

Title

Student, major; Mentor, department

Research Question: How does individual diet and metabolic variation influence reproductive effort in the invasive crab *Carcinus maenas*.

Project Goals and Objectives: The goal of this project is to examine the link between biological variation in diet and metabolism at the individual level and the predictability of reproductive effort within a widespread invasive crab species.

Project Impact: As important aquaculture organisms and marine consumers worldwide, the link between diet and reproduction has been studied extensively for crustaceans in general. However, these studies have not examined variation among individuals, mainly because individual variation is typically difficult to interpret. By examining individual crabs of the same species along a manipulated dietary spectrum, this research will provide insight into broadly applicable patterns in individual dietary and metabolic variation, and thus facilitate development of predictive reproductive models for the crab species *Carcinus maenas*.

Background: All organisms perform a range of integrated functions in order to survive and reproduce. These functions can be examined from an energetic/metabolic perspective as the acquisition and utilization of energy and nutrients. In all consumers, only a proportion of the total energy ingested by an individual is assimilated and available for actual use by the organism. From there, the amount of assimilated energy is broken down into energy used for maintenance and energy used for growth.[1] Whatever is left over of the assimilated energy is then available for reproduction. Understanding and mechanistically predicting the impacts of any population of consumers depends on our ability to accurately quantify this process in order to make useful projections of population growth.

Crabs are important consumers in marine habitats that show a particularly large amount of variation in reproduction across individuals (Fig. 1). This large amount of reproductive variation must be tied metabolically to diet choice. Unfortunately, because diet variation between crabs is so prevalent, this individual variation is often difficult to interpret and so has largely been ignored in the study of ecological and evolutionary processes for these organisms. However, only by understanding the variation between individuals in their acquisition and utilization of

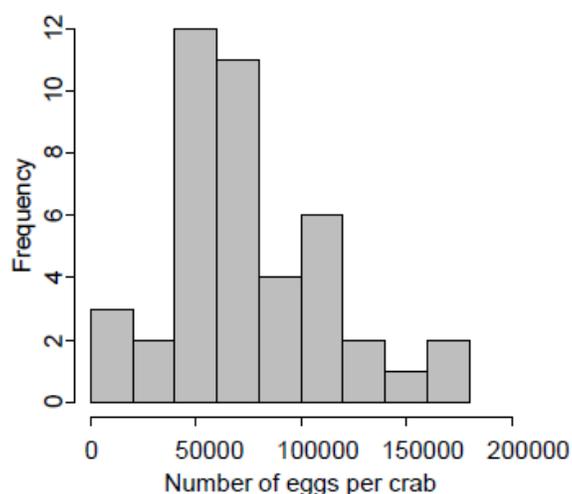


Fig. 1 Variation in number of eggs produced by 45 individual *Carcinus maenas* collected from New England shores. Number of eggs varied by more than a factor of 38 across these crabs.

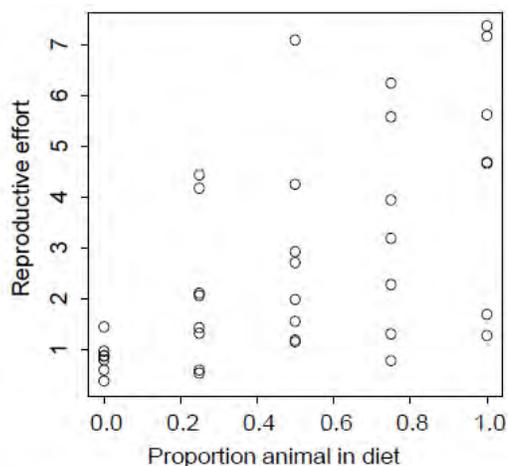


Fig. 2 Percentage of body weight dedicated to reproduction (reproductive effort) as a function of proportion of individual diets made up of animal tissue.

energy can we develop models that ultimately predict population dynamics.[2] This research proposes to develop a mechanistic understanding of individual variation by identifying and exploring broadly applicable patterns in dietary and metabolic variation among individuals of the species *Carcinus maenas*. Within this species of crab, diet plays an important role in crab reproduction; in fact, individual crab variation in diet may explain a substantial portion of crab variation in reproduction.

In a preliminary experiment, we varied individual diets for this omnivore using just one type of animal and one type of plant. The results of this study are shown in Fig. 2. These results demonstrated that reproductive effort increased with the contribution of animal matter to the diet of individual crabs. However, this experiment used just one plant and one animal type, and in their natural environment, *C. maenas* are broad omnivores, consuming many plant and animal food types.[3] Thus, my proposed experiment will examine the implications of a broader diet, with increased variation between individuals, on *C. maenas* reproduction.

One of the great benefits of using crabs for this study is the ability to experimentally control their reproduction. The onset of crab reproduction is controlled by a gonad-inhibiting hormone produced by a gland in the eyestalk, which can be experimentally removed via eyestalk ablation, to stimulate gonad development and the extrusion of eggs within 2-3 weeks.[4][5] This method has been used to determine the nutritional quality of different diets by comparing reproductive output on different artificial diets following eyestalk ablation.[6] Thus, eyestalk ablation provides a clear and practical experimental method for quantifying the connection between reproduction and variation in diet and metabolism.

Project Design: To examine how variation in diet can be linked to variation in reproductive effort of *C. maenas*, I will conduct an experiment in which I directly manipulate the type of food given to each individual crab. There will be 11 different food treatments supplied to the crabs on a daily basis; each treatment will consist of the same amount of food (~4% of crab body weight) but will differ in composition. The number of crabs per treatment will be 6, allowing for a total of 66 crabs in the overall study. In terms of daily food composition, I will use the 4 most prevalent animal and 4 most prevalent plant foods typically found in the *C. maenas* diet. [3] Common animal foods that will be used include herbivorous snails, carnivorous snails, mussels, and juvenile crabs (i.e., cannibalism). Common plant foods include four different types of commonly available algae. Individual crabs will either receive one of these animal or plant foods, or will receive an even mix of all 4 animal food types, or an even mix of all four plant food types, or an even mix of all plant and animal food types together. Crabs will be fed daily. Uneaten food after 24 hours will be removed and quantified, allowing us to determine the precise amount eaten by each crab.

The crabs will be maintained under these feeding conditions for six weeks, after which each crab will undergo eyestalk ablation to stimulate reproduction. Feeding treatments will then continue as before for another two weeks while egg development occurs, after which time the experiment will be stopped and the crabs will be dissected to remove eggs and ovary for determining reproductive effort. We will scale reproductive effort to the size of each individual crab in order to control for differences in individual crab size. Ovary size is an important factor in determining a crab's reproductive effort because it is directly proportional to the number of eggs the crab produces.[7][8] This experiment will be conducted using the recirculating seawater facilities available in the Baruch wet lab (currently rehoused in PSC). Space in these facilities has already been secured, and all materials and supplies needed for this experiment are available in [mentor's] laboratory.

Project Timeline:

Task Description:

Task 1: Collect crabs from the New England coast (June) – to be accomplished by [mentor].

Task 2: Manipulate the daily, dietary conditions for all 11 different treatments of crab (June-July).

Task 3: Perform eyestalk ablation to all treatments of crab in order to stimulate reproduction (July).

Task 4: Continue previous feeding conditions for another two weeks (July).

Task 5: Dissect all crabs to determine reproductive effort based on ovary and body size (August-September).

Task 6: Analyze results and write final report (Fall YEAR).

Anticipated Results and Dissemination: I anticipate that the data from this research will provide clear insights into how individual natural diet variation influences reproduction. Additionally, comparison of variation in reproduction across individuals within a single treatment will allow us to examine the role of individual variation in metabolism, independent of variation in diet. These results will be combined with previous results to yield a mathematical relationship for predicting reproductive effort as a function of individual variation in diet and metabolism.

These findings will be presented at Discover USC. Furthermore, the work I do under this proposal may be developed into a senior thesis later down the road in my academic career. In addition, the results of this experiment will be reported in a peer-reviewed publication that I will participate in as a coauthor.

Personal Statement: Over the course of the past few weeks I have had the opportunity to work in [mentor's] lab on a separate project that involves parasites in crabs and their impacts on crab energetics. In just that short amount of time, I have gained valuable knowledge and skills in basic laboratory procedures and analytical techniques. By continuing my career in undergraduate research with a grant from the Magellan Scholar Program, I will be able to improve my knowledge of laboratory procedures and, as a result, become a much more competitive candidate for graduate school and other career opportunities in the future. Furthermore, by continuing [mentor's] research specifically, I will be able to explore areas of research in biology and ecology that I never before expected to explore as a marine science undergraduate with a focus in chemistry. I am excited and eager to further enhance my understanding of the scientific process as a whole by continuing my research with a grant from the Magellan Scholar Program.

References:

- 1.) Reznick, D. 1983. The Structure of Guppy Life Histories - the Tradeoff between Growth and Reproduction. *Ecology* 64:862-873.
- 2.) Bolnick, D. I., R. Svanback, J. A. Fordyce, L. H. Yang, J. M. Davis, C. D. Hulsey, and M. L. Forister. 2003. The ecology of individuals: Incidence and implications of individual specialization. *American Naturalist* 161:1-28.
- 3.) Griffen, B.D. and Mosblack, H. (2011) Predicting diet and consumption rate differences between and within species using gut ecomorphology. *Journal of Animal Ecology* 28:854-863.
- 4.) Bliss, D. E. 1966. Neurosecretion of Invertebrates Other Than Insects .4. Physiological Processes and Neurosecretion as Related to Ecdysis and Reproduction - Introduction - Relation between Reproduction and Growth in Decapod Crustaceans. *American Zoologist* 6:231.
- 5.) Stowasser, G. 2008. Endocrine control of female reproduction. Pages 267-298 *in* E. Mente, editor. *Reproductive Biology of Crustaceans*. Science Publishers, Enfield.
- 6.) Millamena, O. M. and E. Qunitio. 2000. The effects of diets on reproductive performance of eyestalk ablated and intact mud crab *Scylla serrata*. *Aquaculture* 181:81-90.
- 7.) Annala, J. H. 1991. Factors influencing fecundity and population egg production in *Jasus* species. Pages 301-315 *in* A. Wenner and A. Kuris, editors. *Crustacean egg production*. A.A. Balkema, Rotterdam.
- 8.) Hartnoll, R. G. 2006. Reproductive investment in Brachyura. *Hydrobiologia* 557:31-40.

Magellan Scholar BUDGET FORM

Student's Name: _____

Double-click on table to enter data

Student salary	Hours	Rate	Subtotal
	Estimated number of hours student will work	Enter the hourly wage	
Research hours during semesters when enrolled in classes	90	\$10.50	\$945.00
Research hours during semesters when NOT enrolled in classes	180	\$10.50	\$1,890.00
Fringe: Student salary * student fringe rate (What is fringe? See budget instructions or guidebook)			
Enrolled in classes	\$945.00	0.55%	\$5.20
NOT enrolled in classes	\$1,890.00	8.30%	\$156.87
Materials/Supplies	Enter sub-total from below:		\$0.00
Travel	Enter sub-total from below:		\$0.00
	TOTAL:		\$2,997.07
	Amount requested for MGS award:		\$2,997.07

Budget Justification

Student Salary: Indicate estimated number of student research hours per week and hourly rate separated by semesters when student is enrolled in classes or not enrolled in classes (generally fall or spring vs summer semesters).

While taking classes: 10 hours per week for 9 weeks at \$10.50 per hour
 Over the summer: 20 hours per week for 9 weeks at \$10.50 per hour

Materials/Supplies: Indicate items, quantity, and estimated price. *Be sure to include taxes on all purchases.*

All of the materials and supplies needed for this project will be paid for by mentor's existing research funds. The money awarded by the Magellan grant will go towards my student salary to perform the research.

Travel: Indicate location, purpose of travel, estimate itemized costs (transportation, lodging, registration, etc).

I will not be travelling while doing my research. Crabs will be collected for this study from New England. These collections will be done by mentor using his existing research funds.