Effect of predation threat on repeatability of individual crab behavior revealed by mark-recapture in North Inlet Estuary, Georgetown, SC during 2012 (Variation in Metabolic Processes project)

Website: https://www.bco-dmo.org/dataset/638853
Data Type: experimental
Version: 2016-02-17

Project
» Linking Variation in Metabolic Processes as a Key to Prediction (Variation in Metabolic Processes)

Contributors	Affiliation	Role
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Dataset Description

Effect of predation threat on repeatability of individual crab behavior revealed by mark-recapture.

Related Reference:
Toscano BJ, Gatto J, Griffen BD (2014) Effects of predation threat on repeatability of individual crab behavior revealed by mark recapture. *Behavioral Ecology and Sociobiology* 68:519-527

Related Dataset:
P. herbstii - refuge use (BESB, 2014)

Methods & Sampling

We first surveyed the individual refuge use of 247 mud crabs in the absence of a toadfish chemical cue and the refuge use of 224 separate crabs in the presence of the cue (i.e., under predation threat) from May to August 2012. All crabs were collected by hand from an oyster reef known as Oyster Landing in North Inlet estuary, Georgetown, SC, USA (33°20'N, 79°10'W). Crabs were collected within a 20 m× 20 m area at the center of the reef. Behavioral measurements were made in a screened-in wet laboratory at the adjacent Belle W. Baruch Institute for Marine and Coastal Sciences. Measuring crab refuge use behavior in the field was not possible due to the high turbidity of water in North Inlet during the summer months that limits visibility (Dame et al. 1986).

Initial behavioral measurements:
The following describes our procedure for a single observational block. Thirty-two observational blocks were run over the course of the study (May-August). Sixteen crabs were collected between 20 and 30 mm carapace width (CW) from Oyster Landing reef, and we attempted to ensure that each collection reflected the entire

crab size range (20-30 mm CW). We randomly assigned eight of these 16 crabs to the toadfish cue absent treatment and the other eight to the toadfish cue present treatment. Due to constraints on the number of crabs a single person could observe in a night, we observed eight crabs per night over two consecutive nights, generally from 2000 to 2300 h. During each night, four crabs receiving the no cue treatment and four crabs receiving the cue treatment were observed. The night measured (first or second) had no effect on refuge use behavior (ANOVA: $p > 0.05$), so the blocking factor used in our analyses was the 2-day span over which 16 crabs were measured. Any crabs molting, carrying eggs or dying during their time in the lab were removed from the data set.

Refuge use was measured following the behavioral assay protocol used in Griffen et al. (2012). All crabs were starved for 24 h before their refuge use behavior was measured. Each crab was observed in a separate glass mesocosm (50 cm× 28 cm×30 cm) containing a 3 cm layer of sand/mud substrate and 5 L of oyster shell (8-12 cm shell length) that had been dried and cleaned to remove epifauna. This amount of shell ensured that crabs had ample refuge to hide completely. Mesocosms were completely filled with a continuous supply of seawater. Eight large scorched mussels were suspended near the water surface in a mesh bag to release prey chemical cues and induce crab searching behavior while remaining out of reach of crabs. To create the toadfish cue treatment, crabs received a continuous supply of seawater that was first pumped through a holding chamber that contained a single adult oyster toadfish. Crabs assigned the no cue treatment received a continuous supply of seawater pumped through a holding chamber without a toadfish.

Crabs were observed under red light with the observer located behind a blind to minimize crab disturbance. Crabs were first given a 15-min acclimation period in the observation tanks, after which their refuge use was observed once every 6 min over 3 h (30 observations in total for each crab). Refuge use was measured as the proportion of the 30 observations where crabs were completely in the oyster shell refuge and thus invisible to the observer. The refuge was a matrix of shells, so crabs could be hiding under a single shell or multiple shells (i.e., at the bottom of the matrix). When crabs were observed out of the refuge, they were usually walking on top of the shell substrate (i.e., were active). In addition to refuge use behavior, we measured the carapace width and sex of each crab.

Repeatability and behavioral change:
After refuge use behavior was measured, each crab was marked with a unique ID number and released back into the field. To mark crabs, we glued (with super glue) a piece of laboratory labeling tape numbered with permanent marker to the center of the crab's carapace (Stachowicz and Hay 1999). We realized during the middle of the study that these handwritten numbers were becoming illegible over time in the field, and so the last 80 crabs from the survey were marked using plastic bee tags (queen marking kit: the Bee Works, Orillia, Ontario, Canada) that did not wear over time. All marked crabs were released in a 10 m×10 m area at the center of Oyster Landing reef. To assess the persistence of refuge use behavior for crabs released into the field, we recaptured the crabs and measured their refuge use for a second time using the same behavioral assay procedure in the lab. Recaptured crabs were observed under the same treatment (toadfish cue absent or present) that they were observed under before release. We recaptured the crabs by hand within the release area of Oyster Landing reef. We searched the reef over two separate search periods (end of July and end of August) until no more marked crabs were recovered at each search period. Because crabs were released regularly over the duration of the study (after each block) but resampled just twice, individual crabs were recaptured after different durations in the field, allowing us to test the effects of duration in the field on behavioral change over time.

Data Processing Description

Statistical analysis:
Initial graphical exploration of refuge use behavior over the course of the study revealed persistent oscillations in the mean refuge use observed each night with approximately a 14-day period. These oscillations in behavior appeared to be negatively correlated with the mean tidal level at Oyster Landing (the collection site of crabs) at the time of observation in the lab. Crabs used the refuge most while it was low tide (when they are generally inactive in the field), indicative of a circatidal rhythm in refuge use. We tested for this influence of the tidal cycle on refuge use behavior, among other factors affecting crab refuge use behavior, in the following analysis. To explore factors influencing crab refuge use behavior (pre-release), we tested the effects of toadfish predation threat, crab carapace width, an interaction between threat and carapace width, and mean tidal level during observation on refuge use with generalized linear mixed models (GLMM, lme4 package in the statistical software R). Female crabs were smaller than male crabs (Welch two-sample t -test: $t = -8.267$, $p < 0.001$), which confounded crab sex with crab size. Therefore, we tested the effects of these factors on refuge use separately for males and females. Observational block was modeled as a random factor in both GLMM.

Because crab refuge use (the response variable) was proportional, we modeled this behavior using a binomial distribution and logit link (Bolker et al. 2009).

After recapturing a portion of these original crabs (108 crabs recaptured), we calculated the repeatability of their refuge use behavior using pre-release and post-recapture behavioral measurements. Repeatability (r) is defined as the proportion of the total variation that occurs within individuals as opposed to between individuals and is calculated as r =sA 2 / (s 2+sA 2), where sA 2 is the among-individual variance and s 2 is the within-individual variance (Bell et al. 2009; Nakagawa and Schielzeth 2010). Thus, repeatability provides a metric of the amount of behavioral variation between relative to within individuals, where a higher repeatability value indicates a higher level of individual behavioral consistency between measurements. Again, due to the proportional behavioral measure (refuge use), we used GLMM-based repeatability estimation (rptR package in R, Nakagawa and Schielzeth 2010) with a binomial distribution and logit link. Repeatability was calculated separately for crab refuge use in the absence and presence of the toadfish cue, and confidence intervals (95 %) and statistical significance (p-values) were estimated using parametric bootstrapping with 1,000 resamplings.

Next, we explored factors driving change in refuge use behavior (i.e., deviation from perfect repeatability) of recaptured crabs after time in the field. We calculated behavioral change by subtracting the value of the first behavioral measurement (pre-release) from the second behavioral measurement (post-recapture). Behavioral change was logtransformed to meet assumptions of linear regression. To test for a predominant direction in behavioral change, we first tested whether behavioral change was significantly different than zero in the absence and presence of toadfish predation threat using one-sample t -tests. We then used general linear models testing the fixed effects of duration (days) in the field, crab carapace width, and crab sex on individual behavioral change of recaptured crabs. Two separate linear models were used to test the effects of these factors in the absence and presence of toadfish predation threat.

As previously mentioned, crab refuge use behavior oscillated with a circatidal rhythm over the course of the study. This means that if a recaptured crab was originally observed (pre-release) during one tidal height and observed for a second time (post-recapture) at a different tidal height, then behavioral change would be generated. We tested for this tidal influence on behavioral change as follows. We first subtracted for each individual crab the tidal height when the pre-release observation was made from the tidal height when the postrecapture observation was made. We then used the absolute value of this difference as a factor (termed 'tidal influence') in general linear models testing the effects of duration in the field, carapace width, sex, and the tidal influence on the absolute value of behavioral change in the absence and presence of predation threat. This analysis allowed us to explore the relative influences of these factors on the overall magnitude of behavioral change.

Lastly, we tested for the differential recapture of crabs with low versus high refuge use (i.e., a sampling bias).We did this by comparing the recapture rate of crabs from the lower and upper quartiles of refuge use behavior using Fisher's exact tests. We conducted this analysis separately for crabs with refuge use measured in the absence and presence of toadfish predation threat

BCO-DMO Processing:
- added conventional header with dataset name, PI name, version date, reference information
- renamed parameters to BCO-DMO standard
- reduced number of digits for refuge use and activity level from 9 to 2 places after decimal
- sorted by crab id #

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Data Files

File
Pherb_recapture.csv(Comma Separated Values (.csv), 5.63 KB) MD5:529264a5915ed332df108380d65be3c8 Primary data file for dataset ID 638853

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Related Publications

Bates, D., Maechler, M., & Bolker, B. (2013). lme4: Linear mixed-effects models using S4 classes. R package version 0.999999-2.
Software

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Parameters

Parameter	Description	Units
crab	subject number	unitless
treatment	treatment: nc=no predator cue; c=with predator cue	unitless
carap_width	width of crab carapace at widest point	millimeters
claw_len	length of claw	centimeters
claw_width	width of claw	centimeters
claw_hgt	height of claw	centimeters
sex	sex of crab: m=male; f=female	unitless
refuge_use_1	refuge use during first trial as the proportion of 30 observations (every 6 min over 3 h) where crabs were completely in the oyster shell refuge and thus invisible to the observer	unitless
activity_1	proportion of time spent active during first trial	unitless
refuge_use_2	refuge use upon recapture	unitless
activity_2	proportion of time spent active during secod trial (after recapture)	unitless
days_in_field	number of days the crab spent free in the field between initial trial and recapture	days
tide_1	tidal height at first trial	meters
tide_2	tidal height at recapture	meters
date_recapture	date of crab recapture	yyyy-mm-dd

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Deployments

Griffen_lab

Website	https://www.bco-dmo.org/deployment/638572
Platform	Univ_S_Carolina
Start Date	2012-01-01
End Date	2016-12-31

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Project Information

Linking Variation in Metabolic Processes as a Key to Prediction (Variation in Metabolic Processes)

Description from NSF award abstract:

A major goal of biological and ecological sciences is to understand natural systems well enough to predict how species and populations will respond to a rapidly changing world (i.e., climate change, habitat loss, etc.). A population under any conditions will grow, shrink, or disappear altogether depending on how efficiently individuals consume resources (food), utilize that food metabolically, and eventually reproduce. However, making accurate predictions based on these metabolic processes is complicated by the realities that each species has different resource requirements and that no two individuals within a species are exactly alike. Rather, individuals vary and this variation, both within and across species, is central to many ecological and evolutionary processes. Developing the ability to predict responses of biological systems to a changing world therefore requires a mechanistic understanding of variation. The goal of this project is to improve this mechanistic understanding by examining variation within a metabolic context across a range of species that have a spectrum of commonly-seen resource requirements. Further, the work capitalizes on a unique biological characteristic of this group of species that allows control and manipulation of individual reproduction, facilitating experimental study of the mechanistic links between variation in individual consumption, metabolism, and reproduction. The foundation this research is a combination of field measurements and laboratory experiments using both well-established and newly-developed techniques to quantify these links. The result will be a quantitative framework to predict how individuals will respond reproductively to changes in resource use. Because of the close link between individual reproduction and population dynamics, this research will contribute substantially to predictions in population dynamics under realistic conditions where individuals use more than a single resource, and improve the prediction of responses to current and future ecological changes.

The following publications and data resulted from this project:

Belgrad, B. and B. Griffen. 2016. Predator-prey interactions mediated by prey personality and predator identity.*Proc. Roy. Soc. B*: In Review. [2016-01-20]
P. herbstii mortality data: Mortality of crabs when exposed to either a single blue crab, toadfish, or no predator for a week
P. herbstii personality data: Refuge use of crabs when exposed to predator odor cues from either blue crabs, toadfish, or control of no cue
P. herbstii predator behavior data: Refuge use and mobility of blue crabs and toadfish while in mesocosms for a week - behavior measured during two days.

Belgrad, B. and B. Griffen. 2016. The influence of dietary shifts on fitness of the blue crab, *Callinectes sapidus*. *PloS One. DOI: 10.1371/journal.pone.0145481.*
Blue crab activity: Activity of crabs fed different diets over a summer
Blue crab egg size: Volume of eggs for crabs fed different diets
Blue crab hepatopancreas index (HSI): Weight of hepatopancreas for crabs fed different diets
Blue crab hepatopancreas lipid content: Hepatopancreas lipid content of crabs fed different diets
Blue crab reproductive tissue analysis (GSI): Gonadosomatic index of blue crabs on various diets
Blue crab survival: Blue crab survival data during the dietary study

Knotts ER, Griffen BD. 2016. Individual movement rates are sufficient to determine and maintain dynamic spatial positioning within *Uca pugilator* herds. *Behavioral Ecology and Sociobiology* 70:639-646
Uca pugilator: behavior change with carapace marking: Search space behavior due to carapace treatment (control, nail polish, and food dye)
Uca pugilator: field spatial position: Assessment of individual's position within a herd at 3 min. intervals; for proportion of time found at edge of herd
Uca pugilator: herd position proportion: Individual's proportion of time spent in an edge/alone position among a herd
Uca pugilator: search space distribution: Search space that crabs traveled; to evaluate the sample's distribution of exploratory behavior

Belgrad, B. and B. Griffen. 2015. Rhizocephalan infection modifies host food consumption by reducing host activity levels. *Journal of Experimental Marine Biology and Ecology*. 466: 70-75.
E. depressus digestion time : Time taken for food to pass through gut of flat-backed mud crabs infected by a parasite
E. depressus metabolism: Respiration rate of infected/uninfected flat-backed mud crabs
E. depressus reaction time to prey: Time taken for infected/uninfected flat-backed mud crabs to react to the presence of prey

Blakeslee, A.M., C.L. Keogh, A.E. Fowler, B. Griffen. 2015. Assessing the effects of trematode infection on invasive green crabs in eastern North America. *PLOS One* 10(6): e0128674.(pdf)
Carcinus: hemocyte density: Counts of circulating hemocyte density in Carcinus maenas
Carcinus: parasites physiology behavior: Behavior and physiology of Carcinus maenas infected with trematode

parasite

Griffen BD, Norelli AP (2015) Spatially variable habitat quality contributes to within-population variation in reproductive success. *Ecology and Evolution* 5:1474-1483.
P. herbstii diet: sampling site characteristics (Eco-Evo 2015)
P. herbstii diet: body measurements (Eco-Evo 2015)
P. herbstii diet & reproduction (Eco-Evo 2015)
P. herbstii: collection sites (Ecol-Evol 2015)

Griffen BD, Riley ME (2015) Potential impacts of invasive crabs on one life history strategy of native rock crabs in the Gulf of Maine. Biological Invasions 17:2533-2544.
Cancer consumption and reproduction (Bio.Inv. 2015): Lab experiment linking dietary consumption and reproduction

Griffen BD, Vogel M, Goulding L, Hartman R (2015) Energetic effects of diet choice by invasive Asian shore crabs: implications for persistence when prey are scarce. *Marine Ecology Progress Series* 522:181-192.
Hemigrapsus diet 1 (MEPS 2015)
Hemigrapsus diet 2 (MEPS 2015)

Hogan and Griffen (2014). The Dietary And Reproductive Consequences Of Fishery-Related Claw Removal For The Stone Crab *Menippe* Spp. Journal of Shellfish Research, Vol. 33, No. 3, 795–804.
Stone crab: 052012-DietChoiceExp1: Prey choice for 2-clawed and 1-clawed Stone Crabs (Menippe spp.)
Stone crab: 052012-LongTermConsumption: Long-term consuption for 2-clawed and 1-clawed Stone Crabs (Menippe spp.), summer of 2012
Stone crab: 062013-DietChoiceExp2: Prey choice for 2-clawed and 1-clawed Stone Crabs (Menippe spp.)
Stone crab: 062013-PreySizeSelection: Prey Size selection ranking for 2-clawed and 1-clawed Stone Crabs (Menippe spp.)

Riley M, Johnston CA, Feller IC, and Griffen B. 2014. Range expansion of *Aratus pisonii* (mangrove tree crab) into novel vegetative habitats. *Southeastern Naturalist* 13(4): 43-38
A. pisonii: range expansion: Aratus pisonii survey in native mangrove and novel salt marsh habitats

Riley M, Vogel M, Griffen B. 2014. Fitness-associated consequences of an omnivorous diet for the mangrove tree crab *Aratus pisonii*. *Aquatic Biology* 20:35-43, DOI: 10.3354/ab00543
A. pisonii: fitness and diet: Impact of diet variation on physiological and reproductive condition of A. pisonii

Toscano BJ, Newsome B, Griffen BD (2014) Parasite modification of predator functional response. Oecologia 175:345-352b
E. depressus - parasite and feeding (Oecologia, 2014): Feeding with and without parasitic barnacle infection
E. depressus - parasite and prey handling (Oecologia, 2014): Food handling with and without parasitic barnacle infection
E. depressus - parasite study - field survey (Oecologia, 2014): Parasitised field survey

Toscano BJ, Griffen BD (2014) Trait-mediated functional responses: predator behavioural type mediates prey consumption.*Journal of Animal Ecology* 83:1469-1477
P. herbstii - activity and feeding (JAE, 2014): Activity level and feeding with and without predator cue

Toscano BJ, Gatto J, Griffen BD (2014) Effects of predation threat on repeatability of individual crab behavior revealed by mark recapture. *Behavioral Ecology and Sociobiology* 68:519-527
P. herbstii - recapture behavior (BESB, 2014): Mud crabs refuge use and activity level - initial measurements
P. herbstii - refuge use (BESB, 2014): Effect of predation threat on repeatability of individual crab behavior revealed by mark-recapture

Griffen BD, Altman I, Bess BM, Hurley J, Penfield A (2012) The role of foraging in the success of invasive species. Biological Invasions. 14:2545-2558
Hemigrapsus seasonal diet (Bio.Inv. 2012): Percent herbivory and gut fullness for Hemigrapsus sanguineus at different times of year

Griffen BD, Toscano B, Gatto J (2012) The role of intraspecific trait variation in mediating indirect interactions. Ecology 93:1935-1943
P. herbstii refuge use (Ecology, 2012): Proportion of time that Panopeus herbstii spent using refuge habitats in a lab experiment
P. herbstii: Field personality distribution (Ecology, 2012): Field distribution of personality types in the mud crab Panopeus herbstii relative to tidal height

P. herbstii: Trait mediated indirect effect (Ecology, 2012): Influence of refuge use by the mud crab Panopeus herbstii on consumption of bivalves

Riley ME, Griffen BD (2017) Habitat-specific differences alter traditional biogeographic patterns of life history in a climate-change induced range expansion. PLOS One 12(5):e0176263
A. pisonii: egg size: Comparing egg size in Aratus pisonii populations from mangrove and salt marsh habitats
A. pisonii: fecundity: Determining fecundity of Aratus pisonii populations in mangrove and salt marsh habitats
A. pisonii: larval starvation resistance: Comparing larval quality in Aratus pisonii populations from mangrove and salt marsh habitats
A. pisonii: latitudinal body size: Survey examining latitudinal body size patterns in Aratus pisonii
A. pisonii: predation: Comparing predation pressure on Aratus pisonii in mangrove and salt marsh habitats
A. pisonii: reproductive effort: Survey comparing Aratus pisonii reproductive effort in native and novel habitats
A. pisonii: herbivory: Relationship between leaf herbivory, tree characteristics, and refuge availability
A. pisonii: mangrove tree survey: Mangrove tree distribution and characteristics in a dwarf mangrove system

Cannizzo ZJ, Dixon SR & Griffen BD (2018). An anthropogenic habitat within a suboptimal colonized ecosystem provides improved conditions for a range-shifting species. Ecology and Evolution, 8(3):1524-1533.
A. pisonii: behavior: Proportion of time the mangrove tree crab Aratus pisonii spent in different behaviors related to diet and energy storage
A. pisonii: dock-marsh thermal: Thermal readings from under a dock and in a nearby salt marsh
A. pisonii: sun-shade: Proportion of time that mangrove tree crab Aratus pisonii spent in sun and shade in three habitats, 2015-2016.
A. pisonii: thermal picture: Thermal condition of A. pisonii in three habitats: under dock, mangroves, saltmarsh

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1129166
Slocum-Lunz Foundation	Lerner Grey Memorial Fund of the American Museum of Natural History

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