Consensus and Contention: A Review of Topics

**Week 1: Spatial and Temporal scale of environmental variation**

**Discussion Questions:**

1. Are marine systems more or less variable than terrestrial?

**LSU:**

Variability is complex. Open ocean minimal variability coastal systems have high variability (related to latitude and depth), but perhaps not as high as terrestrial

Open ocean << coastal ocean << terrestrial

**Hal-Dames Rule:**

Water is natural buffer, so environmental variation should be greater in terrestrial systems especially at small temporal or spatial scales. Differences likely become smaller at larger spatial scales as environmental variation increase and approaches amount of variation present in terrestrial systems.

**MSC:**

Open ocean is temporally less variable than terrestrial, but coastal/intertidal systems could be as variable or more variable than terrestrial. Spatial variation is less clear because open ocean can be highly variable in light, temperature, etc. across depths and many species (zoop up to whales) will experience this variation daily. Predictability of variation is likely higher in ocean with exception of intertidal/estuarine. Would’ve like to see more data in the Steele et al. paper.

**NEU**:

Intuition is that marine systems are more variable, so surprised by Steele’s argument based on temperature data. Marine systems are more variable given stochastic ocean currents, upwelling, offshore advection, and possibly pathogens. Intertidal should be more variable given it is subject to stressors of both marine and terrestrial environments and can vary across small spatial scales. Steele downplayed the overlap in adaptive strategies (long life, many offspring, colonial vs. social systems) between marine and terrestrial species.

**UGA/UNH**:

Many exceptions to Steele’s generalizations that they focused on specific systems to make sense of it. It is a novel idea to consider marine life history diversity as the rule, not the exception, and terrestrial environments trying to survive a much more surprising environment. Conclusion of Steele is backward from argument, as marine organisms more likely to respond with differential population expansion/contraction to changing conditions, while possibly terrestrial organisms more likely to respond with plasticity.

**WSU:**

Oceans are more variable in a greater number of conditions (oxygen availability, salinity, pH, light attenuation, substrate stability, etc.) that are not considered when comparing marine and terrestrial systems. Usually these comparisons are biased toward temperature. Therefore, there may be more opportunities for selection/local adaptation/phenotypic plasticity to act in the marine environment that are under appreciated.

**USC:**

Over shorter time scales, terrestrial systems are more variable, but as you increase in scale, the two systems become closer in frequency and variance of environmental change. Land is less predictable and ocean systems are more predictable, but there are many marine systems that are not predictable. Perhaps a better focus is not variability but predictability of system. Oceans are more predictable. Mobility should be considered as strategy for animals to decouple from environmental variability. More sessile marine organisms have to rely on physiological means to deal with environmental changes that occur. Factors other than environmental variability could have strong impacts on reproductive systems that develop on land (no terrestrial equivalent to marine currents so different dispersal methods evolved to respond to different environment challenge, not necessarily the variability).

**RU:**

Agree that marine systems are generally “red noise” systems with variability occurring at longer time scales while terrestrial systems were generally more “white noise”. This is especially evident with thermal variability with marine species typically able to tolerate smaller range of temperatures than terrestrial species (with exception of intertidal species). It is difficult to categorize ocean currents as predictable sources of energy usable by dispersing larvae and argue that currents are more stochastic (especially smaller spatial scales) especially when considering the size of species impacted by those currents. Variability in the environment may act as a selective pressure, but at what level of organization does it act? Individual or higher? Not convinced that trees evolved longer lives as bet hedging strategy to spread out reproductive events and lessen chances of reproducing during bad period. If terrestrial systems are white noise systems, would the environment change quickly enough that organisms wouldn’t have to survive for very long to move past a bad period and into a period more suitable for offspring survival? Perhaps might be a better strategy to capitalize on good conditions when they occur. Also concerned with focus on invertebrate nesting as a way to mitigate environmental change, as eusociality is restricted to hymenoptera and is not dominant strategy.

**FSU:**

Too much variability in the extent of variability within each system to draw broad conclusions about average differences. Differences in the variability and the timescales of variability between habitats and according to species experiencing environment are more informative in studying rapid adaptation. For most examples of terrestrial life history, there are marine examples.

2. How can we link the scale of environmental variability to microgeographic adaptation in the ocean? Could other mechanisms be at play?

**LSU:**

Linking scale of variability is dependent on what variable is being considered. (Example of microgeographic Killifish populations adapting to superfund contamination – Whitehead et al. 2017). Temperature variation more difficult to link but testable in systems like intertidal zones in which selection could occur every generation and remove individuals with low tolerance to increased temp or desiccation.

**Hal-Dames Rule:**

Micro adaptation is likely prevalent and sometimes mistaken for phenotypic plasticity. Prevalence may depend on amount of environmental variability which also varies according to scale (temporal, spatial, organizational).

When are micro-adaptations vs. plasticity a better strategy? Benefit of each could depend on amount of variation experienced during lifetime of organism. To address this, could scale variation by lifetime to compare organisms with different life spans. Amount of variation depends on characteristics of habitat and species. Variation experienced by organism should conform to the variation of the environment if organism cannot move and is physiological conformer. Hypothesize that plastic phenotypes are more common when an organism moves relatively less but habitat varies on a temporal scale, while micro-adaptations are more common when organism moves less but habitat varies on spatial scale. Increases in mobility will increase plasticity relative to micro adaptations. If sea changes to become more variable through time, expect species with higher movement and higher capacity for plasticity to be more successful.

**MSC:**

The most critical thing in this context is environmental variability relative to dispersal and gene flow. Some mechanisms that promote or reinforce microgeographic divergence have little to do with environmental variation. Papers were disconnected because one focused on spatial variation while the other focused on temporal variation. Question claim in Steele et al. that dispersal and recruitment are predictable in marine environments.

**NEU**:

Better data is needed to fully understand scale of environmental variability from perspective of organism experiencing it. Most understanding of variability comes from ice cores, SST from buoys, nearshore data collected by individuals. Hard to determine microgeographic variation for many species due to logistical difficulty. Symbioses could be a mechanism that promotes microgeographic adaptation (e.g. if new coral symbiont allows coral to survive in different habitat, genotype could accumulate advantageous mutations over time).

**UGA/UNH**:

Recognition of scale (population, dispersal, symmetry, time, traits, genomic basis) needs to be more explicit in studies. Some suggest that “population” is a sloppy word to use in evolutionary science. Focused on examples of microhabitat variation in marine intertidal systems (Littorina saxitilis (low dispersal, strong environmental influence on shell shape and genetic composition) vs. Semibalanus balanoides (high dispersal, high environment-mediated mortality of microhabitat, no overall divergence of types). Need to think about scales important for abiotic and for the biotic (range, dispersal, abiotic variation) to be precise with contrasts.

**WSU:**

We need a way to know what phenotypic differences are relevant in order to address what scales of environmental variability are important to look at when addressing adaptation. We cannot link them until we know how and when and where selection is acting. If selection is acting upon one life stage or stress response, other environmental variability is irrelevant. The criteria to address this question vary depending on research bias. Richardson paper accentuated the point that all potential adaptations must be evaluated under common garden conditions and across multiple generations otherwise maternal effects may be playing large role.

Richardson paper sparked conversation about how to differentiate between phenotypic plasticity and micro adaptation and in which situations either of these would be advantageous. A dimensionless gradient metric between the two could be built using specific measurements outlined in Box 4 of the paper, and how this could help compare species that are dissimilar in life history strategy and scale of variation they are exposed to.

**USC:**

Marine dispersal kernels can be large, so does this mean microgeographic scales can be massive? Directed dispersal would incorporate environmental variability (i.e., habitat selection) at certain spatial scales. Is microgeographic variation based on genetic differences or trait differences? As long as you achieve the trait with optimum fitness, then is that considered micrographic adaptation or would there have to be distinct genetic differences (how do you define local adaptation?). Environmental variability would have to be on a scale smaller than the dispersal neighborhood in order to create the steep differential selection gradients needed for microgeographic adaptation (and these scales could be quite large in marine environments). Micro may be a misleading term given the dispersal range of many marine species, but adaptation is still evident over small spatial scales in marine systems even though range of gene flow is large. Does this mean that selection is increased in marine environments to produce this differentiation across smaller scales despite the high potential for gene flow? Other mechanisms at play include predation, sexual selection, genotypic variation, and habitat selection which were all mentioned in the paper.

**RU:**

Defining microgeographic adaptation in terms of dispersal ability is useful in creating a standard for comparing across systems, but the spatial scale of environmental variation may impact the likelihood/degree to which microgeographic adaptation may occur. Organisms in a heterogenous environment at small spatial scales may be more likely to experience microgeographic adaptation than those that inhabit more homogenous environments given equal dispersal ability. Organisms with high dispersal ability (like pelagic larval organisms) may encounter more varied environment as they can travel larger distances (but alternatively have more gene flow across these same distances). Landscape barriers may be less likely to play a role in local adaptation in the ocean, although currents, canyons, etc. likely reduce gene flow. Finally, mechanisms like frequency-dependent and spatially dependent selection might promote spatially balanced polymorphism and standing genetic variation of adaptive significance.

**Discussion Points (Gathered by Molly)**

Temporal vs. spatial variation – are they the same?

Variation in terms of predictability – what is the driver, the amplitude of variability or the stochasticity of it?

Is there difference in plasticity vs. adaptation in marine vs. terrestrial?

What governs how selection is perceived: Is one strength of selection always going to produce the same fitness decline across marine/terrestrial and across scales and phenotypes? What might govern how selection is received