Week 5: Dispersal

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| 18 groups | 76+ participants |

**Summary:** Groups discussed dispersal based on papers by Pringle and Wares (2009, *Marine Ecology Progress Series*) and Connolly et al. 2001 (*Ecology*)

**1. How might pelagic life histories with asymmetrical dispersal, coupled with genetic correlations between larvae and adult traits, constrain or promote adaptation?**

**RU:**

* Pelagic larvae constrain evolution. Things that enable adaptation increase the ratio of local to migrant settlers.
* Shorter pelagic duration could help or other larval behaviors that improve retention, especially if those are correlated with traits that promote adult fitness.
* Increased “pelagicity” would constrain ability to adapt by opening population.

**LSU:**

* Constrain: if there is a trait that is beneficial as larva but harmful as adult, would constrain adaptation.
* Promote: if there is trait correlated to success in both larval and adult.
* Difficult question – larval stage is where selection may be most important, but this stage is also hardest to research.

**NEU:**

* Easy to understand how adaptation may be promoted/constrained by genetic correlations between traits across stages, across different optima across stages, across traits adapting to different environments.
* Adding asymmetrical dispersal makes it difficult to predict.
* Important result – if allele is favored downstream (but not upstream), gene flow can swamp out this allele entirely unless there is barrier to larval transport.
* Huge implications for inferring adaptation from landscape genomic data, as clines may be established because of barriers to gene flow rather than an area where an allele is actually favored.
* Interesting how reproductive success can vary through space only due to variation in effective population size (good vs. bad habitat) and transport (migration).
* Results more broadly applicable to wind pollinated conifers, as wind can be asymmetric.

**WSU:**

* Depends on relative strength of selection in each life stage. Not as simple as beneficial vs. harmful in direct correlations.
* Relative strength of selection between life stages important, and distinction between trait that is expressed in one stage but affects all vs. distinct traits expressed in multiple life stages that have same function.
* Bet hedging is adaptive and can’t make simple connections between high fitness juvenile and adult phenotypes (and genotypes)
* Specific habitats may promote strong connections between life stages, but manifestation in that specific habitat complicates generalizable patterns.

**Hal-Dames:**

* If dispersal created unidirectional gene flow, cline will be transient unless differences are reinforced by selective pressure. (similar to polygenic traits from last week).
* Potentially redundant alleles could temporarily create a locally adapted genotype, but eventually be swamped out by high gene flow from up-current.
* If studies use pop genomics to identify local adaptation, researchers could detect false positives if transient differences are result of asymmetric dispersal in absence of selective pressure.
* Impact of isolation by distance would be difficult to distinguish from local adaptation using genetics alone. Should couple with experiments that connect genotypes to habitat-specific fitness.

**NoCal:**

* Likely to be other factors than upwelling that affect larval community composition.
* Any type of directional force moves genes in one direction- alleles adapted to upstream will be put downstream, leading to source-sink dynamics. Allelic diversity downstream is product of mutation and immigration
* In upstream population, allele frequencies will change like in population with symmetrical dispersal.
* In downstream populations, density dependence limits growth rates and takes a very large selection coefficient to maintain a new allele. Ultimately, this will constrain evolution.
* Another consequence of asymmetrical dispersal is that phenotypes will experience several different environments during different life stages. If there are genetic correlations between larval and adult traits, this can lead to phenotype-environment mismatches.
* Will differential gene expression of same genes in different environments/life stages a mechanism to counteract this disconnection
* RCN should focus on whole life stage view of evolution
* In the absence of quantitative genetics approaches, the heritability of allele frequency changes observed are unclear.

**MIT/Woods Hole:**

* Positive selection for a linked trait among life stages would promote local adaptation, especially in pops with high degree of self-recruitment via forces that limit the delivery and settlement of immigrants or promote retention of local genotypes.
* Coordination in direction of selection upon a trait may shift along species range. When coupled with asymmetrical dispersal, this could have interesting outcomes for establishment and maintenance of genetic differentiation.
* Difficult to assess though.

**FSU:**

* Asymmetric dispersal could lead to areas of the coast where post-settlement environments differ, but where migration > selection and where selected alleles cannot persist and avoid being washed out.
* Genetic correlations between larval and adult traits constrain adaptation when they cause reduced genetic variation along the axis that selection occurs.
* Could in theory, lead to areas of the coast where post-settlement environments differ but selection has removed the larval genotypes that would do best there as adults.

**UTA:**

* Adaptation might be constrained due to two life body plans in one genome. Beneficial traits to larvae may not be good for adults and vice versa but depends on environment.
* Asymmetrical dispersion could lead to rapid extinction of rescue depending on environmental factors.
* Strong selection means adaptation will be forced in one direction. In these cases, shorter larval life spans and production of more offspring would be more favorable to local adaptation.

**MSC:**

* Always returning to basics – tension between gene flow and selection, and how any oceanographic process or life history characteristic that shifts the balance will act to prevent or promote adaptation.
* Strong asymmetrical dispersal will constrain downstream adaptation by dragging allele frequencies away from downstream optimum – which can cause reduced reproductive output and render habitat a sink
* Any genetic correlations between adult and larval traits that would make the incoming larvae less fit in the downstream habitat would reduce their impact on the receiving population. Realized gene flow would be less than predicted based on oceanographic connectivity and dispersal potential.

**Katherine Silliman:**

* Interesting how clines can also arise due to other processes. Any interruption to gene flow (disruptions in larval transport, habitat availability).
* Clines may also shift downstream if mechanism maintaining them is removed. So cline may not be where it was originally described. Could mess with methods.
* Given sea level rise and even last ice age – possible that clines are moving or have moved from their origin.
* Should consider these factors as we consider adaptation in the future.
* Importance of regional variation in habitat quality/disruption of dispersal/larval retention on the strength of selection required for maintenance of adaptive divergence, should consider how these factors will change in the future and how that will alter our predictions for adaptation.

**USC Cee lab:**

* Asymmetrical dispersal would constrain adaptation to downstream but may yet still see adaptation due to constant influx of individuals from upstream.
* Locally adapted adults may produce larvae that are swept away from parental habitat and not larvae will not be adapted to environment it recruits to.
* This would reduce fitness and prevent successful gene flow/migration or depending on the number of larvae immigrating, generate a less adapted population.
* Genetic correlations could constrain or promote adaptation depending on the relationship of that correlation. For example, traits that are beneficial as larvae but not as adults will improve recruitment but hamper later life history stages.

**UCSB:**

* If asymmetric dispersal is causing one population to receive more propagules from the other it could reduce genetic diversity of the source relative to the sink.
* Whether or not asymmetrical dispersal can widen gaps in adaptive potential between populations may depend on a genetic correlation between stages, type and intensity of selective pressures across life history stages, and probability that larvae will experience selective pressures that exist in habitats within dispersal range.
* If there is poor genetic correlation between larvae and adults,, positive selection on larvae could mean that surviving larvae may not improve mean fitness if new population experiences same selection.
* Mating vs. spawning events could have effect on genetic diversity within larval cohort. More partners means more genetic diversity.

**Virtual Group:**

* Selection in the same direction on different stages amplifies selection, but if selection is in opposite directions at various stages, they can cancel each other out
* Selection can be very inefficient with traits on different stages, but depends on strength of selection. If they are opposite, never going to reach peaks at any stage.
* Maybe you can persist where you aren’t most favored, you can do it because larval stage is more favored increasing the spread of favorable allele.
* Could be differences between free and directed dispersal. More probable that different traits are selected in larvae and adults for free-living larval stage and they can have different feeding requirements but can that give more opportunity to persist at different habitats, why this happens so often for marine organisms?
* How about outcome if have two adult populations on two different selective habitats, and larvae only coming from one. Selection for larvae happens only in one habitat but selection on adults happens in both. Possible swamp out?

**CSU Monterey:**

* If adaptive alleles keep getting washed down stream, there may be selection for mechanisms that retain larvae like swimming or lecithorophic life histories, brooding, or shorter pelagic durations.
* Stronger current, the stronger the selection to keep adapted individuals close.
* Should see higher proportion of species with retention mechanisms in vicinity of boundary currents, but do not know if this is true.

**CSUN:**

* If there is strong connectivity between adult and larval populations, expect strong correlation between adult and larval traits, and less of an ability to adapt.
* High connectivity and high allele frequencies constrain local adaptation. Asymmetrical dispersal may promote adaptation. Larvae that come in waves with different genotypes could promote gene swamping thus leading to more adaptation potential over time.

**Cornell:**

* Multivariate breeders equation is good example of how evolution and adaptation in different stages can either be constrained or promoted.
* Dispersal period between the two stages and gauntlet that larvae experience can further complicate things.
* Where there is asymmetric dispersal due to, say advective current, simply having selective advantage is not enough to promote adaptation. Recruits must settle, survive, and reproduce. Selection coefficient alone is not enough to predict.
* How to detect adaptation in such systems? Focus on within-cohort patterns at different stages or with multiple populations at multiple loci over time.
* Under a linear model, also wondered what the implciations for adaptation were for the upstream source populations, assuming they are in marginal habitat.

**ODU:**

* When asymmetrical dispersal occur, there is a possibility of having a source sink type structure where crowding occurs downstream. In this situation, local adaptation is promoted but for migrating alleles, it might be more of a challenge to survive and adapt locally.
* Dispersal increases gene flow, but alleles of migrants migh be maladaptive locally possibly reducing their fitness and constraining adaptation for these alleles.

**UQ:**

* Oceanographic processes like upwelling can dictate where larvae settle. Distribution of alleles is further fine-tuned by a number of abiotic and biotic variables. Genetic clines are maintained if selection for downstream alleles is strong or variance in oceanographic processes is high, such that local recruitment is encouraged and outweighs L\_adv downstream.
* Balancing act between the strength of selection and environmental stochasticity also depends on other factors that modulate larval dispersal like currents and time of pelagic stage.
* These parameters are likely to be species specific, so can we expect to see consistency in where genetic structure forms and persists when different species are compared? Should carefully consider both oceanographic processes and larval behaviors that maximize Ldiff.

**2. When and where do we expect population genetic structure to be generated and/or maintained?**

**RU:**

* Tension between selection and dispersal, open and closed populations.
* Components that maintain differentiation are selection and environmental heterogeneity.
* If selection strong enough, downstream allele with fitness advantage could create genetic cline. Or a neutral allele could be maintained if there is some barrier. Either way, increased retention relative to immigration makes for a more closed population, enabling persistence.
* Real world probably in middle: traits with small selective advantage able to persist in the face of immigration because of environmental heterogeneity that increases larval retention.
* As barriers to dispersal decrease, strength of selection would need to increase, and this would be modulated by life history traits like pelagic duration, fecundity, agency of larvae, etc.

**LSU:**

* 3 criteria: 1. Gradient in selection for downstream allele, 2. Sufficient selection downstream of the cline to retain the downstream allele against advection, 3. Insufficient selection upstream of the cline to prevent the cline from moving upstream.
* May also be affected by habitat quality. If upstream is better quality, may prevent from moving upstream but could swamp out cline.

**NEU:**

* Need better understand the heterogeneous landscape of selection relative to migration across seascapes, the mean and stdev of dispersal distance, variation in effective population size, variation in habitat quality, and nature and strength of selection.
* Connelly paper saw strong patterns which highlights important role of competition when recruitment is high.

**WSU:**

* When there are barriers to dispersal and/or strong selection AND the phenotype is result of specific genotype.

**Hal-Dames:**

* Population structure depends on both pre and post recruitment barriers. Longer pelagic larval duration and more prominent headlands contribute to pre-recruitment barriers, local adaptation and historic effects (e.g. limited space availability) contribute to post-recruitment barriers.
* Distinctions are helpful if population mixing is constrained to one part of the life cycle
* Ability to adapt could be a trait that is under selection (plasticity vs. fixed traits)

**NoCal:**

* Pringle and Wares paper shows the effect of population dynamics on the retention of alleles, and one can discover how to define populations (demes) in a coastal system, id source/sink populations, and show how these populations are related to ocean circulation that drives dispersal.
* What is population (deme)? Can we label regions of relatively uniform allele frequency as a population? Any novel allelic diversity that arises will be swept downstream by currents and will not contribute to evolution of allelic diversity upstream.
* Including spatial structure of habitat and circulation will help define population genetic patterns.

**MIT/Woods Hole:**

* Genetic structure would be promoted by strong differential fitness across species range, especially when coupled with discontinuities in connectivity and/or heterogeneity in habitat quality.
* Very relevant given Connolly paper, interesting to compare with genetic studies.
* Differences in upwelling probably play some role, but wondered how differences in adult abundance between OR and CA may be responsible for differences in recruitment. Mention that magnitude of difference in recruitment vs. density is greater, but its possible its non-linear (possibly quadratic)
* Because difference in recruitment was mostly just across Cape Blanco and not gradual latitudinal pattern, could be any number of biogeographical differences that contribute to the observed difference in recruitment.

**FSU:**

* Important part of paper not only showing how alleles that are favored can persist without being washed out, but how asymmetric dispersal can keep an allele from being common in many places where it is selectively favored.
* Structure still generated by migration-selection balance, but in continuous space, oceanographic features may cause the break/cline to form in places not predicted by divergent selection or environmental differences.
* Could mean results from reciprocal transplant experiments might differ depending on where within the downstream region individuals were sampled and transplanted.

**UTA:**

* For genetic structure to be generated, there must be strong selection downstream relative to upstream or restricted gene flow from downstream to upstream.
* As selective pressures and dispersal types vary across a large range for species, can expect genetic structure to be generated.

**MSC:**

* Pringle and Wares demonstrates importance of barriers to gene flow – expect structure adjacent to such barriers.
* Interesting that geographical feature maintaining genetic cline may not be necessarily what generated it.
* Could be genetic cline that slides down coastline until they “catch” at a spot where the demography/geography shifts the gene flow/selection balance.
* Spent time on Fig. 7, could use reciprocal transplant to see GxE as source effect.

**USC Cee lab:**

* Should see genetic structure maintained when there is change in selection across dispersal range. Produce individuals more suited to local environment and thus local adaptation.
* Similar to last week’s discussion of local/microgeographic adaptation where selection must be large enough to outweigh gene flow.
* For asymmetrical dispersal, a break in larval dispersal would generate differentiation either by selection or drift between upstream and downstream populations.
* Where selection is not unidirectional, you would expect to see population genetic structure based on reduced gene flow such as with dispersal in Connolly paper.

**Virtual Group:**

* Connolly paper was purely ecological – patterns may look like selection but are actually due to dispersal currents.
* What is role of species evolutionary history/geologic history?
* Historic gene flow due to sea level leads to enough divergence to prevent mixing when oceanographic/sea level would permit.
* Secondary contact vs. selection patterns.
* Need to collaborate more with physical oceanographers, connect them to genetic people.

**CSU Monterey:**

* Absence of genetic structure does not necessarily indicate a high level of gene flow. Even in simple allopatric scenario, Fst will be 0 in 33% of replicates.
* Genetecists should take greater notice of coastal boundary layers that may decrease U and L\_adv while increasing L\_diff. Paper only discusses when L\_adv is greater than L\_diff, but opposite could be true, meaning dispersal against boundary current should not only be possible but perhaps common. Would lower threshold for selection to maintain cline or allow absence of habitat to more readily create structure.

**CSUN:**

* Expect it when there is some sort of gradient in abiotic or biotic conditions. These tend to be maintained when alleles are not swamped.
* In certain areas, larvae have larger impact on adult populations via influx of beneficial alleles.

**Cornell:**

* Structure could exist from simply neutral stochastic patterns and or from a spatial gradient in habitat selection.
* In terms of the Connolly paper, north and south seemed to have different selection pressures (space, recruitment, predation) and so there could be genetic structure and adaptive differences.
* Even with a gradient in recruitment along coast, was it truly local recruitment? How many were carried from north via current?
* Plasticity and responsiveness and sensitivity to environmental conditions/cues can lead to adjustments and fine tuning of the timing of recruitment. Predictability of such events would facilitate a response.

**ODU:**

* Genetic structure is expected to be generated in areas with barriers to gene flow. When and where depends on duration of barrier.
* Oceanographic events can both restrict and promote gene flow. Some of these have seasonal differences which can cause variation in gene flow depending on a species’ life history.

**UQ:**

* Strong links between larvae and adult phenotypes can influence the strength of selection required for structuring and adapting marine population with strong asymmetric dispersal.
* Selection against settling larvae manifests through habitat availability and competition, which does not capture selection acting on adult phenotypes and reproductive success.
* Given that strength and direction of selection can vary between life stages, question whether alleles favored in downstream environments at settlement would also be favored in adults if larval experiences in the plankton impose strong evolutionary constraints on adult populations.
* Knowing about such tradeoffs is central for understanding how selection operates across life cycles.