Chapter 17

Predator Prey Experiment

Over two lab periods, you will investigate the coevolutionary relationship between shelled snails and crabs. In the first part, you will make morphometric measurements of shells from the whelk *Nucella lamellosa* collected from an eelgrass bed and a rocky shore. All shells came from Marine Park in Bellingham. The eelgrass bed and rocky shore sites were about 100 meters apart. In the second part of the lab (to be completed later in the quarter), you will measure the force exerted by the chelipeds of the crab*Cancer magister*, a common whelk predator. The research paper from these labs is due one week from the crab lab.

17.1 Scaling of snail shells

Experimental Question: Are gastropod shells from different habitats morphologically different?

1. The whelk *Nucella lamellosa* is known to exhibit variable shell morphologies depending on habitat (see Kitching et al., 1966; Palmer, 1985). We will investigate relationships of various morphometric dimensions (i.e length, mass, areas). In other words, we are going to discover how these dimensions may differ between populations of snails from different habitats. For example, we might expect that snails in dangerous habitats might grow relatively thicker shells for their length than snails from less predated habitats.

2. Measure several dimensions of each shell from both populations of snails (we will do this as a class to save time). The data can be analyzed with Student's t-test (see section below)

Suggested readings

Donovan, D.A., J.P. Danko, and T.H. Carefoot. (1999) Functional significance of shell sculpture in gastropod molluscs: test of a predator-deterrent hypothesis in *Ceratostoma foliatum* (Gmelin). J. Exp. Mar. Biol. Ecol. 236: 235-251.

Kitching, J.A., L. Muntz, and F.J. Ebling. (1966) The ecology of Lough Ine. XV. The ecological significance of shell and body forms in *Nucella*. J. Snim. Ecol. 35: 113-126.

Palmer, A.R. (1977) Function of shell sculpture in marine gastropods: hydrodynamic destabilization in *Ceratostoma foliatum*. Science 197:1293-1295.

Palmer, A.R. (1985) Adaptive value of shell variation in *Thais lamellosa*: effect of thick shells on vulnerability to and preference by crabs. Veliger 27: 349-356.

Vermeij, G.J. (1976) Interoceanic differences in vulnerability of shelled prey to crab predation. Nature 260: 135-136.

Vermeij, G.J. (1982) Phenotypic evolution in a poorly dispersing snail after arrival of a predator. Nature 299: 349-350.

17.2 Crustacean claws

Experimental question: What is the crushing force generated by the left and right chelae and does it vary along the chelae?

1. Measure with the transducer system the forces of the left and right dactylus of *Cancer magister*. To do this, hook the loop on the transducer to the tip of the dactylus. Tickle the joint of the cheliped to induce the claw to close. **Make sure to mark the location where the string is attached.** Repeat twice for each cheliped. The transducer will record the maximum value.

   Figure 17.1 shows the transducer system. The transducer has been calibrated with known weights, and the calibration equation is on the board. Use this equation to convert the transducer value to the force (F_{output}) in Newtons ($N = kg \cdot m \cdot s^{-2}$).

2. Place the crab in boiling water for approximately 5 minutes. This will kill the crab, but still allow you to dissect both claws and both first walking legs to make the measurements for the force generated by the muscles and mechanical advantage.

3. Calculate the force generated by the flexor muscles of both the right and the left chelipeds. Do this by measuring the following **external distances** (do this **before** dissecting the claws):

   L_{input} Measure the distance from the flexor apodeme attachment (the soft membrane at the base of the dactylus) to the fulcrum (point about which the dactylus rotates). This distance is shown by the 1 in Fig. 17.1.

   L_{output} Measure the distance from the fulcrum to where the string was attached. This distance is shown by the 2 in Fig. 17.1.

4. Use Equation 17.1 to calculate the force generated by the flexor muscle.

$$F_{input} = \frac{F_{output} \cdot L_{output}}{L_{input}} \qquad (17.1)$$

   where F_{output} is the force of the dactylus you measured with the transducer (converted to Newtons).

5. Dissect both chelipeds. *Carefully* separate and remove the flexor muscles from the apodemes. *Leave the apodemes intact and the appendage still functioning as a lever system.* Individually weight the flexor muscles from both chelipeds.

6. Record all your data in Table 17.1.

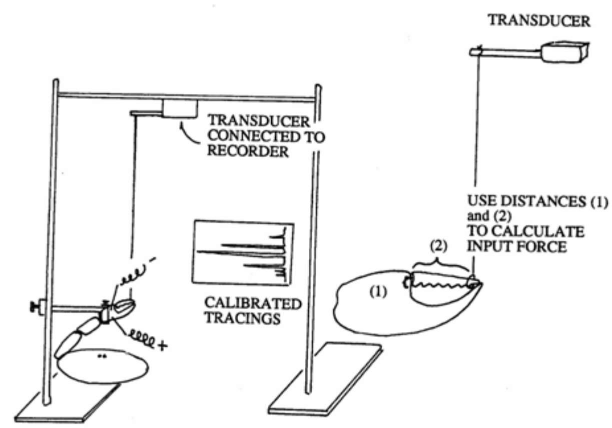

Figure 17.1: Transducer system used to measure the force of the chelae.

Table 17.1: Forces and lengths of the left and right chelae.

Chelae	$F_{output}(N)$	$L_{input}(mm)$	$L_{output}(mm)$
L			
R			

Experimental question: Is there a difference in the mechanical advantage of different crab appendages?

1. Measure the mechanical advantage of the dactylus closing (flexor muscle) of both chelipeds and the two first walking legs.

2. Pull on the apodeme and measure the distance, D_a (mm), it moves and the straight-line distance, D_d (mm), the tip of the dactylus moves (see Fig. 17.2). Mechanical advantage is calculated as the lateral distance that the apodeme moves divided by the distance that the dactylus tip moves (Equation 17.2), and is presented as a fractional value between 0 and 1[1].

$$mechanical advantage = \frac{D_a}{D_d} \tag{17.2}$$

3. Record the mechanical advantages of both claws and both first walking legs in Table 17.2

4. After you are finished measuring the mechanical advantages of the crab appendages, you will dissect the rest of the crab following the instructions in the Arthropod lab handout.

[1]The mechanical advantage values you calculate give no direct information on strength of force. However, a fair assumption is that mechanical advantage represents a "trade-off" between distance and force. Thus, the system is strong but slow when the value is larger. Conversely, a lower value suggests a system designed for quick but weak movements.

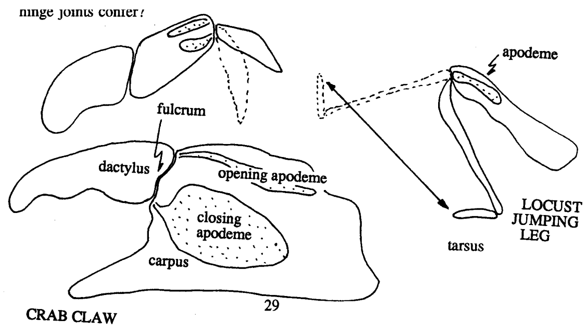

Figure 17.2: Crab claw and insect walking leg showing apodeme placement and tip movement.

Table 17.2: Mechanical advantages of the chelae and walking legs.

Appendage	Side	Mechanical Advantage
Chelae	L	
	R	
Walking leg	L	
	R	

Suggested readings

Brown, S.C., S.R. Cassuto, and R.W. Loos. (1979) Biomechanics of chelipeds in some decapod crustaceans. J. Zool. 188:143-159.

Elner, R.W. and A. Campbell. (1981) Force, function and mechanical advantage in the chelae of the American lobster *Homarus americanus* (Decapoda: Crustacea). J. Zool., Lond. 193: 269-286.

Hughes, R.N. and R.W. Elner. (1979) Tactics of a predator, *Carcinus maenas*, and morphological responses of the prey, *Nucella lapillus*. J. Anim. Ecol. 48: 65-78.

Vermeij, G.J. (1977) Patterns in crab claw size: the geography of crushing. System. Zool. 26:138-151.

Warner, G.F. and A.R. Jones. (1976) Leverage and muscle type in crab chelae (Crustacea: Brachyura) J. Zool., Lond. 180:57-68.

Watanabe, J.M. (1983) Anti-predator defenses of three kelp forest gastropods: contrasting adaptations of closely related prey species. J. Exp. Mar. Biol. Ecol. 71: 257-270.

17.3 Laboratory Report

For your laboratory report, you need to include the following.

- Two metrics to test whether gastropod shells differ between habitats (i.e dot and no-dot populations). You can either compare the populations using T-tests or you can regress various measurements against length and compare the regressions using ANCOVA.
- Compare the output force (i.e. the force generated by the dactylus closing) and the

input force (i.e. the force the muscle exerts on the flexor apodeme).

- Compare two crab appendages to test whether those appendages differ in their mechanical advantage. For example, you could compare the right and left chelae to see if the claws are monomorphic (the same size) or dimorphic (different sizes, as they are in lobsters). You could also compare the chelae to the walking legs and infer some difference in function.
- Relate these measurements with data on the relationship between shell thickness and the force required to crack a shell. I will provide you with these data.

All data will be posted on our course web site. Using these data, you will test for differences with a t-test (see below). You must come up with a biological question and use these data to address that question. Please remember that patterns in the data are as important as whether the differences are significant. Please think carefully about your question and whether data support or refute your hypotheses. Think critically!

There a re tips for writing scientific papers posted on the course web site. I highly suggest you pay close attention to these instructions as you write your paper.

Please come and see me during office hours or make an appointment if you have any questions.

17.4 T-test

1. You can use Excel or another stats program to perform t-tests on your selected data. To use Excel go to Tools then Data Analysis. If you don't see Data Analysis then click on Add-Ins and select the Analysis toolpacks (there are two I think so just select both). Alternatively, you can just paste your data into the last worksheet on the Excel workbook with the data. Those who took Biometrics with Ben will of course want to use R.
2. Remember that all statistical tests make assumptions about the data. For a T-test the assumptions are that the data come from a normally distributed population, and that the variances are equal between the two groups. Make sure to consider these assumptions when preforming your analyses.