KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-FIFTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2012
Amherst College, Amherst, MA

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Keck Geology Consortium: Projects 2011-2012
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Research Advisor: Jon Woodruff

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ANTHROPOGENIC IMPACTS AND ENVIRONMENTAL CHANGES RECORDED IN THE IN THE DEPOSITIONAL HISTORY OF THE LOWER CONNECTICUT RIVER

SUZANNE OCONNELL, Wesleyan University

INTRODUCTION: CONNECTICUT RIVER

The Connecticut River (Figs. 1A-C) is the longest river in New England, extending almost 700 km (410 miles) from the Quebec border at an elevation of 814 m (2,670 ft.) to Long Island Sound (LIS) at sea level. Its Abenaki name, Quinnetukut, means long tidal river. The word Connecticut is a transliteration of the Abenaki name. This River drains an area of 2.9 x 10^4 km^2 (7.2 x106 acre, 1.1 x 10^4 mi^2) of urban, rural, and wild land, delivering 70% of the fresh water that enters LIS. The lower 58 km (36 miles), south of Middletown, CT and extending to LIS is the least disturbed tideland area of any large river in the Northeast. This important tideland area was recognized by both the Nature Conservancy (1993) and the Ramsar Convention (1994) as a tideland of international significance. In 1998, President Clinton designated the Connecticut (CT) River as one of 14 American Heritage Rivers because of its historic and cultural significance to the nation.

Beginning in 1991, parts of the rural watershed in all four states through which it flows (Vermont, New Hampshire, Massachusetts and Connecticut) were designated the Silvio O. Conte National Fish and Wildlife Refuge. This was the first watershed-wide refuge of its kind in the country. The refuge was established to conserve the abundance and diversity of native plants and animals and their habitats. Bald eagles (*Haliaeetus leucocephalus*), and peregrine falcons (*Falco peregrinus*) are found throughout the watershed. Osprey (*Pandion haliaetus*) are abundant along the river in Connecticut and a few have been reported in Massachusetts. It is home to federally threatened and endangered species of birds, fish, insects, and plants. Twelve species of freshwater mussels have been identified. The dwarf wedgemussel (*Alasmidonta heterodon*) is a federally endangered species. Eight of the other species are listed as either threatened, endangered, or of special concern in one or more states.

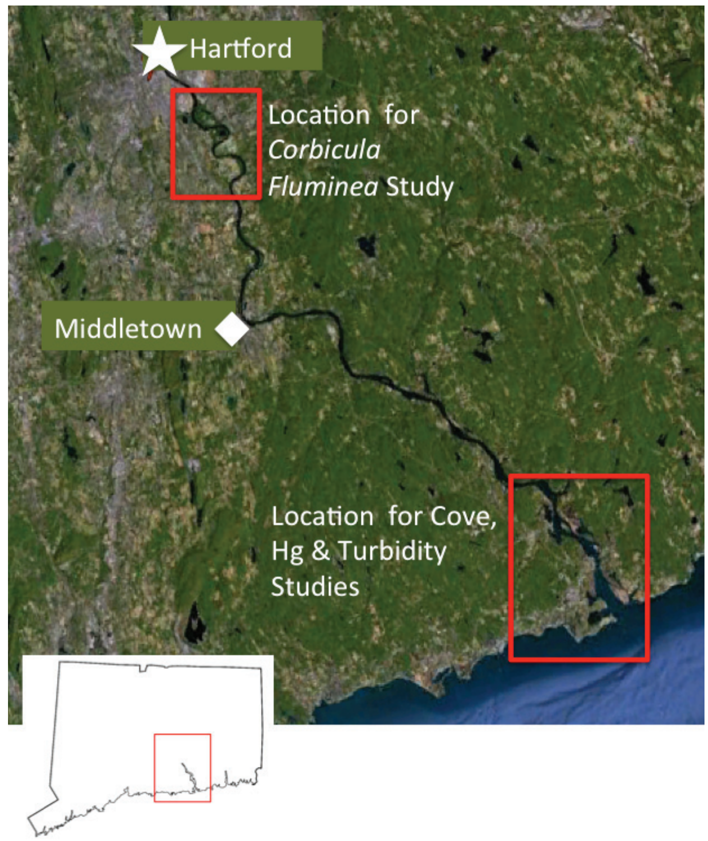

Figure 1A. Location map for Connecticut River studies describe in this volume, modified from Google Earth.

Human habitation first occurred here over 10,000 years ago when Paleo-Indians arrived from the west after the ice retreated. Adrien Block, the first European to sail up the CT River, got as far as Hartford in 1614. He described many Native Americans living along the shoreline. Hartford, CT, the oldest city was settled in 1635 and Springfield, MA the following year. Former glacial lakes underlie the area between Middletown, CT and the northern Massachusetts border. Unlike most of the rest of New England, this rich, fine-grained silt and clay, provided excellent flat farmland and fields, as reflected in the names of the

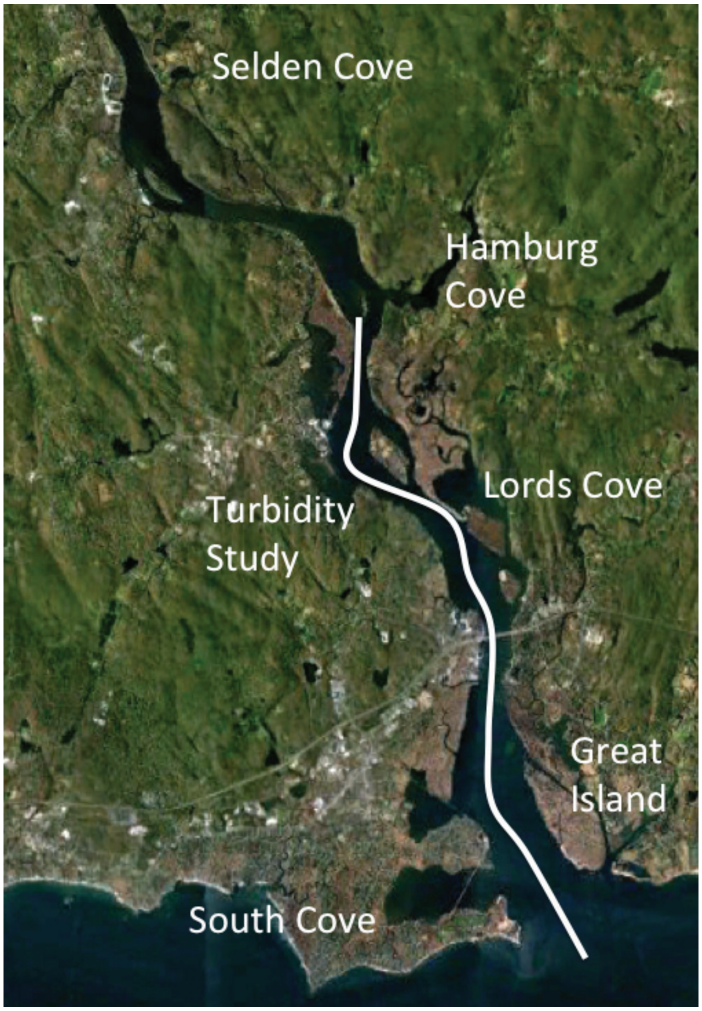

Figure 1B. Expanded map of lower Connecticut River study area shown in Figure 1A. The white line shows the location of Cuttler's suspended sediment/turbidity survey.

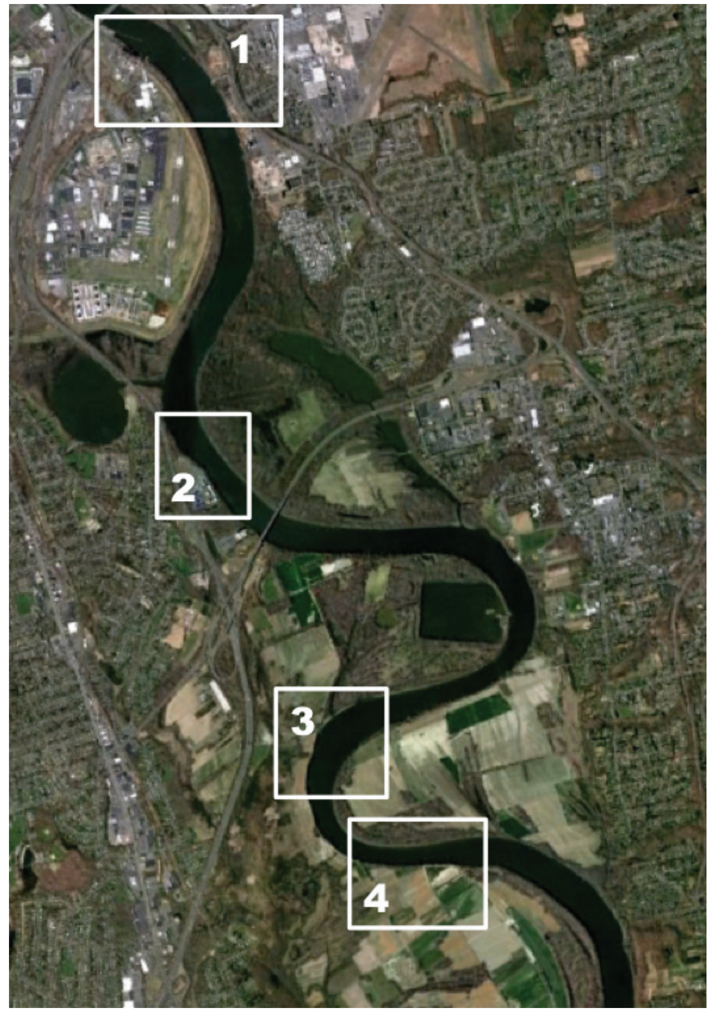

Figure 1C. Location of bedforms in Martin study.

towns e.g. Wethersfield, Enfield, Suffield, Springfield, Deerfield, and Northfield. It was a rich agricultural area during colonial times through the early nineteenth century. (All facts in this section are taken from the Connecticut River Watershed Council.)

PROJECT OVERVIEW

Six different investigations were conducted during summer 2011 and the following academic year. The lower CT River is a tidal river from just north of Hartford to LIS. It has a gradient of < 1 %. South of Middletown, CT, many small coves connect the River with adjacent land. These coves record the natural and anthropogenic history of the area (Fig. 1B).

Dams were an important source of manufacturing power throughout New England. Over 1000 dams are located along the tributaries to the Connecticut River and over a dozen are placed along the main stem. Accompanying the manufacturing power was industrial waste and the rivers were the waste repositories. Following Varekamp et al. (2003), we use the sharp increase in mercury to mark 1850 in our cores.
Four projects investigated the depositional history of tidal ponds and adjacent areas along the lower CT River. These show different depositional histories, with highly variable sedimentation rates (0.5 cm/yr. to 4 cm/yr.) and amounts of mercury pollution. A fifth project documented and modeled the location and movement of the estuarine turbidity maximum zone at the salt-water wedge at the confluence of the Connecticut River freshwater and Long Island Sound saltwater. This is a zone of high sediment resuspension and deposition. Understanding the processes will aid in the identification of areas where contaminants are

Figure 2. Participants in the Connecticut River 2011-2012 project. From left to right Suzanne OConnell (with dog, Bridie), Michael Cuttler, Jonathan Schneyer, Hannah Blatchford, Tirzah Abbott, Danielle Martin, Peter Patton, and Elizabeth George.

Figure 3. Tirzah Abbott and Hannah Blatchford recording information at the mouth of the Connecticut River.

concentrated. A sixth project (Fig. 1C) documented the abundance and size of *Corbicula fluminea*, greater than 0.063 microns, in the sandwaves of the Glastonbury Meanders, located between Hartford and Middletown, CT.

INDIVIDUAL PROJECTS

Tirzah Abbott, Figure 3, (Beloit College) examined the diatom assemblages from Selden Cove to see if the high levels of mercury influenced them. Jacobacci, (2011) estimates that about 16 kg of mercury is accumulated in the pond. Abbott sampled core SDC6 at 30 cm intervals between 0 and 210 cm and identified 140 different species. She selected six taxa for close examination. Three taxa, Achnanthidium minutissiumum, Achnanthidium sp, and Nitzschia, are considered to be tolerant to pollution and three that were sensitive to pollution, Encyonema, Tabellaria, Cymbella. The abundance was low for all three sensitive species.

In cores collected in Selden Cove during field season 2010, Jacobacci (2011) found that the elevated intervals of mercury began at about 180 cm. This would have provided two samples (180 and 210 cm) prior to mercury pollution. Unfortunately in SDC6, mercury increased from <100 ppb to >1400 ppb between about 240 and 200 cm depth (1850) (Schneyer, this volume Fig. 2A). Thus no mercury-free samples were analyzed. Not surprising, there was no statistically significant correlation between taxa and mercury pollution. However one of the tolerant taxa, Nitzschia, showed a negative, but not statistically significant decrease. Another tolerant species, A. minutissiumum, increased in abundance at about 1850, but this may be due to an additional fluvial complication. Around 1854 a new channel formed between the River and the Cove, and this may also have influenced the diatom assemblage.

Hannah Blatchford, Figure 3, (Beloit College) examined Carbon/Nitrogen (C/N)ratios of cores from Selden Cove, Lord Cove and South Cove (Fig. 1B). C/N ratios vary with the source of organic matter. Terrestrial plants generally have ratios above 20 and aquatic plants ratios below 10. This analysis could indicate changes in the sources of organic matter. For example, in Selden Cove, was terrestrial organic matter more abundant prior to industrialization? Is organic matter near coarse layers, indicative of downslope movement on the steep hills surrounding the cove bringing terrestrial sediment, or more aquatic vegetation associated extensive washover and even new channel incision. Lord Cove and South Cove by comparison, are located in a relatively flat lying area and are unlikely to be influenced by downslope movement. South Cove, close to the mouth of the River, might be expected to show a change in organic source area as sea level rises and the size of the pond expanded. Blatchford also examined the $\delta^{13}C$ isotopes for samples from Selden and South Coves. $\delta^{13}C$ isotopes indicate a freshwater or marine source. Temperate marine vegetation have $\delta^{13}C$ values of, -18 ‰ to

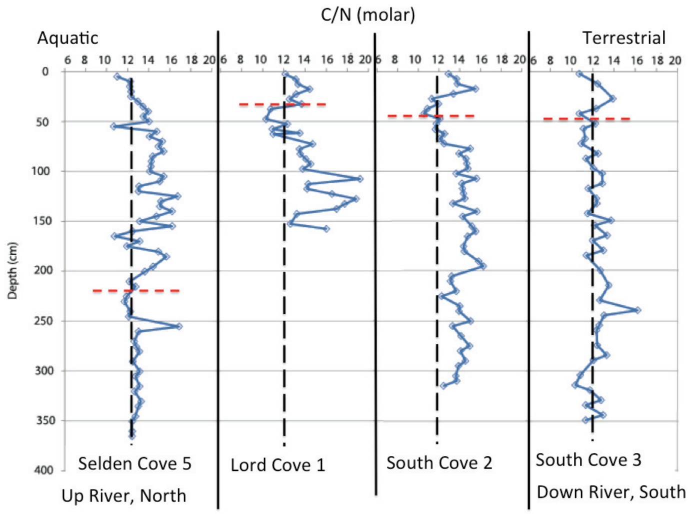

Figure 4. C/N ratios for four cores from Selden Cove, Lord Cove and South Cove. The horizontal dashed line is equal to 1850, based on elevated mercury levels.

Figure 5. Jonathan Schneyer taking a core.

- 24 ‰ while temperate freshwater plant values are lower Unfortunately the turn around time for these analyses is over two months, so we didn't have the opportunity to refine the study with additional stable isotopic analyses.

C/N analyses for cores from the three coves (Fig. 4) show a mixing of aquatic and terrestrial sources. All show a recent trend towards a higher component of aquatic sources and an earlier interval that was more dominated by terrestrial sources. Unfortunately, using the increased mercury signal to date 1850, the increased aquatic source occurs at different times. Combining the C/N and $\delta^{13}C$ data, Blatchford shows a clear distinction between the dominantly freshwater Selden Cove and the mixed water entering South Cove.

Jonathan Schneyer, Figure 5, (University of Massachusetts) focused on depositional patterns and rates using mercury levels in sediment cores. Previous work (Woodruff and Martini,, 2012) had shown high concentrations of mercury and high sedimentation rates in tidal coves. This was attributed to tidal pumping, where tides bring sediment into a cove or tidal pond two times/day and thus generating a high sedimentation rate. In contrast, sedimentation rates on Great Island above the tidal range were much lower

Hamburg Cove, between Great Island and Selden Cove (Fig. 1B) is deeper and larger than Selden Cove. However, sediment influx is controlled by a narrow (~200 m wide), shallow channel connecting the Cove to the River. Mercury levels that almost reach 3000 ppb at 240 cm (Schneyer, Figure 2) and remain high throughout the lower core. However, in the upper, more recent part of the core, Mercury levels decrease steadily above 130 cm. Thus sedimentation rates vary from < 0.4 cm/yr. on Great Island to > 2 cm/yr. in Hamburg Cove. The focus of Schneyer's investigation is identifying the causes of the different sedimentation rates as well as the differences in mercury concentration.

Elizabeth George, Figure 7, (Washington and Lee University) examined the diatom assemblages in a three-meter long core from South Cove (SCC1/2). This Cove is the largest, shallowest and closest to Long Island Sound. Her study focused on environmental changes of salinity, nutrients and temperature. Mercury measurements suggest that 1850 lies at approximately 30 cm in SCC1/2 and 45 cm in SCC3 and reach levels of 630 and 700 ppb respectively (Fig. 6), yielding a sedimentation rate of about 0.25 cm/year. A ^{14}C ago of 2330 +/- 30 BP at 122.5 cm, suggests an even slower 0.05 cm/yr., sedimentation rate and extrapolates to a bottom age of approximately 5700 years.

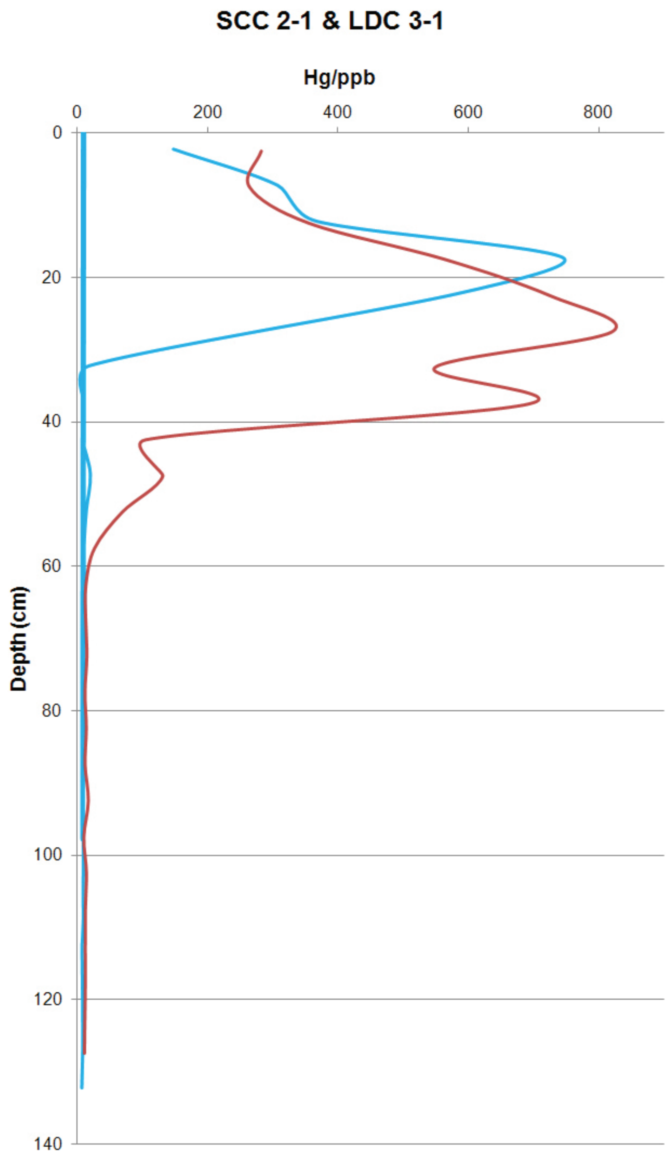

Figure 6. Mercury values for South Cove Core (SCC) 1and 2 and Lord Cove Core (LDC). (This figure is referred to as "Martin this Volume" in George study because Martin made the measurements).

Environmental information derived from diatom assemblages indicate relatively continuous brackish water (George, Figure 2). It thus appears that the sedimentation rate was approximately the same as sea-level rise and the cove has had a relatively constant depth. The biggest assemblage change occurs between 82.5 cm and 122.5 cm. Extrapolating from the mercury age this could reflect the influence of European visitation and settlement, which began in the early seventeenth century. Extrapolating from the ^{14}C age, this interval lies between about 440 AD and 330 BC and thus has no European influence.

Figure 7. Elizabeth George cutting a core.

Possibly the most important environmental feature recorded by these species is temperature. Warmer species are found at the top and bottom of the core, with cooler species in between. The wide sampling interval, in conjunction with the slow sedimentation rate make it impossible to correlate these changes with known temperature changes, e.g. the Little Ice Age, the Neoglacial period, mid-Holocene warm interval. However the length of this core suggests that detailed analysis could shed light on temperature change in the lower Connecticut River Valley and adjacent LIS.

Michael Cutler, Figure 8, (Boston College) investigated the presence, location and movement of the turbidity-maximum (TM) during four different tidal cycles (white line in Fig. 1B). Discharge during the study ranged from 852 m3/s (3.0 x 10^4 ft^3/s) to 334 m^3/s (1.2 x 10^4 ft^3/s) at Thompsonville (only CT location where CT River discharge is gaged) and was generally above the 86-year average for the river (Fig. 9). Stratified conditions were observed on the higher discharge days (June 16 and June 27) and partially-mixed conditions were observed on the lower discharge days (June 21 and July 6).

Figure 8. Michael Cuttler pulling stuck anchor and creating turbidity.

The TM is a common feature in partially mixed estuaries. It generally marks the landward extent of the salt wedge, but can also form in other areas where there are strong longitudinal-density gradients. In the lower Connecticut River these formed at Turbidity maximum also formed between 2-3 and 4-6 km up (north) the estuary (Cuttler, Figs. 2-4). These areas of high estuarine suspended-sediment concentration (SSC) are areas of active deposition and resuspension and are locations where contaminants, such as heavy metals may collect.

Daniele Martin, Figure 10, (Wesleyan University) investigated the abundance and size of *Corbicula fluminea*, a rapidly reproducing invasive, freshwater clam, also referred to as the Asian Clam, golden clam or good luck clam. It is a surface dwelling or slightly

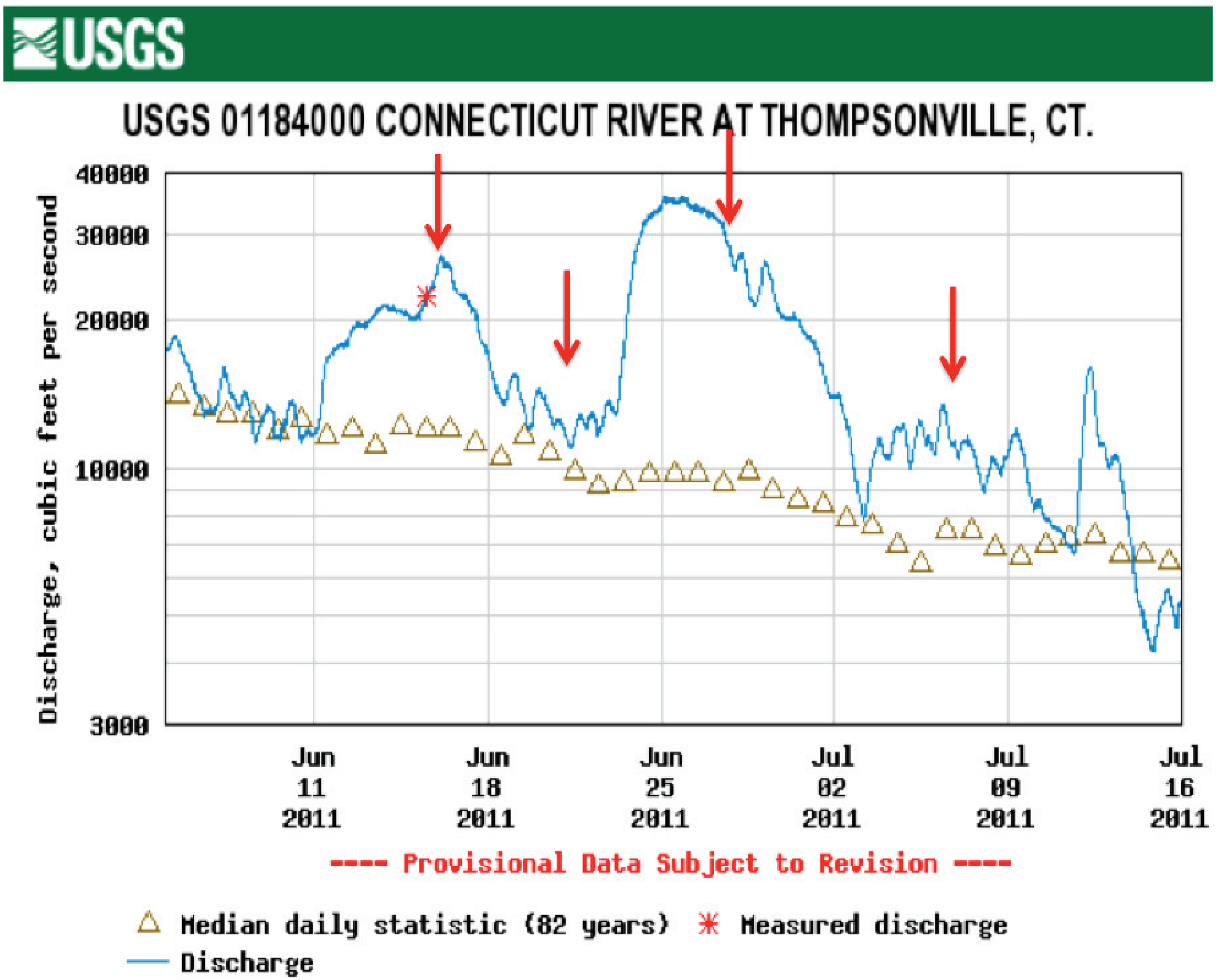

Figure 9. CT River discharge showing discharge for study period, discharge averaged over 86 years, and sampling days for Cuttler study (USGS).

Figure 10. Danielle Martin bagging a grab sample from the lower CT River.

buried filter feeder with a life span of one to seven years. An economic and ecological pest, it causes extensive biofouling, in power plant and industrial water systems, irrigation canals and pipes, and drinking water supplies. It also alters benthic substrates and competes with native species for limited resources (Foster et al., 2012). In Lake George, New York, an eradication effort, deploying hundreds of 50 ft. x 7.5 ft. PVC mats is being employed to smother and eliminate *Corbicula fluminea* (Lake George). Prior to Martin's study there were only two reported occurrences in the Connecticut River, across from the Haddam Neck Nuclear Power Plant (now decommissioned) in 1990 and South of Essex in 1999. Both siting's considered them established. Our siting, roughly 40 km (23 miles) north of Haddam Neck has been reported to the Nonindigenous Aquatic Species Database.

The objective of this study was to test the hypothesis that the clams would preferentially accumulate on the sots side of sand waves because bottom water flowing up the stoss side would provide abundant nutrients for these filter feeders and the substrate would be stable. No preferential location was found, but Bedform 2 had the highest abundance overall. Troughs had the highest abundance, suggesting a stable environment might be the most important criteria. However, photographs taken by the SCUBA divers who collected the samples showed aquatic vegetation and abundant organic matter in the trough of Bedform 2, so nutrient abundance is also important.

CONCLUSION

All students participated in the collection and description of cores and grad samples, and the turbidity and salinity data. The variety of projects allowed students to purse research of interest to them and their research advisors, and allowed all of them to see some of the variety of tools that are used to study estuarine and riverine systems.

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