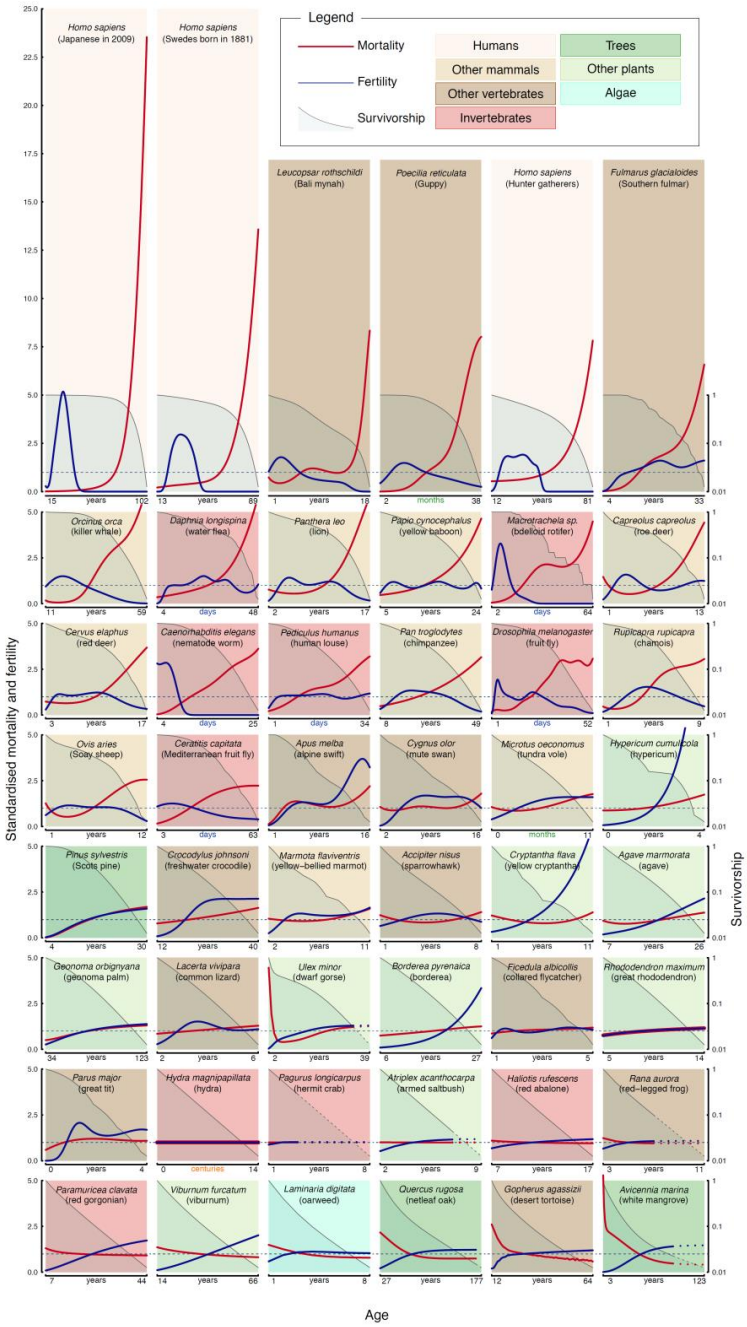
UNIVERSITY OF SOUTHERN DENMARK

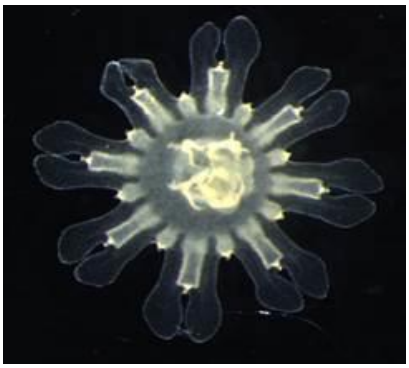
Max-Planck Odense Center on the Biodemography of Aging

MAX-PLANCK-GESELLSCHAFT

Max-Planck Odense Center on the Biodemography of Aging

ANNUAL REPORT 2014





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People affiliated with MaxO in 2014

Leadership:

James W. Vaupel, Professor, Public Health, Director
Kaare Christensen, Professor, Public Health, Deputy Director
Donald Canfield, Professor, Biology, Deputy Director

Annette Baudisch, Professor of Biodemography, Biology
Hal Caswell, Adjunct Professor, Biology

Research staff:

Jim Oeppen, Senior Researcher, Public Health

Vladimir Canudas-Romo, Associate Professor, Public Health
Rune Lindahl-Jacobsen, Associate Professor, Public Health
Ulrich Steiner, Associate Professor, Biology

Fernando Colchero, Assistant Professor, Mathematics
Dalia Amor Conde, Assistant Professor, Biology
Johan Dahlgren, Assistant Professor, Biology
Owen Jones, Assistant Professor, Biology
Daniel Levitis, Assistant Professor, Biology

Paul Dunn, Post Doc, Biology
Raisa Hernández Pacheco, visiting Post Doc, Biology
Lionel Jouvet, Post Doc, Biology
Adam Lenart, Post Doc, Public Health
Virginia Zarulli, Post Doc, Public Health

Marie-Pier Bergeron Boucher, PhD student , Public Health
Josephine Goldstein, PhD student, Biology
Lars Kumala, PhD student, Biology
Marius Pascariu, PhD student, Public Health
Danielle Sherman, PhD student, Biology
Johanna Stärk, PhD student, Biology

Maria Baden, Research Assistant, Biology
Julia Barthold, Research Assistant, Biology
Vibeke Jensen, Secretary, Biology
Kim Lundgreen, Academic Assistant, Biology
Anthony Medford, Research assistant, Public Health

Note: This report focuses on the Research Staff of MaxO. For information about the leadership of MaxO, please see:

James Vaupel: http://user.demogr.mpg.de/jwv/

Kaare Christensen: http://www.sdu.dk/staff/kchristensen

Donald Canfield: http://www.sdu.dk/staff/dec

Annette Baudisch: www.sdu.dk/staff/baudisch

Hal Caswell: http://www.uva.nl/en/about-the-uva/organisation/staff-members/content/c/a/h.caswell/h.caswell.html

Demography of MaxO 2014

Arrivals to the group in 2014

Annette Baudisch, Professor of Biodemography, Biology
James Oeppen, Senior Researcher, Public Health
Rune Lindahl-Jacobsen, Associate Professor, Public Health
Marius Pascariu, PhD student, Public Health
Danielle Sherman, PhD student, Biology
Johanna Stärk, PhD Student, Biology
Maria Baden, Research Assistant, Biology
Julia Barthold, Research Assistant, Biology
Anthony Medford, Research Assistant, Public Health

Babies born in 2014

Dan Levitis had a baby girl in August
Annette Baudisch had a baby boy in October
Paul Dunn had a baby boy in December

Research staff highlights

Jim Oeppen, Senior Researcher, Public Health

Main research interest

"Forecasting Mortality by Cause of Death"

Forecasting mortality is a difficult problem that is undertaken by many international, government, and financial institutions. It would be useful to disaggregate these forecasts by cause of death because that would allow policy makers to identify target areas for future reductions in mortality. In addition, the ultimate cause of death may be a good guide to the period of ill health that precedes most deaths and help to indicate its cost to society. At the moment, very few institutions try to forecast mortality by cause of death because of the technical difficulties.

One of the reasons it is more difficult is that even though the average age at death is generally rising, each person must die, so if the forecast suggests that a cause will become less important in the future, one or more of the other causes has to absorb extra deaths and not necessarily at the same age. A second problem arises because we would like the sum of the forecasts for each cause to match the existing forecasts that do not separate the causes of death. This project undertakes basic research to explore new statistical methods that are explicitly designed to address these problems.

Ongoing work

"Forecasting Mortality by Cause of Death"

Planners in public and private institutions would like coherent forecasts of the components of age-specific mortality, such as causes of death. This has been difficult to achieve because making a separate forecast for each cause, or group of causes, has proved inadequate. The relative values of the separate forecast components often fail to behave in a way that is coherent with historical experience. In addition, when the individual forecasts are combined the result is often incompatible with an all-groups forecast. It has been shown that cause-specific mortality forecasts are pessimistic when combined and compared with all-cause forecasts.

This research abandons the conventional approach of forecasting separate time-series of log mortality rates for each cause and forecasts the cause-specific density of deaths d(x) in a single model of a time-series of multiple-decrement life tables. Demographers have given a little theoretical attention to "life-saving" models that treat survival improvement as a perturbation of the density of the death distribution by age d(x), but there have been no previous attempts to define such models for forecasting in a single- or multiple-decrement context.

Conferences/activities

50th Anniversary of the Cambridge Group for the History of Population and Social Structure. 16 Sep 2014 - 18 Sep 2014

First Conference of the European Society of Historical Demography (ESHD) in Sassari/Alghero, Sardinia, Italy 25 Sep 2014 - 27 Sep 201

Vladimir Canudas-Romo, Associate Professor, Public Health

Main research interest

My research interests can be classified in two groups:

- Life tables and causes of death models and forecasts, are among my most deep interests. Demography has a central role in the public debate because it informs about existent "Disparities" in populations. I believe the future rise in life expectancy will be heavily dependent on public health interventions, as it was the case in the past (sanitation, living standards, clean water, health-education, etc). However, also medical innovations will have a central part of this change. Demography, and more specifically the study of mortality by causes of death, will be at the center of this debate helping experts of other fields disentangle the contribution of the new advancements in both public health and clinical practices.

- Formal demography or the existent mathematical relations between demographic measures is also at the core of my interests: I keep working on developing new demographic measures and methods that help explicate the observed population phenomena. Recently I have also investigated the experience of cohort measures, as opposed to the results of period studies on longevity. I believe there are great contributions to our field hidden in the study of mathematical demography.

Publication highlights

Canudas-Romo, V., García-Guerrero, V.M., Echarri-Cánovas, C.J. 2014 "The stagnation of the Mexican male life expectancy in the first decade of the 21st century: the impact of homicides and diabetes mellitus". JECH 68(10):1-7, doi:10.1136/jech-2014-204237

In the first decade of the twenty first century, the Mexican life expectancy changed from a long trend of increase to stagnation. We quantify the impact of causes of death on life expectancy from 2000 to 2010. Two approaches to analyze causes of death are used: the number of life years lost due to each of the causes of death in a given year, and cause-decomposition techniques for comparisons of life expectancy from 2000 to 2010. The apparent stagnation in life expectancy is the result of an increase in deaths by homicides and diabetes mellitus on the one hand, and the positive improvements observed in other causes of death on the other. The negative impact of homicides is particularly observed for ages 15 and 50, and for that of diabetes mellitus at ages above 45 years. There is little basis for optimism regarding the future scenarios of the health of the Mexican population based on the first decade of the twenty-first century. Male life expectancy would have increased by two years if deaths by homicides and diabetes mellitus had been avoided.

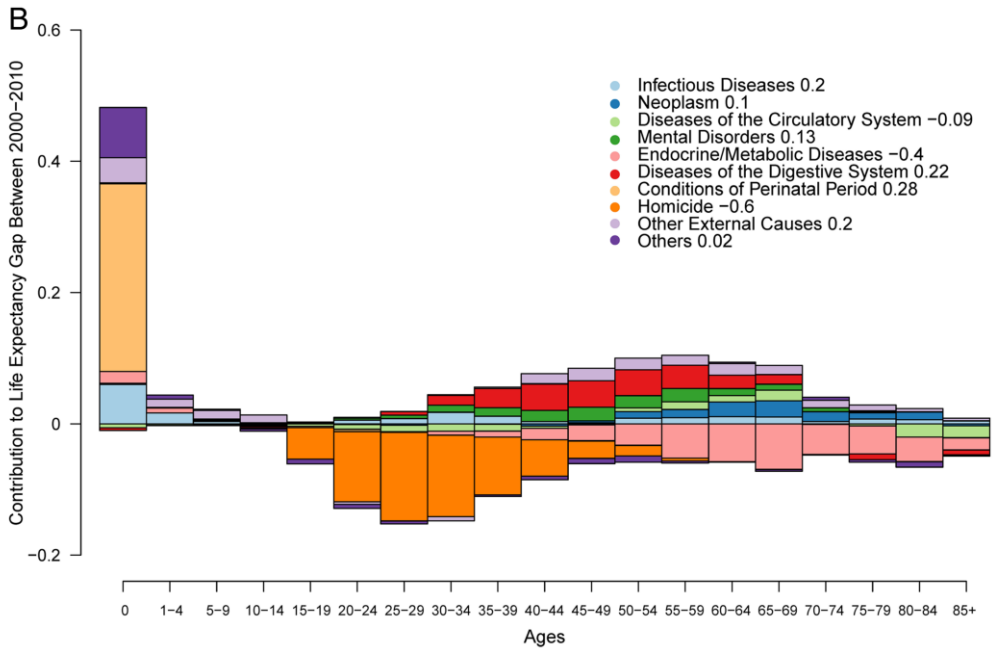

Figure 1. Age- and cause-contribution to the 0.07 years of difference in male life expectancy between 2000 (LE=71.97) and 2010 (LE=72.04) in Mexico. The age-specific causes of death that contribute to the increase in the Mexican life expectancy are shown above the (zero) horizontal axis, and the causes of death that oppose this trend are below. Sources: Authors' calculations, data from INEGI. Note: Causes of death used and their specific ICD-10 codes defined in Table 1. Legends include the overall contribution of each cause of death to the change in life expectancy (negative contributions correspond to an increase in the cause of death between 2000 and 2010).

DuGoff, E. H., Canudas-Romo, V., Buttorff, C., Leff, B., & Anderson, G. F. 2014. "Multiple Chronic Conditions and Life Expectancy: A Life Table Analysis." Medical care, 52(8), 688-694.

The number of people living with multiple chronic conditions is increasing, but we know little about the impact of multimorbidity on life expectancy. We analyze life expectancy in Medicare beneficiaries by number of chronic conditions aged 67 and older as of January 1, 2008. We categorize study subjects by sex, race, selected chronic conditions (heart disease, cancer, chronic obstructive pulmonary disease, stroke, and Alzheimer disease), and number of comorbid conditions. Comorbidity was measured as a count of conditions collected by Chronic Conditions Warehouse and the Charlson Comorbidity Index. Our results show that life expectancy decreases with each additional chronic condition. A 67-year-old individual with no chronic conditions will live on average 22.6 additional years. A 67-year-old individual with 5 chronic conditions will live 7.7 fewer years, respectively. The average marginal decline in life expectancy is 1.8 years with each additional chronic condition—ranging from 0.4 fewer years with the first condition to 2.6 fewer years with the sixth condition. These results are consistent by sex and race. We observe differences in life expectancy by selected conditions at 67, but these differences diminish with age and increasing numbers of comorbid conditions.

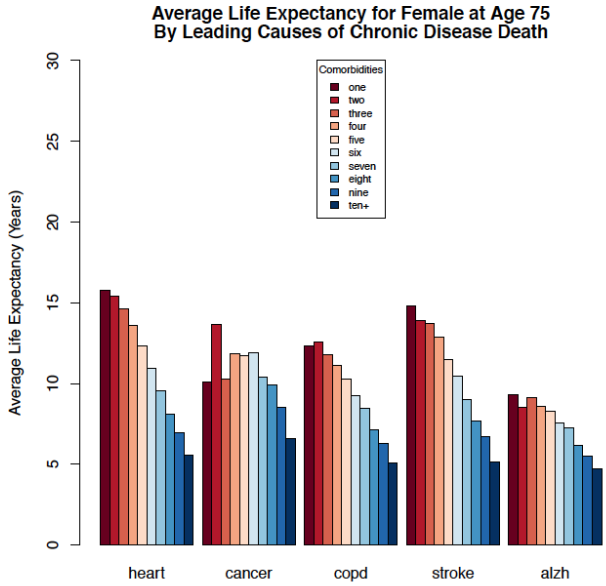

Figure 2. Average life expectancy among individuals with selected conditions by numbers of chronic conditions at age 75, 2008. Source: Medicare Beneficiary Summary File and Chronic Condition Warehouse File, 2008; Murphy et al.30

Canudas-Romo, V., Guillot, M. (forthcoming). "A Measure for Comparing the Mortality History of Cohorts: TCAL." Population Studies

The commonly used period life expectancy comparisons between populations correspond to current mortality levels. In order to construct actual life expectancies as experienced by cohorts one needs complete historical series of mortality, which are only found in a subset of developed countries. The Truncated Cross-sectional Average Length of life (TCAL) is a novel measure that captures historical information of all the cohorts present at a given moment and is not limited to countries with complete cohort mortality data. The value of TCAL depends on the rates used to complete the cohort series. However, differences between TCALs of two populations remain very similar irrespective of the data used to complete the cohort series. We illustrated this by comparing the mortality of the United States with Denmark, Japan, and other high-longevity countries using TCAL. Specific cohorts that account for most of the disparity in mortality between the populations are identified.

Ongoing work

"Am I halfway? Life lived = expected life"

Canudas-Romo, V., Zarulli, V., Lenart, A.

We have reached halfway in life when our age equals our remaining life expectancy at that age. The trends over time and over populations with historical data are investigated. Period and cohort perspectives show increase in the age where halfway in life is found, however the pace of the increase is different. In a period perspective, when halfway-age is compared with life expectancy at birth, e0, a marked disparity in the tempo of change is observed: over the observed time e0 doubles while halfway increases by 25%. In a cohort perspective, as it is the case with life expectancy, cohort halfway-age is higher than period halfway-age. Our estimates of cohort halfway-age for the most recent birth cohorts result in a halfway-age of about 50 years for females, approximately 10 years older than the observed period halfway-age.

"Mortality of the Oldest-Old"

Canudas-Romo, V., Lenart, A.

An 80-year-old is as healthy today as a 70-year-old yesterday", such phrases are not uncommon, and we can actually observe that the probability of death of an 80-year-old in Japan in 2009 corresponds to the mortality of a 70-year-old in 1959. This significant change in the mortality level of the oldest-old population, i.e. people 80 years and older, is the focus of the present article. Among others, we focus on the age-patterns, time changes, and population variation in mortality among the oldest age group of the population.

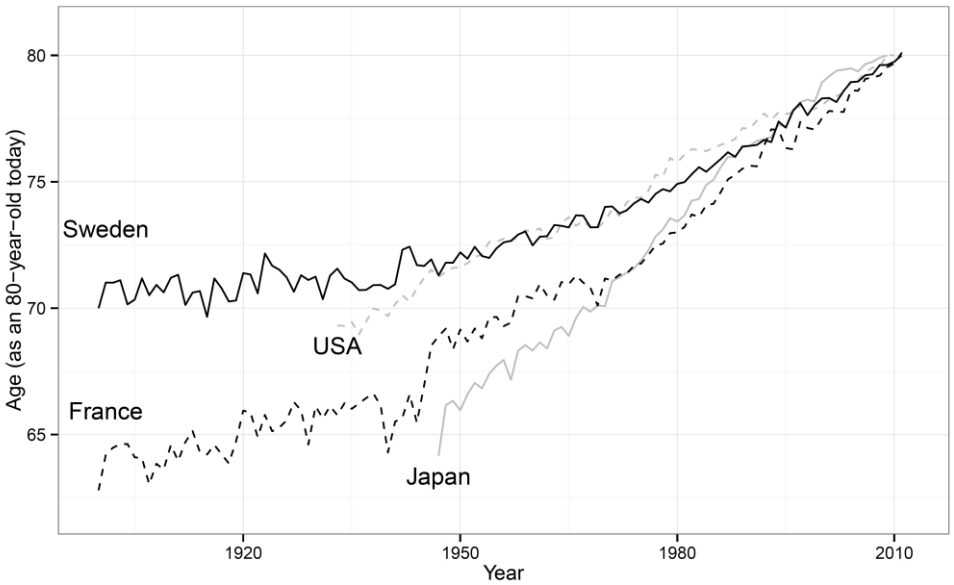

Figure 3. Ages in the twentieth century which show similar levels of mortality as 80 year olds females and males in 2010 for the USA, France, Sweden and Japan.

New grants awarded

Visiting scholar, Australian Research School of Social Science

Ongoing grants

European Research Council Starting Grant

Media highlights

http://time.com/3025289/chronic-medical-conditions-life-expectancy/#3025289/chronic-medical-conditions-life-expectancy/

In Spanish: **http://www.jornada.unam.mx/2014/05/30/politica/007n2pol**

Conferences/activities

"Longevity, disparity and models" (presentation). Mathematical Demography Workshop, held in Stanford University, 24-26 March 2014.

"American life expectancy in 2040: Experts opinion " (presentation & organizer). Population Association of America 2014 annual meeting, held in Boston Mass, 1-3 May 2014.

"A measure to study truncated cohort mortality information: TCAL" (presentation). Latin American Population Association held in Lima Peru, 12-15 August 2014.

"Am I halfway? Life lived =life left" (presentation & chair). The 19th Nordic Demographic Symposium, held in Aalborg Denmark, 18-20 Sep 2014

"Life expectancy at age 65" (presentation). The Bankers, Markets & Investors Workshop, held in Paris, France, 24 October 2014.

"A measure to study truncated cohort mortality information: TCAL" (presentation & chair). Dansk Selskab for Teoretisk Statistik, held in Odense Denmark 18 Nov 2014.

Rune Lindahl-Jacobsen, Associate Professor, Public Health

Main research interest

A special research area of interest is sex differences in mortality and health with focus on 'The male-female health survival paradox' (e.g. why men die whereas women suffer). Its determinants have been studied in both animal and human populations and this research may provide additional clues on why women outlive men in all human populations World Wide. Trends in life expectancy and mortality and explanations for these trends at a population level have been one of my important research areas with the aim of pointing towards possible factors explaining these trends. That these factors could act both in time and on specific generation and methods for examining this has been a part of my research through time. One factor I have studied with particular interest is the effect of smoking and the smoking epidemic on mortality patterns on various populations.

On the developmental part, fertility patterns and its associations with reproductive hazards has further been a research field with studies ranging from trends in assisted reproductive techniques to trends in childlessness.

Publication highlights

Nygaard M, Lindahl-Jacobsen R, Soerensen M, Mengel-From J, Andersen-Ranberg K, Jeune B, Vaupel JW, Tan Q, Christiansen L, Christensen K, Birth cohort differences in the prevalence of longevity-associated variants in APOE and FOXO3A in Danish long-lived individuals, Exp Gerontol. 2014 Sep;57:41-6. doi: 10.1016/j.exger.2014.04.018. Epub 2014 May 5.

In most high-income countries the probability of reaching 100 years increases by 50-100% per decade, i.e. there is far less selection in more recent cohorts. In this study we investigated the cohort specificity of two genes (APOE and FOXO3A) and compared the frequencies of the alleles associated with reduced longevity (APOE ε4 allele and the minor alleles of two variants in FOXO3A) at age 95+ and 100+ in 2712 individuals from the genetically homogeneous Danish birth cohorts 1895-96, 1905, 1910-11, and 1915. We found a decrease in the allele frequencies of the investigated APOE and FOXO3A longevity unfavourable gene variants in individuals from more recent birth cohorts suggesting cohort differences in selection pressure on survival to the highest ages are reflected in the prevalence of longevity gene variants.

Ongoing work

"Cause of death and the male-female health-survival paradox"

The increase in the male-female survival gap in Western societies during the second half of the twentieth century had a peak in the 1960s and 1970s followed by a decline, with a narrowing of the female advantage. One explanation for this reduction in the female advantage is that females have lower age-specific death rates than males, thus making for them harder to achieve even lower levels. Including the age component to the gap, death rates at younger ages has lead to an equal pace of reductions, and the sex-gap in life expectancy keeps narrowing. At older ages the gap is still increasing favouring females. Including causes of death analysis will highlight the factors of the narrowing: heart diseases, accidents and violence, respiratory diseases etc. However, these same causes of death are also found as the drivers of the still expanding disparity in life expectancy for the old. Our interest in the present study is to test and compare the trends in female and male survival in societies with different behavioural patterns: On the one hand Denmark with a widespread smoking and alcohol consumption by both females and males and on the other Utah where smoking and drinking are limited.

"Effects of smoking on the male-female Health survival paradox"

The smoking epidemic during the last century where first men took up smoking and later on women, has had tremendous influence on the mortality patterns seen in many Western populations. The different onset of taking up smoking and the influence on later mortality is a factor that influence the sex differences seen in life expectancy in these populations. In these studies we aim to quantify the influence of smoking on the sex differences seen in life expectancy seen in the Denmark, Sweden and Utah populations. Using lung cancer death rates from the extensive Danish, Swedish and Utah population registers on causes of death we will be able to calculate the smoking component of the age specific deaths responsible for the sex differential mortality. This, by using the revised version for estimating smoking-attributable mortality by Preston, Glei, and Wilmoth (the PGW-R method). Using the Utah population will further make us able to address the applicability of the PGW-R method as causes of death is available by religious setting including Mormons where smoking is not allowed.

Conferences/activities

Ph.d. Board, Faculty of Health Science, University of Southern Denmark (2013-2014)

"The Danish Twin Cohorts" (Presentation) 25-27 May 2014

EHLEIS: Health Inequalities in Europe (Participating), 1-3 June 2014

"Recurrent primary spontaneous pneumothorax is more common than previously reported" EACTS: 28th Annual Meeting (presenting), 10-15 October 2014

Ulrich Steiner, Associate Professor, Biology

Main research interest

I am interested in how stages, be they morphological, physiological, or developmental, influence age and reproductive patterns. We develop and advance demographic methods and theories in stage- and age-structured populations rooted in Markov chain theories. We aim at scaling individual level stage dynamics to population level processes. In particular we are interested in how we can interpret variability in individual fitness components with respect to the evolution of life histories, and ecological and evolutionary demographic dynamics. The influence of stochastic processes on individual variation within and among genotypes and environments is also studied using a microfluidic device to collect individual level demographic data on E. coli. Beside this theoretical and experimental work, I am also interested in changes in the rate of aging in humans across time, using a citizen science project approach to explore the difference between chronological and biological age.

Publication highlights

"Generation Time, Net Reproductive Rate, and Growth in Stage-Age-Structured Populations" (American Naturalist, 183(6), 771-83)

Major insights into the relationship between life-history features and fitness have come from Lotka's proof that population growth rate is determined by the level (expected amount) of reproduction and the average timing of reproduction of an individual. But this classical result is limited to age-structured populations. Here we generalize this result to populations structured by stage and age by providing a new, unique measure of reproductive timing that, along with net reproductive rate, has a direct mathematical relationship to and approximates growth rate. We use simple examples to show how reproductive timing and level are shaped by stage dynamics, selection on the trait, and parent-offspring phenotypic correlation. Such stage dynamics allow diverse patterns of aging to evolve. Our results contribute to a new framework of population and evolutionary dynamics in stage-and-age-structured populations.

"Evolutionary Change in Continuous Reaction Norms" (American Naturalist, 183(4), 453-67)

Understanding the evolution of phenotypic plasticity (reaction norms), the ability of a genotype to express different phenotypes in changing environments, remains a major challenge in ecology and evolution. Investigating differences in plasticity that has evolved among between populations and closely related species showed that even among closely related species large differences in the evolution of phenotypic plasticity occurs and that most of the differences are of non-linear function. Still congeneric species had greater differences in reaction norms than populations, and novel environmental conditions increased the differences in reaction norms between populations or species. Biological details about traits and environments, including cryptic variation expressed in novel environmental conditions, may be critical to understanding how reaction norms evolve in novel and rapidly changing environments. The high divergence even among closely related species raises challenges for forecasting population and species response to climate change.

Ongoing work

"Aging in Escherichia coli bacteria, not only a question of age"

Aging is the deterioration of function with age resulting from damage accumulation. In simple dividing organisms this damage is purged by asymmetric division. Here we tracked isogenic individual Escherichia coli bacteria in a microfluidic system, and showed substantial differences in lifespan and reproduction

among individuals. Despite this stochastic variability, classical aging patterns with an early exponential increase in mortality followed by a late age mortality plateau are detected. Surprisingly, these aging patterns are not age related but rather driven by underlying stochastic processes. Only daughters born early in the life of mothers show such "aging" patterns, whereas daughter cells produced at the end of a mother's life do not age. Further, these late offspring do not realize the expected rejuvenation by asymmetric division. The missing heritability in lifespan and the lack of aging patterns of late offspring, in combination with the strong stochastic influences questions the generality of evolutionary theories of aging, such as the mutation accumulation theory or theories rooted in arguments about pleiotropic effects. Our finding that classical aging patterns are rather driven by stochastic processes than by age challenges in a fundamental way our understanding of senescence.

Figure 4. Mortality hazard plateaus in bacteria at older ages. Surprisingly this pattern is likely driven by stochastic processes and not by age itself

"Demographic consequences of genetic, environmental and individual stochastic variability in Plantago lanceolata"

Predicting population dynamics requires understanding how individual fitness components are influenced by genetic and environmental parameters. However such a focus often neglects the stochastic events that individuals experience throughout their lives. Here we illustrate, for an experimental population of Plantago lanceolata, how variation in fitness components among individuals explained by environment, genes, and their interaction was modest compared to the stochastic (unexplained) variation in lifespan and reproduction among individuals, despite substantial fluctuation in the environment. Such large stochastic variation, if neutral, slows adaptive change, enhances drift, and lowers population growth. For instance full sibs that showed high expected lifetime reproduction (R0) and a generation time (Tc) close to the population mean, did not exhibit high expected fitness (λ), because within "genotypic" variance among individuals in reproduction was large. Our results call for more focus on stochastic variation in fitness components, rather than dismissal of this variation as uninformative noise.

Ongoing grants

AXA Research Grant: research dissemination grant

Conferences/activities

Heterogeneity of life histories in a nonhuman primate population, with Hernández Pacheco, R.; Evolutionary demography meeting, 10-12.11., Stanford

Demographic parameters of individual E.coli within and among controlled environment, with Jouvet, L.; Evolutionary demography meeting, 10-12.11., Stanford

Aging in Escherichia coli: stochasticity, individual heterogeneity and mortality plateaus. Evolutionary demography meeting, 10-12.11., Stanford

Demographic dynamics, markovian processes, and stochastic variability. Danish Society for Theoretical Statistics, 18-19.11. Odense, Denmark.

Fitness variation: real vs random. Stanford workshop in Formal Demography, 24.-25.3. Stanford, United States.

Individual stochasticity and demographic dynamics. New Directions in Probabilistic Models of Evolution, 28.4.-2.5. Berkeley, United States.

Late age mortality plateaus rather a question of stage than of age surprising insights from individual bacteria. 19th Nordic Demographic Symposium, 18.-20.9., Aalborg, Denmark.

Fernando Colchero, Assistant Professor, Mathematics

Main research interest

I am interested in understanding how demographic rates in animals and plants differ within and between populations, and how the environment contributes to shaping these rates.

In particular, I work on linking mathematics, statistics and demography to understand how age, heterogeneity and environmental factors affect mortality and fertility in wild populations, and how these may determine age-specific demographic rates, ageing, and population growth.

Publication highlights

Colchero, F. and R. Schaible (2014) Mortality as a bivariate function of age and size in indeterminate growers. Ecosphere 5(12): 161.

Mortality in organisms that grow indefinitely, known as indeterminate growers, is thought to be driven primarily by size. However, a number of ageing mechanisms also act as functions of age. Thus, to explain mortality in these species, both size and age need to be explicitly modeled. We developed a model that treats age- and size-specific mortality as a bivariate process. This method facilitates the exploration of the underlying (unobserved) contributions of age and size to mortality. We show that, in theory, a population can show declining mortality with age and size while the underlying contribution of age, as a proxy for chronological deterioration, is of typical senescence; while a seemingly senescent population can have underlying age-related negative senescence, which is, however, overcome by negative underlying size effects (Figure 5). We then developed a Bayesian model that recovers accurately all of the mortality parameters. We argue that this method can improve the demographic models commonly applied to a vast number of species of commercial and conservation importance such as fish, trees or bivalves. In addition, the application of these methods can contribute to our understanding of the evolutionary mechanisms of senescence in species that do not fit the established theories.

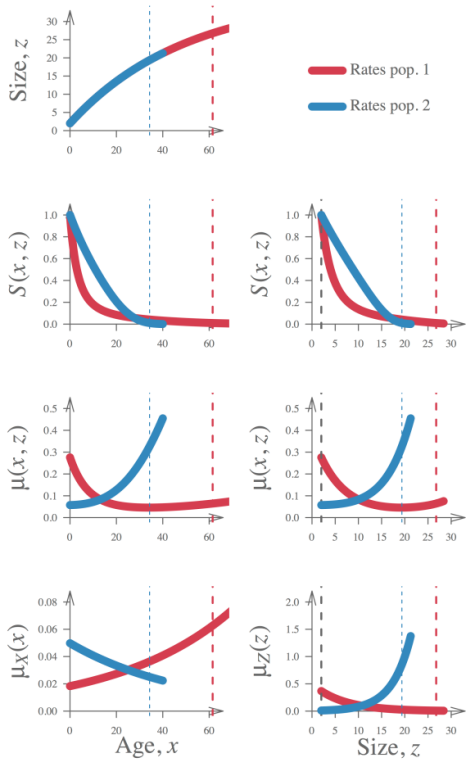

Figure 5. Observed growth, bivariate survival, $S(x, z)$, and mortality, $\mu(x, z)$, and unobserved univariate mortality, $\mu_X(x)$ and $\mu_Z(z)$, for two simulated populations. In population 1 the observed bivariate age- and size-specific mortality suggests declining mortality although the underlying age-specific mortality is typically senescent (i.e., an increase in mortality with age); thus, the decline in mortality is entirely driven by size. In population 2 the observed bivariate mortality suggests strong senescence, although the underlying age-specific mortality is driven by negative senescence.

Ongoing work

"Primate ageing: males, females, and the uniqueness of modern humans"

Colchero F., J. Barthold, O.R. Jones, D.A. Conde, the Primate Life-History Research Group, A. Baudisch, S. Alberts, J.W. Vaupel

The evolutionary and social forces that shape human ageing, and the female life-expectancy advantage in nearly all human societies, are major topics of research in demography, medicine, and evolution. Understanding these forces and patterns requires data—unavailable until now— on mortality patterns in diverse populations of humans and nonhuman primates. Here we present evidence that, in life expectancy and lifespan disparity, humans in modern industrial societies are as different from our human ancestors as our ancestors were from other primates. However, all humans and nonhuman primates share an important similarity: females tend to live longer than males. Further, for male and female nonhuman primates and non-industrial humans, the relationship between the pace of ageing (e.g., life expectancy) and the shape of ageing (e.g., lifespan disparity) is remarkably regular, regardless of how these parameters are measured. Thus, in addition to the well-known fast-slow pace continuum, there is also a shape continuum and a pace-shape continuum for primate life histories.

"Aging in the wild and its implications for population biology and conservation"

Colchero F., Owen R. Jones, D. A. Conde, David Hodgson, Felix Zajitschek, Benedikt R. Schmidt, Aurelio F. Malo, Susan C. Alberts, Peter H. Becker, Sandra Bouwhuis, Anne M. Bronikowski, Kristel M. De Vleeschouwer, Richard J. Delahay, Stefan Dummermuth, Eduardo Fernández-Duque, Thomas Flatt, John Frisenvænge, Martin Hesselsøe, Sam Larson, Jean-François Lemaître, Jennifer McDonald, David A.W. Miller,

Colin O'Donnell, Craig Packer, Becky E. Raboy, Chris J. Reading, Ben C. Sheldon, Erik Wapstra, Henri Weimerskirch, Geoff M. While, Annette Baudisch, Tim Coulson, Jean-Michel Gaillard

Despite increasingly abundant evidence that survival and fertility rates in wild populations decline with age due to senescence, the vast majority of empirical demographic models used in wildlife studies still assume constant rates for adults. Here we demonstrate, using Bayesian methods on 24 vertebrate species, that constant mortality (the complement of survival) is rare in nature, and that a variety of mortality trajectories are possible, including negative senescence (i.e. improvement). We then show that, with environmental stochasticity, assuming constant rates of survival and fertility in adults (i.e. two-stage models) can cause serious errors in predictions of future population dynamics (Figure 6). These errors can produce the illusion that the population is crashing when it is in fact prosperous or, in extreme cases, that it is thriving when in reality it is doomed to extinction.

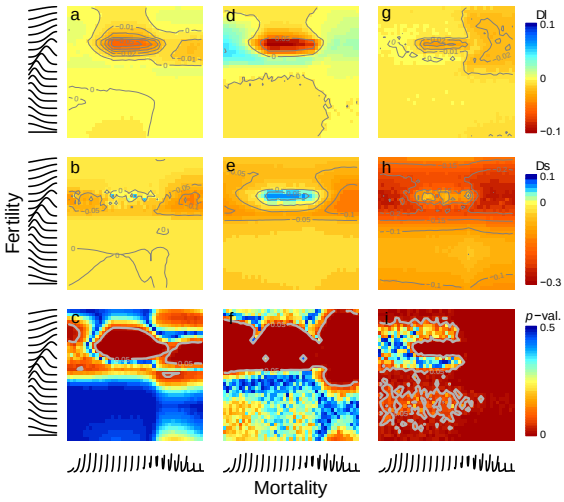

Figure 6. Differences in stochastic population growth rate (λ_s) between fully age-dependent and two-stage models. The abscissa (x-axis) depicts mortality curves and the ordinate (y-axis) fertility curves. Three scenarios are depicted where survival and fertility rates are modelled as fully-covarying (a-c), partially-covarying (d-f) and non-covarying (g-i) as a function of environmental perturbations. The heat maps show: a, d, g) differences between mean λ_s values ($\Delta\lambda_s$); b, e, h) differences in standard deviations of both λ_s values ($\Delta\sigma$); and c, f, i) *p*-values from two-sampled Welch's *t*-test between the two distributions of λ_s

Pending grants

SDU E-science PhD project.

ERC Starting Grant 2015.

Conferences/activities

Workshop on Demographic Forecasting, speaker, 29 September 2014.

Danish Society for Theoretical Statistics (DSTS) two-day Meeting, organizing committee, 18-19 November 2014.

Dalia A. Conde, Assistant Professor, Biology

Main research interest

My work focuses mainly on the field of conservation demography. I explore ways to incorporate demographic methods to manage species that are at risk of extinction. My research ranges from species habitat modeling, prioritization of conservation opportunities, and the role of zoos and captive breeding in slowing down current extinction trends. I am exploring demographic methods to understand and forecast species extinctions. However, a major issue to manage endangered populations is the lack of reliable demographic data. Therefore, I am especially interested in finding ways to parameterize models for species with little or no demographic data. However, the first task has been to develop an assessment of the extent of demographic data available in public databases. Given the current extinction trends, I am particularly interested in the amphibian extinction crisis so I am working with different collaborators on two amphibian species to analyze mortality patterns to understand senescence and how to incorporate species environmental variability and senescence for management plans. My work involves collaborations with local communities, other universities, NGOs, zoos and academic and multilateral institutions. I am member of the Conservation Breeding Specialist Group of the Species Survival Commission of the IUCN, a fellow of the WINGS World Quest, the American Association of University Women and the Max Planck Society's Minerva Femme Net "Women mentoring program".

Publication highlights

Salguero-Gomez, R., Jones, O., Archer, C. R., Buckley, Y., Che-Castaldo, J., Caswell, H., ... Vaupel, J. W. (2014). The COMPADRE Plant Matrix Database: an Open Online Repository for Plant Demography. Journal of Ecology. 10.1111/1365-2745.12334

This is a database that will allow the study of senescence on plants, additionally it will open opportunities for the development of ecological studies across populations and species.

Ongoing work

"Demography of Amphibians: Bufo calamita and Rana temporaria"

We have started a project to monitor different populations of Bufo calamita across its latitudinal gradient to understand mortality rates across and within regions. In February 2014 we started collaboration with AmphiConsult, Copenhagen Zoo and the University of Tartu. Our project has an experimental and a fieldwork component: for the experimental we are studying the effects of temperature in tadpole mortality and development on populations in Denmark and Estonia. In collaboration with Ivan Gomez-Mestre, we will incorporate into the analyses the effects of temperature on the tadpoles' metabolic rate and oxidative stress by performing new experiments of B. calamita on populations from its lowest latitudinal range in Sevilla, up to its highest in Estonia. On the fieldwork side, we are developing a new protocol to pursue population analyses using Mark Capture Recapture methods to study the population dynamics and mortality of Bufo calamita at its highest latitudes. With Rana temporaria we are starting a collaborative project to reintroduce the species in three types of city ecosystems and assess their demographics in areas with different levels of human activities, with the aim to explore the potential of city ecosystems.

"Demographic Index of Species Knowledge: DISKo"

Phase 1. Demographic Index of Species Knowledge

I am leading the development of the database: DISKo (Demographic Index of Species Knowledge). DISKo contains more than 400 million records on 37 thousand species of vertebrates (excluding fish), across 27 public databases. DISKo is the result of a collaborative effort between MaxO; the MPIDR; Copenhagen Zoo; Center of Evolutionary and Functional Ecology (CEFE) Université Montpellier; Evolutionary Ecology and Population Processes Group, Laboratoire de Biométrie et Biologie Évolutive, Université Lyon; Imperial College London; Bir Ventures International; International Species Information System (ISIS); Centre for Avian Population Studies; The Quantitative & Applied Ecology Group, University of Melbourne; Antwerp Zoo & Auckland Zoo.

DISKo can be best described as a meta-database where the data have been standardized across 27 databases for taxonomic names and life history variables. We standardized the taxonomy on more than 30,000 species using the Catalogue of Life as a baseline and with the support of Scott Chamberlain, one of the developers of Taxize. The demographic variables have been standardized across 27 data sources, in which the majority are online databases such as AnAge, PanTHERIA, and the MPIDR databases (DATLife and ComADRE). In the case of amphibians and reptiles, the data were digitalized from papers that contained at least 20 recorded species, since there are very few databases for these groups. The DISKo results from an algorithm that generates per each species an index that shows the level of demographic knowledge on Fertility and Mortality for each species. Hassan Syed, Bird Ventures, implemented the database architecture and development. This database is now being processed for publication.

Phase 2. Demographic Dynamic Index of Species Knowledge

DISKo 2 will be a more complex and dynamic database. The goal is to have a database that has the capability to get updated every six months with the online repositories we used to create DISKo 1, and allow a curator to easily import up-to-date databases that are not available online but appear as publications (e.g., the CRC Hand Book of Avian Body Masses). The DISKo 2 database (2DISKo) should automatically standardize the taxonomy according to the Catalogue of Life by cross-referencing the information from all databases per species. As in DISKo 1 it should as well include ancillary information such as the taxon ID number, the most recent IUCN Red List status, and the number of sequences and nucleotides from GenBank. Additionally, all new variables that appear in the online repositories should be standardized to estimate the most up-to-date Demographic Knowledge Index per species. We want a dynamic database so the user can have the possibility to generate their own index according to which variables the user considers more important for his/her field of demographic research or other; this should be possible by allowing the user to give different values to the variables already standardized.

New grants awarded

50,000 Euros by the The Gerhard and Ellen Zeidler Foundation (Gerhard und Ellen Zeidler-Stiftung) Germany.

Ongoing grants

20,000 Euros from The Gerhard and Ellen Zeidler Foundation

Media highlights

Press conference: ESOF Zoos collaboration:

https://www.youtube.com/watch?v=hG7DxpgnlTI

Conferences/activities

"Ageing research on vertebrates shows knowledge gaps and opportunities for species conservation and management" (Invited Speaker) Leibniz Institute for Zoo and Wildlife Research in the Forschungsverbund Berlin e.V., held in Berlin, Germany, 29 January 2014.

"Management of global biodiversity: the need for a biodiversity demographic bank" (presentation & organizer). EuroScience Open Forum, held in Copenhagen, Denmark, 26 June 2014.

"Demographic Index of Species Knowledge" (presentation & organizer). DISKo Workshop, held in Odense, Denmark, 27-29 June 2014.

First Annual Meeting on *Bufo calamita* (organizer), held in Copenhagen & Odense, Denmark, 29 September - 1 October 2014.

"Opportunities for Conserving Some of the Most at Risk Species on the Planet" (presentation), WINGS WorldQuest Fellows Forum, held at the Explorer's Club in New York City, 17 October 2014.

"The Extinction Crisis: The Amphibian Case" (presentation). University of Southern Denmark Science Day Inspirational Lecture for High School Teachers, held in Odense, Denmark, 30 October 2014.

"The Importance of Demographic Data to Manage Threatened Species: The Role of Natural History Museums" (presentation). Annual Conference of the KULTUR-, NATURHISTORISK OG KUNSTFAGLIGT ORIENTERINGSMØDE, held in Kolding, Denmark, 13 November 2014.

Member of the Conservation Breeding Specialist Group.

Associate Researcher at Centre for Research and Conservation, Royal Zoological Society of Antwerp

Johan Dahlgren, Assistant Professor, Biology

Main research interest

I conduct research on plant demography, with two major focus areas. The first is aging in plants. A gradual physiological deterioration occurs over high ages in all mammals and many other animals, with an associated increased risk of death and a lowered fecundity with age. However, whether plants in general age and if they do how aging progresses, is still unknown. One major reason for this lack of knowledge is simply a lack of data on the age-dependence of plant demographic rates. I am addressing this in two ways. First, I collaborate with field biologists that are collecting long-term monitoring data, and use that data to determine age trajectories of demographic rates for plants. In addition I am combining neglected age-determination techniques based on root anatomy with field monitoring to collect new data.

My second main research interest is to elucidate how the environment drives the demography of plants. This gets right at the heart of the main ecological goal of understanding the distribution and abundance of species. I analyze existing data on plant demographic rates, physical environment, interacting species and population density. I also collect new such data, primarily for the forest herb *Actaea spicata* (Baneberry), on which I also conduct field experiments, manipulating environmental conditions and density. I fit statistical models of effects of environmental drivers on individual survival, fecundity and growth, and analyze population properties using Integral Projection Models (IPMs).

Publication highlights

Local environment and density-dependent feedbacks determine population growth in a forest herb, Dahlgren et al. 2014. Oecologia.

This publication reports results of a study on how spatial variation in the environment (shade) affected demographic rates and population density of the forest understory plant Lathyrus vernus. Even though spatial variation in the level of shading by canopy trees had clear effects on the population density and the average individual size of the understory plant, none of the demographic rates survival, fecundity and growth were correlated with shade. This is a well-known effect of that parts of the population experiencing worse environmental conditions (more shade) will also be less densely populated and/or contain smaller individuals, which results in less negative effects of competition among individuals. However, by including density and shade simultaneously in statistical models that were used as components in a population model (integral projection model), we were able to identify the demographic effects of shade and realistically predict population density in different shade-environments. This is an important result, because it shows how demographic models based on observational data can be used both to further our understanding of how the environment drives population dynamics and in population viability analyses of threatened species, if environmental drivers and density-effects are both explicitly included in population models.

Ongoing work

"Mortality senescence in a long-lived orchid becomes evident when accounting for reproductive effort"

Together with researchers in Uppsala, Sweden, and Trondheim, Norway, who have monitored several Norwegian populations of the orchid *Dactylorhiza lapponica* for more than 30 years, and with Fernando Colchero and Owen Jones, I am studying aging (demographic senescence) in this plant. We have started

with looking at how mortality changes with age. The length of the monitoring period has allowed us to estimate the total life time reproductive effort for several thousand individuals, as well as mortality over their adult life span. Interestingly, when accounting for reproductive effort, we find a clear increase in mortality with age, providing a unique example of a clear indication of aging in a non-woody plant. The importance of accounting for reproductive effort to detect senescence is in agreement with life history theory, where reproduction–survival trade-offs are expected to drive the evolution of senescence. We also found important effects of the local physical environment on mortality trajectories. We are now in the process of writing up a paper, presenting these first results.

"Age determination based on root anatomy"

In cooperation with experts on dendrochronology at the Swiss Federal Research Institute WSL, I have determined ages of individuals in several non-woody plant species based on their root anatomy. Research assistant Maria Baden has assisted with setting up monitoring plots for the plant *Plantago lanceolata*, and has also visited WSL in Zürich to determine the ages of several hundred plants of this species (Figure 7). We are now starting with analyses of this data to determine shapes of vital rate – age relationships.

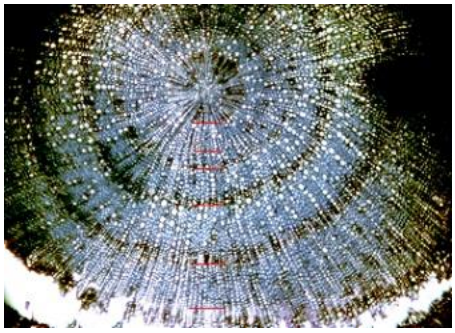

Figure 7: Cross-section of the root collar in a six-year-old *Plantago lanceolata* individual (50x magnification). Areas where large xylem vessels have been formed in the spring are marked with red lines.

Pending grants

The Danish Council for Independent Research

Conferences/activities

"Density-dependent feedbacks can mask environmental drivers of populations" (invited presentation) Ecological Society of America 2014 annual meeting held in Sacramento, California 10-15 August 2014.

Owen Jones, Assistant Professor, Biology

Main research interest

The variety of life histories displayed by the world's animals and plants has fascinated scientists for centuries. One of the oldest and most fundamental life history questions is that of why some animals live a long time, while others only live a short time. Demography is at the core of this question and my research focusses on understanding the diversity of demographic behaviour in species across the tree of life. I address the topic at three hierarchical levels (1) the single population level, for example using tools such as Bayesian Survival Trajectory Analysis; (2) the species level where I take a 'macrodemographic' approach and study multiple populations of the same species separated spatially; and (3), a comparative level where I conduct comparative analyses of demographic traits across multiple species to gain a deeper understanding of the evolution of aging. This work requires the development and use of sophisticated analytical approaches to confront demographic and phylogenetic data. Therefore, in addition to working to address the evolution of demography I spend time contributing to statistical approaches and building demographic databases.

Publication highlights

"Diversity of aging across the tree of life"

Underlying the huge diversity of typical lifespans in animals and plants are their demographic trajectories that capture their changing probabilities of death and offspring produced with age. The evolutionary theories of aging, developed in the 1950s-1970s collectively predict that, "no species should escape [the] forces of senescence, even in the farthest reaches of any bizarre universe". This paper addresses this prediction by examining life table and population matrix model data from 46 species of animals and plants. We demonstrate that although patterns consistent with theory (fertility declines, while mortality increases) are seen in many species, there are others that defy the canonical theories. These include hydra, where mortality and fertility are unchanged with age, and others like the desert tortoise where mortality declines while fertility increases. We point out that more theory is needed if want our understanding of aging to be universal.

Jones, O.R. et al. (2014) Diversity of ageing across the tree of life. *Nature* 505, 169–173

I also published a popular account of the article on the news website The Conversation:
http://theconversation.com/why-do-humans-deteriorate-with-age-its-a-biological-puzzle-21824

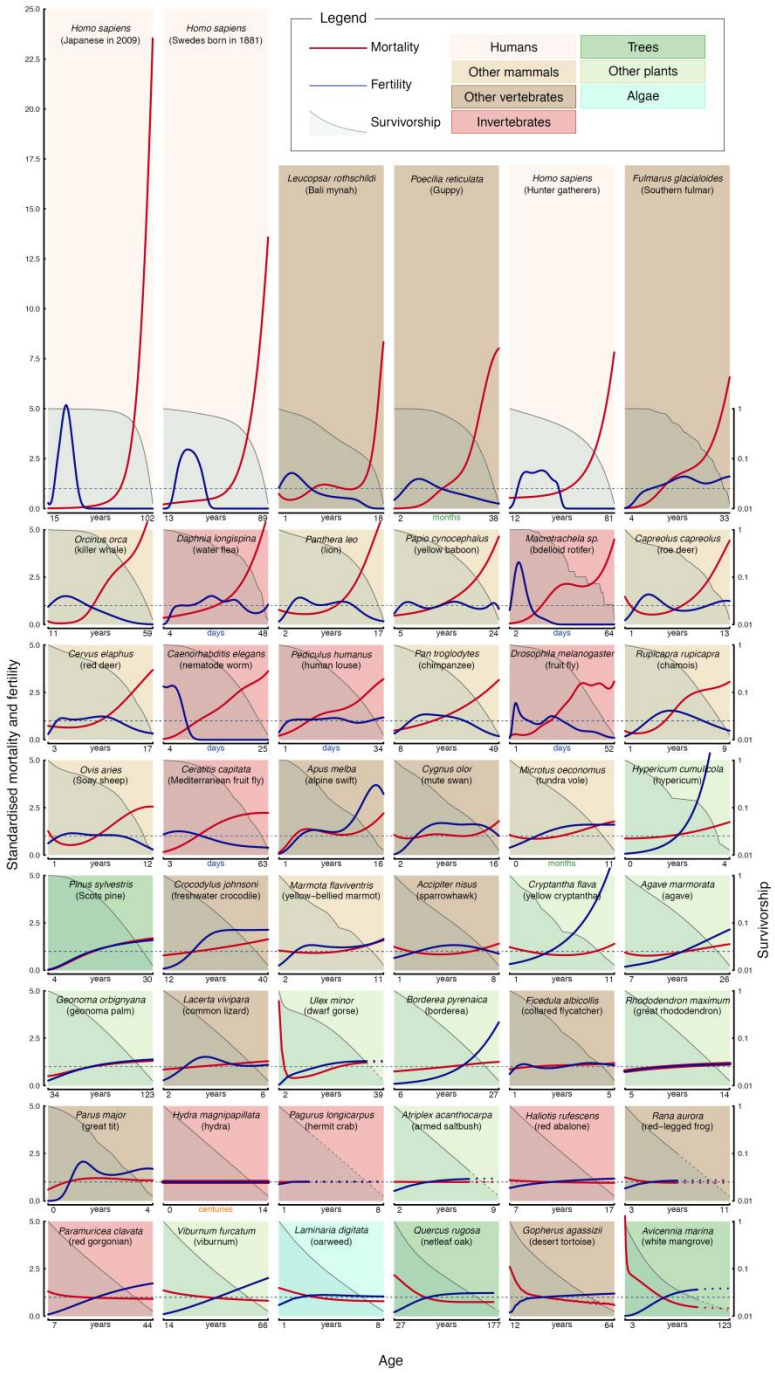

Figure 8: Demographic trajectories show great diversity across the tree of life.

"The COMPADRE Plant Matrix Database"

Over the past few years, beginning when I was a research scientist at the Max Planck Institute for Demographic Research, I have been working with Roberto Salguero- Gomez (University of Queensland) to lead a team developing a database containing demographic information on the plant kingdom. This work has now culminated with the release of COMPADRE Plant Matrix Database as an online open-access resource for the academic community. The database contains information in the form of matrix projection models for approximately 600 species distributed globally. It also contains ancillary information to aid interpretation including any experimental treatments used, ecoregion, growth form and taxonomy. The database will allow researchers to address a wide range of ecological and evolutionary questions.

Salguero-Gómez, R., Jones, O. R., et al. (2014), The COMPADRE Plant Matrix Database: an open online repository for plant demography. *Journal of Ecology*. doi: 10.1111/1365-2745.12334

COMPADRE
Plant Matrix Database

Figure 9: The COMPADRE Plant Matrix Database was launched as an open access resource in 2014.

Ongoing work

"Demographic trade-offs in parasitic plants"

The demography of parasitic plants is understudied, even though they are excellent models to explore ecological trade-offs. These plants use their hosts for support, and resource provisioning. They thus partially escape several costs that non-parasites endure. With colleagues Roberto Salguero-Gomez (University of Queensland) and Sydne Record (Smith College) I am exploring the significance of this "cheating" strategy using European mistletoe (*Viscum album*), an iconic species across much of Europe. Like other parasitic species, mistletoe derives much of its nutrients by stealing resources of the trees on which they live. We are collecting data on establishment, survival, growth, and reproduction of the species, and building demographic models to estimate the relative importance of various demographic processes. In particular, we are focusing on the role of trade-offs between those vital rates in explaining the species' success.

Figure 10: Hemiparasitic plants like European mistletoe (Viscum album) are good models for studying the role of trade-offs in demography.

"Demographic impacts of domestic cat predation"

Domestic cats are believed to take a terrible toll on wild animals, especially birds. In some regions, including Australia and New Zealand they have even been implicated in species extinctions. I have initiated a project with a MSc student, Emilie Marie Hansen, and Thomas Bjørneboe Berg (Naturama), to study the impacts of domestic cats on the Danish island of Fyn. We have recruited 140 cat owners to participate in data collection and are interested in the potential impact of their cats on birds and small mammals. We are particularly interested in age patterns of hunting behaviour - does hunting behaviour change with age? - and on whether the prey that are taken are juvenile, senescent or diseased. The work has implications for conservation biology well-beyond the shores of Fyn.

Figure 11: Domestic cats take a toll on wild animals (Photo: Mark Merek)

New grants awarded

BioVeL grant for "COMPADRE Data Access Services" (Declined due to named contractor illness)

Ongoing grants

British Ecological Society Small Project Grant

SDU "Laeringsrum og undervisningsteknologi" grant for "Innovative teaching of theory and method in evolutionary demography""

Pending grants

ERC Horizon 2020 Grant

Det Frie Forskningsråd - Natur og Univers (FNU) Research Project 2

Siemens Foundation Technology Grant

Media highlights

My Nature paper on the diversity of aging across the tree of life was highlighted as an "Exceptional" paper by the prestigious Faculty of 1000 http://f1000.com/prime/718201299#eval793491436

Conferences/activities

"Exploring the landscape of ageing and lifespan across the tree of life" an Invited seminar at the BioSciences Department of University of Swansea, UK. 8th May 2014.

"Potential for species diversity monitoring in Svanninge Bjerge" an invited talk at the Ornitologisk artsdiversitet i Svanninge Bjerge conference in Svanninge Bjerge, Denmark. 10th June 2014.

"The COMPADRE and COMADRE population matrix databases" a talk at the csv,conf 2014 conference, in Berlin, Germany. 15th July 2014.

"Diversity of ageing across the tree of life" an invited talk at the 19th Nordic Demographic Symposium in Aalborg, Denmark. 20th September 2014.

Participant of the session on "Management of global biodiversity: the need for a biodiversity demographic bank" at the European Science Open Forum, held in Copenhagen, 26 June 2014.

DISKo Workshop (participant) held in Odense, Denmark, following up from the EuroScience Open Forum, 27-29 June 2014.

"Mortality and immortality across the tree of life" an invited seminar at the SDU Science Day conference for highschool teachers in Odense, Denmark. 30th October 2014 .

"Senescence and its consequences across the tree of life" a talk at the Joint 2014 Annual Meeting of the British Ecological Society and Société Française d' Ecologie in Lille, France. 12th December 2014.

Honours and awards

The paper “Diversity of ageing across the tree of life” (Nature 505, 169–173) by Jones, O.R. et al. (2014) was nominated for the Årets Danske Forskningsresultat 2014 [Danish Research Result of the year 2014]

Dan Levitis, Assistant Professor, Biology

Main research interest

I study the evolution of patterns of longevity and mortality, focusing on aging, mortality early in life (including inviability) and post-reproductive lifespan. As with any evolved trait, figuring out how a demographic trait came to be requires understanding not only its current selective effects, but also its evolutionary history and how the biological mechanisms underlying it constrain how natural selection can change it. I take an integrative biology approach to these problems, combining comparative, experimental and theoretical approaches to better define, and answer my evolutionary questions. I dedicate considerable time to mentoring student research, helping students to find their own interests and ask and answer their own questions. My student co-authors initiate many of these projects, including recently submitted journal articles on starfish and ravens.

Conferences/activities

Member of the Evolutionary Demography Society (EvoDemoS) Board (Secretary), 2012 → 2015.

Levitis DA, Zimmerman, K, Pringle A. (2014) Meiotic faults as a major cause of offspring inviability: Comparative evidence and implications for the evolution of sex. Presentation to the Evolutionary Demography Society, Stanford, CA, 10-12 Nov, 2014

Proske B, Burger O, Levitis DA. (2014) Survival to reproductive cessation drives variation in post-reproductive lifespan. Presentation to the Evolutionary Demography Society, Stanford, CA, 10-12 Nov, 2014

Levitis, DA. (2014) The Demography, Evolution and Semantics of Post-reproductive Lifespan. Invited Lecture to the Population Studies Center, University of Pennsylvania, Philadelphia. 3 Feb, 2014.

Paul Dunn, Post Doc, Biology

Main research interest

I am broadly interested in the ecology and evolution of invertebrate animals. My research is currently focused on the forces driving mortality risk during different stages of an organism's life. Observed patterns of high early-life mortality across many taxa is particularly intriguing because natural selection should act against dying before the age of first reproduction. Although some of this mortality can be attributed to naiveté and lack of parental care, the persistence and pervasiveness of the phenomenon in taxa exhibiting a wide variety of life history characteristics requires much broader hypotheses. Together with Dr. Daniel Levitis, I develop and conduct experiments that test such hypotheses and help explain why so many animals die young. For example, we have found that mortality in larval barnacles is concentrated around major metamorphosis events, suggesting that body reorganizations may directly contribute to high early-life mortality.

I also study late-life mortality and senescence across the Metazoa. I am currently involved in research looking for evidence of senescence in basal invertebrate animals. My colleagues and I have constructed a "sponge farm" in a Danish fjord with hundreds of individual sponges, each with a unique ID tag. We use monthly SCUBA surveys to detect possible senescence in terms of growth, reproduction, physical performance, and mortality risk as a function of age. Determining which animal taxa senesce and which do not, particularly in basal groups like sponges, is an important step in understanding when, how, and why senescence evolved.

Raisa Hernández Pacheco, Guest Post Doc, Biology

Main research interest

To develop population models using matrix based projections to estimate mean contributions of stage/age classes in order to understand the evolution of life histories.

Ongoing work

"Effects of population density on population entropy "

Density- dependence is understood as a major mechanism of population control and, therefore, one of the most important factors to consider when assessing population dynamics. A multi-stage model using a first-order Markov process describing reproductive dynamics will be constructed and annual entropy – diversification of life histories – will be estimated. For this, Cayo Santiago rhesus macaques demographic data will be used. Population density effects on the diversity of life histories will be assessed.

New grants awarded

Caribbean Primate Research Center, University of Puerto Rico

Conferences/activities

Heterogeneity of life histories in a nonhuman primate population., with Steiner, U. (2014). Evolutionary Demography Meeting, Stanford, 10-12 Nov, 2014

Lionel Jouvet, Post Doc, Biology

Main research interest

At the frontier of applied and fundamental sciences, I am passionate about the development of new tools to accurately and precisely answer my research questions in ecology and evolution.

In our research group, I study the biodemographic parameters of the bacteria *Escherichia coli* in a highly controlled experimental setup. Variability is the key in evolutionary processes. A precise control of the environment and genetics of the bacteria allows us to quantify and identify the origin of this variability. In a state-of-the-art experimental setup (microfluidics, fluorescence microscopy, image analysis), I aim to understand how fundamental aspects of aging and biodemographic parameters are impacted by the environment (temperature, food availability, temperature/food availability variation, antibiotics).

Before joining the MaxO team, I worked for the biotechnology company Partec GmbH developing new instruments and applications for the fields of research, health, and industry. I visited a large array of laboratories from Lithuania to Saudi Arabia, where I trained researchers and engineers, and participated in numerous conferences. From the close collaborations with researchers, health specialists, and industry partners, I acquired a broader view of biology and its applications. In my university research projects, I developed numerous new techniques and procedures to investigate several ecological systems in collaboration with ecologists, biologists and physicists.

Conferences/activities

Jouvet, L., & Steiner, U. (2014). Demographic parameters of individual E.coli within and among controlled environment, Evolutionary demography meeting, 10-12.11., Stanford

Adam Lenart, Post Doc, Public Health

Main research interest

My research is motivated by the application of probability theory in demography. Additionally to a general treatment of probability theory in demography, I concentrate on forecasting methods and compositional data analysis.

As I see it, many demographers already use probability theory implicitly by calculating age-specific rates and probabilities or expected values such as life expectancy or mean age at childbearing. More recently, demographers became interested in the standard deviation or variance of indicators as well. Population biologists started to measure the pace and shape of similar processes. However, all of these approaches could be unified using a formal treatment of demographic measures based on probability theory.

Moreover, by applying probability theory to distributions describing the schedules of death, it is possible to calculate the minimal failure time of vital systems of an organism. It fascinates me that demographic methods might aid answering profound questions such as the biological processes leading to death.

In the field of mortality forecasting, currently used methods can be too conservative in projecting the level of old age mortality. However, forecasting the moments of the distribution of deaths themselves can open new ways in projecting mortality.

Compositional data analysis, a method recently introduced to demography concentrates on the proper analysis of data with a constant sum. Demography is teeming with such data, for example, the age structure of the population or relatedly, dependency ratios.

Ongoing work

"Comparing the performance of health systems in providing life expectancy"

The health systems of lower and higher level of life expectancy countries should not be compared with each other. Data envelopment analysis, a tool seldom used in demography or public health provides an objective framework for such a comparison. Data on OECD member nations suggest that irrespectively of which life expectancy group a country belongs to, higher expenditure, higher level of education, less tobacco consumption and higher level of preventive and curative care lead to increases in life expectancy. Moreover, benchmarking the performance of a country's health system can help policymakers in setting achievable goals.

"Problems with disregarding the compositional nature of some demographic data"

Compositional data analysis concentrates on the proper analysis of data with a constant sum. Demography is teeming with such data, for example, the age structure of the population or relatedly, dependency ratios. Analyses such as the ones focusing on number of hours spent on different activities in time use surveys or factors of gross domestic product measured in percentages might yield biased results if the constraints placed by this type of data is disregarded.

Conferences/activities

Lenart, A., & Zarulli, V. (2014). A comparison of the efficiency of health systems in providing life expectancy. Poster session presented at EPC 2014, Budapest, Hungary.

Virginia Zarulli, Post Doc, Public Health

Main research interest

I am mostly interested on mortality and aging.

My work spans from statistical demography and the application of frailty models to socioeconomic mortality inequality for controlling for latent individual differences that can lead to biased estimates, to the age and cause pattern of inequalities in life expectancy, to the effect of external factors, such as environmental shocks or cigarette smoking, on the human rate of aging. Recently I broadened my research to the fields of health demography, health economics and Biodemography of aging among humans and non-humans.

Publication highlights

Zarulli, V. (2014), "Post-War Migration Flows and Disparities in Mortality from Age 50 Years Onwards: the Case of Turin in Italy." Population, Space and Place (Online)., 10.1002/psp.1862

Compositional changes due to internal migration can modify the distribution of health outcomes, socioeconomic characteristics and patterns of socioeconomic inequalities in mortality of a geographical area. However, despite the importance of these inequalities, there is still little empirical evidence on this effect. This paper investigates whether post-war internal migration in Italy affected the pattern of mortality inequality by socioeconomic status, from age 50 onwards, in the industrial city of Turin, where many low educated individuals from the southern regions migrated. Migrants might be selected in terms of robustness because of the healthy migrant effect. However, lowly educated individuals are employed in heavier and riskier jobs. They are thus exposed to higher mortality risk that selects the most robust individuals. This paper hypothesized that the interplay of these mechanisms might have produced a homogenization towards robustness of the population, by reducing the unobserved heterogeneity in survival chances, and that these processes affected men more than women, because women were likely to be more passive actors in the migratory decisions and less heavily involved in the industrialization process. The results support both hypotheses.

Ongoing work

"Am I halfway? Life lived = expected life"

Canudas-Romo, V., Zarulli, V., Lenart, A.

We have reached halfway in life when our age equals our remaining life expectancy at that age. The trends over time and over populations with historical data are investigated. Period and cohort perspectives show increase in the age where halfway in life is found, however the pace of the increase is different. In a period perspective, when halfway-age is compared with life expectancy at birth, e0, a marked disparity in the tempo of change is observed: over the observed time e0 doubles while halfway increases by 25%. In a cohort perspective, as it is the case with life expectancy, cohort halfway-age is higher than period halfway-age. Our estimates of cohort halfway-age for the most recent birth cohorts result in a halfway-age of about 50 years for females, approximately 10 years older than the observed period halfway-age.

"The Statistics of Health and Longevity: A Dynamic Analysis of Prevalence Data"

Caswell, H., Zarulli, V.

Increases in human longevity have made it critical to distinguish healthy longevity from longevity without regard to health. We present a new method for calculating the statistics of healthy longevity which

extends, in several directions, current calculations of health expectancy (HE) and disability-adjusted life years (DALYs), from data on prevalence of health conditions. Current methods focus on binary conditions (e.g., disabled or not disabled) or on categorical classifications (e.g. in good, poor, or very bad health) and report only expectations. Our method, based on Markov chain theory, applies to both binary and continuous measures, and provides not only the expectation but also the variance, coefficient of variation, skewness and other distributional properties of longevity. We apply the method to 9 European countries using the SHARE survey data on disability and on grip strength. The method can extend DALY calculations to produce information on variance as well as expectations

"Comparing the Performance of Health Systems in Providing Life Expectancy"

Lenart, A., Sopina, E., Zarulli, V.

The health systems of lower and higher level of life expectancy countries should not be compared with each other. Data envelopment analysis, a tool seldom used in demography or public health provides an objective framework for such a comparison. Data on OECD member nations suggest that irrespectively of which life expectancy group a country belongs to, higher expenditure, higher level of education, less tobacco consumption and higher level of preventive and curative care lead to increases in life expectancy. Moreover, benchmarking the performance of a country's health system can help policymakers in setting achievable goals.

Conferences/activities

"A comparison of the efficiency of health systems in providing life expectancy" (poster). European Population Conference 2014, Budapest 26-28 June 2014.

"Post war migration flows and disparities in mortality from age 50 onwards: The case of Turin in Italy" (poster). European Population Conference 2014, Budapest 26-28 June 2014.

Marie-Pier Bergeron Boucher, PhD student, Public Health

Main research interest

-The future of mortality and longevity: modelling and forecasting

-Understanding mortality changes through decomposition

-Changes in causes of death structure

Ongoing work

"Decomposing mortality changes: compression versus shifting mortality"

We study the shifting and compression of mortality through two components of mortality: modal age at death and variability of the age at death. These two components inform us about the timing and age patterns of mortality respectively. We introduce a new decomposition method, using a recent expression of the Gompertz force of mortality, and study the changes in its components. Our approach allows differentiating between the two underlying processes in mortality and their relevance to understand the dynamics of mortality. The results suggest that the increase in life expectancy, since the 1950's, is largely driven by a shift in the modal age at death.

"Coherent mortality forecasts among industrialized countries"

Mortality forecasts have failed in many cases to offer coherent forecasts among their subpopulations: among sexes in a population, countries in a region, or even between ages and causes of death. The coherence problem emerges from an inability of different forecast models to offer disaggregated forecasts which are consistent with an overall forecast. We adapt existing forecasting models and compare with new models that include common regional trends and consider covariance structures among mortality components. We assess which model best describes the past and future pattern of mortality in industrialized countries. The forecasting proposal by Li and Lee and the Compositional Data Analysis (CoDa) approach introduced by Oeppen in the context of forecasting causes of death are compared and combined. These two approaches tap different aspect of the coherent forecasting problem and we make the hypothesis that a combination of the two might be the optimal methodology.

Conferences/activities

"Coherent mortality forecasts among industrialized countries" (presentation). Population Association of America 2014 annual meeting, held in Boston Mass, 1-3 May 2014.

"Decomposing mortality changes: Compression or shifting mortality?" (presentation). European Population Conference 2014, held in Budapest Hungary, 25-28 June 2014.

"Coherent mortality forecasts: The case of Nordic countries" (presentation). 19th Nordic Demographic Symposium, held in Aalborg Denmark, 18-20 September 2014.

"Coherent mortality forecasts: The case of Nordic countries" (presentation). Dansk Selskab for Teoretisk Statistik, held in Odense Denmark, 18 November 2014.

Coherent mortality forecasts: The case of Nordic countries. Danish Society for Theoretical Statistics two-day meeting, 18 Nov 2014

Josephine Goldstein, PhD Student, Biology

Main research interest

Jellyfish have the potential for rapid somatic growth and reproduction and show large population fluctuations over a variety of temporal scales. The booms and busts of their demographic dynamics may provide valuable information regarding the health of ecosystems worldwide. Jellyfish blooms are often caused by members of Scyphozoa (Cnidaria), which have complex life cycles with a sexually reproducing pelagic medusa and an asexually reproducing benthic polyp stage. My PhD project aims to document the sensitivity of each vital rate of the moon jellyfish *Aurelia aurita*, identifying key transitions relevant for the population growth of bloom-forming jellyfish species. Combining laboratory experiments with field studies, the overall goal is to describe the influence of environmental stochasticity on stage-specific mortality, growth and fertility patterns. Results obtained from these studies are used to parameterize a matrix projection model, demonstrating how stage (stage = developmental stage or life stage) and size influence population growth in *A. aurita* and projecting the potential capacity of demographic rates under "optimum" conditions. The project further aims to describe the bioenergetic trade-offs triggering variability in the longevity of *A. aurita* medusae, with an overall goal to reveal important basic knowledge on complex life-history traits and the factors ultimately controlling demographic shifts in jellyfish populations on both a regional and global scale.

Ongoing work

"The demographic dynamics of Aurelia aurita as a function of age/stage and size"

The moon jellyfish *Aurelia aurita* is periodically abundant in coastal waters around the world, where it can exert considerable predatory impact on prevailing food web structures. In most regions, medusae reach umbrella diameters of 10-30 cm during the summer months. In the Danish fjord system Kertinge Nor/Kerteminde Fjord, medusae of the same species are usually food-limited, restricting their own growth by high population density to a maximum umbrella diameter of a few centimeters. Size is a key variable for fertility and mortality in medusae, since sexual maturity is often followed by shrinkage ("degrowth") and morphological degradation. Both age (and/or developmental stage) and size are therefore considered in a stage and size-structured population matrix model, aiming to explain the demographic dynamics of jellyfish blooms in context with environmental change.

"Energetic trade-offs in the moon jellyfish Aurelia aurita – growth, fertility and senescence"

The evolution of a bipartite life history may reduce the need for the sexually-reproducing medusae to be long-lived. The short lifespan of medusae in the field, and observations that medusa can survive for more than two years in captivity may indicate that environmental factors (e.g. predation, disease, parasitism and food limitation) govern longevity in wild populations. However, energy losses due to fertility might be the driving force for mortality of pelagic life stages. Considering growth and degrowth (i.e. shrinkage of medusae after the onset of reproduction due to food deprivation) as an important indicator for the allocation of energy from somatic growth to reproduction, the study aims to answer if and how *A. aurita* medusae senesce.

Lars Kumala, PhD student, Biology

Main research interest

While many organisms undergo senescence, i.e. increasing mortality over age, often accompanied by decreasing fertility and/or deterioration in physiological functions, several basal multicellular organisms have been shown to experience negligible or negative senescence (i.e. decreasing mortality and increasing fertility over age). My research interests include the ecophysiology and biodemography of aging in modular Metazoans and currently focus on sponges, which are considered to form the basal branch of Metazoa, in order to shed light into the ancestral state of early animals and the evolution of senescence.

Since the demography of sponges has to date received little attention, my PhD project will unveil age- and size-related patterns in existing literature on sponge growth, mortality, survival and reproduction to identify indicators for senescence.

My experimental studies focus on the bioenergetics and physiological responses of sponges with respect to environmental change. The breadcrumb sponge *Halichondria panicea* is therefore cultivated in the laboratory to explore growth, respiration and filtration activity under different levels of food availability and temperatures. The project aims to gain deeper insight into energy allocation strategies that may ultimately prevent sponges from environmental and age-related mortality.

Marius Pascariu, PhD student, Public Health

Main research interest

My main research interest is in mortality modelling and life expectancy forecasting. Understanding the history of the evolution of life expectancy is of crucial importance for demographers and actuaries who want to develop more accurate forecasting models. The overall objective is to develop more accurate methods to forecast longevity and to estimate mortality indices and actuarial life tables using the forecasts. My research plan can be classified in three categories:

Improvements in Mortality: we analyse the rise in life expectancy over the past 200 years by decomposing the expectation of life into a measure of the rate of mortality improvement and a measure of lifespan disparity.

Life expectancy forecasting: we develop methods to determine future life expectancy by making use of the remarkable regularity of the rise in best-practice life expectancy.

Decomposition of life expectancy: we use our forecasts of life expectancy to estimate age-schedules of death rates at older ages using parametric and nonparametric methods.

Ongoing work

"Decomposing change in remaining life expectancy"

For the world as a whole, life expectancy has more than doubled over the past two centuries, from about 25 years to about 65 for men and 70 for women (Riley J., 2001). This transformation of the duration of life has greatly enhanced the quantity and quality of people's lives. It has fueled enormous increases in economic output and in population size, including an explosion in the number of the elderly (Fogel R.W. 1997 and Martin L.G. 1994). Yet little research has been done on why the revolution in human longevity started about 200 hundred years ago, why the sustained rise started in Scandinavia, and why progress in increasing record life expectancy has been so steady. Decomposing the change in remaining life expectancy into a measure of the rate of mortality improvement and a measure of lifespan disparity, is the focus of the present article.

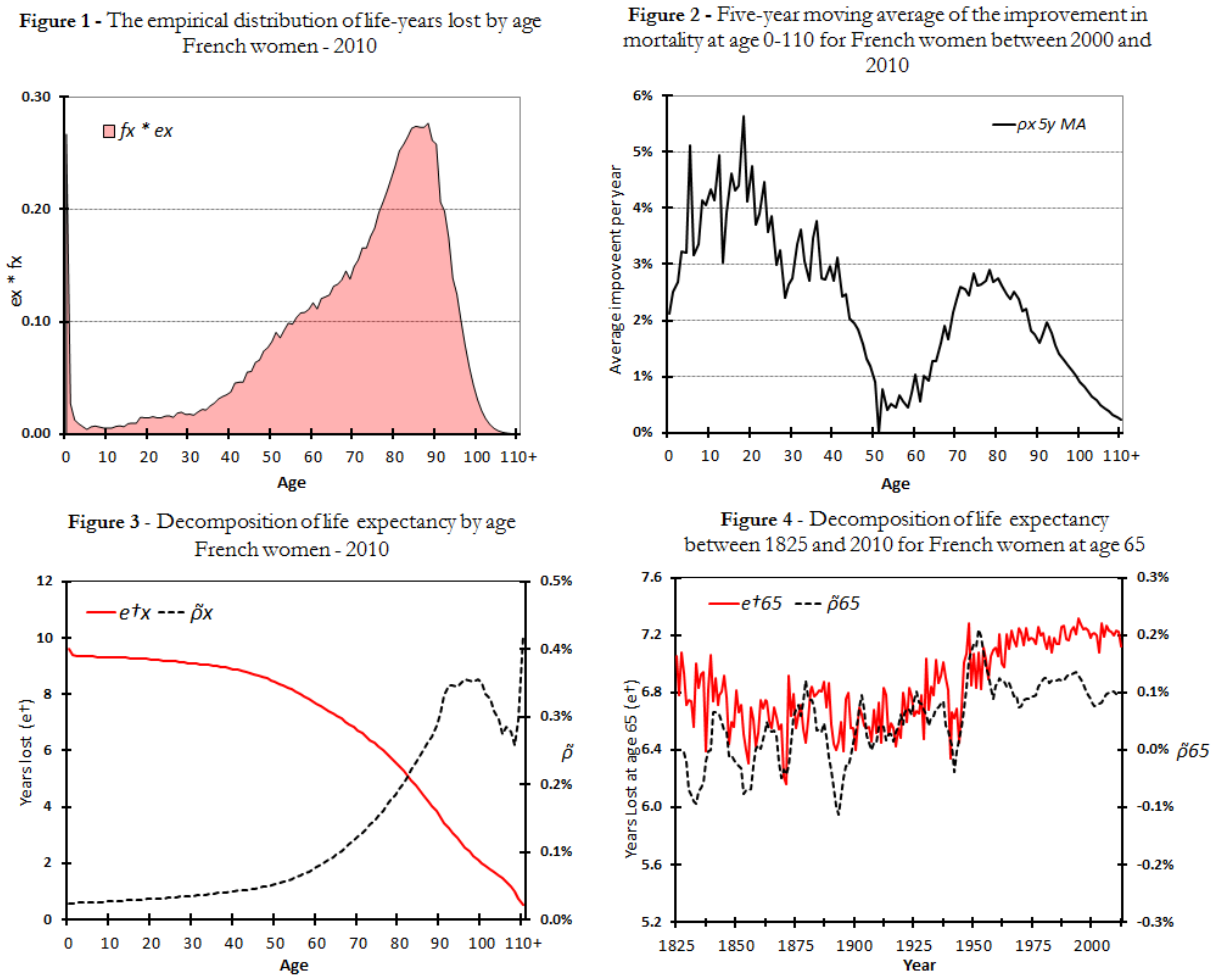

Figure 12. Figures depicting life lost, improvement in mortality and decomposition of life-expectancy in Frency women.

Pending grants

SCOR Corporate Foundation for Science

Maria Baden, Research Assistant, Biology

Main research interest

My research interest covers topics in plant geography, community ecology, systematics, biodiversity conservation and habitat restoration. I place a high value on facilitating the communication and co-operation between researchers from multi-disciplinary backgrounds. My current work focusses on generating experimental data on the role of environment in the physiology and life cycle of several local species. In particular, I explore trade-offs between growth, development, reproduction and survival in amphibians as well as perennial herbs. I am interested to better understand the interplay of demographic and environmental parameters that influence their distribution and population density to better predict population stability, for example for species threatened with extinction. I aim to apply my background in ecology, botany and geography to develop spatial and temporal models that include demographic, ecological and physiological data, while considering the important factors of human population pressure and climate change, to make realistic management plans for habitat conservation and restoration projects.

Conferences/activities

Management of global biodiversity: the need for a biodiversity demographic bank (session co-organizer). EuroScience Open Forum, held in Copenhagen, Denmark 26 June 2014.

DISKo Workshop (co-organizer) held in Odense, Denmark, following up from the EuroScience Open Forum, 27-29 June 2014.

First Annual Meeting on *Bufo calamita* (co-organizer) held in Copenhagen & Odense, Denmark, 29 September - 1 October 2014.

Honours and awards

I participated in the making of Glacial Mystery, a short science movie that won first prize as best science video on the web (category substance) in the competition “fast forward science – die besten Wissenschaftsvideos im Web 2014”

http://www.fastforwardscience.de/gewinner-2014.htm

Anthony Medford, Research Assistant, Public Health

Main research interest

Mortality modelling and forecasting; formal demography

Ongoing work

"An Extreme Value Theory approach to Analyzing record Life Expectancy"

Various methods have been used to analyze the rise in life expectancy and the maximum life expectancies observed from among the leading countries. To the best of the author's knowledge no one has used Extreme Value Theory (EVT) to study the time series of annual maximum life expectancy. EVT has been used to examine life span by looking at the maximum ages of death directly but no one has so far applied this theory to the study of the maximum life expectancies. This work will examine record life expectancy via the rigorous theory set out in Extreme Value Statistics, using the results to make inferences and forecasts about expected future life expectancy.

Media appearances of research staff

Print/online news

Fyens Stiftstidende, Fast Company's magazine, SciStarter, New York Magazine, LINKiesta, BRIT+CO, pijamasurf, Jyllands posten, Times magazine, dailyRx News, La Jornada, National Geographic, Conservation Magazine, El Economista, Jyllands-Posten, Videnskab.dk, Scientific Computing, DR, Horticulture Week, Zee News, TV2 Fyn, Faculty of 1000, Deccan Herald, Mannheimer Morgenweb, The Journal.ie, and MHV havforskersejlads

Radio

KABC Radio, WJBD Radio

TV

TV2, DR2, Danish Television, coverage of the research on Amphibians (Bufo calamita in Denmark and Estonia), TV MIDTVEST

Other media

ESOF science in the city, Forskningsdag-TV2, AXA People Protectors

Teaching of research staff

The research staff of MaxO put in approximately nine hundred and fifty hours of teaching in 2014 in courses and workshops both at SDU and elsewhere:

Applying Demographic methods to biodiversity conservation, IDEM School, MPIDR

Biodemography, SDU

Biodiversity Conservation and Management, SDU

Biostatistical Consulting of PhD students – Faculty of Health Science, SDU

Biostatistics I, SDU

Demografi og Folkesundhed, SDU

Demography and Public Health, SDU

Epidemiology and biostatistics for medical students, SDU

Evidence-Based Medicine Use and Biostatistics, SDU

Experimental design and analysis of biological data, SDU

Field Course in Terrestrial Zoology, SDU

Formal Demography, European Doctoral School of Demography, - Warsaw School of Economics

Forskningens Døgn Kerteminde, SDU

Fundamentals of Life Tables, Johns Hopkins University

Havbrug, SDU

Introduction to Biodemography, SDU

Marin- og brakvandsøkologi, SDU

Mathematics, Statistics and Physics for Biologists and Pharmacists, SDU

Planning and evaluation of biological studies, SDU

Planter, protister og svampe, SDU

Population biology and evolution, SDU

Pre-PhD course at the Faculty of Health Science – “Epidemiology and Registry research”, SDU

SDU first year projects, SDU

Software Carpentry Workshop, SDU

Stanford formal demography workshop, Stanford University

Statistical Modelling, SDU

Study-start assignments for medical students, SDU

Survival analysis in medical research, SDU

Survival Analysis, SDU

Workshop on Demographic Methods and Models, Radboud University, Utrecht

Zoology & Evolution, SDU

Visitors

Alexander Scheuerlein, Research Scientist, Max-Planck Institute for Demographic Research, Rostock.

Alexandro Rodriguez Rojas, Postdoctoral research associate, Freie Universitaet Berlin, Germany.

Beate Proske, Student, European Doctoral School of Demography.

Cristina Acasuso Rivero, Masters Student, INSERM U1001, Paris, France.

Elin Soomets, Post Doc, University of Tallinn.

Francisco Villavicencio, PhD student, Max Planck Institute for Demographic Research and the University of Rostock.

Gunnar Andersson, Professor of Demography, University of Stockholm.

Hassan Syed, Founder and Chief Executive Officer of Bir Ventures International.

Heather Booth, Associate Professor of Demography, Australian National University.

Jean-Dominique Lebreton, Directeur de recherche – CNRS, Center for Evolution and Functional Ecology, Université Montpellier.

Jean-Michel Galliard, Directeur de recherche – CNRS, Evolutionary Ecology and Population processes Group, Laboratoire de Biométrie et Biologie Évolutive, Université Lyon.

Jennifer Lynch, Guest researcher, University of Southern Denmark.

Johan Ehrlén, Professor at the Department of Ecology, Environment and Plant Sciences, Stockholm University.

John E. Fa, Visiting Professor, Imperial College London.

Jonas Wastesson, PhD Student, Karolinska Institute.

Kolea Zimmerman, Graduate Student, Harvard University.

Lucie Bland, Research Associate, The Quantitative & Applied Ecology Group, University of Melbourne.

Luis Pedro Coelho, Post Doc, European Molecular Biology Laboratory (EMBL), Heidelberg.

María Begoña Garcia, Tenured Scientist at Instituto Pirenaico de Ecología, Spain.

Matthew Tye, Doctoral student, Department of Ecology and Genetics, Uppsala University.

Riinu Rannap, Professor, University of Tartu.

Roberto Salguero-Gomez, Research fellow, University of Queensland, Brisbane, and Max-Planck Institute for Demographic Research, Rostock.

Ruth Archer, Post Doc, Max-Planck Institute for Demographic Research, Rostock.

Steven Koenig, PhD student, Technische Universität München.

Thomas Kiørboe, Professor, Centerleader, Centre for Ocean Life, DTU-Aqua.

Uffe Thygesen, Associate Professor, DTU AQUA, Institut for Akvatiske Ressourcer, DTU-Aqua.

Yvonne Buckley, Professor, Trinity College Dublin.

Sabine Holst, Research Scientist, German Centre for Marine Biodiversity Research, Hamburg

Janina Fiebig, Masters Student, University of Hamburg

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National Institutes of Health, National Institute on Aging

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The Committee on Medical and Natural Sciences Research of the Novo Nordisk Foundation

The Danish Council for Independent Research - Medical Sciences

The Research Council at Odense University Hospital

The Velux Foundation

Publications of research staff

Published/accepted publications

Baden, H. M., & Tenbergen, B. (2014). DIE PFLANZENSAMMLUNG VON JOACHIM WATTENDORFF (1928-2008) IM HERBARIUM MÜNSTER (MSTR): Sammelreisen und floristische Studien eines bedeutenden westfälisch-schweizerischen Botanikprofessors: Ein erster Überblick. Natur und Heimat, 74(2), 39-50. [74. Jahrg., Heft 2, 2014].

Baden, H. M., Särkinen, T., **Conde, D. A.**, Matthews, A. C., Vandrot, H., Chicas, S., Pennil, C., Bayly, W. D. R., Chance, R., Bridgewater, S. G. M. & Harris, D. J. (accepted). A botanical inventory from the Raspaculo River in the eastern Chiquibul Forest, Cayo District, Belize (Central America). Edinburgh Journal of Botany.

Canudas-Romo, V., García-Guerrero, V. M., & Echarri-Cánovas, C. J. (2014). The stagnation of the Mexican male life expectancy in the first decade of the 21st century: The impact of homicides and diabetes mellitus. Journal of Epidemiology & Community Health. 10.1136/jech-2014-204237

Canudas-Romo, V., Guillot, M. (forthcoming). A Measure for Comparing the Mortality History of Cohorts: TCAL. Population Studies

Canudas-Romo, V., Lenart, A. (forthcoming). Mortality of the Oldest-Old. International Encyclopedia of the Social & Behavioral Sciences, 2nd edition

Canudas-Romo, V., Liu, L., Zimmerman, L., Ahmed, S., & Tsui, A. (2014). Potential Gains in Reproductive-Aged Life Expectancy by Eliminating Maternal Mortality: A Demographic Bonus of Achieving MDG 5. P L o S One, 9(2), e86694. 10.1371/journal.pone.0086694

Colchero, F., & Schaible, R. (2014). Mortality as a bivariate function of age and size in indeterminate growers. Ecosphere 5(12): 161.

Conde, D. A. (2014). Ageing research on vertebrates shows knowledge gaps and opportunities for species conservation and management. Abstract from Leibniz Institute for Zoo and Wildlife Research in the Forschungsverbund Berlin e.V., Berlin, Germany.

Conde, D. A., Colchero, F., Güneralp, B., Gusset, M., Skolnik, B., Parr, M., Byers, O., Johnson, K., Young, G., Flesness, N., Possingham, H., & Fa, J. E. (accepted). Opportunities and costs for preventing imminent species extinctions. Current Biology.

Dahlgren, J. P., Östergård, H., & Ehrlén, J. (2014). Local environment and density-dependent feedbacks determine population growth in a forest herb. Oecologia, 176(4), 1023-1032.

Dahlgren, J. P., & Roach, D. (accepted). Demographic senescence in herbaceous plants. Peer-reviewed chapter in the coming book The Evolution of Senescence in the Tree of Life, Cambridge University Press.

DuGoff, E. H., **Canudas-Romo, V.**, Buttorff, C., Leff, B., & Anderson, G. F. (2014). Multiple chronic conditions and life expectancy: a life table analysis. Medical Care, 52(8), 688-94. 10.1097/MLR.0000000000000166

Dunn, P., & Young, C. (2014). Larval Settlement of the Nemertean Egg Predator *Carcinonemertes errans* on the Dungeness Crab, *Metacarcinus magister*. Invertebrate Biology, 133(3), 201-212.

Fa, J., Gusset, M., Flesness, N., & **Conde, D. A.** (2014). Zoos have yet to unveil their full conservation potential. Animal Conservation, 17(2), 97–100. [10.1111/acv.12115].

Jones, O.R. (2014). Why do humans deteriorate with age? It's a biological puzzle The Conversation. Accessed Jan 14, 2014, from http://theconversation.com/why-do-humans-deteriorate-with-age-its-a-biological-puzzle-21824

Jones, O.R. (accepted) Survival and fertility patterns in animals and plants. Encyclopedia of Evolutionary Biology, ed. R.M.Kliman. Elsevier.

Jones, O.R., Scheuerlein, A., Salguero-Gómez, R., Camarda, C. G., Schaible, R., Casper, B. B., ... Vaupel, J. W. (2014). Diversity of ageing across the tree of life. Nature, 505, 169–173. 10.1038/nature12789

Juel Ahrenfeldt, L., Skytthe, A., Czene, K., Petersen, I., **Lindahl-Jacobsen, R.,** & Christensen, K. (2014). Prenatal exposure to sex-hormones and cancer risk: A Danish-Swedish cohort study in twins. Poster session presented at 22nd Nordic Congress of Gerontology, Göteborg, Sverige.

Juel Ahrenfeldt, L., Skytthe, A., Szene, K., **Lindahl-Jacobsen, R.,** & Christensen, K. (2014). Cancer Risk in Opposite-Sexed Twins. Twin Research and Human Genetics, 17(5), 412.

Koons, D., **Colchero, F**., Hersey, K., & Gimenez, O. (2015). Disentangling effects of climate, density dependence and harvest on the population dynamics of an iconic large herbivore. Ecological Applications. 10.1890/14-0932.1

Lenart, A. (2014). Goodness-of-fit tests for the Gompertz distribution. Communications in Statistics: Theory and Methods. 10.1080/03610926.2014.892323

Levitis DA. (2014) Evolutionary Demography: a synthesis of two population sciences. In: International Encyclopedia of Social and Behavioral Sciences, 2nd Edition. ed.: J.D. Wright. In Press

Merow, C., **Dahlgren, J. P**., Metcalf, C. J. E., Childs, D. Z., Evans, M. E. K., Jongejans, E., ... McMahon, S. M. (2014). Advancing population ecology with integral projection models: a practical guide. Methods in Ecology and Evolution, 5(2), 99-110.

Murren C.J., Auld, J.R., Callahan, H.C., Ghalambor, C.K., Handelsman, C.A., Heskel, M.A., Kingsolver, J.G., Maclean, H.J., Masel, J., Maughan, H., Pfennig, D.W., Relyea, R.A., Seiter, S., Snell-Rood, E., **Steiner, U.K.,** & Schlichting, C.D. (2015 in press). Constraints on the evolution of phenotypic plasticity: limits and costs of phenotype and plasticity. Heredity.

Murren, C. J., Maclean, H. J., Diamond, S. E., **Steiner, U.**, Heskel, M. A., Handelsman, C. A., ... Kingsolver, J. (2014). Evolutionary change in continuous reaction norms. American Naturalist, 183(4), 453-67. 10.1086/675302

Nygaard M, **Lindahl-Jacobsen R**, Soerensen M, Mengel-From J, Andersen-Ranberg K, Jeune B, Vaupel JW, Tan Q, Christiansen L, Christensen K. (2014) Birth cohort differences in the prevalence of longevity-associated variants in APOE and FOXO3A in Danish long-lived individuals. Experimental Gerontology 57C:41-46. PMCID: PMC4149928

Oeppen, J. (2014). Cohort-Specific Mortality Response in the 1918 Influenza Pandemic. Book chapter, translated into Russian.

Olesen, W. H., Katballe, N., Sindby, J. E., Titlestad, I. L., **Lindahl-Jacobsen, R**., Andersen, P. E., & Licht, P. B. (2014). Recurrent primary spontaneous pneumothorax is more common than previously reported. Abstract from EACTS: 28th Annual Meeting, Milano, Italien.

Oravecz Z, **Levitis DA**, Faust K, Batchelder WH. (2014) Studying the existence and attributes of consensus on psychological concepts by a cognitive psychological model. American Journal of Psychology. In Press

Plante, S., **F. Colchero** and S. Calmé (2014) Foraging strategy of a Neotropical primate: how intrinsic and extrinsic factors influence destination and residence time. Journal of Animal Ecology. 83: 116-125

Priskorn, L., Jensen, T. K., **Lindahl-Jacobsen, R.,** Skakkebæk, N. E., Bostofte, E., & Eisenberg, M. L. (2014). Parental age at delivery and a man's semen quality. Human reproduction (Oxford, England), 29(5), 1097-102. 10.1093/humrep/deu039

Riisgård, H. U., & **Goldstein, J.** (2014). Jellyfish and Ctenophores in Limfjorden (Denmark): mini-review, with recent new observations. Journal of Marine Science and Engineering, 2(4), 593-615. doi:10.3390/jmse2040593

Salguero-Gomez, R., **Jones, O**., Archer, C. R., Buckley, Y., Che-Castaldo, J., Caswell, H., ... Vaupel, J. W. (2015). The COMPADRE Plant Matrix Database: an Open Online Repository for Plant Demography. Journal of Ecology. 103(1): 202-218.

Steiner, U., Tuljapurkar, S., & Coulson, T. (2014). Generation time, net reproductive rate, and growth in stage-age-structured populations. American Naturalist, 183(6), 771-83. 10.1086/675894

van der Meer, S., **Dahlgren, J. P.,** Mildén, M. & Ehrlén, J. (2014) Differential effects of abandonment on the demography of the grassland perennial *Succisa pratensis*. Population Ecology. 56, 1, p. 151-160.

Zajitschek, F., Jin, T., **F. Colchero**, and A. Maklakov (2014) Aging differently: diet- and sex-dependent late-life mortality patterns in Drosophila melanogaster. Journal of Gerontology: Series A. 69(6): 666-674

Zarulli, V. (2014), "Post-War Migration Flows and Disparities in Mortality from Age 50 Years Onwards: the Case of Turin in Italy." Population, Space and Place (Online)., 10.1002/psp.1862

Zubillaga, M., Skewes, O., Soto, N., Rabinovich, J., & **Colchero, F.** (2014). Bayesian inference on the effect of density dependence and weather on a guanaco population from Chile. PloS One e115307.

Submitted publications

Colchero, F., Jones, O. R., Conde, D. A., Hodgson, D., Zajitschek, F., Schmidt, B. R., Malo, A. F., Alberts, S. C., Becker, P. H., Bouwhuis, S., Bronikowski, A. M., De Vleeschouwer, K. M., Delahay, R. J., Dummermuth, S., Fernández-Duque, E., Flatt, T., Frisenvænge, J., Hesselsøe, M., Larson, S., Lemaître, J.-F., McDonald, J., Miller, D. A. W., O'Donnell, C., Packer, C., Raboy, B. E., Reading, C. J., Sheldon, B. C., Wapstra, E., Weimerskirch, H., While, G. M., Baudisch, A., Coulson, T., & Gaillard, J.-M. (in review). Aging in the wild and its implications for population biology and conservation. Science.

Dahlgren, J. P., Bengtsson, K., & Ehrlén, J. (submitted). Demographic mechanisms of climate-driven and density-regulated population dynamics in a perennial plant. Ecology Letters.

Dunn, P., & Young, C. (2014). Physiological tolerance of the nemertean egg predator *Carcinonemertes errans* to salinity and temperature stress. Biological Bulletin.

Ehrlén, J., Raabova, J., & **Dahlgren, J. P.** (submitted). Timing of reproduction in a perennial plant - life-history trade-offs, seed predation and lifetime fitness. Ecology.

Harris, Heidi**, Adam Lenart**, Iris Levitis and **Daniel A. Levitis** (submitted): Synanthropic range expansion by Common Ravens in the eastern United States. The Condor.

Hin, Saskia C., **Conde, D. A.** and **Adam Lenart** (submitted): New light on Roman census papyri through computer-assisted record linkage. Historical Methods.

Larson, S.M., **F. Colchero, O.R. Jones**, L Williams, E. Fernández-Duque (In review) Age and sex specific mortality of wild and captive populations of a monogamous primate (*Aotus* sp.). American Journal of Primatology. American Journal of Primatology

Lehtilä, K., **Dahlgren, J. P**., Garcia, M.B., Leimu, R., Syrjänen, K., & Ehrlén, J. (submitted). Forest succession and population viability of grassland plants: long repayment of extinction debt in Primula veris. Journal of Ecology.

Levitis, D., Harris, H., Levitis, I., & **Lenart, A.** (in revision). Synanthropic range expansion by Common Ravens in the eastern United States. The Condor: Ornithological Applications.

Lindahl-Jacobsen R, Jeune B, Rau R, **Canudas-Romo V, Lenart A**, Christensen K, Vaupel JW, The rise, stagnation and rise of Danish women's life expectancy, PNAS

Missov, Trifon, **Adam Lenart**, Laszlo Nemeth, **Vladimir Canudas-Romo**, James W. Vaupel (submitted): The Gompertz force of mortality in terms of the modal age of death. Demographic Research.

Olsen, T. B., Christensen, F. E. G., **Lundgreen, K., Dunn, P.**, & **Levitis, D.** (in revision). Coelomic transport and clearance of foreign bodies by sea stars (*Asterias rubens*). Biological Bulletin.

Salguero-Gómez, R **Jones, O.R**., Jongehans, E., Blomberg, S., Franco, M., Hodgson, D., Mbeau-Ache, C., Zuidema, PA, de Kroon, H, & Buckley, Y (in review) The maintenance-reproduction framework of plant life history strategies. PLOS Biology.

Shefferson, R., Salguero-Gómez, R, & **Jones, O.R.** (eds.) (Book in process, due to be published 2015) The Evolution of Senescence in the Tree of Life. Cambridge University Press

Steiner, U.K., Tuljapurkar, S., Roach, D.A. (resubmission). Demographic consequences of genetic, environmental and individual stochastic variability in Plantago lanceolata. Ecology Letters.

Zarulli, V., "Unobserved Heterogeneity of Frailty in the Analysis of Socioeconomic Differences in Mortality." (submitted to European Journal of Population, currently under review)

Zimmerman, K., **Levitis, D**., & Pringle, A. (2014). Maternal parentage influences spore production but not spore pigmentation in the anisogamous and hermaphroditic fungus Neurospora crassa. Heredity.