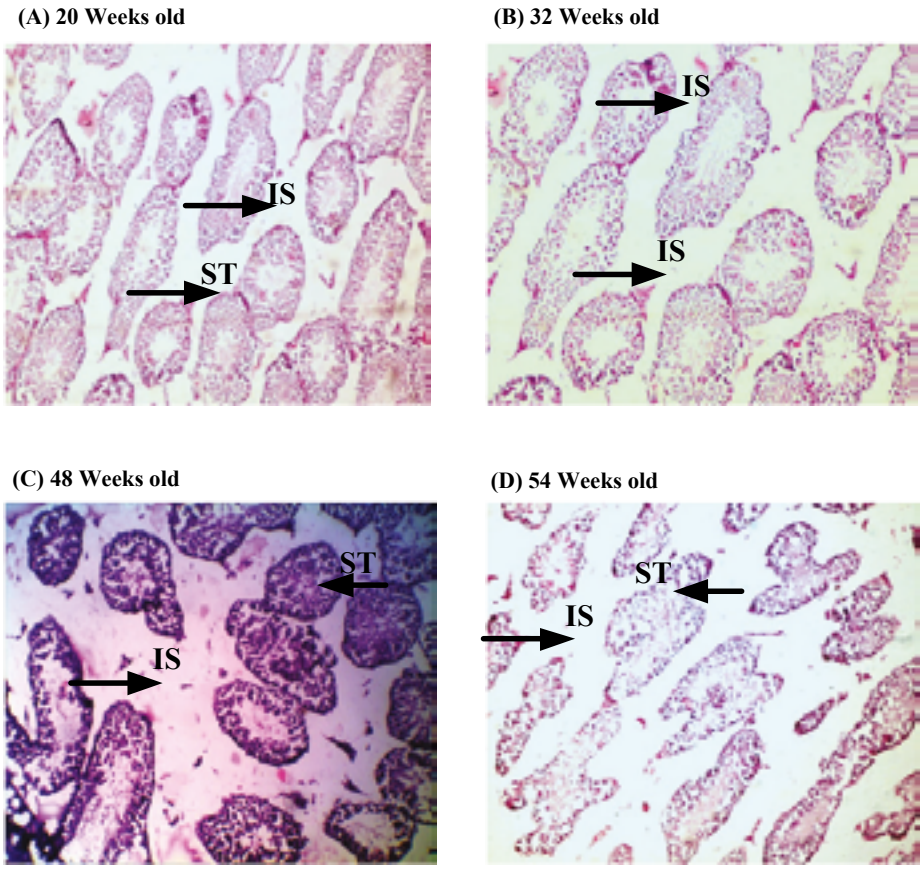
Figure 2. *Histological Observations of Seminal Vesicle in mice at various age groups (10X)*



★ Indicates crypts (C); Coloidal content (GC), in figure A, B, C and oedematous (OD) figure

Testis are an essential organ of the male reproductive system. Testicular architecture revealed normal arrangement of the internal structures showing seminiferous tubules having a distinct morphology and lumen in 20 weeks old mice. A decreased number of seminiferous tubules and a visible increase in the interstitial spaces were seen in 32 weeks old mice. Cell counts in seminiferous tubules were found to be decreased, in particular, the number of primary spermatocytes, secondary spermatocytes and spermatids in 48 and 54 weeks old mice. LDH is a testicular marker. Decreasing levels of the marker indicates improper functioning of the testis. for LDH in this study, no significant trend was observed. This could be due to the distortion which is seen in the histoarchitecture of testis where the number of Sertoli cells did not change but the interstitial space was found to be increased [Graph 1; Figure 3].

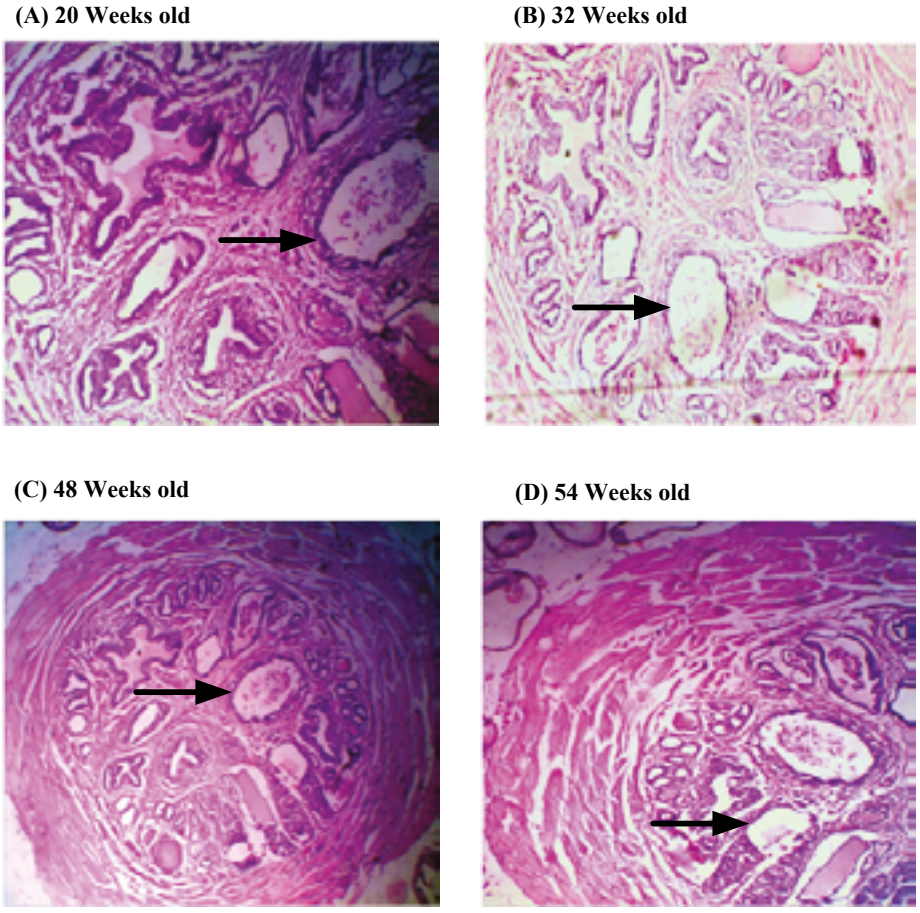
Figure 3. *Histological Observations of Testis in mice various groups (10X)*



ST- Compact seminiferous tubules and interstitial space (IS) in all the figures.

The prostate is made up of several lobules, each consisting of typical prostatic follicles with a definite lumen. Acid phosphatase is considered to be a prostatic marker. Prostate glands appeared to be normal in all the age groups. Hence, no biochemical assay was performed [Graph 1; Figure 4].

Figure 4. *Histological Observations of Prostate in mice various age groups (10X)*



→ Indicates lobule in the figure A and B and Distortion in the figure C and D.

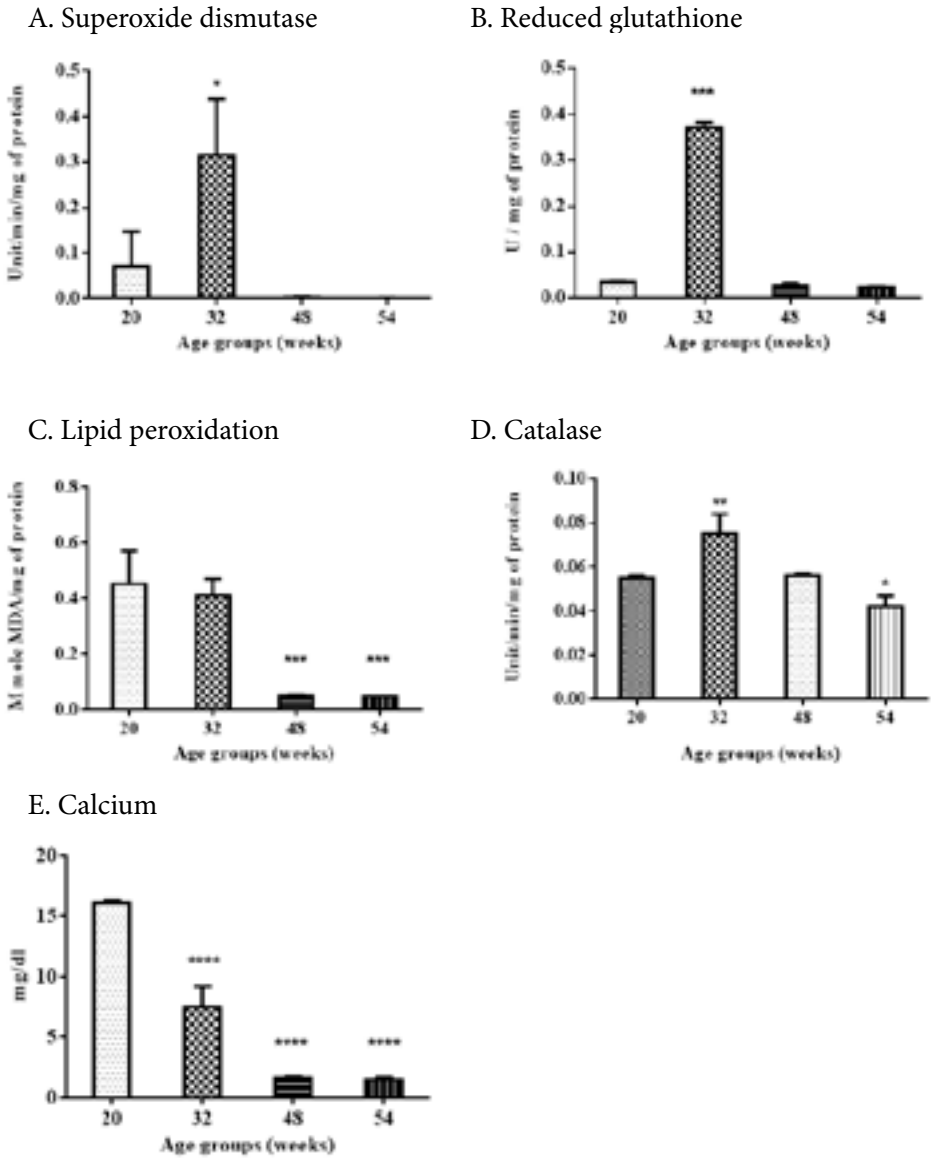
Antioxidants Assay

The 20 weeks old mice were considered to be the control with which the rest of the age groups were compared to perform the statistical evaluation.

Observation:

SOD, GSH, LPO and catalase are important indicators of antioxidant status. Antioxidant levels of various age groups of mice indicate a decrease in levels of SOD, GSH, LPO and catalase with progression of age respectively. In SOD and GSH a sharp elevation is seen in 32 weeks old mice and a significant drop is seen in 48

weeks old mice and 54 weeks old mice. A decreasing trend is observed in LPO with significant low levels in 48 and 54 weeks old mice. Catalase is showing a decreased level in 54 weeks old mice compared to 20 weeks mice. 32 weeks and 48 weeks old mice did not show any significant decrease. A significant decreasing trend can be seen in the levels of calcium with the progression of age [Graph 2 (A-E)].



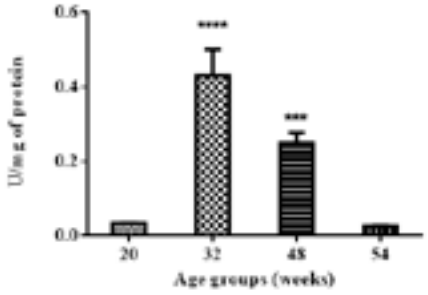
Graph 2. *Seminal Plasma Antioxidants and Calcium With the Progression of Age*

SERUM BIOCHEMISTRY

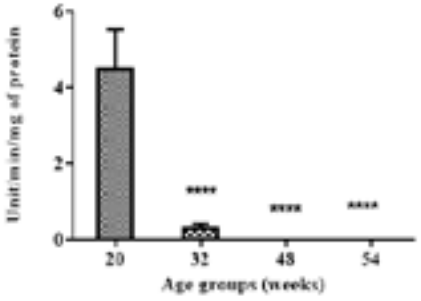
Antioxidants Assays

Antioxidant levels in the serum of various age groups of mice indicated a decrease in levels of SOD, GSH and LPO with aging. The level of SOD in 20 weeks old mice was found to be high while there was a sharp decline in 32 weeks, 48 weeks and 54 weeks old mice. GSH showed a decreasing trend with age but also showed a low level in 20 weeks old mice [Graph 3]. LPO showed similar results to that of the SOD. LPO displayed greatly diminished levels with the progression of age. However, this is contradictory according to the studies reported earlier which stated that SOD inhibits LPO levels but in our data it can be justified that the SOD levels were not sufficient to act upon the inhibitory mechanism thereby leading to the imbalance in the LPO levels which also decreased with age. In the case of catalase, no trend was observed with the increase in age. LDH showed an increasing trend with aging with a slight decrease in the levels in 32 weeks old mice. A decreasing trend was seen in the levels of calcium with the progression of age [Graph 3 (A- F)].

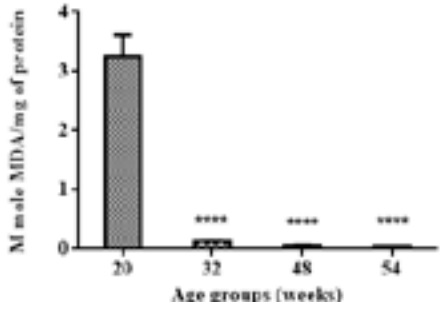
A. Superoxide Dismutase



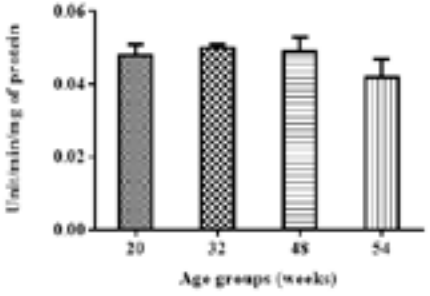
B. Reduced glutathione

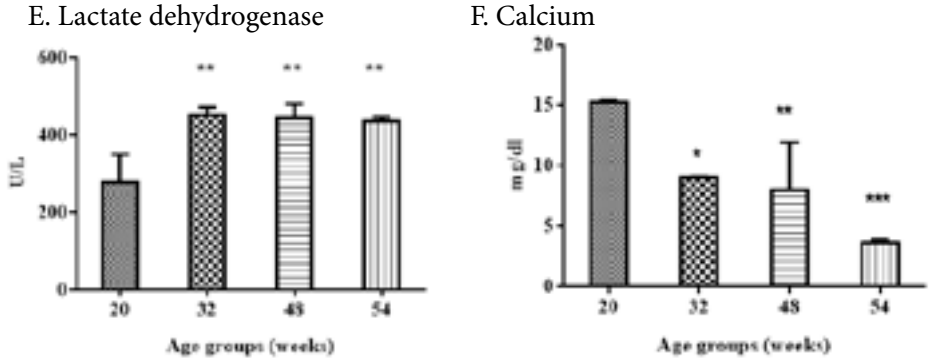


C. Lipid Peroxidation



D. Catalase



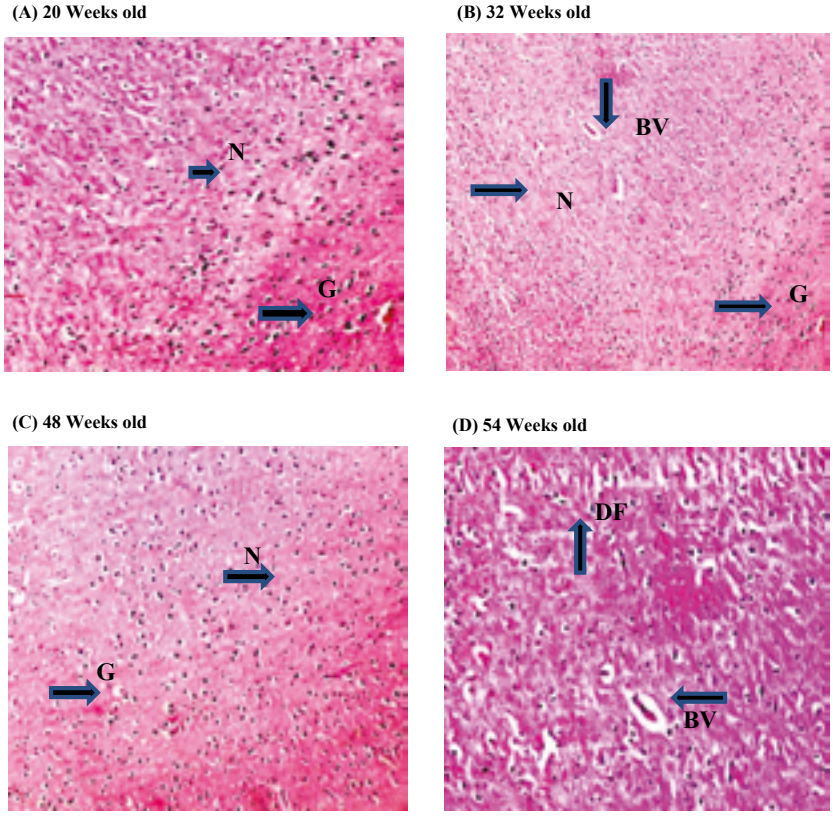


Graph 3. *Serum Biochemistry and Antioxidant Analysis in Mice*

HISTOLOGY

Brain

Figure 5. *Histological Observations of Brain in mice at various age groups (10X)*



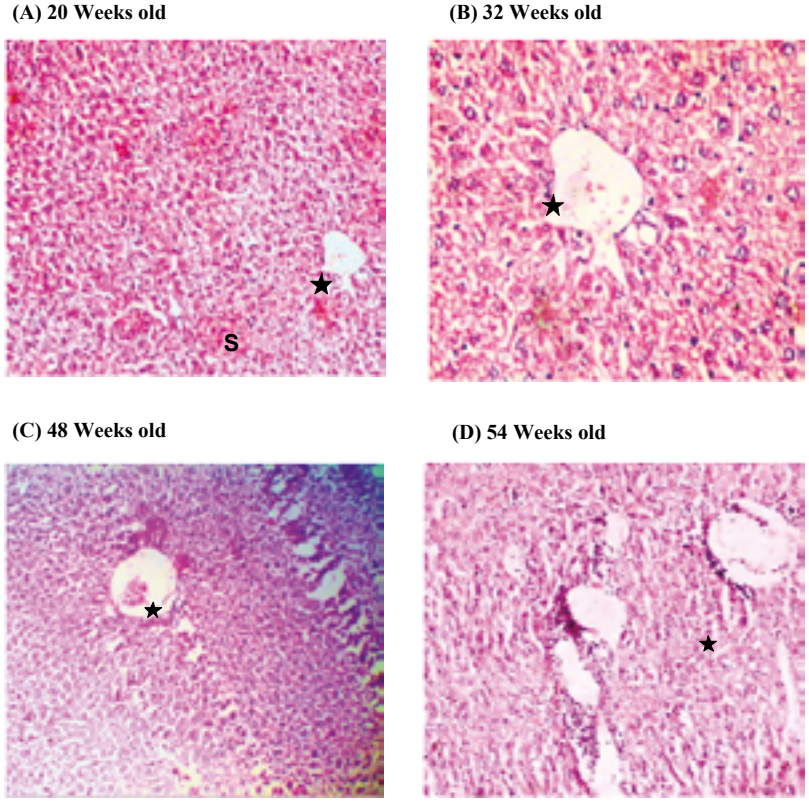
N – Neuropil; G – Glial cells; DF – Dentate Fascia; BV – Blood Vessel

Micrographs of brain sections of the hippocampal region of all four age groups [Figure 5 (A-D)] appeared to be normal. Histology of 20 weeks old, 32 weeks old and 48 weeks old mice were rich in neurophil (N), glial cells (G) and Blood vessels (BV). 54 weeks old mice showed normal dentate fascia (DF). Overall, the brain did not show alterations with the progression of age.

Liver

The micrographs livers revealed a normal architecture in 20 weeks mice. The liver lobule contained a number of hepatic acini and each centered on a portal tract. The tissue also contained sparse collagenous tissue acting as a cushion for development and functioning of the acini. The hepatic venules were also observed on the terminal of the heptocytes. The spacing between the hepatic cells was observed to be regular. In 32 weeks mice, increased sinusoidal space (indicated by a circle) and vacuolization were seen in hepatocytes.

Figure 6. *Histological Observations of Liver in mice at various age groups (10X)*



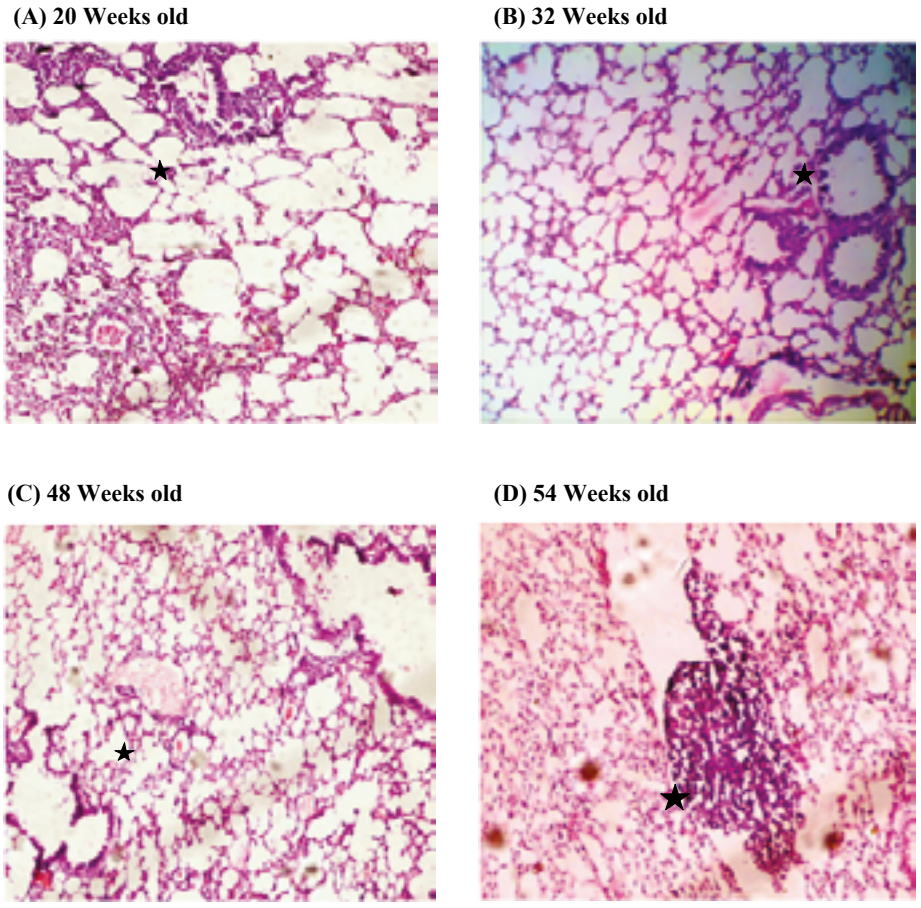
★Indicates sinusoidal space (S) and increased sinusoidal space in figure A and B respectively and infiltration of the mononuclear cells in the figure C and D.

The histoarchitecture of 48 week and 54 weeks showed similar changes which was infiltration of mononuclear cells around the arteries and veins (indicated by circles) [Figure 6 (A- D)].

Lung

The micrograph of a 20 week old lung showing the bronchiole section; emphysema was observed with slight congestion and less infiltration (indicated by a star). In the 32 weeks section, the histoarchitechture showed more congestion, less emphysema and infiltration of mononuclear cells around the arteries. The histoarchitecture of 48 weeks and 54 weeks showed low emphysema, infiltration of mononuclear and increased multiplication of type II pneumocytes (indicated by a star) [Figure 7 (A- D)] .

Figure 7. *Histological Observations of Lungs in mice at various groups (10X)*

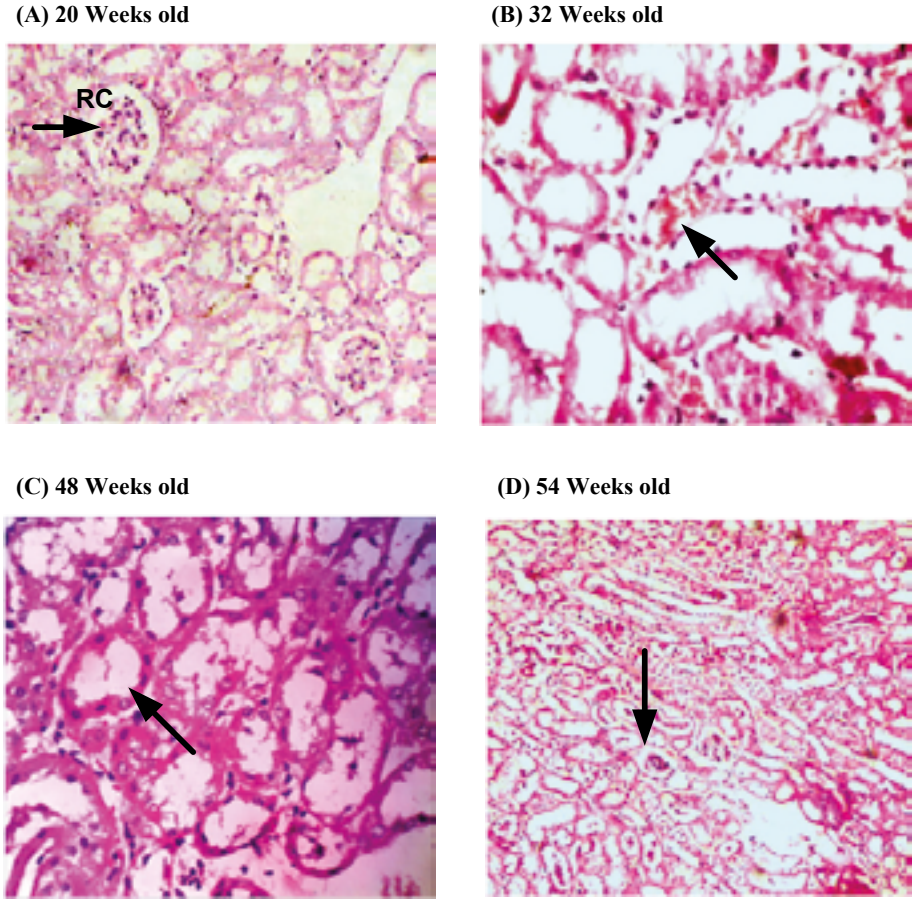


★Indicates Emphysema and Infiltration of mononuclear cells in the figure A and B respectively and multiplication of the type II pneumocytes in the figure C and D.

Kidney

The micrograph of the kidney was found to be normal in 20 weeks old mice, illustrating dense renal corpuscle (RC) and glomerulli surrounded by a narrow Bowman's space. Cortical tubules were observed which mainly consisted of proximal con-volute tubules and with a smaller number of cortical tubules and 30 collecting ducts. As compared to 20 weeks mice, various deformities were found in 32 weeks old mice showing ruptures of tubular epithelial cells (indicated by a thick arrow) and intratubular haemorrage. The histoarchitecture of 48 weeks and 54 weeks showed similar changes which were increased oedema, tubular necrosis, slight glomerular degeneration and rupture of tubular epithelial cells (indicated by a thick arrow) [Figure 8 (A- D)].

Figure 8. *Histological Observations of Kidney in mice at various groups (10X)*



RC stands for Renal corpuscle; → indicates intratubular haemorrage in figure B and Rupture of the tubular epithelial cells in the figure C and D.

DISCUSSION

The aim of the present study was to compare age-related oxidative stress parameters in healthy mice from middle age to older age groups. Aging is characterized as a progressive decline in biological functions with time (Kregel and Zhang 2006). Aging results in a decreased resistance to multiple forms of stress, as well as an increased susceptibility to numerous diseases such as diabetes, male infertility, hyperglycemia, hyperlipidemia, cardiovascular diseases, renal dysfunction and bone diseases.

Oxidative stress is defined as a disturbance in the balance between the production of reactive oxygen species (free radicals) and antioxidant defenses, and is discussed in relation to its possible role in the production of tissue damage. There is abundant experimental and observational evidence supporting the idea that aging is the sum of all free radical reactions throughout all cells and tissues, or that they are at least a major contributor to it (Harman 1998; Finkel and Holbrook 2000).

Increased levels of ROS and other reactive oxidants have been reported to cause oxidative modifications of lipids, proteins, and DNA in aged animals (Miquel and Weber 1990; Chen et al. 2000). Immature spermatozoa are the main source of ROS in semen. (Garrido et al. 2004). Low level production of ROS by spermatozoa play an important role in normal physiological processes such as sperm capacitation, acrosome reaction, maintenance of fertilizing ability, but an imbalance between ROS generation and scavenging activity is detrimental to the sperm and is associated with male infertility (Sharma and Agarwal 1996). Damage accumulated with age induces changes in target organs such as the testis, penis and prostate.

A mouse life span ranges 52-54 weeks, in our study we evaluated mice from 20 weeks to 54 weeks age groups as they provided a varied age group for sampling and histological studies of reproductive as well as somatic tissues which is required to understand the changes with aging. During aging, there is a decline in biological functions of the systems and in the ability to adapt to metabolic stress. One of the results of aging is the decline in functioning of the reproductive system which could be attributed to oxidative stress in the physiological system of the animal. One of these biological indicators, detoriated morphology of the sperm, is revealed by this current study. The altered morphology could be attributed to increased MDA levels (which is the end product of the lipidperoxidation) in the older mice. Lipid peroxidation is sensitive to ROS attack which results in decreased sperm motility, presumably by a rapid loss of intracellular ATP leading to axonemal damage, decreased sperm viability, and increased mid-piece sperm morphological defects with deleterious effects on sperm capacitation and acrosome reaction (Bansal and Bilaspuri 2007).

The age-related alterations of antioxidant defenses in free-living elderly are not yet ascertained, and there is a lack of information regarding their evolution from middle-aged to older elderly (Andriollo-Sanchez et al. 2005).

Antioxidants, in general, are compounds and reactions that dispose, scavenge, suppress the formation of ROS, or oppose their actions. Among the well known biological antioxidants, superoxide dismutase (SOD) and catalase have a significant role (Sikka et al. 1995). Reactive oxygen species induce DNA damage that accelerates the process of germ and somatic cell apoptosis, leading to the decline in sperm count associated with male infertility and several diseases such as cancer, heart diseases, stroke and aging. Our data shows the levels of antioxidants with the progression of age, specifically, there was a constant decrease in the activity of SOD and GSH in serum as well as seminal fluid with increasing age. The 32 weeks age group mice showed elevated levels in SOD and GSH in seminal fluid as well as in serum. This can be correlated to mitochondrial biogenesis and the increased stress level during middle age leading to an imbalance in the free radical system. The decrease in these antioxidants causes the production of more ROS in serum and seminal fluid which leads to deleterious effects.

Lipid peroxidation (LPO) is broadly defined as "oxidative deterioration of PUFA (Polyunsaturated fatty acids)" which contains more than two carbon–carbon double bonds (Halliwell 1984). The LPO cascade occurs in two fundamental stages: initiation and propagation. The hydroxyl radical (OH•) is a powerful initiator of LPO (Aitken and Fisher 1994). The amount of lipid peroxidation (LPO) indicates the production of malonaldehyde (MDA) as an end product of LPO. The larger amount of MDA produced, more ROS damage occurs in the serum as well as in the seminal fluid via the process of lipid peroxidation. Here, the level of LPO decreases linearly with increasing age in 20 Weeks, 32 weeks, 48 weeks and 54 weeks mice both in the serum as well as in the seminal fluid, supporting our data for the diminished semen quality. Patel et al. (2009) reported the negative correlation between the MDA levels and the normal sperm motility and morphology, and the damaging effects of free radicals on sperm membrane integrity. A study conducted by Nabi et al.(2008) stated that MDA concentration in oligozoospermic and azoospermic men was significantly higher than normozoospermic while glutathione, ascorbic acid and total antioxidant status were significantly reduced in oligozoospermic and azoospermic men compared to the normozoospermic group. Our study suggests that high ROS levels in semen lead to lipid peroxidation, represented by MDA in semen, which may contribute to low motility. Hence, with the data obtained and the literature available, performing the lipid peroxidation assay becomes an important factor to determine male infertility

The marker enzymes of various glands of male reproductive system analyzed were α-glucosidase as a marker for epididymis, fructose as a marker for proper functioning of the seminal vesicles, and LDH as a testicular marker. In our data, the level of α- Glucosidase and fructose decreased with increasing age. Here, we obtained an elevated level in fructose in 32 weeks old mice. The concentration of fructose was directly correlated to the motile sperm concentration. In addition to

the motile sperm concentration, higher levels of fructose will be utilized as a source of energy and thus a lower concentration of fructose is observed in the seminal fluid (Lewis et al. 1996). Later, in 48 and 54 weeks old mice, the level of fructose showed a decreasing trend.

Lactate dehydrogenase plays an important role in providing energy for cell metabolism and is present in most cells and biological fluids (Aydm et al. 1997). Lactate dehydrogenase is a testicular marker and is supposed to be specific for germinal epithelium activity. The enzyme does not correlate with motility, but a high degree correlation does exist between motile sperm count (Tuncbilek et al. 1996; Cevik 1998). Here, an increasing trend was seen in the activity of LDH with the age progression which can be correlated to the decreasing motile sperm count. The 32 weeks old mice in this study revealed high levels of LDH otherwise showing an increasing trend in the serum and in the seminal fluid.

L-Carnitine contributes to shielding sperm membranes against harmful ROS because of its antioxidant activity (Gulcin 2006) and also as an epididymal marker (WHO Manual, 2010). L-Carnitine has been shown to improve resistance to oxidative stress by decreasing DNA damage (Banihani et al. 2011). In our study, the activity of L-carnitine decreases with increasing age, suggesting that as the level of L-carnitine decreases, the oxidative stress also increases supporting the data obtained.

Intracellular calcium concentration is directly correlated with sperm morphology, motility and fertility potential. Calcium influx is required for acrosome reaction, hyper activated motility and for fertilization. In our study, calcium level in the serum as well as in the seminal fluid decreased with the progression of age as it had been reported in Purandhar et al. (2013).

The epididymis showed distorted connective tissue and reduction in the number of sperm. Normal epithelial architecture and cellular structures are necessary for normal physiological functioning of the epididymis including the processes of molecular synthesis in the secretion that contributes regionally to successful sperm maturation (Smithwick and Young 2001). It has been reported that a significantly lower number of sperm are bound to the zona pellucida in a zona-binding assay in samples with a low α-glucosidase activity (Ben et al. 1994). In our data, changes were seen in the histology of epididymis with age which can be correlated with the above report.

The seminal vesicle showed more compact crypts and reduced amounts of granular cytoplasm. In our data, the alternations in the seminal vesicle histology can be correlated with a decrease in fructose levels of 20 weeks old mice compared to 30 weeks old mice. Regressive histologic changes in seminiferous tubules occured spontaneously, and developed with age. Such changes have been reported in men, rats, oxen, mice and cats but their causes remain unclear (Lutzen and Ueberberg 1973; Humphrey and Ladds 1975; Hatakeyama et al. 1979; Gosden et al. 1982; Elcock and Schoning 1984).

The histological studies performed in this study revealed a decline in the functioning of the reproductive system. Decreased numbers of the primary and secondary spermatocytes and reduced interstitial space in the histoarchitechture of the testes was observed with the progression of age. It has been reported that aged mice show testicular degeneration similar to that induced by irradiation, artificial cryptorchidism, and experimental autoimmunization in laboratory animals (Nebel and Murphy 1960; Sato et al. 1981; Jegouet al. 1983). Lactate dehydrogenase (LDH) in the serum and the seminal fluid showed an increase as the age increased. The distortion in the anatomy of the testes can be related to the increased level of the LDH which supports our hypothesis at the biochemical level.

The prostate gland is an exocrine gland found in almost all mammals which secretes enzymes, amines, lipids and metal ions essential for the normal function of the spermatozoa (Kindblom et al. 2003). In the present investigation, the prostates appeared to be normal in their histoarchitechture with the progression of age. However, a study performed by Gabry et al. (2014) stated that the dorsolateral lobe (DL) of the prostate showed some changes during aging, including increased height of epithelial folds, thick fibromascular stroma, inflammatory cellular infiltration and congestion which could be due to changes in the integrity of blood vessels with old age causing disruption of the endothelial barrier and increased capillary permeability evoking an inflammatory response through activation of oxidative stress-sensitive signaling pathways (Adamson et al. 1990; Krouwer et al. 2012).

Aging of the brain leads to impairments in cognitive and motor skills. Our micrographs showed necrosis in the brain cells. Recent studies suggest that normal brain aging is associated with subtle morphological and functional alterations in specific neuronal circuits as opposed to large-scale neuronal loss. In fact, aging of the central nervous system in diverse mammalian species shares many features, such as atrophy of pyramidal neurons, synaptic atrophy, decreases of striatal dopamine receptors, accumulation of fluorescent pigments, cytoskeletal abnormalities, and reactive astrocytes and microglia (Lee et al. 2000).

The liver changes with age leading to an impaired ability to respond to hepatic insults and increased incidence of liver disease in the elderly (Greg et al. 2013). Liver sinusoidal endothelial cells (LSEC) line the hepatic microvasculature, express little to no basement membrane, and exhibit numerous fenestrations necessary for filtering lipopoteins from the portal blood supply. Pseudocapillarization, is commonly seen in aged livers (Mclean et al. 2013), as is non-alcoholic fatty liver disease or steatosis (Kagansky et al. 2014). However, our liver micrographs showed increased sinusoidal space, vacuolization in hepatocytes and infiltration of mononuclear cells. The underlying cause for such alterations could be diabetes mellitus, oxidative stress, mitochondrial dysfunction or metabolic and hormonal imbalances. All of these age-related liver changes in humans are recapitulated in the mouse (Warren et al. 2005; Hoare et al. 2010; Ito et al. 2007; Ohtsubo and Nomaguchi 1986; Pieri et al. 1980).

A decrease in antioxidant levels has been seen in the serum as well as the seminal fluid. Therefore, the lower respiratory tract may be less able to defend against external attack, including attack by oxygen-derived active molecules, in senescent mice. The decrease of the antioxidant screen of the lungs may be associated with impaired lung defense in relation to oxidant-antioxidant balance in aged mice (Teramoto et al.1994). An increase in the total alveolar surface area in combination with the continual increase in the total air volume of alveoli, ducts and sacs strongly suggests that the aging process in the mouse lung results in a hyper inflated lung with significant air space distension (Tebow et al. 2008). In support to our data, their study suggested that there is some evidence for the loss of the alveolar surface area (broken alveoli) in Swiss albino mice with increases in age. It can be said that age related changes could significantly affect the normal function of the lungs as well as greatly increase the host susceptibility to injury. Although little information is available to adequately describe the effects of aging in mouse lungs, a number of studies have implicated that aging in mice is associated with a decrease in specific functional and structural parameters (Pinkerton et al. 2015). This includes increases in the mononuclear cells present in the lung's air spaces and also a decrease in the antioxidants defense system with age.

Glomerulosclerosis and interstitial fibrosis increase in the aging kidney and glomerular filtration rate (GFR) decreases with increasing age. Decreases in stem cell numbers and function contribute to renal aging (Yang and Fogo 2014). In the case of oxidative stress, which plays a fundamental role in the aging process in peroxisomes (Beier et al. 1995), differential expressed proteins associated with stress response were observed in the kidney. Our study revealed increased oxidative stress intratubular haemorrhage that is evident in some of the reported studies. Structural changes occur along with functional changes: the renal mass regresses progressively with aging (Zhou et al. 2008), the percentage of glomerulosclerosis and tubulointerstitial fibrosis increases (Neugarten et al. 1999) and hyalinization of afferent arterioles may develop (Hill et al. 2003).

CONCLUSION

Decreases in the biochemical parameters in both serum as well as seminal fluid suggests a decreased organ functioning in higher age groups, thereby leading to impaired organ functioning with the progression of age. The alteration in the histoarchitecture is indicative of increased oxidative stress in mice, specifically in the middle age group. However, the alterations cannot be directly correlated as a part of aging but definitely shows that the fluctuations in the oxidative stress could lead to distorted architecture and can be correlated with aging in mice.

ACKNOWLEDGEMENTS

The authors thank Nirma Education and Research Foundation (NERF) for providing the financial support and also heartfelt thanks to Dr. Amit kanani, Deputy Director, Animal Husbandry Division, Govt of Gujarat, India.

ABBREVIATIONS

SOD – Superoxide dismutase; GSH – Reduced glutathione; LPO – Lipid peroxidation; LDH – Lactate dehydrogenase; ROS – Reactive oxygen species

BADANIA NAD ZMIANAMI W HISTOARCHITEKTURZE I BIOCHEMII U SAMCÓW MYSZY WRAZ Z PROGRESJĄ WIEKU

STRESZCZENIE

Głównym celem naszej pracy była analiza zmian biochemicznych (funkcjonalnych) i morfologicznych w wybranych tkankach somatycznych i rozrodczych, zachodzących wraz ze starzeniem się samców myszy. Uzyskane wyniki wskazują na istotne obniżenie jakości spermy wraz z wiekiem u badanych zwierząt. Analizy biochemiczne nasienia wykazały, malejący z wiekiem trend peroksydacji lipidów oraz stężenia dysmutazy ponadtlenkowej, glutationu zredukowanego i katalazy, podczas gdy ilość dehydrogenazy mleczanowej nie zmieniała się. Poziom markerów tkankowych takich jak: α-glukozydaza, fruktoza, i L-karnityna obniżał się z wiekiem, podczas gdy stężenie dehydrogenazy mleczanowej ponownie nie zmieniało się. Analizy biochemiczne surowicy wskazują na analogiczny trend w odniesieniu do peroksydacji lipidów jak i badanych enzymów, tj.: dysmutazy ponadtlenkowej, zredukowanego glutationu, i dehydrogenazy mleczanowej. Poziom wapnia obniżał się wraz ze starzeniem się myszy. Postępujące z wiekiem zmiany architektury histologicznej obserwowane były we wszystkich badanych narządach. Niski poziom markerów tkankowych może być bezpośrednio związany z potwierdzonymi zniekształceniami anatomicznymi gruczołów rozrodczych. Generalnie, organizacja i funkcjonalność struktur w analizowanych narządach układu rozrodczego jak i tkankach somatycznych zmniejszały się wraz z wiekiem. Obniżenie parametrów biochemicznych osocza i nasienia sugeruje spadek aktywności narządów w starszych grupach wiekowych, co ostatecznie prowadzi do upośledzenia funkcji tych organów wraz ze starzeniem się zwierząt. Obserwowane zmiany architektury histologicznej u myszy w średnim wieku wskazują na wzrost stresu oksydacyjnego u tych zwierząt.

REFERENCES

Adamson I.Y., Hedgecock C., Bowden D.H. 1990. Epithelial cell fibroblast interactions in lung injury and repair. Am. J. Pathol 137: 385–392.

Aebi H.1984. Catalase in vivo. Meth Enzymol 105: 121-126.

Aitken RJ., Fisher H. 1994. Reactive oxygen species generation and human spermatozoa: The balance of benefit and risk. Bioassays 16: 259–67.

Andriollo-Sanchez M., Hininger-Favier I., Meunier N., Venneria E., O'connor M.J., Maiani G., Coudray C., Roussel M.A. 2005. Age-related oxidative stress and antioxidant parameters in middle-aged and older European subjects: the ZENITH study. Eur J Clin Nutr 59, Suppl 2: S58–S62.

Aydm S., Yilmaz Y., Odabas O., Sekeroglu R., Tarakgioglu M., Atilla M.K. 1997. A Further Study of Seminal fluid: Lactate Dehydrogenase and Lactate Dehydrogenase-X Activities and Diluted Semen Absorbance 35(4): 261 -264.

Banihani S., Sharma R., Bayachou M., Sabanegh E And Agarwal A. 2012. Human sperm DNA oxidation, motility and viability in the presence of L -carnitine during in vitro incubation and centrifugation. Andrologia 44: 505–512.

Beier K., Volkl A., Fahimi H.D. 1993. The impact of aging on enzyme proteins of rat liver peroxisomes: quantitative analysis by immunoblotting and immunoelectron microscopy. Virchows Arch B Cell Pathol Incl Mol Pathol 63:139-146.

Ben A.H., Guerin J.H., Pinatel M.C., Mathieu C., Boulieu D., Tritar B. 1994. Relationship between semen characteristics, α-glucosidase and the capacity of spermatozoa to bind to the human zona pellucida. Int j androl 17(3): 121-126.

Bernheim F., Bernheim MLC., Wilbur K.M. 1948. The reaction between thiobarbituric acid and the oxidation products of certain lipids. J. Biol. Chem 174: 257–264.

Beutler E., Duron O., Kelly M.B. 1963. Improved method for the determination of blood glutathione. J. Lab. Clin. Med 61: 882-888.

Carlsen E., Giwercman A.j., Keiding N., Skakkebaek N.e. 1995. Declining semen quality and increasing incidence of testicular cancer: Is there a common cause? Environ Health Perspect 103: 137-139.

Cevik C.,1988. Tikamkligm place by a sperm analysis determination foundations. Gureba Hospital tubular magazine.15 146-8.

Chen T.S., Richie Jr J.P., Nagasawa H.T., Lang C.A. 2000. Glutathione monoethyl ester protects against glutathione deficiencies due to aging and to acetaminophen in mice. Mech. Aging Dev. 120: 127–139.

Cini M., Moretti A., 1995. Studies on lipid peroxidation and protein oxidation in the aging brain. Neurobiol. Aging 16: 53–57.

Comhaire F.H., Dhooge W., Mahmoud A., Depuydt C.,Verh K. 1999. A strategy for the prevention of male infertility. Verk K Acad Geneeskd Belg 61: 441-452.

Elcock L.H., Schoning P. 1984. Age-related changes in the cat testis and epididymis. Amer. J.Vet.Res 45: 2380-2384.

Finkel T., Holbrook N.J. 2000. Oxidants, oxidative stress and the biology of aging. Nature 408: 239–247.

Gabry S.M., Kader A.H.D., Moustafa M., Elenany H.A. 2014. Effect of some antioxidants on the prostate of adult and aged albinorats: a histological and immunohistochemical study. Journal of Applied Pharmaceutical Science 4(2): 017-026.

Gregg S.Q., Gutierrez V., Robinson A.R., Woodell T., Nakao A., Ross M.A., Michalopoulos G.K., Rigatti L., Rothermel C.E., Kamileri I., Garinis G.A., Stolz D.B., Niedernhofer L.J. 2012. A mouse model of accelerated liver aging caused by a defect in DNA repair. Hepatology 55(2): 609-621.

Gosden R.G., Richardson D.W,, Brown N., Davidson D. 1982. Structure and gametogenic potential of seminiferous tubules in aging mice. J.Reprod.Fertil 64: 127-133.

Gulcin I. 2006. Antioxidant and antiradical activities of l-carnitine. Life Sci 78: 803–811.

Halliwell B. 1984. Tell Me about Free Radicals, Doctor: A Review. J. Roy. Soc. Med 82: 747 –752.

Harman D. 1998. Aging and oxidative stress. J. Int. Fed. Clin. Chem. 10: 24–27.

Hatakeyama S., Takizawa T., Kawahara Y. 1979. Focal atrophy of the seminiferous tubule in the human testis. Acta pathol.jap 29: 901-910.

Hill G.S., Heudes D., Bariety J. 2003. Morphometric study of arterioles and glomeruli in the aging kidney suggests focal loss of autoregulation. Kidney Int. 63: 1027–1036.

Hoare M., Das T., Alexander G. 2010. Aging, telomeres, senescence, and liver injury. J Hepatol 53: 950–961.

Humphrey J.D, Ladds P.W. 1975. A quantitative histological study of changes in the bovine testis and epididymis associated with age. Res.Vet.Sci 19: 135-141.

Ito Y., Sorensen K.K., Bethea N.W., Svistounov D., McCuskey M.K., Smedsrod B.H., McCuskey R.S. 2007. Age-related changes in the hepatic microcirculation in mice. Exp Gerontol 42: 789–797.

Jegou B., Laws A.O., De Kretser D.M. 1983. The effect of cryptorchidism and subsequent orchidopexy on testicular function in adult rats. J.Reprod.Fertil 69: 137-145.

Kagansky N., Levy S., Keter D., Rimon E., Taiba Z., Fridman Z., Berger D.. 2004. Non-alcoholic fatty liver disease-a common and benign finding in octogenarian patients. Liver Int 24: 588–594.

Kasapoglu M., Ozben T. 2001. Alterations of antioxidant enzymes and oxidative stress markers in aging. Exp Gerontol 36(2): 209-20.

Kindblom J., Dillner K., Sahlin L., Robertson F., Ormandy C.J., Tornell J., Wennbo H. 2003. Prostate hyperplasia in a transgenic mouse with prostate-specific expression of prolactin. Endocrinology in press.

Kono Y. 1978. Generation of superoxide radical during auto-oxidation of hydroxylamine and an assay for superoxide dismutase. Arch Biochem Biophys 186: 189 -195.

Kregel K., Zhang H. 2006. An integrated view of oxidative stress in aging: basic mechanisms, functional effects, and pathological considerations. Am J Physiol Regul Integr Comp Physiol 292: R18–R36.

Krouwer V.J., Hekking L.H., Langelaar-Makkinje M., Regan-Klapisz E., Post J.A. 2012. Endothelial cell senescence is associated with disrupted cell-cell junctions and increased monolayer permeability. Vasc. Cell 4(1): 12.

Lee K.C., Weindruch R., Prolla A.T. 2000. Gene-expression profile of the aging brain in mice. Nature Genetics 25: 294–297.

Lewis J.D.I., Aird I.A., Biljan M.M., Kingsland C.R. 1996. Effects of sperm activity on zinc and fructose concentrations in seminal fluid. Hum Reprod 11(11): 2465-2467.

Lutzen L., Ueberberg H. 1973. A study on morphological changes in the testes of old albino rats. Beitr. Pathol 149: 377-385.

McLean A.J., Cogger V.C., Chong G.C.., Warren A., Markus A.M., Dahlstrom J.E., Le Couteur D.G. 2003. Agerelated pseudocapillarization of the human liver. J Pathol 200: 112–117.

Miquel J., Weber H. 1990. Aging and increased oxidation of the sulfur pool. In Glutathione: Metabolism and physiological functions (ed) Vina J, pp 187–192. Boca Raton, FL: CRC Press

Mukhopadhyay D., Varghese A.C., Pal M., Banerjee S.K., Bhattacharyya A.K., Sharma R.K. 2010. Semen quality and age-specific changes: a study between two decades on 3729 male partners of couples with normal sperm count and attending an andrology laboratory for infertility related problems in an Indian city. Fertil Steril 93 (7): 2247-2254.

Garrido N., Meseguer M., Simon C. 2004. Proxidative and antioxidative imbalance in human semen and its relation with male infertility. Asian Journal of Andrology 6(1): 59–65.

Nabil H., Moemen LA., and Elela MHA., 2008. Studying the levels of malondialdehyde and antioxidant parameters in normal and abnormal human seminal plasma. Aust J Basic Appl Sci. 2008. 2(3), 773-8.

Nebel B.R., Murphy C.J. 1960. Damage and recovery of mouse testis after 1000 r acute localized X-irradiation, with reference to restitution cells, Sertoli cell increase, and type A spermatogonial recovery. Rad. Res 12: 626-641.

Neugarten J., Gallo G., Silbiger S., Kasiske B. 1999. Glomerulosclerosis in aging humans is not influenced by gender. Am J Kidney Dis 34: 884–888.

Ohtsubo K., Nomaguchi T.A. 1986. A flow cytofluorometric study on age-dependent ploidy class changes in mouse hepatocyte nuclei. Mech Aging Dev 36: 125–131.

Pieri C., Giuli C., Del Moro M., Piantanelli L. 1980. Electron-microscopic morphometric analysis of mouse liver. II. Effect of aging and thymus transplantation in old animals. Mech Aging Dev 13: 275–283.

Pinkerton E.K., Herring J.M., Hyde M.D., Green Y.H.F. 2015. The Lung; Development aging and the environment. In: Pinkerton E.K and Harding R. (Eds.). Normal aging of lung. IInd Edition. Academic Press, UK.

Poljsak B., Milisav I. 2013. In: JA MORALES-GONZALES, (ed.). Aging, Oxidative Stress and Antioxidants. Croatia: Intech publisher 332-53.

Purandhar K., Seshadri S. 2013. Age associated variations in human neutrophil and sperm functioning, APJR 1(3): 201-208.

Sato K., Hirokawa K., Hatekeyama K.. 1981. Experimental allergic orchitis in mice. Histopathological and immunological studies. Virchows Arch.,pathol. Anat 392: 147-158.

Sharma K.R., Agarwal A. 1996. Role of reactive oxygen species in male infertility Urology 48(6): 835–850.

Sikka S., Rajasekaran M., Hellstrom W. 1995. Role of Oxidative Stress and Antioxidants in Male Infertility. J Androl 16(6).

Smithwick E.B., Young L.G. 2001. Histological effects of androgen deprivation on the adult chimpanzee epididymis. Tissue cell 33(5): 450-461.

Sohal R.S. 2002. Role of oxidative stress and protein oxidation in the aging process. Free Rad Biol Med 33: 37–44.

Sun J., Tower J. 1999. FLP recombinase-mediated induction of Cu/Zn-superoxide dismutase transgene expression can extend the lifespan of adult Drosophila melanogaster flies. Mol Cell Biol 19: 216–28.

Tebow G., Sherrill D.L., Lohman I.C., Stern D.A., Wright A.L., Martinez F.D et al. 2008. Effects of parental smoking on interferon γ production in children. Pediatrics 121: 1563-1569.

Teramoto S., Fukuchi Y., Uejima Y., Teramoto K., Ito H., Orimo H. 1994. Age-related changes in the antioxidant screen of the distal lung in mice. Lung 172(4): 223-30.

Tuncbilek E., Aydoganh L., Cevik C., Baykam M., Cengiztakalm Z. 1996. Normospermic , oligospermia and azoospermia donor dlu semen and sperm count in groups may absorbance (DS) test In relating the tams between azoospermia and dsa'nm obstriiktif the yen. Turkey Type Journal, 2: 99-109.

Vieira C., Pasyukova E.G., Zeng Z.B., Hackett J.B., Lymann R.F., Mackay T.F. 2000. Genotype–environment interaction for quantitative trait loci affecting lifespan in Drosophila melanogaster. Genetics 154: 213–27.

Warren A., Bertolino P., Cogger V.C., McLean A.J., Fraser R., Le Couteur D.G. 2005. Hepatic pseudocapillarization in aged mice. Exp Gerontol 40: 807–812.

WHO 2010. World Health Organization Laboratory Manual for the examination and processing of human semen: 5th edition. Cambridge press.

Yang C.H., Fogo B.A. 2014. Fibrosis and renal aging. Kidney International Supplements 4: 75-78.

ZHOU XJ., RAKHEJA D., YU X., SAXENA R., VAZIRI ND., SILVA FG. 2008. The aging kidney. Kidney Int. 74: 710–720.

Zoologica Poloniae (2016) 61/1. 85-90

SHORT REPORT

UNTYPICAL COLOURATION OF THE JACKDAW *CORVUS MONEDULA* AS THE EXAMPLE OF THE PLUMAGE ABERRATIONS IN BIRDS

Sebastian Mertowski [1], Paweł Buczyński [2], Edyta Buczyńska[3]

[1] Department of Nature Conservation, Department of Biology and Biotechnology, Maria Curie-Skłodowska University in Lublin
[2] Department of Zoology, Department of Biology and Biotechnology, Maria Curie-Skłodowska University in Lublin
[3] Department of Zoology, Animal Ecology and Wildlife Management, Faculty of Biology, Animal Sciences and Bioeconomy, University of Life Sciences in Lublin

Corresponding author: s.mertowski@o2.pl

Abstract: On the basis of many observations and ornithological studies several types of aberrations in the plumage colouration of birds have been identified: albinism, leucism, schizochroism, melanism, carotenism and dilution. Observations of atypically coloured birds have also provided a great deal of information on their behaviour and interaction with other birds in the vicinity. The subject of this report is the observation of the leucistic jackdaw *Corvus mendula* with a pigment defect of feathers and the beak. Observations were made in the Public Park in Nałęczów, in eastern Poland.

Key words: *Corvus monedula*, plumage aberration, birds

INTRODUCTION

During ornithological observations, one can come across individuals that differ in colour from the rest of the population of their species (Sage 1962). The colouration in birds depends on the various combinations of pigments that give colour to the feathers (Guay et al. 2012). The most common pigments are black eumelanin and brown phaeomelanin (McGraw 2006). Equally common carotenoids can be yellow, orange or red (McGraw 2006). Specific pigments can be synthesised by parrots (Stradi et al. 2001). Some colours of bird feathers such as blue and green are the result of light scattering due

to the specific structure of the feather. Different cases of pigment synthesis disorders or the lack of possibility of their deposition in the feathers are the causes of aberration in the colouration. Literature distinguishes six types of pigment aberration of feathers in birds: albinism, leucism, schizochroism, melanism, carotenism and dilution (Guay et al. 2012).

Each aberration is characterized by a particular type of colouration and is caused by specific factors. The first factor causing pigment aberrations in bird feathers is genetic mutation. The example of this type of aberration is albinism, probably caused by the lack of the enzyme tyrosinase, which is essential for the production of pigments (Van Grouw 2006). The second possible cause of atypical bird colouration is a diet in which there are no compounds like carotenoids that allow for the synthesis of pigments by the organism, as well as the deficiency of some amino acids such as lysine whose absence is responsible for whitened (decoloured) plumage. The third possible factors are diseases and parasites. In the case of diseases, decolouration or changes in pigmentation appear locally at the site of the disease. In turn, the presence of internal and external parasites can disturb the absorption of carotenoids, mainly red, to newly growing feathers. The last reason for colour changes in birds is aging. The cause of this phenomenon is the accumulation of somatic mutations over the lifetime that affect the colour change of the feathers (Guay et al. 2012).

TYPES OF ABERRATIONS

There are two main types of plumage aberrations associated with albinism in birds. Both diseases cause the same effect. The first one is albinism characterized by the lack of melanin in all feathers as well as the skin (Grouw 2006). However, in leucism, the lack of melanin can occur in the entire feather or only in its individual areas. In addition, the colour of the eye or skin remains the same as in the typical individuals, in contrary to albinism where the individuals have discoloured eyes, characterized by red colour caused by numerous and well visible blood vessels. These are the main differences by which we can distinguish these two major types of aberrations (Guay et al. 2012).

The next aberrations are characterized by the intensification of one specific colour or the lack or reduction of one pigment in the feathers. The first phenomenon is melanism, characterized by the increase in the amount of melanin, usually causing a darker colouration of individuals. This is the only mutation in which there is no pigment absence or the changes in the shape of melanin molecules. In this case there is only colour intensification (Van Grouw and Nolazco 2012). There are two types of overexpression of melanine. The first is to enhance the colour of the dark elements of the colouring in birds: the colour is then more intense than the typical colour of the bird. The other way is to increase the intensity of the entire colouration of feathers, from dark brown to almost black (Van Grouw 2017).

Another case of aberration in which colouration is changing is carotenism. This is an abnormality characterized by changes in the amount and distribution of the pigment, or the conversion of melanin to carotenoid pigments. It is mainly manifested in red or yellow plumage. Schizochronism and dilution are phenomena in which pigment is lost. In dilution, the amount of the pigment decreases in both feathers and in the whole body, however, the trace amounts are still present and give colour to the individual. On the other hand, schizochronism is a phenomenon in which there is a lack of one of the pigments of colouration. There are two types of this aberration: the first is the lack of eumelanin, which results in the lack of black pigment, and the second refers to the deficiency of phaeomelanin that is brown pigment (Guay et al. 2012).

FEATHER COLOUR ABERRATIONS OBSERVED IN POLAND

The colour aberrations of commonly occurring bird species have been observed in Poland for many years. Individuals with untypical colouration have been found throughout the country. Literature data shows that the pigment aberrations of individuals cover almost every family of birds in Poland from aquatic birds to the predators. Bird species among which the most often aberrations were found are as follow: mallards (*Anas platyrhynchos*), harriers (*Circus* sp.), skuas *(Stercorariidae* sp.), sterlings (*Sturnus vulgaris*), sparrows (*Passer domesticus*) and jackdaws (*Corvus monedula*) (Olszewski 2007). Ptaszyk (1981) provided other species with similar disorders of feather colour: great crested grebe *Podiceps cristatus*, grey heron *Ardea cinerea*, rook *Corvus frugilegus*, white wagtail *Motacilla alba*, swallow *Hirundo rustica*, goldfinch *Carduelis carduelis* or corn bunting *Emberiza calandra*. Similar feather colour disorders were observed in great spotted woodpecker *Dendrocopos major* (Olszewski 2007) or bearded tit *Panurus biarmicus* (Stępniewski 2006).

The notable fact that appears during the observation is not only the unusual appearance of the individual but also his behaviour and the behaviour of other birds towards him. Various types of behaviours of atypically coloured birds have been observed in relation to other individuals in the population. There are known cases when a bird with aberration stayed far away from the group (Fleszer 1969; Mielewczyk 1962) or aggressive behaviour of non-typical individuals to normally-coloured individuals observed in an albino greenfinch by Kaczmarek (1974). Adverse behaviour is also quite common when an untypically coloured bird is driven off by other members of the flock. Birds with aberrations behave differently towards the observer than birds with normal plumage, an example is the finch observed in Łazy, which was more skittish than others (Górska et al. 1977). These birds are also subject to strong predator pressure, because due to their unusual colouration they can be easily detected by predators.

OBSERVATION OF THE LEUCISTIC JACKDAW IN THE PUBLIC PARK IN NAŁĘCZÓW

Fig. 1. *Untypical colouration of jackdaw, bird was observed in the Public Park in Nałęczów, Eastern Poland (photo: Paweł Buczyński)*

The area of the conducted observation was the Public Park in Nałęczów, located in the Lublin Region, in eastern Poland. This park is located in the city centre and is adjacent to the spa facilities. The park grounds are covered by old stands, ornamental shrubs and lawns. In the centre of the park is a pond. The park, frequently used by tourists, is eagerly inhabited by many species of birds (e.g. swans, mallards, great spotted woodpeckers, wood pigeons, blackbirds, chaffinches, great tits, blackcaps, garden warblers, yellowhammers, rooks or jackdaws) due to the availability of suitable habitats and large amounts of food of anthopogenic origin. In May 2017, an untypically coloured jackdaw *Corvus monedula* was observed (Fig. 1). This difference was not only in appearance (feathers and beak) but also in behaviour. The jackdaw was distinguished by the white feathering on both the wings and the main body, with the presence of traces of normal pigmentation. The colour of this individual's eyes did not differ significantly from the other jackdaws indicating that it was not a typical red-eye albino. Based on this type of observation, it can be said that the aberration characteristic for this case was leucism, not albinism. This individual was in a group of other jackdaws that were fed by humans. During the observation there were distinct differences in the behaviour of the leucistic individual. It was on the margins of the group and had a larger escape distance. When other jackdaws were able to get close to a man at a distance of about 0.5 m, the untypically coloured jackdaw showed twice the distance of escape. Although the individual kept standing on the side, it was

able to obtain food thrown by humans. It was not observed that the unusual jackdaw was pecked by other individuals but the obvious manifestation of aggression was pushing a leucistic individual away with wings from food by other jackdaws.

SUMMARY

The appearance of atypically coloured birds is not dependent on the species. Deviations from standard colouration are quite common. However, no accurate data has yet been compiled on the fate of individuals with aberrations and the frequency of this phenomenon in individual species and their offspring. The development of individuals with aberrations is conditioned not only by genetic defects, but also by environmental factors. The leucistic jackdaw observed in the Public Park in Nałęczów had a chance to develop as a typical individual due to its special habitat rich in easily accessible food of anthropogenic origin. In such case, the individual has a better chance of normal life despite pigment defect, predator pressure and aggression from other birds.

STRESZCZENIE

Na bazie wielu obserwacji i badań ornitologicznych wyróżniono kilka rodzajów abberacji w ubarwieniu ptaków: albinizm, leucyzm, schizochroizm, melanizm, karotenizm oraz dilutionizm. Obserwacje nietypowo ubarwionych ptaków dostarczyły również wielu informacji dotyczących ich zachowania oraz interakcji z innymi ptakami przebywającymi w pobliżu Przedmiotem niniejszego doniesienia jest obserwacja leucystycznej kawki *Corvus monedula* posiadającej defekt w pigmentacji piór i dzioba. Obserwacje wykonano w parku w Nałęczowie, we wschodniej Polsce.

REFERENCES

Fleszar F. 1969. Flawistyczny okaz bogatki, *Parus major.* Notatki Ornitologiczne T. 10(1): 15.

Górska E., Bereszyński A., Lewartowski Z., Busse P. 1977. Przypadki nietypowego ubarwienia u ptaków, Notatki ornitologiczne T. 18 (1-2): 57-60

Guay P.J., Potvin D.A., Robinson R.W. 2012. Aberrations in plumage coloration in birds Australian Field Ornithology, 29: 23-30.

Kaczmarek J. 1974. Albinotyczny dzwoniec (*Carduelis chloris*). Notatki ornitologiczne, T. 15(3-4): 132.

McGraw K.J. 2006. Mechanics of melanin-based coloration. In: Hill G.E and McGraw K.J (Eds.), Birds Coloration – Vol.1: Mechanisms and Measurements. Harward University Press, Cambridge, Massachusetts USA.

Mielewczyk S. 1962. Uwagi o częściowym bielactwie niektórych ptaków na terenie Gniezna. Przyroda Polski Zachodniej 6(1-4): 80-82.

Olszewski A. 2007. Kilka przypadków aberracji barwnych u dzięcioła dużego Dendrocopos major w Puszczy Kampinoskiej. Notatki ornitologiczne, 48(3): 210-213.

Ptaszyk J. 1981. Nietypowe ubarwienie u ptaków. Notatki Ornitologiczne, T. 22 (1-2): 37-46.

Sage B.L. 1962. Albinism and melanism in birds. British Birds 55:201-225.

Stępniewski J. 2006. Nietopowo ubarwione wąsatki Panurus biarmicus. Notatki Ornitologiczne 47:271-272.

Stradi R., Pini E., Celetano G. 2001. The chemical structure of the pigments in Ara macao plumage. Comparative Biochemistry and Physiology B, 130:57-63.

Van Grouw H. 2006. Not every bird is an Albino; sense and nonsense about colour aberrations in birds. Dutch Birding 28(2): 79-89.

Van Grouw H. 2017. The dark side of birds: melanism – facts and fiction. Bull. B.O.C. 137(1)12-36.

Van Grouw H., Nolazco S. 2012. The nature of melanism and some other colour aberrations in the vermilion flycatcher (*Pyrocephalus rubinus obscurus*) Boletin informativo UNOP Vol. 7, N. 1, January.