Population fitness measurements collected for Acartia tonsa during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA)

Website: https://www.bco-dmo.org/dataset/923908
Data Type: Other Field Results, experimental
Version: 1
Version Date: 2024-03-28

Project
» Collaborative Research: Response of marine copepods to warming temperature and ocean acidification (Copepod Response to Warming Temp and OA)

Contributors	Affiliation	Role
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Abstract
These data include population fitness measurements collected for Acartia tonsa during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA) including a benign ambient condition temperature and CO2 control (AM). These data were estimated as the population net reproductive rate collected every third generation between F0 and F15 and at F25 for all treatments. These data were estimated via age-structured leslie matrices using the existing survival, fecundity (egg production and hatching success), development time, and sex ratio data for this experiment.

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Coverage

Location: University of Connecticut, Avery Point campus
Spatial Extent: **Lat**:41.320725 **Lon**:-72.001643
Temporal Extent: 2017-07-02 - 2018-08-15

Methods & Sampling

Copepods were collected in June of 2016 from Esker Point Beach in Groton, Connecticut, USA (41.320725°N, 72.001643°W) and raised for at least three generations as stock cultures prior to the start of transgenerational experiments to limit maternal effects (Falconer, 1989. *Introduction to Quantitative Genetics*). Stock cultures were split evenly into eight groups of 160 females and 80 males. Four of these eight groups were acclimatized to high temperature at 1 degree Celsius per day and used to seed the two high temperature treatments (OW and OWA). The other four groups remained at ambient temperature and were used to seed the ambient and acidification treatments. After temperature acclimatization, groups of stock cultures seeded the parental (F0) individuals for two days. Stock culture groups yielded an average of 7,173 eggs per group to produce approximately 57,000 parental (F0) eggs. Resulting parental eggs and N1 nauplii were acclimated to one of four experimental treatments over the entire F0 generation. The four lines of the copepods were established with four replicates of each condition. The target (actual ± standard deviation) conditions were: ambient temperature = 18 degrees Celsius (°C) (18 ± 0.34, N = 330), ambient pCO2 = 400 µatm (379 ± 36, N = 18; pH = 8.26 ± 0.1, N = 330); high temperature = 22°C (22 ± 0.81, N = 336), and high pCO2 = 2000 µatm (2301 ± 215, N = 18; pH = 7.55 ± 0.08, N = 330). Copepods were fed every 48-72 hours at food-replete concentrations (≥800 micrograms (µg) Carbon per liter (L)) consisting of equal proportions of the phytoplankters *Tetraselmis* sp., *Rhodomonas* sp., and *Thalassiosira weissflogii*, deliberately raised under ambient conditions for the entire length of the experiment to avoid confounding effects of possible changes in food quality due to the different temperature and CO2 among treatments.

The population net reproductive rate, λ, was calculated as the dominant eigenvalue of an assembled projected age-structured Leslie matrix constructed from survival and fecundity data (Caswell, H. 2001. *Matrix Population Models: Construction, Analysis, and Interpretation*). Briefly, day-specific probabilities of survival are calculated from day-specific survival as $Px = l_x /(l_x{-}1)$ where l_x represents the proportion of individuals on day *x* and l_x - 1 represents the proportion of individuals on day $x - 1$. Probabilities of survival on day 1 are assumed to be 100%, or a value of 1.0. EPR was calculated as $(E_u{+}E_h)/t$ where E_u represents unhatched eggs, E_h represents hatched eggs (nauplii) and t represents egg-laying time. HS was calculated as $E_h/(E_u{+}E_h)$. Fecundity rates equal the product of EPR and HS. Because only females produce offspring, total fecundity rates must be scaled to the sex ratio (proportion of females to males). To account for differences in individual development time for each treatment, fecundity rates are assigned to all days after the first matured adult is observed. We assume that surviving individuals represented by the survival experiments are equally as likely to experience any of the fecundity values observed in EPR experiments. Therefore, each mate-pair fecundity rate was paired with each survival beaker to construct a matrix. This yields a maximum of 120 matrices per treatment per generation (3 survival beakers × 4 replicate cultures × 10 mate pairs). Relative measures of each value are calculated as the trait value divided by the mean value of that trait. Standardized measures of each value are calculated as the trait value minus the mean trait value and divided by the standard deviation. The target (actual ± standard deviation) conditions were as follows: ambient (AM) temperature = 18 °C (18 ± 0.34, N = 330), AM pCO2 = 400 µatm (379 ± 36, N = 18; pH = 8.26 ± 0.1, N = 330); high temperature = 22 °C (22 ± 0.81, N = 336); and high pCO2 = 2,000 µatm (2,301 ± 215, N = 18; pH = 7.55 ± 0.08, N = 330). AM target levels represented extant conditions for this species in northeast Atlantic estuaries. Full methods can be found in Dam, et al. 2021 Nature Climate Change. doi: 10.1038/s41558-021-01131-5.

Data Processing Description

Data were processed and analyzed with R (v 4.0.2). Code for data analysis and visualization is located in Zenodo at: https://doi.org/10.5281/zenodo.5115103.

BCO-DMO Processing Description

- Imported original file "lambda_results_devtime_surv_epr_hf_sex_standardized_relative.txt" into the BCO-DMO system.
- Renamed fields to comply with BCO-DMO naming conventions.
- Saved final file as "923908_v1_a_tonsa_population_fitness.csv".

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Data Files

File
923908_v1_a_tonsa_population_fitness.csv (Comma Separated Values (.csv), 562.48 KB) MD5:94dd4069052ae8b8a7a3b704760c321f Primary data file for dataset ID 923908, version 1

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Related Publications

Dam, H. G., deMayo, J. A., Park, G., Norton, L., He, X., Finiguerra, M. B., Baumann, H., Brennan, R. S., & Pespeni, M. H. (2021). Rapid, but limited, zooplankton adaptation to simultaneous warming and acidification. Nature Climate Change, 11(9), 780–786. https://doi.org/10.1038/s41558-021-01131-5
Results

R Core Team (2020). R: A language and environment for statistical computing. R v4.0.2. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
Software

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Related Datasets

IsRelatedTo

Dam, H. G., Baumann, H., Finiguerra, M., Pespeni, M., Brennan, R. (2024) **Body size measurements collected for Acartia hudsonica during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-04-03 doi:10.26008/1912/bco-dmo.924236.1 [view at BCO-DMO]
Relationship Description: These datasets result from the same set of experiments.

Dam, H. G., Baumann, H., Finiguerra, M., Pespeni, M., Brennan, R. (2024) **Development (i.e. maturation) time measurements for Acartia hudsonica during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-04-03 doi:10.26008/1912/bco-dmo.924206.1 [view at BCO-DMO]
Relationship Description: These datasets result from the same set of experiments.

Dam, H. G., Baumann, H., Finiguerra, M., Pespeni, M., Brennan, R. (2024) **Egg production rate (EPR) and egg hatching success (HS) data for Acartia tonsa during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-04-02 doi:10.26008/1912/bco-dmo.924126.1 [view at BCO-DMO]
Relationship Description: These datasets result from the same set of experiments.

Dam, H. G., Baumann, H., Finiguerra, M., Pespeni, M., Brennan, R. (2024) **Population fitness measurements collected for Acartia hudsonica during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-03-29 doi:10.26008/1912/bco-dmo.923960.1 [view at BCO-DMO]
Relationship Description: These datasets result from the same set of experiments.

Dam, H. G., Baumann, H., Finiguerra, M., Pespeni, M., Brennan, R. (2024) **Survivorship measurements collected for Acartia hudsonica during multigenerational exposure to ocean warming (OW), ocean acidification (OA), and combined ocean warming and acidification (OWA).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-04-01 doi:10.26008/1912/bco-dmo.924088.1 [view at BCO-DMO]
Relationship Description: These datasets result from the same set of experiments.

Dam-Lab, & Rsbrennan. (2021). *dam-lab/Transgenerational_manuscript: Dam, H. G., et al. Data and code repository for 'Rapid, but limited, zooplankton adaptation to simultaneous warming and acidification'* (Version 1.4.0) [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.5115103 https://doi.org/10.5281/zenodo.5115103

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Parameters

Parameter	Description	Units
Generation	The generation at which fitness was estimated	unitless
Treatment	The treatment that the orgnaisms were evaluated in, and where traits were measured and fitness was estimated. 1 = ambient (AM): temperature = 18 °C, pCO2= 400 µatm. 2 = ocean acidification (OA): temperature = 18 °C, pCO2= 2000 µatm. 3 = ocean warming (OW): temperature = 22 °C, pCO2= 400 µatm. 4 = ocean warming and acidification (OWA): temperature = 22 °C, pCO2= 2,000 µatm.	unitless
Rep	The biological replicate associated with the population fitness estimates	unitless
lambda	The net reproductive rate estimates	per generation
surv	The corresponding survival probabilities	unitless
epr	The corresponding egg production rate measurements	eggs per female per day
hf	The corresponding hatching success rates	nauplii per number of eggs laid
sex	The corresponding sex ratio	females per total copepods
dev_time	The corresponding development time	days to adulthood
lambda_stand	The standardized lambda value	unitless
surv_stand	The standardized survival value	unitless
epr_stand	The standardized egg production rate (epr) value	unitless
hf_stand	The standardized hatching success	unitless
sex_stand	The standardized sex ratio (proportion of females to males)	unitless
dev_stand	The standardized development time	unitless
lambda_rel	The relative lambda value	unitless
surv_rel	The relative survival value	unitless
epr_rel	The relative epr value	unitless
hf_rel	The relative hatching success	unitless
sex_rel	The relative sex ratio	unitless
dev_rel	The relative development time	unitless

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Project Information

Collaborative Research: Response of marine copepods to warming temperature and ocean acidification (Copepod Response to Warming Temp and OA)

Coverage: North western Atlantic ocean; Gulf of Maine, coastal and estuarine habitats

NSF Award Abstract:
Over time, our oceans are becoming both warmer and higher dissolved carbon dioxide. The latter condition is called ocean acidification. The consequences of these simultaneous changes for populations of marine organisms are not well understood. For this project, the investigators will conduct a series of laboratory experiments to determine how two closely-related, common species of Acartia copepods will respond to the interactive effects of warming and acidification and also how well these species can adapt over multiple generations to changing ocean conditions. Since these copepods are key species in coastal food webs, results will have important implications for understanding and predicting how marine ecosystems may respond to future climate change. The investigators will share results from the research through traditional print media, case studies, and video mini lectures. The goal will be for educators of all levels to easily access material on climate change and ocean acidification to include in teaching curricula, in alignment with recommendations for universal design for learning. The project is a collaborative effort between an established professor at the University of Connecticut and an early-career female scientist at the University of Vermont. It will provide training and opportunities for collaborative, interdisciplinary research for two postdoctoral investigators, two graduate students and an undergraduate student.

The project's main goals are: 1) to test the simultaneous effects of temperature and carbon dioxide under current and future conditions on life history traits throughout the life cycle for two key copepod species, warm-adapted Acartia tonsa and cold-adapted Acartia hudsonica; 2) to test for adaptive capacity of both copepod species to a warmer and carbon-dioxide-enriched ocean; 3) to measure the genetic and maternally-induced changes across multiple generations of experimental selection in future conditions in both copepod species, and to identify the genes and pathways responding to selection. The investigators will use experiments encompassing current and projected temperature and carbon-dioxide conditions, will determine the roles of each variable and their interaction on traits that affect the fitness of both copepod species. They will also determine which life stages are most sensitive to individual or simultaneous stress conditions. Through multigenerational selection experiments, the investigators will identify and characterize the mechanisms of copepod evolutionary adaptation. Finally, they will measure genomic changes across the generations under all four experimental conditions to quantify the relative contributions of genetic and maternally-induced change in the physiological and life history traits of copepods in response to near-future climate conditions.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1559075
NSF Division of Ocean Sciences (NSF OCE)	OCE-1559180

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