Update on Coastal Marsh Dieback
Prepared for GA DNR – Coastal Resources Division

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Overview

Salt marsh dieback continues to be an issue of interest on the coast of Georgia. We are still recovering from the widespread event of 2001-2002, and new dieback areas were reported this past year (2007). Below we provide the following: a) a description of the 2001-2002 event, b) a summary of the various research activities that are underway to address the issue, c) a brief description of the current dieback event, and d) a list of recent newspaper articles on the subject. More information on marsh dieback can be found on the GCRC website: http://www.gcrc.uga.edu/FocusAreas/marsh_dieback.htm

Characteristics of Dieback in Georgia (2001-2002)

The following is a list of characteristics of the Georgia dieback event. This list (and the accompanying figures) is excerpted from a talk that was presented at the 2007 biennial conference of the Estuarine Research Federation (Alber et al. 2007). The complete presentation can be found at: http://www.gcrc.uga.edu/MarshDieback/marsh_meetings.htm

1. Occurred coastwide – Dieback was reported in all coastal Georgia counties in 2001 and 2002, with approximately 40 sites and almost 2000 acres affected. Most sites were in the northern part of the state (Chatham County), although all coastal counties were affected. Dieback was also observed in South Carolina during the same time period.

2. Affected different parts of the marsh – At affected sites, dieback occurred along the creekbank, in the middle of the marsh, near the upland edge, or throughout the marsh. This contrasts with dieback in other states, where it was often confined to only one area (i.e. the creekbank). The variety of dieback patterns makes it difficult to come up with a single explanation for the event.

3. Affected both cordgrass (*Spartina alterniflora*) and needlerush (*Juncus roemerianus*) – Although *Spartina* was the primary plant affected, there were several sites where both *Spartina* and *Juncus* died back, and others where dieback affected a *Juncus* marsh. This contrasts with other states, where only different species of *Spartina* (*S. alterniflora*, *S. patens*) were commonly affected.

4. Rapid onset (1-2 growing seasons) – There is both photographic and direct evidence that some of the affected areas showed a rapid onset of dieback. In a few cases, the vegetation was noticeably thinned before it turned into a rhizome stubble (Fig.1). However, not all of the dieback areas were new. Aerial photographs reveal that some of the sites reported in 2001-2 were present in previous years (although they may have increased in extent during this event). For example, whereas the sites on Sapelo Island were not observed in photographs from 1999 (Fig. 2), those on Ossabaw Island appear in photographs from both 1999 and 1993 (Fig. 3).

5. Not persistent – Evidence from field transplants conducted in 2003 demonstrated that plants could flourish in the dieback areas (Ogburn and Alber, 2006). The fact that many of the areas are showing signs of recovery (Figs. 4, 5), albeit some more slowly than others, also suggests that there was no permanent damage to the marsh. See summary of monitoring data, below, for more details.

6. No obvious cause – Most of the suggested causes of dieback can be ruled out for the Georgia event. In other cases there is simply not enough evidence to either accept or rule out a potential cause.
    a. Seasonal removal processes, such as wrack damage, were not observed in conjunction with most of the 2001/2002 sites.
    b. Subsidence/Sea level rise has been documented as a cause of dieback in some areas. Louisiana, for example, has documented salt marsh loss in conjunction with subsidence. This is unlikely to have occurred in Georgia because it would have been expected to act more uniformly, and affected areas would not have been expected to recover.
    c. Point source pollution (such as a pesticide) was ruled out primarily because of the widespread distribution of affected sites. The observation that affected areas are now recovering is also circumstantial evidence against a pesticide or other unknown pollutant, unless it was something that was used only temporarily. .
    d. Hydrologic alteration – There are reports in the literature of changes in marshes adjacent to dikes, bridges, and other structures that cause changes in flooding patterns. A survey of 18 dieback sites in 2003 did not observe a consistent link with structures (Ogburn, 2004), and the subsequent recovery of most sites suggests that this was not the case. There were also no observed differences in soil pH or salinity in dieback areas, although an ephemeral change could have been missed because investigators often did not visit the site until several months after the initial event.
    e. Biotic factors – Two biotic causes have been suggested.
        i. Fungal pathogens – Pathogens are often specialized, so the fact that both *Spartina* and *Juncus* were affected by dieback makes it more difficult to support this argument. There were no fungal pathogens isolated in association with affected plants, but this negative result is not conclusive.
        ii. Snail herbivory – Although herbivory by the periwinkle, *Littoraria irrorata*, has been suggested (Silliman et al. 2005), the majority of dieback areas (and the most extensively affected sites) were at inland locations

with low snail densities (Fig. 6). Moreover, there were no observed differences in snail densities between dieback and affected sites. It is possible that snails can expand or even initiate salt marsh dieback when they are in high enough densities, we have never observed the densities reported by Silliman et al. (2005).

7. Associated with drought – The dieback that occurred in 2001-2 was associated with low rainfall and low river inflow. The Palmer Drought Severity Index for the coast was characterized as "extreme drought" (Fig. 7), and several sites were noticeably cracked and desiccated (Fig. 1). Although most investigators agree that drought caused a stress that was probably related to the dieback event, it is unclear what specific characteristics might have been linked to dieback. Investigators in Louisiana reported elevated concentrations of iron and aluminum in dying plants collected from dieback areas and suggested that drought-associated dieback in that state was caused by soil desiccation resulting in periods of low pH and increased bioavailability of toxic metals (McKee et al. 2004). No dying plant tissue was available during the 2001-2 event in Georgia, but Chandra Franklin (Savannah State University) observed particles of metal (possibly iron) clogging xylem tissue in *Spartina* plants and suggested this as a possible mechanism for dieback. Marsh plants were collected in 2007 and are being analyzed for metal concentrations (see below). The fact that both Louisiana and Georgia have observed dieback in association with drought also prompted a larger cross-site evaluation (described below).

Dieback research activities

<u>1. GCRC Monitoring Program</u> (www.gcrc.uga.edu/MarshDieback/marsh_monitoring.htm.)
A series of monitoring sites were set up in 2003. These were sampled quarterly for 2 years, and continue to be sampled annually.

The following sites are being monitored:

Jerico River (Coastal Resources Division, lead = Jan Mackinnon)
Highway 17 (Coastal Resources Division, lead = Jan Mackinnon)
Sapelo Island (Sapelo Island National Estuarine Research Reserve, lead = Dorset Hurley)
Melon Bluff Plantation (University of Georgia, lead = Merryl Alber)
Isle of Wight Road (University of Georgia, lead = Merryl Alber)
Talahi Island (Savannah State University, lead = Carla Curran)

Data are collected on pore water characteristics, plant height and density, and animal abundance, at dieback areas and in nearby control areas. All data are compiled by the Georgia Coastal Research Council. To-date, plant densities have increased at all dieback sites, but at varying rates: at the Jerico River site, densities in dieback areas are actually greater than those in the adjacent healthy areas, whereas those at the Melon Bluff dieback areas are still much lower than in healthy areas (Figs. 4, 5). The monitoring data show no obvious differences in terms of soil salinity, temperature, or organism abundance between healthy and dieback areas.

2. GIS analysis – Doug Atkinson (UGA Marine Extension) is working on a project to map areas of dieback using aerial photographs taken between 2002 and 2003. This project was funded by a Coastal Incentive Grant from CRD. The identification of dieback from photos has proven difficult, as the photos were taken at varying stages of the tide and under different light conditions. To the extent possible, areas identified as dieback are being ground-truthed using low altitude oblique aerial photos that were shot at approximately the same times as the vertical aerial photos. However, in many areas inconsistencies in the original photos make it difficult to evaluate the accuracy of areas identified as dieback. Note that one of the products of this project will be an updated map of dieback areas, with links to available vertical photos. The updated map will be posted on the GCRC website.

3. Salt marsh health and recovery – www.gcrc.uga.edu/Research/frischer_saltmarsh_health.htm
Marc Frischer (Skidaway Institute of Oceanography), Jeffrey King (US Army Corps of Engineers), Carla Curran and Dionne Hoskins (Savannah State University) are working on a project funded by a Coastal Incentive Grant from CRD. The project is evaluating four marsh sites representing a range of marsh health (including dieback and recovered dieback areas). The project is ongoing, but results to-date indicate that 4 variables (porewater concentration of NH4, NO_3/NO_2, PO_4, and the ratio of total bacterial respiration rates to sulfate reduction rates) can be used to evaluate marsh health status. They also suggest that seasonal difference in plant growth during the spring/summer growing season provides a good indicator of marsh health. Development of a quantitative model that includes these different characteristics is ongoing.

4. Comparison of dieback and vegetated marshes -
www.gcrc.uga.edu/Research/EPA_marshes.htm
This is an EPA-funded project that is being conducted by investigators from University of Georgia (M. Alber and S. Joye) in association with those from Louisiana (M. Hester, University of Louisiana Lafayette and I. Mendelssohn, Louisiana State University). The project involves manipulating the density of salt marsh plants and evaluating how different ecological characteristics vary across a gradient from no plants (dieback areas) all the way to normal plant densities. Study sites are set up at Sapelo Island, GA and also in Port Fourchon, LA.

Characteristics being studied at each site include biogeochemical variables (soil physical properties, porewater and solid-phase inventories, sediment metabolism and denitrification, and benthic microalgal production), belowground processes (belowground production, organic matter decomposition), aboveground processes (aboveground cover and productivity, instantaneous net CO_2 assimilation, photosynthetic nutrient-use efficiency), sediment elevation and accretion, and invertebrates responses (infauna and epifauna inventories, predation rates, and food-web analyses).

This project is ongoing, but to-date we have found that abundances of all animals at the Sapelo Island site are higher in vegetated as compared to dieback areas. In October 2006 snail density (*Littoraria irrorata)* averaged 166 ± 47 (SE) m^{-2} in vegetated areas, whereas no snails were found in dieback areas. Fiddler crab density (*Uca* spp.) was approximately triple in vegetated areas versus dieback areas (472 ± 61 m^{-2} and 147 ± 25 m^{-2}, respectively). Preliminary analysis of small organisms (meiofauna) also showed a trend toward more animals in vegetated areas. These results suggest that salt marsh dieback has a strong effect on marsh fauna.

5. Cross-site comparison – Over the past 5-7 years, marsh dieback has been reported in many areas along the east and gulf coasts, including sites in New England (Maine, Massachusetts, Connecticut, Rhode Island), the mid-Atlantic (Delaware, Virginia), the southeast (Georgia, South Carolina) and the gulf (Florida, Louisiana). M. Alber (UGA) is coordinating an effort to compile information on dieback from each of the affected areas and to evaluate similarities and differences across the sites. It is not clear whether salt marsh dieback is truly on the rise, as this may be a case of increased scrutiny/awareness on the part of investigators and the public. Even if there is an increase in dieback, there are enough differences between the events to suggest that they are probably not all related.

Of particular interest for Georgia is an analysis of climate patterns at the various sites. This analysis is ongoing, but the results to-date suggest that drought co-occurred with the observed dieback in Georgia, South Carolina, and Louisiana, but not at the other sites. This may be due to local variability in rainfall that is not captured by weather stations (which may be at some distance from the actual dieback site), or it may be that the dieback in the mid-Atlantic and New England areas can be attributed to other causes. This work is being written up as an invited paper for Estuarine Coastal and Shelf Science.

Current Dieback (2007-2008)

There were new observations of dieback in both Georgia (Fig. 8) and South Carolina (J. Morris, pers. comm.) in 2007, although these were not as widespread as in 2001-2. The fact that we are currently in a drought adds further support to the idea of drought-associated dieback, although large quantities of wrack were also observed and likely affected some areas. It is worth noting that the areas affected in 2007 are not the same as those in 2001-2, which suggests that vulnerability to dieback is not linked to specific topographic features, or perhaps that areas that were affected earlier have now been modified.

J. Mackinnon (CRD) has collected plant tissue from the new dieback areas for metal analysis. These have now been dried and the samples have been submitted to the laboratory of Dr. Samantha Joye (Dept. of Marine Sciences, UGA) for metal analysis. This will allow us to determine whether the metal concentrations in plants affected by dieback are higher than controls, as was observed in Louisiana (McKee et al. 2004). In addition, S. Joye has a Ph.D. student (P. Baas) studying how metal cycling in sediments varies in dieback areas, and whether stressed plants may release organic material that affects these processes. They are paying particular attention to aluminum.

One of the lessons from the first dieback event was the recognition that it is important to be aware of dieback and to document new areas. The fact that there is a coordinated monitoring program already in place gives us valuable baseline information that will allow us to determine whether the ongoing drought is affecting the marshes. In addition, funding has been available for CRD to conduct regular aerial surveys of dieback sites, during which oblique photos are taken at each site. These photos are also useful for tracking changes over time, as well as for verification of mapping efforts. The public is also encouraged to report signs of dieback to DNR and to take regular photographs of the site.

Media Coverage

There continues to be media attention focused on dieback. Over the past two years, the following articles have been written about this issue with information about Georgia:

- Georgia salt marshes healthy for now. The Darien News. January 3, 2008
- Salt marsh still drought-sensitive, Savannah Morning News. November 23, 2007.
- Drought, what drought? Savannah Morning News. October 22, 2007
- Drought attacking marsh grass, The Brunswick News. June 25, 2007.
- Cause sought as marshes turn into barren flats, Boston Globe. July 17, 2006.

References Cited

Alber, M., J. Mackinnon, D. Hurley, and C. Curran. 2007 Salt marsh dieback in Georgia. Talk presented at the Estuarine Research Federation Conference, Providence, RI.

McKee, K.L., I.A. Mendelssohn and M.D. Materne. 2004 Acute salt marsh dieback in the Mississippi River deltaic plain: a drought-induced phenomenon? *Global Ecology and Biogeography* 13:65-79.

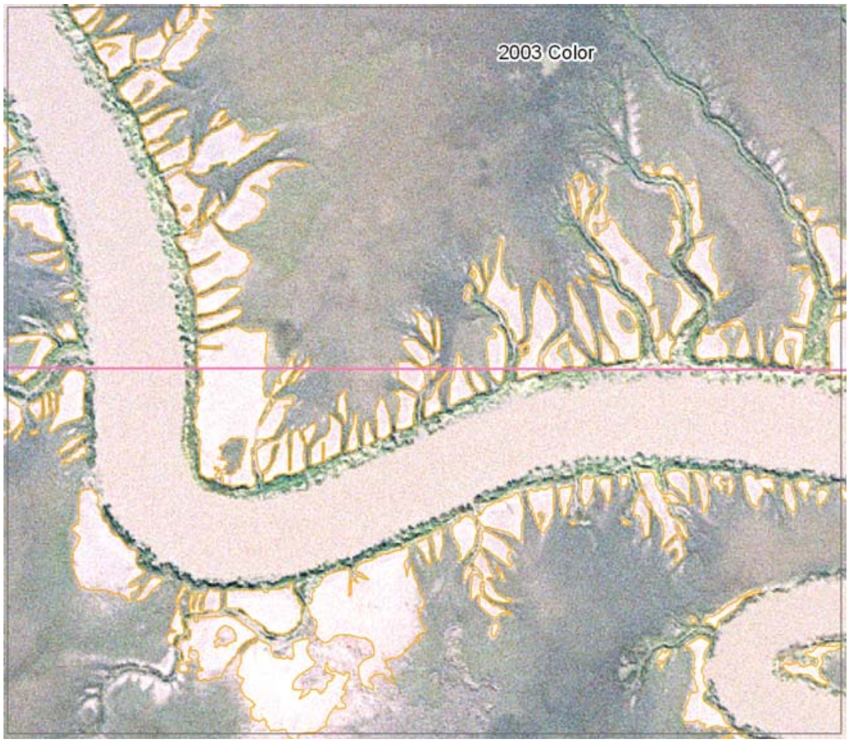
Ogburn, M.B. 2004 Salt Marsh Dieback in Georgia: Field Survey and Transplant Experiments. Master's thesis, The University of Georgia.

Ogburn, M.B., and M. Alber 2006 An investigation of salt marsh dieback in Georgia using field transplants. *Estuaries and Coasts* 29: 54-62.

Silliman, B. R., J. van de Koppel, M. D. Bertness, L. E. Stanton, I. A. Mendelssohn, 2005 Drought, snails, and large-scale die-off of southern U.S. salt marshes. *Science* 310:1803-1806.

Figure 1. Lighthouse Marsh, Sapelo Island Georgia in December 2002. Top: Thinning vegetation is evident, along with rhizome stubble in the foreground. Bottom: Close-up showing evidence of soil desiccation. (Photos courtesy Dale Bishop, UGA Dept. of Marine Sciences).

Figure 2. Aerial photographs of Sapelo Island in 2003 (top) and 1999 (bottom). Areas of dieback in 2003 (white areas outlined in orange) are also outlined in a 1999 photo, but dieback areas are not in evidence in 1999. (Photos, GIS analysis by Doug Atkinson, UGA Marine Extension Service).



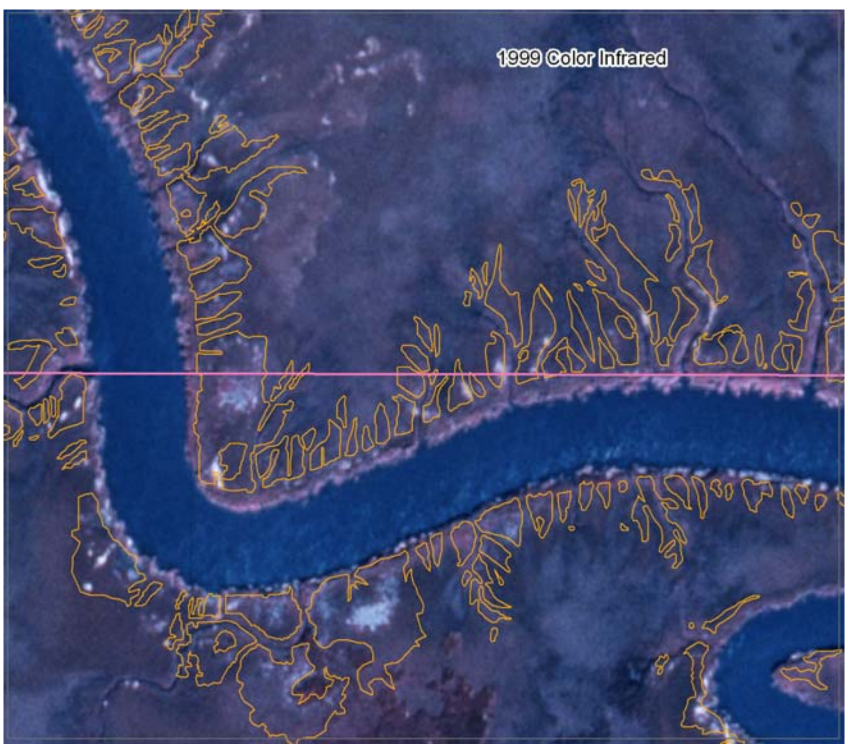


Figure 3. Aerial photographs of Ossabaw Island in 2003 (top), 1999 (middle), and 1993 (bottom). Areas of dieback in 2003 (white areas) can also be seen in 1999 and 1993. (Photos, GIS analysis by Doug Atkinson, UGA Marine Extension Service).

Figure 4. Comparison of plant densities over time at four sites being monitored as part of the GCRC monitoring program. Note that *Spartina alterniflora* is being monitored at Sapelo Island, the Jerico River, and Melon Bluff, whereas *Juncus roemerianus* is being monitored at the Isle of Wight. Monitoring of Sapelo Island by the Sapelo Island National Estuarine Research Reserve, of Jerico River by the Coastal Resources Division of GA DNR, and of Melon Bluff and Isle of Wight by the Dept. of Marine Sciences at UGA.

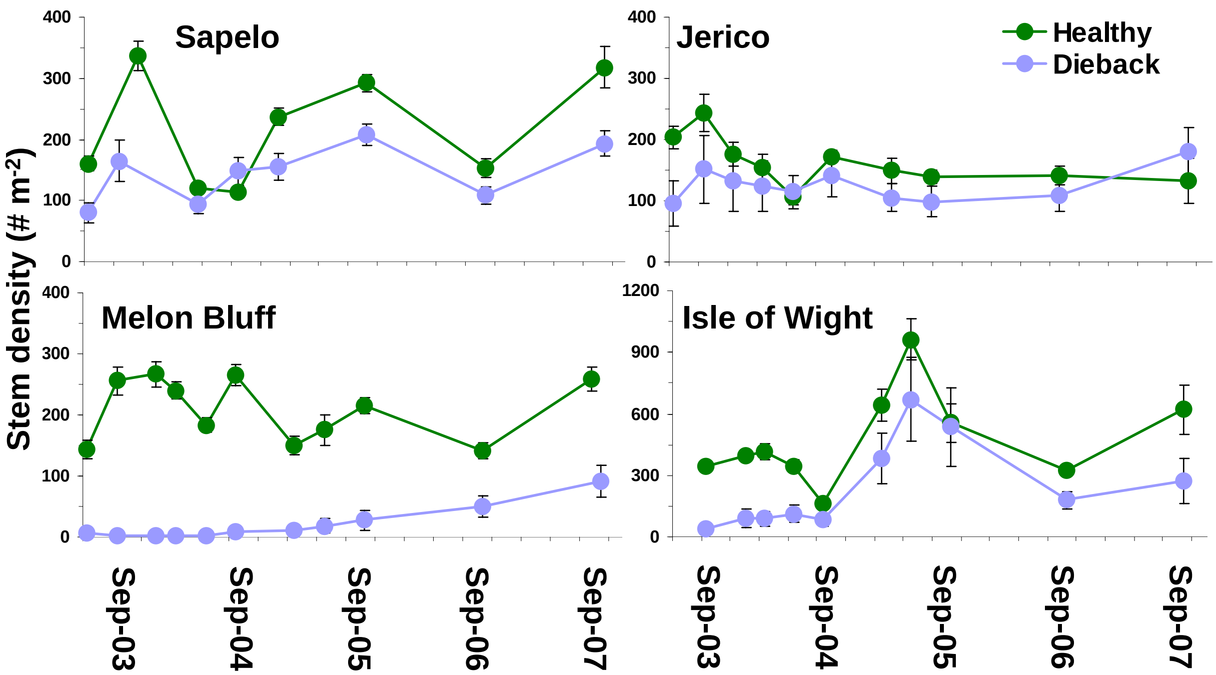


Figure 5. The Jerico River dieback monitoring site in 2004 as compared to 2007. PVC markers for permanent plots are circled in blue; the arrow shows the same site in both images. (Photo by Jan Mackinnon, DNR Coastal Resources Division.)

Figure 6. Map showing dieback location (main map) and snail density (inset). Red circles denote the locations and size classes of dieback areas included in a coastwide survey. Inset shows densities of *L. irrorata* (individuals m^{-2}) measured in June 2002 as part of the Georgia Coastal Ecosystems Long Term Ecological Research monitoring program. Yellow circle areas are proportional to snail densities, ranging from 0 to 657 snails m^{-2} (top right). Bar graph shows snail densities at inland vs. barrier island stations.

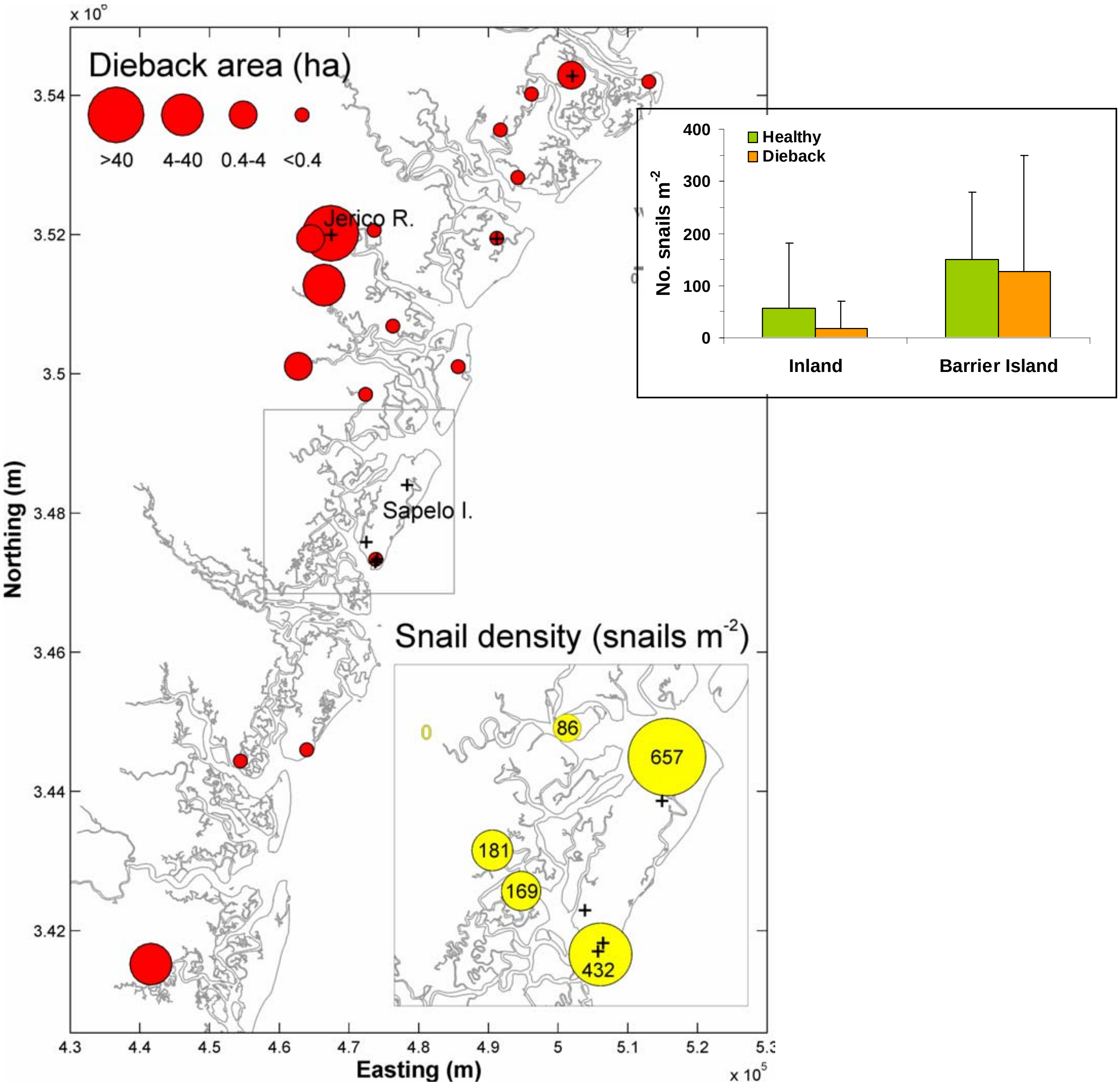


Figure 7. Palmer Drought Severity Index (PDSI) over time for Georgia Climate Division 3, with extreme wet (+4) and extreme drought (-4) noted. Approximate times of dieback observations are depicted as grey bars. Data from National Climate Data Center. (Slide courtesy Erick Swenson, Louisiana State University).

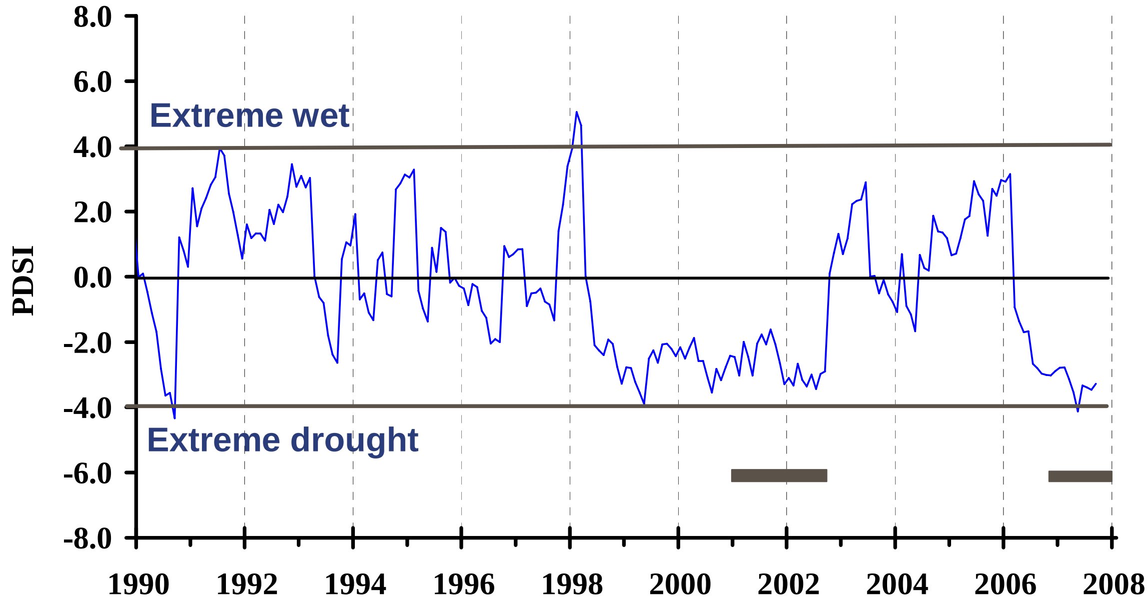


Figure 8. Dieback site, Torras Causeway, Brunswick, August 2007. Top: Thinning vegetation; Bottom: rhizome stubble. (Photos by Peter Baas, UGA Dept. of Marine Sciences)