

Meta-analytic data for tolerance plasticity study - literature review from 2019-2020

Website: <https://www.bco-dmo.org/dataset/1009144>

Data Type: Synthesis

Version: 1

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Project

» [Investigating mechanisms underlying adaptive capacity to ocean warming](#) (URO)

Contributors	Affiliation	Role
Cheng, Brian	University of Massachusetts Amherst	Principal Investigator
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Abstract

Many species face extinction risks owing to climate change, and there is an urgent need to identify which species' populations will be most vulnerable. Plasticity in heat tolerance, which includes acclimation or hardening, occurs when prior exposure to a warmer temperature changes an organism's upper thermal limit. The capacity for thermal acclimation could provide protection against warming, but prior work has found few generalizable patterns to explain variation in this trait. Here, we data for a meta-analysis to examine within-species variation in thermal plasticity, using results from 20 studies (19 species) that quantified thermal acclimation capacities across 78 populations. These results advance our understanding of variation in populations' susceptibility to climate change and imply that populations with the highest thermal tolerance may have limited phenotypic plasticity to adjust to ongoing climate warming.

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Coverage

Location: Global meta-analytic data from published studies.

Spatial Extent: N:65.4529 E:146.4769 S:-40.65 W:-161.58333

Temporal Extent: 1998-01-01 - 2019-12-31

Methods & Sampling

Studies which measure thermal tolerance plasticity typically collect organisms from nature and acclimate them to different temperatures for defined periods of time in the lab before measuring thermal tolerance. Important methodological considerations for these types of studies include (1) for how long and at what temperature organisms are acclimated, (2) how fast the temperature is changed, and (3) whether measurements are made on field collected or F1 individuals, given that parental conditions are known to influence thermal plasticity. To identify publications for use in our study, we followed PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines (supplemental figure S1 in Barley et al. 2021). We searched titles, abstracts, and key words in Web of Science (Clarivate Analytics, Philadelphia, USA) using the following search string: (Thermal OR temperatures) AND (Lethal OR "Thermal tolerance" OR "Thermal limit" OR CTmax OR CTmin OR LT50 OR "freezing tolerance") AND ("Local* Adapt*" OR ""Latitud* Var" OR Intraspecific). We conducted an initial literature search on 24 August 2019 and updated the search on 28 July 2020. We also

added studies that we were aware of but were not returned in the literature search. We used the following criteria for inclusion, where each study must have: (1) reported new results of whole-organism upper thermal limit in degrees Celsius for at least 2 populations of the same species, (2) experimentally measured thermal tolerance after acclimating all individuals to at least two temperatures, (3) reported a measure of error for the thermal tolerance estimate, and (4) not measured tolerance of introduced species, hybrid lines, cultivars, domesticated species, or later generations of experimental laboratory populations (greater than F2). Although we initially included both cold and heat tolerance studies, we later excluded cold tolerance studies from our analysis due to insufficient data. Studies of cold tolerance, and additional studies that met criteria (1) and (2) but were excluded based on (3) and/or (4) are listed in supplemental table S1 in Barley et al. 2021. We screened 400 publications that measured thermal tolerances across populations and identified 20 studies to include in our meta-analysis, representing 19 species. The studies that were accepted after looking through titles and abstracts but were later excluded from our analysis are listed in Table S1 in Barley et al. 2021. We extracted data from each publication using relevant figures, tables, text, or supplementary material. In the case of figures, we used WebPlotDigitizer (version 4.3; Rohatgi 2020) to extract means and error estimates.

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Related Publications

Adachi, T., Costa, D. P., Robinson, P. W., Peterson, S. H., Yamamichi, M., Naito, Y., & Takahashi, A. (2016). Searching for prey in a three-dimensional environment: hierarchical movements enhance foraging success in northern elephant seals. *Functional Ecology*, 31(2), 361–369. Portico. <https://doi.org/10.1111/1365-2435.12686>

Methods

Armstrong, J. J., Takebayashi, N., & Wolf, D. E. (2020). Cold tolerance in the genus *Arabidopsis*. *American Journal of Botany*, 107(3), 489–497. Portico. <https://doi.org/10.1002/ajb2.1442>

Methods

Armstrong, J. J., Takebayashi, N., Sformo, T., & Wolf, D. E. (2015). Cold tolerance in *Arabidopsis kamchatica*. *American Journal of Botany*, 102(3), 439–448. Portico. <https://doi.org/10.3732/ajb.1400373>

Methods

Barria, A. M., & Bacigalupe, L. D. (2017). Intraspecific geographic variation in thermal limits and acclimatory capacity in a wide distributed endemic frog. *Journal of Thermal Biology*, 69, 254–260. <https://doi.org/10.1016/j.jtherbio.2017.08.010>

Methods

Bewick, S. (2016). Current and future challenges of predictive insect population modelling. *Functional Ecology*, 30(7), 1028–1029. Portico. <https://doi.org/10.1111/1365-2435.12678>

Methods

Bible, J. M., Evans, T. G., & Sanford, E. (2020). Differences in induced thermotolerance among populations of Olympia oysters. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 239, 110563. <https://doi.org/10.1016/j.cbpa.2019.110563>

Methods

Boomsma, J. J. (2016). When every sperm is sacred: the emergence and decline of superorganismal chimeras. *Functional Ecology*, 30(4), 504–505. Portico. <https://doi.org/10.1111/1365-2435.12617>

Methods

Bugg, W. S., Yoon, G. R., Schoen, A. N., Laluk, A., Brandt, C., Anderson, W. G., & Jeffries, K. M. (2020). Effects of acclimation temperature on the thermal physiology in two geographically distinct populations of lake sturgeon (*Acipenser fulvescens*). *Conservation Physiology*, 8(1). <https://doi.org/10.1093/conphys/coaa087>

Methods

Burghardt, K. T. (2016). Nutrient supply alters goldenrod's induced response to herbivory. *Functional Ecology*, 30(11), 1769–1778. Portico. <https://doi.org/10.1111/1365-2435.12681>

Methods

Campbell-Staton, S. C., Bare, A., Losos, J. B., Edwards, S. V., & Cheviron, Z. A. (2018). Physiological and regulatory underpinnings of geographic variation in reptilian cold tolerance across a latitudinal cline. *Molecular Ecology*, 27(9), 2243–2255. Portico. <https://doi.org/10.1111/mec.14580>

Methods

Case, E. J., Harrison, S., & Cornell, H. V. (2016). Do high-impact invaders have the strongest negative effects

on abundant and functionally similar resident species? *Functional Ecology*, 30(8), 1447–1453. Portico. <https://doi.org/10.1111/1365-2435.12615>

Methods

Chen, T.-C., Kam, Y.-C., & Lin, Y.-S. (2001). Thermal Physiology and Reproductive Phenology of *Buergeria japonica* (Rhacophoridae) Breeding in a Stream and a Geothermal Hotspring in Taiwan. *Zoological Science*, 18(4), 591–596. <https://doi.org/10.2108/zsj.18.591>

Methods

Darveau, C.-A., Taylor, E. B., & Schulte, P. M. (2012). Thermal Physiology of Warm-Spring Colonists: Variation among Lake Chub (*Cyprinidae: Couesius plumbeus*) Populations. *Physiological and Biochemical Zoology*, 85(6), 607–617. <https://doi.org/10.1086/665539>

Methods

Diamond, S. E., Chick, L. D., Perez, A., Strickler, S. A., & Martin, R. A. (2018). Evolution of thermal tolerance and its fitness consequences: parallel and non-parallel responses to urban heat islands across three cities. *Proceedings of the Royal Society B: Biological Sciences*, 285(1882), 20180036.

<https://doi.org/10.1098/rspb.2018.0036>

Methods

Dong, Y., Han, G., Ganmanee, M., & Wang, J. (2015). Latitudinal variability of physiological responses to heat stress of the intertidal limpet *Cellana toreuma* along the Asian coast. *Marine Ecology Progress Series*, 529, 107–119. <https://doi.org/10.3354/meps11303>

Methods

Dong, Y.-w., & Zhang, S. (2016). Ecological relevance of energy metabolism: transcriptional responses in energy sensing and expenditure to thermal and osmotic stresses in an intertidal limpet. *Functional Ecology*, 30(9), 1539–1548. Portico. <https://doi.org/10.1111/1365-2435.12625>

Methods

Eaton, D. A. R., Hipp, A. L., González-Rodríguez, A., & Cavender-Bares, J. (2015). Historical introgression among the American live oaks and the comparative nature of tests for introgression. *Evolution*, 69(10), 2587–2601. Portico. <https://doi.org/10.1111/evo.12758>

Methods

Evans, J. A., Lankau, R. A., Davis, A. S., Raghu, S., & Landis, D. A. (2016). Soil-mediated eco-evolutionary feedbacks in the invasive plant *Alliaria petiolata*. *Functional Ecology*, 30(7), 1053–1061. Portico.

<https://doi.org/10.1111/1365-2435.12685>

Methods

Fangue, N. A., Hofmeister, M., & Schulte, P. M. (2006). Intraspecific variation in thermal tolerance and heat shock protein gene expression in common killifish, *Fundulus heteroclitus*. *Journal of Experimental Biology*, 209(15), 2859–2872. <https://doi.org/10.1242/jeb.02260>

Methods

Fernando, A. V., Lochmann, S. E., & Haukenes, A. H. (2016). Critical thermal maxima of juvenile alligator gar (*Atractosteus spatula*, Lacépède, 1803) from three Mississippi-drainage populations acclimated to three temperatures. *Journal of Applied Ichthyology*, 32(4), 701–705. Portico. <https://doi.org/10.1111/jai.13047>

Methods

Gunton, R. M., & Pöyry, J. (2016). Scale-specific spatial density dependence in parasitoids: a multi-factor meta-analysis. *Functional Ecology*, 30(9), 1501–1510. Portico. <https://doi.org/10.1111/1365-2435.12627>

Methods

Healy, T. M., Bock, A. K., & Burton, R. S. (2019). Variation in developmental temperature alters adulthood plasticity of thermal tolerance in *Tigriopus californicus*. *Journal of Experimental Biology*.

<https://doi.org/10.1242/jeb.213405>

Methods

Herrera Paredes, S., & Lebeis, S. L. (2016). Giving back to the community: microbial mechanisms of plant–soil interactions. *Functional Ecology*, 30(7), 1043–1052. Portico. <https://doi.org/10.1111/1365-2435.12684>

Methods

Jensen, A., Alemu, T., Alemneh, T., Pertoldi, C., & Bahrndorff, S. (2019). Thermal acclimation and adaptation across populations in a broadly distributed soil arthropod. *Functional Ecology*, 33(5), 833–845. Portico.

<https://doi.org/10.1111/1365-2435.13291>

Methods

Kelley, A. L., de Rivera, C. E., & Buckley, B. A. (2011). Intraspecific variation in thermotolerance and

morphology of the invasive European green crab, *Carcinus maenas*, on the west coast of North America. *Journal of Experimental Marine Biology and Ecology*, 409(1-2), 70–78.

<https://doi.org/10.1016/j.jembe.2011.08.005>

Methods

Lachapelle, J., Bell, G., & Colegrave, N. (2015). Experimental adaptation to marine conditions by a freshwater alga. *Evolution*, 69(10), 2662–2675. Portico. <https://doi.org/10.1111/evo.12760>

Methods

Lenz, A., Hoch, G., Körner, C., & Vitasse, Y. (2016). Convergence of leaf-out towards minimum risk of freezing damage in temperate trees. *Functional Ecology*, 30(9), 1480–1490. Portico. <https://doi.org/10.1111/1365-2435.12623>

Methods

Lodjak, J., Mägi, M., Sild, E., & Mänd, R. (2016). Causal link between insulin-like growth factor 1 and growth in nestlings of a wild passerine bird. *Functional Ecology*, 31(1), 184–191. Portico. <https://doi.org/10.1111/1365-2435.12679>

Methods

Ma, C., Xiong, Y., Li, L., & Guo, D. (2016). Root and leaf decomposition become decoupled over time: implications for below- and above-ground relationships. *Functional Ecology*, 30(7), 1239–1246. Portico. <https://doi.org/10.1111/1365-2435.12619>

Methods

Manis, M. L., & Claussen, D. L. (1986). Environmental and genetic influences on the thermal physiology of *Rana sylvatica*. *Journal of Thermal Biology*, 11(1), 31–36. [https://doi.org/10.1016/0306-4565\(86\)90014-8](https://doi.org/10.1016/0306-4565(86)90014-8)

Methods

McCann, S. M., Kosmala, G. K., Greenlees, M. J., & Shine, R. (2018). Physiological plasticity in a successful invader: rapid acclimation to cold occurs only in cool-climate populations of cane toads (*Rhinella marina*). *Conservation Physiology*, 6(1). <https://doi.org/10.1093/conphys/cox072>

Methods

Morris, J. R., Costa, J. T., & Berry, A. (2015). Adaptations: Using Darwin's *Origins* to teach biology and writing. *Evolution*, 69(10), 2556–2560. Portico. <https://doi.org/10.1111/evo.12759>

Methods

Park, S., Gilmour, S. J., Grumet, R., & Thomashow, M. F. (2018). CBF-dependent and CBF-independent regulatory pathways contribute to the differences in freezing tolerance and cold-regulated gene expression of two *Arabidopsis* ecotypes locally adapted to sites in Sweden and Italy. *Plos One*, 13(12), e0207723. <https://doi.org/10.1371/journal.pone.0207723>

Methods

Pereira, R. J., Sasaki, M. C., & Burton, R. S. (2017). Adaptation to a latitudinal thermal gradient within a widespread copepod species: the contributions of genetic divergence and phenotypic plasticity. *Proceedings of the Royal Society B: Biological Sciences*, 284(1853), 20170236. <https://doi.org/10.1098/rspb.2017.0236>

Methods

Phillips, B. L., Muñoz, M. M., Hatcher, A., Macdonald, S. L., Llewelyn, J., Lucy, V., & Moritz, C. (2015). Heat hardening in a tropical lizard: geographic variation explained by the predictability and variance in environmental temperatures. *Functional Ecology*, 30(7), 1161–1168. Portico. <https://doi.org/10.1111/1365-2435.12609>

Methods

Rundle, H. D., & Dyer, K. A. (2015). Reproductive character displacement of female mate preferences for male cuticular hydrocarbons in *Drosophila subquinaria*. *Evolution*, 69(10), 2625–2637. Portico. <https://doi.org/10.1111/evo.12761>

Methods

Sasaki, M. C., & Dam, H. G. (2019). Integrating patterns of thermal tolerance and phenotypic plasticity with population genetics to improve understanding of vulnerability to warming in a widespread copepod. *Global Change Biology*, 25(12), 4147–4164. doi:[10.1111/gcb.14811](https://doi.org/10.1111/gcb.14811)

Methods

Sasaki, M., Hedberg, S., Richardson, K., & Dam, H. G. (2019). Complex interactions between local adaptation, phenotypic plasticity and sex affect vulnerability to warming in a widespread marine copepod. *Royal Society Open Science*, 6(3), 182115. doi:[10.1098/rsos.182115](https://doi.org/10.1098/rsos.182115)

Methods

Tepolt, C. K., & Somero, G. N. (2014). Master of all trades: thermal acclimation and adaptation of cardiac

function in a broadly distributed marine invasive species, the European green crab, *Carcinus maenas*. Journal of Experimental Biology, 217(7), 1129–1138. <https://doi.org/10.1242/jeb.093849>

Methods

Towner, A. V., Leos-Barajas, V., Langrock, R., Schick, R. S., Smale, M. J., Kaschke, T., Jewell, O. J. D., & Papastamatiou, Y. P. (2016). Sex-specific and individual preferences for hunting strategies in white sharks. Functional Ecology, 30(8), 1397–1407. Portico. <https://doi.org/10.1111/1365-2435.12613>

Methods

Tsai, C.-H., Hsieh, C.-h., & Nakazawa, T. (2016). Predator–prey mass ratio revisited: does preference of relative prey body size depend on individual predator size? Functional Ecology, 30(12), 1979–1987. Portico.

<https://doi.org/10.1111/1365-2435.12680>

Methods

Underwood, Z. E., Myrick, C. A., & Rogers, K. B. (2012). Effect of acclimation temperature on the upper thermal tolerance of Colorado River cutthroat trout *Oncorhynchus clarkii pleuriticus*: thermal limits of a North American salmonid. Journal of Fish Biology, 80(7), 2420–2433. Portico. <https://doi.org/10.1111/j.1095-8649.2012.03287.x>

Methods

Villeneuve, A. R., Komoroske, L. M., & Cheng, B. S. (2021). Diminished warming tolerance and plasticity in low-latitude populations of a marine gastropod. Conservation Physiology, 9(1).

<https://doi.org/10.1093/conphys/coab039>

Methods

Visser, M. D., Bruijning, M., Wright, S. J., Muller-Landau, H. C., Jongejans, E., Comita, L. S., & de Kroon, H. (2016). Functional traits as predictors of vital rates across the life cycle of tropical trees. Functional Ecology, 30(2), 168–180. Portico. <https://doi.org/10.1111/1365-2435.12621>

Methods

Wasserman, R. J., Alexander, M. E., Dalu, T., Ellender, B. R., Kaiser, H., & Weyl, O. L. F. (2016). Using functional responses to quantify interaction effects among predators. Functional Ecology, 30(12), 1988–1998. Portico.

<https://doi.org/10.1111/1365-2435.12682>

Methods

Weldon, C. W., Nyamukondiwa, C., Karsten, M., Chown, S. L., & Terblanche, J. S. (2018). Geographic variation and plasticity in climate stress resistance among southern African populations of *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). Scientific Reports, 8(1). <https://doi.org/10.1038/s41598-018-28259-3>

Methods

Wong, M. K.-S., Nobata, S., & Hyodo, S. (2019). Enhanced osmoregulatory ability marks the smoltification period in developing chum salmon (*Oncorhynchus keta*). Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 238, 110565. <https://doi.org/10.1016/j.cbpa.2019.110565>

Methods

Wood, H. L., Nylund, G., & Eriksson, S. P. (2014). Physiological plasticity is key to the presence of the isopod *Idotea baltica* (Pallas) in the Baltic Sea. Journal of Sea Research, 85, 255–262.

<https://doi.org/10.1016/j.seares.2013.05.009>

Methods

Wüest, R. O., Litsios, G., Forest, F., Lexer, C., Linder, H. P., Salamin, N., Zimmermann, N. E., & Pearman, P. B. (2016). Resprouter fraction in Cape Restionaceae assemblages varies with climate and soil type. Functional Ecology, 30(9), 1583–1592. Portico. <https://doi.org/10.1111/1365-2435.12629>

Methods

Yu, D., Zhang, Z., Shen, Z., Zhang, C., & Liu, H. (2018). Regional differences in thermal adaptation of a cold-water fish *Rhynchocypris oxycephalus* revealed by thermal tolerance and transcriptomic responses. Scientific Reports, 8(1). <https://doi.org/10.1038/s41598-018-30074-9>

Methods

Zhao, L., Zhang, Q.-G., & Zhang, D.-Y. (2015). Evolution alters ecological mechanisms of coexistence in experimental microcosms. Functional Ecology, 30(8), 1440–1446. Portico. <https://doi.org/10.1111/1365-2435.12611>

Methods

Zuo, J., Berg, M. P., Klein, R., Nusselder, J., Neurink, G., Decker, O., Hefting, M. M., Sass-Klaassen, U., van Logtestijn, R. S. P., Goudzwaard, L., van Hal, J., Sterck, F. J., Poorter, L., & Cornelissen, J. H. C. (2016). Faunal community consequence of interspecific bark trait dissimilarity in early-stage decomposing logs. Functional Ecology, 30(12), 1957–1966. Portico. <https://doi.org/10.1111/1365-2435.12676>

Methods

van Heerwaarden, B., Kellermann, V., & Sgrò, C. M. (2016). Limited scope for plasticity to increase upper thermal limits. *Functional Ecology*, 30(12), 1947–1956. Portico. <https://doi.org/10.1111/1365-2435.12687>

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Parameters

Parameters for this dataset have not yet been identified

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Project Information

Investigating mechanisms underlying adaptive capacity to ocean warming (URO)

Coverage: Coastal marine waters of western Atlantic ocean from 31 to 44 degrees latitude N

NSF Award Abstract:

Understanding how marine life copes with drastically different environmental conditions now and into the future is essential for the management and conservation of biodiversity in the ocean. One complicating factor is the observation that populations within a given species are often fine-tuned to the environment that they live in. Yet, it is often unclear what components of the environment create these differences across populations. This project focuses on Atlantic oyster drills, a predatory snail that consumes farmed and wild oysters on the Atlantic coast of North America, the location of one of the strongest temperature gradients in the world. The investigators combine field and laboratory studies to understand how differences in temperature affect the growth and survival of oyster drills sourced from populations throughout their range. This information is paired with molecular analyses to help determine genetic and physiological differences among populations. In addition to benefitting oyster reefs, this information broadly contributes to the understanding of how marine life will respond to rapidly changing environmental conditions. The project also supports the education and marine science training of students at the undergraduate, graduate, and postdoctoral level. In partnership with the non-profit organization Waterstrong, the investigators will provide marine science and swimming skills training to thirty girls from historically underrepresented groups.

Predicting how marine communities will respond to rapid environmental change is difficult because species responses can vary across populations and because organisms may evolve over time. Knowledge of how such evolutionary potential arises and is maintained is limited. A useful approach for examining species response to environmental change is to investigate how species have locally adapted to environmental differences across their range. This project tests competing mechanisms that can generate countergradient variation (CnGV; a widespread form of local adaptation) in an ecologically important marine species (Atlantic oyster drill, *Urosalpinx cinerea*). The objectives of this integrative research are to 1) quantify the strength of seasonality and mean temperature in generating CnGV and to 2) identify if these responses are correlated across biological traits using a combination of field sampling and common garden experimentation. These objectives are complemented with a molecular approach that 3) quantifies neutral genetic structure across populations and 4) identifies the roles of genetic adaptation and transcriptional plasticity in facilitating physiological adaptation to environmental change. The proposed work is significant because it provides a novel test for different environmental drivers of a commonly observed form of local adaptation. This research also reveals the genetic underpinnings of how such local adaptation arises and will give insight into the adaptive capacity of organisms to rapid change.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

Other project information:

Further information about this project and related work can be found on the UMass Amherst website "MARINE GLOBAL CHANGE ECOLOGY" (<http://bscheng.com>).

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023571

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