Faculty Profile: Dr. Michael A. McCartney

Molecular ecology and evolution of marine invertebrates and fishes

UNCW

RESEARCH

The evolution of gamete incompatibility Animal sperm often fail to fertilize, or fertilize less efficiently, eggs from a different species when combined *in vitro*. This "gamete incompatibility" was noticed over a century ago by developmental biologists. Nowadays, we know that sperm-egg incompatibility can evolve rapidly, so it may serve an important role in marine species formation and form a strong barrier to hybridization. We also know that the proteins that control sperm-egg compatibility (*gamete recognition proteins)* evolve under strong natural selection that promotes change in their amino acid sequences. In organisms from unicellular algae to bivalves to mammals, these and other reproductive proteins show more rapid, selection-driven evolution than the average protein expressed elsewhere. Marine invertebrates offer the advantage of linking molecular evolution to *in vitro* gamete assays to help biologists understand why reproductive proteins evolve so rapidly.

My past work used sea urchin species split by closure of the Isthmus of Panamá about 3 million years ago to examine the evolution of gamete incompatibility. The sperm protein **bindin** allows sea urchin sperm to adhere to and to fertilize eggs (Fig. 1), and our work showed that bindin evolves rapidly under selection. But this occurs only in the sea urchin species in the Caribbean that has highly incompatible eggs, not in the two species in which eggs have evolved a mild block, or no block to fertilization by sperm of other species (Fig. 2). This suggests that molecules in eggs and sperm are caught up in "cat and mouse" game that may help explain their often unusually rapid pace of evolution.

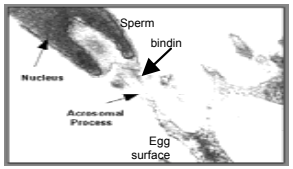

Figure 1. Photomicrograph of sea urchin sperm/egg binding, mediated by the sperm protein bindin.

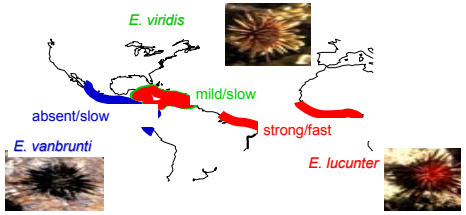

Fig. 2. Geographic distribution and egg incompatibility/rate of sperm bindin evolution in Neotropical species of the sea urchin *Echinometra.*

Our current work at UNCW involves hybridizing blue mussels in the genus *Mytilus.* Collaborators in Maine and graduate student **Christin Slaughter** have demonstrated a strong block to fertilization between the two species *Mytilus edulis* and *M. trossulus*, which overlap and often hybridize within the Gulf of Maine and along the coast of the Canadian Maritimes (Fig. 3). Our current work examines between-species selection against hybridization. We have been contrasting the degree of gamete incompatibility of *M. edulis* females collected inside and outside of the hybrid zone. If selection against hybridization is strong, we should find that females inside the zone should be less compatible than females from allopatric populations outside the zone, but so far, we have found no evidence of this. Our future work is designed to examine sperm competition and polyspermy, two of the within-species forces that have been implicated in the evolution of gamete incompatibility.

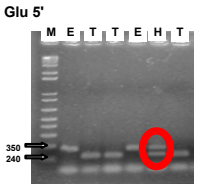

Figure 3. Left panel shows Cobscook Bay, Maine, and typical interstitial habitat for mussels (inset). Right panel shows how *Mytilus edulis* (**E**) and *M. trossulus* (**T**) and their common hybrids (**H**) are typed in our lab using codominant nuclear DNA markers. The agarose gel shown here shows PCR products of the *Glu-5'* locus, which codes for a byssal thread protein. Photos by Christin Slaughter.

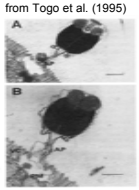

Figure 4. We study sperm-egg incompatibility, which in these mussels may be due to the failure of sperm lysin to dissolve the egg vitelline coat (VC).

Molecular ecology of incipient speciation in the sea Model systems in which speciation is incipient or "in progress" have led both empirical and theoretical advances in animal speciation research, but nearly all of these are terrestrial or freshwater organisms. Our work in marine incipient speciation has centered on two species complexes in the western Atlantic. The first is a species flock of small colorful reef fishes known as hamlets, genus *Hypoplectrus* (Fig. 5). This consists of about a dozen morphs that are morphologically identical except for strikingly distinct color patterns. The color morphs (described as species) coexist broadly. Large Caribbean reefs often contain 5 or 6 species that occupy the same habitats during the daytime, but in the evening, they pair up to spawn, like with like. Our behavioral work in the Florida Keys has confirmed that strong assortative mating occurs there as well. Studies of mitochondrial and microsatellite DNA, and of Amplified Fragment Length Polymorphism (AFLP) makers, in our lab with graduate student **Felipe Baretto** show this species flock to be very young and in the process of differentiating. Our second system is the Caribbean *Montastraea* coral species complex (Fig. 6), in which we have been performing DNA sequence analysis of an AFLP locus, and microsatellite genotyping to examine the porous species boundaries in this, the most ecologically dominant genus of reef building corals in the western Atlantic.

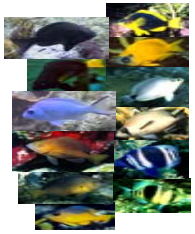

Figure 5. The hamlets, a coral reef fish species flock that is the subject of continuing molecular and behavioral studies. Photos: P. Humann, M. McCartney.

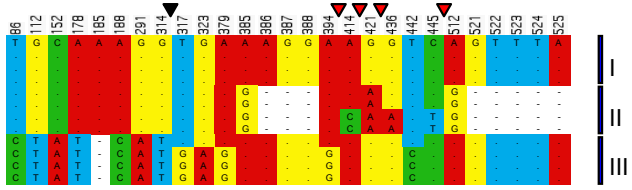

Figure 6. The three species in the *Montastraea annularis* species complex (left) are partially differentiable using our DNA sequence markers, which also detect likely past events of hybridization (above, arrows).

Conservation genetics We also have applied projects in conservation genetics. We have been studying the unusual biota of Lake Waccamaw, a freshwater Carolina Bay in SE North Carolina. Our first project was funded by US Fish and Wildlife, and was a DNA-based study of species status of an endemic fish, the Waccamaw darter (below, left). Now graduate student **Kristi Sommer, Dr. Ami Wilbur** and I are developing non-lethal genetic identification methods for freshwater mussels in the lake (below, center) and in adjacent river systems. This work is funded by the NC Dept. of Transportation. Finally, we are also funded by the National Marine Fisheries Service for a microsatellite DNA analysis of mutton snapper populations (below, right), with special focus on the spawning aggregations in the newly created Dry Tortugas Ecological Reserve. Graduate student **Katie Shulzitski** and NMFS biologist **Mike Burton** are collaborators on this last project.

PROFESSIONAL BACKGROUND AND APPOINTMENTS

Dr. McCartney received his Ph.D in Ecology and Evolution from the State University of New York at Stony Brook in 1994, his M.S. in Environmental Sciences from Case Western Reserve University in 1988, and his B.S. in Biological Science from Florida State University in 1981.

He served as a Postdoctoral Research Associate at Florida State University, a Postdoctoral Research Fellow at the University of California, Davis, and as a NSF/Sloan Molecular Evolution Postdoctoral Fellow at the Smithsonian Tropical Research Institute in Panamá and at the Scripps Institute of Oceanography.

Dr. McCartney has been an Assistant Professor in the Department of Biological Sciences and Center for Marine Science at UNCW since January 2000.

STUDENTS

M.S. *Graduates:* Ning Zhang (now at Tufts Univ.), Amy Pogge (now at National Center for Toxicological Research), Felipe Barreto (Ph.D. student, Univ. of GA); *Current* : Katie Shulzitski, Christin Slaughter, Kristi Sommer.

Honors Biology *Graduates:* L. Montoya, M. Meadows, A. Germane, and R. Melton; *current:* A. Barber

COURSES

BIO 206, Animal Biology
BIO 430, Evolutionary Biology
BIO 466, Conservation Biology
BIO 539, Molecular Ecology

CONTACT

Office:126 Friday Hall and 2328 CMS (X2391)
Lab: 2313 CNS (X2390)
Email: mccartneym@uncw.edu