Published in Coastal Environment and Water Quality (ed. by Y. J. Xu & V. P. Singh), 383-396.

31

ECOLOGICAL CONSEQUENCES OF CHANGING HYDROLOGICAL CONDITIONS IN WETLAND FORESTS OF COASTAL LOUISIANA

Richard F. Keim, Jim L. Chambers, Melinda S. Hughes, J. Andrew Nyman, Craig A. Miller, and J. Blake Amos
School of Renewable Natural Resources, Louisiana State University Agricultural Center
Renewable Natural Resources Building, Baton Rouge, LA 70803, USA

William H. Conner
Department of Forestry and Natural Resources, Baruch Institute of Coastal Ecology & Forest Science, Clemson University P.O. Box 596
Georgetown, SC 29442, USA

John W. Day, Jr.
School of the Coast and Environment, Coastal Ecology Institute, Louisiana State University
Energy Coast and Environment Building,
Baton Rouge, LA 70803, USA

Stephen P. Faulkner
National Wetlands Research Center, USGS
700 Cajundome Blvd., Lafayette, LA 70506, USA

Emile S. Gardiner
Center for Bottomland Hardwoods Research, USDA Forest Service, Southern Hardwoods Laboratory
P.O. Box 227, Stoneville, MS 38776, USA

Sammy L. King
LSU Agricultural Center
School of Renewable Natural Resources
USGS Louisiana Coop. Fish & Wildlife Rsch Unit
Renewable Natural Resources Building
Baton Rouge, LA 70803, USA

Kenneth W. McLeod
Savannah River Ecology Laboratory
University of Georgia
P.O. Drawer E, Aiken, SC 29802, USA

Gary P. Shaffer
Department of Biological Sciences, Southeastern Louisiana University
Meade Hall 107, Hammond, LA 70402, USA

ABSTRACT

Large-scale and localized alterations of processes affecting deltaic coastal wetlands have caused the complete loss of some coastal wetland forests and reduced the productivity and vigor of many areas in coastal Louisiana. This loss and degradation threatens ecosystem functions and the services they provide. This paper summarizes ecological relationships controlled by hydrological processes in coastal wetland forests of the Mississippi River delta and presents two case studies that illustrate the complexity of assessing hydrological control on swamp forest establishment and growth. Productivity of overstory trees has been affected by these changes, but the first case study illustrates that the relationship between flooding and growth may be site-specific. An important effect of increased flooding has been to reduce regeneration of swamp forest trees. The second case study is an outline of the kind of hydrological analysis required to assess probability of regeneration success.

31.1. INTRODUCTION

Wetland hydrology and vegetation are closely linked, and most wetland functions rely on their interaction. However, understanding how hydrology controls wetland ecosystems is often hampered by the complex nature of this interaction and sparse data (NRC, 1995). Interactions between hydrological processes and ecosystems are critically important in coastal wetlands of Louisiana, where extensive hydrological engineering works coincide with globally significant wetlands composed of diverse ecosystems vulnerable to loss by coastal erosion, land subsidence, sea-level rise, and saltwater intrusion (Day et al., 2000). Of these coastal ecosystems, coastal marshes have received the most attention because it is there that land loss is prominent. However, the same processes place coastal wetland forest ecosystems at risk of loss or conversion to other ecosystems (Conner and Brody, 1989; Conner and Toliver, 1990).

Louisiana's coastal wetland forests are of tremendous economic, ecological, cultural, and recreational value. Large-scale and localized alterations of processes affecting coastal wetlands have caused the complete loss of some coastal wetland forests and reduced the productivity and vigor of remaining areas. This loss and degradation threatens ecosystem functions and the services they provide. An example of the societal importance of coastal wetland forests is the commission by the Governor of Louisiana of an *ad hoc* group of scientists, the Coastal Wetland Forest Conservation and Use Science Working Group (SWG), to assess management issues in coastal forests (Chambers et al., 2005). This paper builds upon the results of that collaborative effort.

In the deltaic plain of the Mississippi River, coastal forested swamp wetlands occupy an ecotone topographically below the bottomland hardwoods that occupy natural levees of distributary channels, and topographically above treeless freshwater and saltwater marshes that are at sea level. Of the 800,000 ha of forested wetlands throughout Louisiana, over half are in the coastal parishes (Figure 1). Both swamps and bottomland hardwoods are formally classified as palustrine wetlands in the Cowardin classification of the National Wetlands Inventory (Cowardin et al., 1979), but swamps are flooded for most if not all of the growing season and are dominated by baldcypress, pondcypress and water tupelo (Conner and Buford, 1998). Bottomland hardwoods are seasonally inundated for varying lengths of time and contain as many as 70 commercial tree species depending on the hydroperiod (Hodges, 1997). The SWG concentrated on swamps in the deltaic plain, and referred to them as "coastal wetland forests".

The objectives of this paper are to (1) summarize ecological relationships controlled by hydrological processes in coastal wetland forests of the Mississippi River delta, and (2) compare hydrological regimes of two pairs of typical sites to illustrate the complexity of assessing hydrological control on swamp forest establishment and growth.

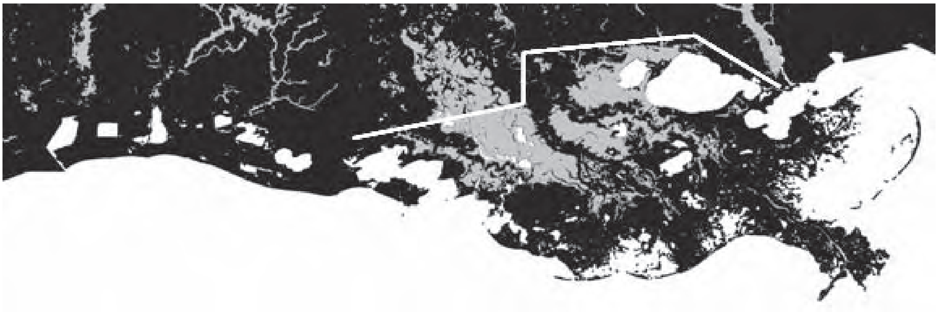

Fig. 1. Wetland forests of the delta of the Mississippi River and coastal Louisiana. The white line indicates the approximate ecological boundary between riverine-dominated forests to the north and deltaic, coastal forests to the south, although deltaic geological processes encompass all of the Atchafalaya Basin.

31.2. HYDROLOGICAL CHANGES

The geological processes controlling the physical development of the Mississippi River delta are aggradational (accumulation of riverine sediment) and degradational (consolidation of freshly deposited sediments). Aggradational processes in the Mississippi River delta have been on balance larger than degradational processes over the past 5,000 years, with the result being seaward growth of the deltaic plain as delta lobes were progressively formed and abandoned (Roberts, 1997; Coleman et al., 1998). Net growth of the delta occurs where the local rate of accretion is greater than consolidation, but subsidence can result in land loss where local additions are less than consolidation rates.

Management of the wetlands and the river has altered the stochastic patterns of sediment accumulation and contributed to subsidence land loss. The foremost cause is the flood-control levees along the Mississippi River that eliminated diffuse riverine input to most of the delta and contributed to wetland loss. Hydrological disruption via control of rivers has reduced freshwater and sediment inputs, while canal construction has led to much greater saltwater intrusion into coastal wetlands (Turner, 1997; Day et al., 2000). Increasing water levels resulting from eustatic sea-level rise and subsidence are also major degradation factors. Without the annual flood of new sediments, subsidence exceeds sedimentation in many areas (Baumann et al., 1984), and most of coastal Louisiana is presently experiencing an apparent water level rise of up to 1 m per century (Gagliano, 1998). Large-scale processes have been exacerbated by management practices and societal infrastructure that have also altered and degraded ecosystems. Local alterations to hydrological patterns include impoundments by highways, railroads, and dredge spoil; river diversions; and water level stabilizations by flood control structures.

Evidence of long-term, slow changes in hydrological processes can be found in water level records maintained by the USGS and US Army Corps of Engineers. For example, subsidence and diversion of Mississippi River water into the Atchafalaya River have combined to raise the average water level in Morgan City, Louisiana, by nearly 1 m from

1936-2004 (Figure 2). These gauge records can be extrapolated to infer historical water levels in wetland forests. Doing this, Conner and Day (1988) found that one swamp forest changed from being flooded about half the year to being flooded nearly continuously in the 1970s. Another swamp forest changed from infrequent inundation to flooding for more than half of the year, and a nearby hardwood ridge became flooded for up to 250 days per year (Figure 3). Since the 1950s, flood water levels in the swamps of the Pontchartrain Basin have doubled (Thomson et al., 2002).

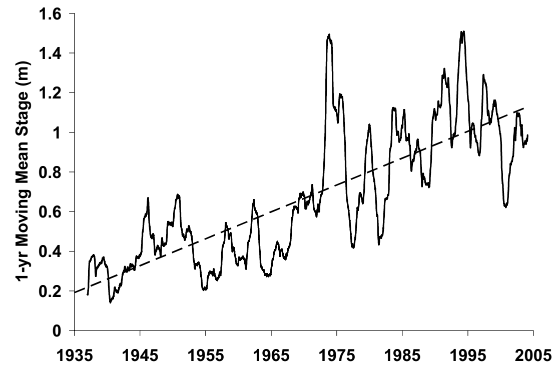

Fig. 2. 365-day moving mean water level on the Atchafalaya River in Morgan City, Louisiana, from 1936-2004. The dashed line is the best-fit 68-year linear trend.

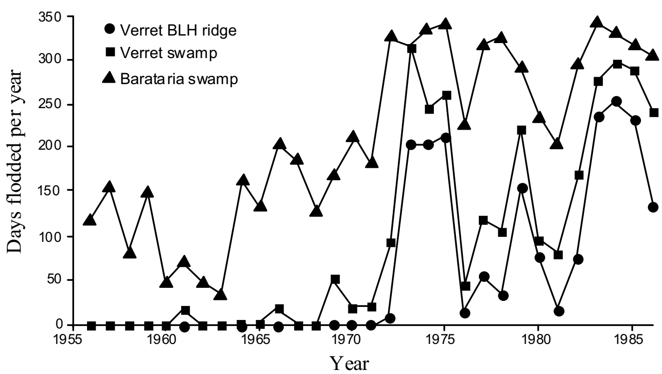

Fig. 3. The number of days flooded per year in the Barataria and Verret swamp forests (Conner and Day, 1988). Reprinted by permission from Allen Press.

31.3. ECOLOGICAL CONSEQUENCES

As water levels continue to rise, coastal forests will be subjected to more prolonged and deeper flood events. Even though many of the forest species growing in these areas are adapted to prolonged inundation (Kozlowski, 1984), extended flooding during the growing season can cause mortality of these tree species. Already, many of the trees in these areas are showing evidence of severe stress (Conner et al., 1981). Even baldcypress and water tupelo, two of the dominant species in Louisiana's coastal forests, slowly die when exposed to prolonged, deep flooding (Harms et al., 1980; Brown, 1981).

Pre-settlement baldcypress–water tupelo swamps in the delta, which may have exceeded 1,000,000 ha in extent, were mostly clearcut from about 1890–1930 and subsequently either converted to agriculture or other land uses or naturally regenerated to second-growth, even-aged stands (Conner and Toliver, 1990). Some data to assess historical growth of these stands comes from the US Forest Service Forest Inventory and Analysis (FIA) program, which has measured tree growth on permanent plots since the 1930s. Total volume of baldcypress in the region has not increased since the 1974 FIA measurement (Figure 4), but diameter of the average-sized tree increased from 22.3 cm in 1974 to 28.1 cm in 2003. The fact that baldcypress trees are continuing to grow in diameter but little additional wood volume is accumulating indicates environmental stresses are causing mortality.

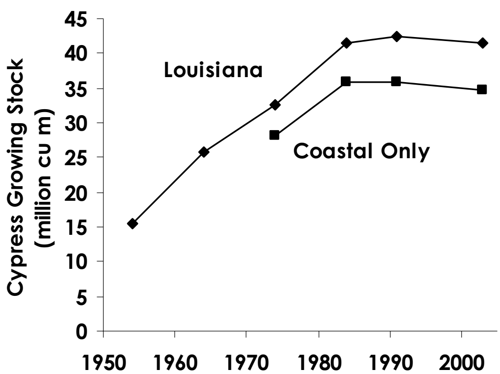

Fig. 4. Baldcypress growing stock volume in Louisiana from US Forest Service data.

Another important factor to be considered in these coastal forests is the recruitment of new individuals into the forest. Baldcypress and water tupelo must have dry periods for the seed to germinate and establish (DeBell and Naylor, 1972; Hook, 1984; Kozlowski, 1997). In many cases, dry periods have not been sufficient for seedling establishment (Conner et al., 1986) and if water levels continue to rise, coastal forested areas will eventually be replaced by scrub-shrub stands, marsh, or open water. Young seedlings in a wetland environment must grow rapidly to reduce the risk of canopy submersion by future floods during the growing season (Conner et al., 1986). Baldcypress seedlings can withstand complete inundation for up to 45 days in the laboratory (Souther and Shaffer, 2000), but long-term flooding above the foliage results in high mortality and longevity in turbid water is likely less. Natural regeneration of swamplands after the widespread logging of 1890–1930 occurred when hydrological conditions were less affected by levees and subsidence.

The SWG developed a hydrological classification for coastal wetland forests to reflect the hydrological conditions controlling tree regeneration (Chambers et al., 2005). Class I (best) sites have seasonal flooding with sufficient dry-down during the growing season for seedlings to grow tall enough to withstand flooding during the next growing season. Class II (artificial regeneration only) sites experience sufficient flooding during the growing season to prevent establishment of seedlings, but are not too deeply flooded (maximum of about 0.6 m) to prevent artificial regeneration during the winter months. Class III (no regeneration) sites experience sufficient flooding during the growing season to prevent establishment of seedlings, and are too deeply flooded to allow practical artificial regeneration.

Changes to ecological structure affect wildlife habitat in important ways. Songbirds, wading birds, waterfowl, raptors, reptiles, amphibians, mammals, crawfish, and fish are all common inhabitants of Louisiana’s coastal forests. Millions of songbirds migrate through Louisiana’s coastal forests, including virtually all of the eastern landbird species in the United States and numerous species from the western United States (Lowery, 1974; Barrow et al., 2005). While several dozen songbird species breed in Louisiana’s coastal forests, Zoller (2004) found that the number of species of breeding migrant songbirds was less in forests degraded by hydrologic changes than in relatively undegraded or moderately degraded forests. Louisiana’s coastal forests are also important habitat for two bat species listed as federal species of concern (the southeastern bat and Rafinesque’s big-eared bat) and the threatened Louisiana black bear. Bats utilize hollow trees for roost and hibernation sites (Gooding and Langford, 2004), and black bears commonly use tree dens in frequently flooded areas (Alt, 1984; White et al., 2001; Hightower et al., 2002). Though other tree species are used, Rafinesque’s big-eared bat frequently uses hollow water tupelo trees > 90 cm dbh that are characteristic of older baldcypress–water tupelo forests (Lance et al., 2001; Gooding and Langford, 2004). The U.S. Fish and Wildlife Service listing rule for the Louisiana black bear defines candidate den trees as baldcypress or water tupelo > 91 cm dbh with a visible cavity, occurring along rivers, lakes, streams, bayous, sloughs, or other water bodies. Thus, forest structure is critical for the maintenance of wildlife populations in these forests.

31.3.1. Case Study I: Inundation and Productivity

To better understand how hydrological changes are affecting the coastal forest ecosystem, Amos et al. (2005) used dendrochronology of baldcypress at two contrasting sites to compare the historical relationship of hydrology and productivity of overstory trees. Both sites are adjacent to long-term records of water levels, and are in similar topographic positions near lakes in backswamps of the historical Atchafalaya River distributary basin, but have strongly contrasting hydrological conditions. The first site is near Grand Lake, where diversion of Mississippi River water into the Atchafalaya Basin Floodway has drastically increased flooding and sediment and nutrient additions. The second site is near Lake Verret, where flood control levees have eliminated seasonal riverine flooding but inundation has increased because of subsidence, impeded drainage, and backwater flooding from the outlet of the Atchafalaya Basin.

Growth rates of overstory baldcypress trees in the two stands have decreased over the past 30 years (Figure 5). Qualitatively, the growth decrease coincides with increased flooding, especially at the Lake Verret (non-riverine) site (Figure 6). A principle component ordination of stage variables resulted in significant correlation between the first PCA axis and growth at each site. At the Grand Lake (riverine) site, the first axis was positively correlated with annual growth ($r = 0.77$), and was most related to average annual stage in the current and previous years. This suggests that deeper flooding in the riverine wetland may increase growth. At the Lake Verret (non-riverine) site, the first axis was negatively correlated with annual growth ($r = -0.56$), and was most related to 5- and 10-year average stage. This suggests that long-term increases in flooding in the non-riverine wetland may decrease growth. At both sites, the flooding variables were much more correlated to growth rates than were climate variables such as temperature and precipitation.

The mechanisms by which flooding affects growth rates in these two stands are not clear; two possible explanations are that (1) flooding in the riverine site brings nutrients that increase growth, whereas flooding in the non-riverine site only produces hypoxia and stresses trees; or (2) the reduction in growth at the non-riverine site may be caused by the change in hydrological conditions, which has been more severe than in the riverine site. We are adding new plots to the analysis to determine whether the differences in these sites are consistent.

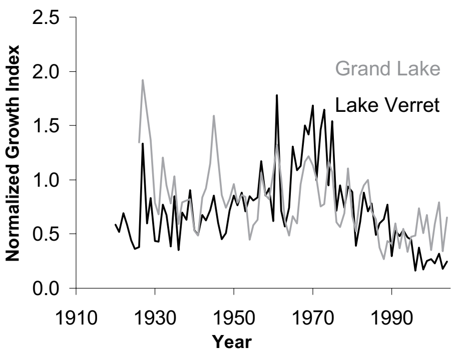

Fig. 5. Tree ring growth indices (normalized to remove biological trends) for two baldcypress stands in contrasting hydrological conditions in Louisiana.

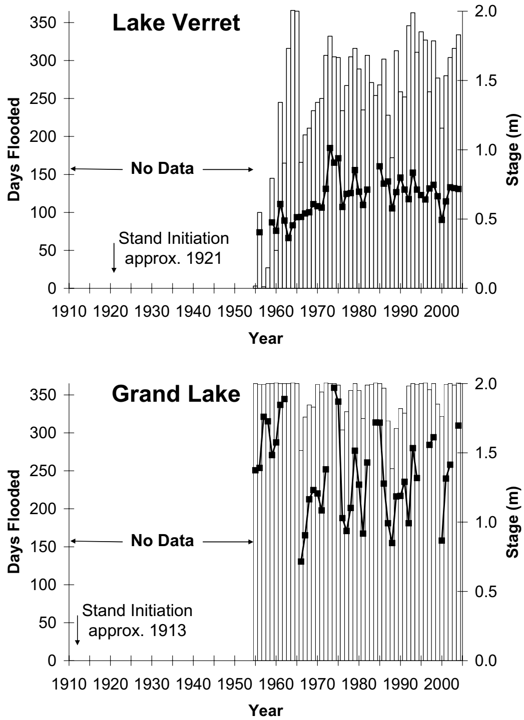

Fig. 6. Inundation histories for two baldcypress stands with contrasting hydrological conditions in Louisiana. Yearly average stage (symbols/lines) was obtained from a nearby, hydrologically connected water level gauge, and number of days flooded per year (bars) were estimated from site elevations.

31.3.2. Case Study II: Inundation and Regeneration

Complexity of hydrological interactions with regeneration arises because seasonality and timing of inundation are not easily quantifiable in ecological terms. Here we attempt to classify two swamps into the SWG hydrological condition classes (Chambers et al., 2005). The sites are both in the Atchafalaya Basin Floodway (ABF), Louisiana, and both are in the same swamp bounded on the north by Bayou Pigeon. One site is near the upper topographic limit of baldcypress-tupelo forest, near the natural levee of the brownwater Bayou Pigeon. The other site is lower, and occupies the low natural levee of the blackwater Bayou Mallet about 5.7 km south of the Bayou Pigeon site. Tree growth and response to thinning at these sites have been previously reported by Dicke and Toliver (1988, 1990). The annual hydrograph of the ABF mostly follows that of the Mississippi River, because most ABF flow originates as diverted river water. Thus, seasonally high flows in the spring following snowmelt often last into the summer, and are followed by low flows in the fall.

To obtain flooding variables relevant to regeneration, we used the US Army Corps of Engineers water level gauge at Bayou Sorrell, which is 6.3 km north of the Bayou Pigeon site. This gauge has a daily record beginning in 1955, and shows no long-term changes in mean water level. Thus, it is a good candidate for analysis of flooding probabilities. Field experience is that water levels in the area do not vary appreciably in space in this part of the ABF, so we assumed historical water depth at the sites would be fully recoverable from the gauge record by simple subtraction based on spot field observations of water depth at the sites. Based on these assumptions, Bayou Pigeon floods at stage 1.6 m MSL, and Bayou Mallet floods at stage 0.8 m MSL. We assumed the limiting hydrological factor for regeneration is consecutive unflooded days during the growing season (April 1 – October 31: 214 days), in which time a seedling must grow tall enough to withstand flooding during the next growing season.

The average length of seedling growing time at Bayou Pigeon is 116 days, 25% of years have at least 137 days, and 75% of years have at least 97 days (Figure 7). The average

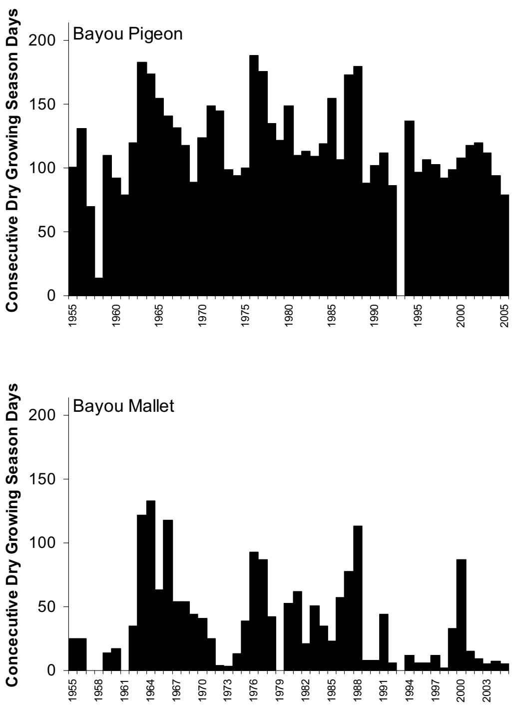

Fig. 7. Maximum consecutive non-inundated days during the growing season at two sites in the Atchafalaya Basin Floodway, Louisiana.

length of seedling growing time at Bayou Mallet is 35 days, 25% of years have at least 54 days, and 75% of years have at least 6 days. Assuming a baldcypress seedling is able to germinate on the first dry day and grow at maximum rate of 0.9 m yr^{-1} (Williston et al., 1980; Keeland and Conner, 1999), these flooding regimes dictate that seedlings can grow to be 49 cm in an average year at Bayou Pigeon, but just 15 cm at Bayou Mallet. In dry years (25% probability), seedlings can grow 58 cm at Bayou Pigeon and 23 cm at Bayou Mallet. In wet years (75% probability), seedlings can grow 41 cm at Bayou Pigeon and 3 cm at Bayou Mallet.

These estimates clearly indicate that Bayou Mallet cannot be classified as Class I (best), because seedlings 15–23 cm tall are unlikely to withstand the summer flooding of the next year, and regeneration will likely be successful only in extraordinary circumstances outside the range of the observed flooding. In contrast, the expected seedling height of about 50 cm at Bayou Pigeon may be sufficient to withstand flooding the next year. More information is needed about the specifics of seedling flood tolerance to confidently classify Bayou Pigeon as Class I (best). For example, is the early-growing-season flooding that is typical of these sites more tolerable than late season flooding?

The operational possibility of artificial regeneration at the two ABF sites is defined by dormant-season flooding of less than 0.6 m. Bayou Pigeon is flooded to this depth on average 28% of the dormant season and Bayou Mallet is flooded to this depth on average 66% of the dormant season (Figure 8). Although it might be difficult to schedule a planting

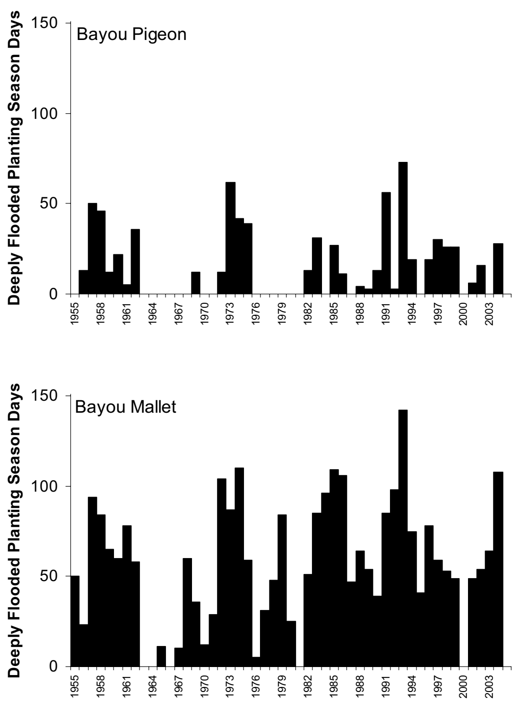

Fig. 8. Number of days flooded to depth >0.6 m during the dormant, planting season at two sites in the Atchafalaya Basin Floodway, Louisiana.

time at Bayou Mallet, it would not likely be impossible, and planting at Bayou Pigeon would usually not be a problem. Thus, neither site seems to warrant status as Class III (no regeneration), with the main caveat being that seedlings would need to be large enough to withstand flooding the next few years.

31.4. CONCLUSIONS

Widespread changes have been made to hydrological and delta-building processes in the Mississippi River delta. These changes have mainly exacerbated subsidence and increased flooding. Productivity of coastal wetland forests has been reduced by this increased flooding, but the mechanisms responsible for changes in site-specific productivity are not clear. Regeneration of coastal wetland forest tree species has also been reduced by the increased flooding. The Coastal Wetland Forest Conservation and Use Science Working Group, convened by the Governor of Louisiana, has developed a hydrological classification to aid in assessing sustainability of coastal wetland forests based on their potential to regenerate. A detailed analysis of the hydrologically-mediated regeneration capacity of two sites in the Atchafalaya Basin Floodway illustrates that more research is needed before confident assessment of wetland forest sustainability can be made.

REFERENCES

Alt, G.L., 1984. Black bear cub mortality due to flooding of natal dens. Journal of Wildlife Management 48:1432–1434.

Amos J.B., Keim, R.F., and Doyle, T.W., 2005. Coastal forest productivity and wetland hydrology: A dendrochronological study. Eos, Transactions, American Geophysical Union, 86(18), Joint Assembly Supplement, Abstract NB33C–06.

Barrow, W.C., Jr., Johnson, L.A., Randall, L., Woodrey, M.S., Cox, J., Ruelas, E., Riley, C.M., Hamilton, R.B., and Eberly, C., 2005. Coastal forests of the Gulf of Mexico: a description and some thoughts on their conservation. In: USDA Forest Service General Technical Report PSW–GTR–191.

Baumann, R.H., Day, J.W., Jr., and Miller, C.A., 1984. Mississippi deltaic wetland survival: sedimentation versus coastal submergence. Science 224:1093–1095.

Brown, S., 1981. A comparison of the structure, primary productivity, and transpiration of cypress ecosystems in Florida. Ecological Monographs 51:403–427.

Chambers, J.L., Conner, W.H., Day, J.W., Faulkner, S.P., Gardiner, E.S., Hughes, M.S., Keim, R.F., King, S.L., McLeod, K.W., Miller, C.A., Nyman, J.A., and Shaffer, G.P., 2005. Conservation, Protection and Utilization of Louisiana's Coastal Wetland Forests, Final Report to the Governor of Louisiana from the Science Working Group on Coastal Wetland Forest Conservation and Use. 102 p.

Coleman, J.M., Roberts, H.H., and Stone, G.W., 1998. Mississippi River delta: an overview. Journal of Coastal Research 14:698–716.

Conner, W.H., and Brody, M., 1989. Rising water levels and the future of southeastern Louisiana swamp forests. Estuaries 12:318–323.

Conner, W.H., and Buford, M.A., 1998. Southern deepwater swamps. Pages 261–287 in M.G. Messina and W.H. Conner, editors. Southern Forested Wetlands, Ecology and Management. Lewis, Boca Raton, Florida, USA.

Conner, W.H., and Day, J.W., Jr., 1988. Rising water levels in coastal Louisiana: implications for two forested wetland areas in Louisiana. Journal of Coastal Research 4:589–596.

Conner, W.H., and Toliver, J.R., 1990. Long-term trends in the bald-cypress (*Taxodium distichum*) resource in Louisiana (U.S.A.). Forest Ecology and Management 33/34:543–557.

Conner, W.H., Gosselink, J.G., and Parrondo, R.T., 1981. Comparison of the vegetation of three Louisiana swamp sites with different flooding regimes. American Journal of Botany 68:320–331.

Conner, W.H., Toliver, J.R., and Sklar, F.H., 1986. Natural regeneration of baldcypress (*Taxodium distichum* (L.) Rich.) in a Louisiana swamp. Forest Ecology and Management 14:305–317.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T., 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services, FWS/OBS–79/31, Washington, DC.

DeBell, D.S., and Naylor, A.W., 1972. Some factors affecting germination of swamp tupelo seeds. Ecology 53:504–506.

Day, J.W., Shaffer, G.P., Britsch, L.D., Reed, D.J., Hawes, S.R., and Cahoon, D., 2000. Pattern and process of land loss in the Mississippi delta: A spatial and temporal analysis of wetland habitat change. Estuaries 23:425–438.

Dicke, S.G., and Toliver, J.R., 1988. Effects of crown thinning on baldcypress height, diameter, and volume growth. Southern Journal of Applied Forestry 12:252–256.

Dicke, S.G., and Toliver, J.R., 1990. Growth and development of bald-cypress water-tupelo stands under continuous versus seasonal flooding. Forest Ecology and Management 33:523–530.

Gagliano, S.M., 1998. Faulting, Subsidence, and Land Loss in Coastal Louisiana. Coastal Environments Inc., Baton Rouge, LA.

Gooding, G., and Langford, J.R., 2004. Characteristics of tree roosts of Rafinesque's big-eared bat and southeastern bat in Northeastern Louisiana. The Southwestern Naturalist 49:61–67.

Harms, W.R., Schreuder, H.T., Hook, D.D., and Brown, C.L., 1980. The effects of flooding on the swamp forest in Lake Ocklawah, Florida. Ecology 61:1412–1421.

Hightower, D.A., Wagner, R.O., and Pace, R.M. III., 2002. Denning ecology of female American black bears in south central Louisiana. Ursus 13:11–17.

Hodges, J.D., 1997. Development and ecology of bottomland hardwood sites. Forest Ecology and Management 90:117–125.

Hook, D.D., 1984. Waterlogging tolerance of lowland tree species of the South. Southern Journal of Applied Forestry 8:36–149.

Keeland, B.D., and Conner, W.H., 1999. Natural regeneration and growth of *Taxodium distichum* (L.) Rich. In Lake Chicot, Louisiana after 44 years of flooding. Wetlands 19:149-155.

Kozlowski, T.T., 1984. Responses of woody plants to flooding. Pages 129–163. In T.T. Kozlowski (ed.). Flooding and Plant Growth. New York: Academic Press.

Kozlowski, T.T., 1997. Responses of woody plants to flooding and salinity. Tree Physiology Monograph No. 1. 29 pp.

Lance, R.F., Hardcastle, B.T., Talley, A., and Leberg, P.L., 2001. Day-roost selection by Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) in Louisiana forests. Journal of Mammalogy 82:166–172.

Lowery, G.H. Jr., 1974. Louisiana Birds. Louisiana State University Press, Baton Rouge.

National Research Council, 1995. Wetlands, Characteristics and Boundaries. National Academy Press, Washington.

Roberts, H.H., 1997. Dynamic changes of the holocene Mississippi river delta plain: the delta cycle. Journal of Coastal Research 13:605–627.

Souther, R.F., and Shaffer, G.P., 2000. The effects of submergence and light on two age classes of baldcypress (*Taxodium distichum* (L.) Richard) seedlings. Wetlands 20:697–706.

Thomson, D.A., Shaffer, G.P., and McCorquodale, J.A., 2002. A potential interaction between sea-level rise and global warming: implications for coastal stability on the Mississippi River deltaic plain. Global Planetary Change 32:49–59.

Turner, R.E., 1997. Wetland loss in the northern Gulf of Mexico: multiple working hypotheses. Estuaries 20:1–13.

White, T.H. Jr., Bowman, J.L., Jacobson, H.A., Leopold, B.D., and Smith, W.P., 2001. Forest management and female black bear denning. Journal of Wildlife Management 65:34–40.

Williston, H.L., Shropshire, F.W., and Balmer, W.E., 1980. Cypress management: a forgotten opportunity. Forestry Report SA-FR 8. USDA Forest Service, Southeastern Area, Atlanta, GA.

Zoller, J.A., 2004. Seasonal differences in bird communities of a Louisiana swamp and manipulation of the breeding density of Prothonotary Warblers. M.S. Thesis, Southeastern Louisiana University, Hammond.