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Rising Water Levels in Coastal Louisiana: Implications for Two Coastal Forested Wetland Areas in Louisiana

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ABSTRACT

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The coastal Barataria and Verret basins of Louisiana contain extensive areas of forested wetlands. Analysis of water gauge data in each basin reveals that apparent water level rise is 8.5 mm/year and 13.7 mm/yr for the Barataria basin and Verret basin, respectively. This high apparent water level rise is due mainly to regional subsidence. Sedimentation in the cypress-tupelo forests of Barataria basin is 6 mm/year versus 8.8 mm/yr in the cypress-tupelo forests of Verret basin. On the higher and drier bottomland ridge in the Verret basin, sedimentation is only 2.7 mm/yr. Apparent water level rise is greater than sedimentation in all areas leading to vertical accretion deficits of 2.5 mm/yr and 4.9 mm/yr in the swamps of Barataria basin and Verret basin, respectively, and 10.8 mm/yr on the bottomland ridge in Verret basin. This deficit is cumulative and is leading to a significant increase in the number of days flooded per year in each basin. If present trends continue, the forested wetlands in these basins will eventually be continually flooded and unable to reproduce themselves.

ADDITIONAL INDEX WORDS: *Louisiana, subsidence, sea level rise, coastal forests, swamps, wetlands.*

INTRODUCTION

In recent papers, the impacts of sea-level rise on coastal marshes has been detailed (BAUMANN *et al.*, 1984; BOESCH, 1982; HACKNEY and CLEARY, 1987; SALINAS *et al.*, 1986, STEVENSON *et al.*, 1986; ORSON *et al.*, 1985; KANA *et al.*, 1986). Very little attention, however, has been placed on the impact rising water levels might have on the more inland coastal forests. CLARK (1986) studied tide gauge records of sea level rise in New York and discussed the importance for long-term change in forest population with rising sea level. Sea level rise in the New York coastal forest has averaged 3 mm/year since 1930 (CLARK, 1986). In Louisiana, however, water levels are rising rapidly, and it has been suggested that this will affect seedling survival (CONNER *et al.*, 1986b; SALINAS *et al.*, 1986). Because of the lack of data in coastal forests, this paper is designed to determine the historical trend in flooding patterns in two Louisiana forested coastal watersheds.

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METHODS

Study Area

The Barataria basin and Lake Verret basin which are located in south central Louisiana (Figure 1) contain extensive freshwater wetland forests. There are approximately 98,000 ha of seasonally flooded forests and wooded swamps in the Barataria basin and 41,000 ha in Verret basin. Both watersheds were once overflow basins of the Mississippi and Atchafalaya Rivers. With the construction of the flood protection levees along these rivers in the 1920-1940's, the only source of freshwater is rainfall (CONNER and DAY, 1976; CONNER *et al.*, 1986a). When these areas received riverine input, sediment deposition served to offset apparent water level rise due to land subsidence. With the cessation of sediment input, regional subsidence is leading to increased flooding of these areas.

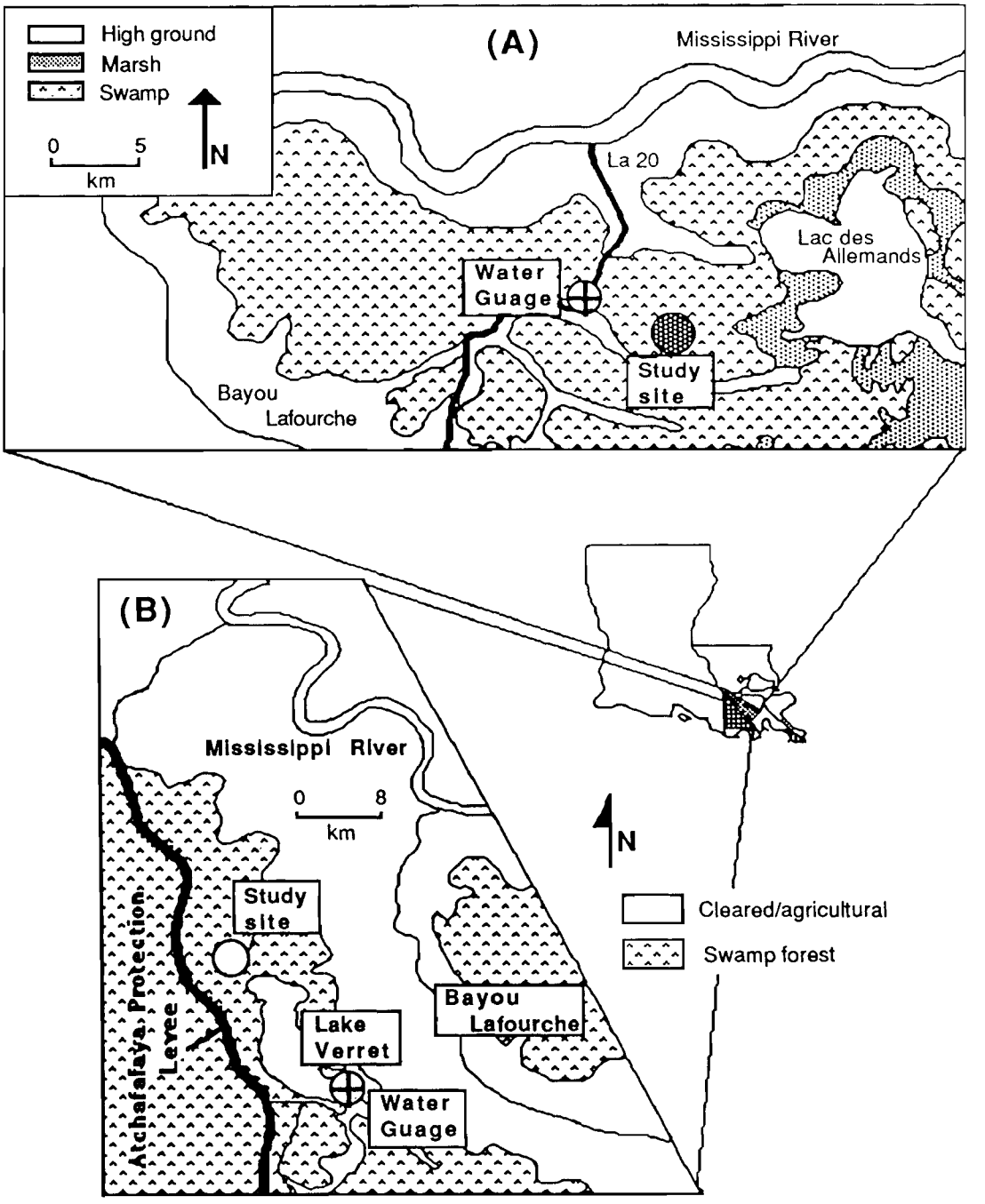

Figure 1. Map of south central Louisiana showing the location of the Barataria (A) and Verret (B) watersheds.

The study plot in the Barataria basin is a deepwater cypress-tupelo (*Taxodium distichium-Nyssa aquatica*) forest. The study plots in the Verret basin are a bottomland hardwood forest growing on a natural ridge and a cypress-tupelo forest growing in a low area adjacent to the ridge. The major tree species growing in the Verret bottomland area are Nuttall oak (*Quercus nuttalli*), water oak (*O. nigra*), sweetgum (*Liquidambar styraciflua*), and sugarberry (*Celtis laevigata*).

Forest Water Levels

Within each watershed, studies have been conducted on a variety of ecological parameters (CONNER and DAY, 1976; CONNER *et al.*, 1981; SKLAR, 1983; HOPKINSON, 1978; CONNER *et al.*, 1986a and b; SLATER, 1986). One of the routine measurements made in many of these studies was water level over the forest surface. Water levels were determined by taking 20-30 water level measurements within study plots during a sampling trip and then averaging these values to obtain mean depth of flooding. This average water level was compared to a nearby U.S. Army Corps of Engineers (USACOE) gauge for each trip made during 1978 in the Barataria basin, and 1984 in the Verret and regression equations were formulated to estimate the depth of flooding for any gauge reading during the base years of 1978 and 1984.

Apparent Water Level Rise

Daily water level readings from the Bayou Chevreuil (Barataria basin) and Attakapas (Verret basin) USACOE water gauges (see Figure 1) for 1956 through 1986 were used to calculate average yearly water levels. These values were then plotted and the slope of the regression line reflects apparent water level rise (BAUMANN 1980).

Sedimentation

In the Verret basin ten randomly placed 0.25 m^2 marker horizons were established by applying a 3-5 cm layer of feldspar clay (BAUMANN, 1980; BAUMANN *et al.*, 1984) over the forest floor of the bottomland hardwood ridge and cypress-tupelo area in October 1984 while the area was dry. In June 1985, after flood waters had receded from the study area, the plots were sampled with a coring device consisting of a sharpened core tube with an internal piston with an O-ring (SWENSON, 1982). Four samples were taken from each 0.25 m^2 plot for a total of 40 samples. The depth of the sediment over the feldspar layer was measured to the nearest mm and then averaged to obtain one number for sedimentation.

For the Barataria basin, we estimated sedimentation based on several studies. Previous work by BAUMANN (unpublished data, Center for Energy Studies, Louisiana State University) in the swamps of Barataria basin and HATTON *et al.* (1982) in the freshwater marshes adjacent to the Barataria basin swamp forests found sedimentation rates of 6 mm/yr and 6.5 mm/yr, respectively. For this exercise a sedimentation rate of 6 mm/yr was used as the sedimentation rate for the Barataria basin swamp forests.

Historical Trends in Water Level

The regression equations calculated using water gauge data versus forest flooding data were used to estimate the water gauge level at which the forest floor was dry. This value was compared to the daily record of gauge readings for the years 1978 and 1984 in Barataria basin and Verret basin, respectively, and the number of days the plots were flooded was determined. Since apparent water level rise was greater than sedimentation in all areas, the gauge readings were adjusted each year by the vertical accretion deficits to determine flooding back to 1956. It was assumed that sedimentation and apparent water level rise were constant through the time period of study.

RESULTS

Forest Water Levels and AWLR

Water levels in Louisiana's coastal forests follow a seasonal pattern of flooding and drying with the extent of flooding depending on the elevation of the site and seasonal water budget. For Barataria basin, the study area is very near sea level and it was flooded almost year round with a short dry period during late July-early August, a time when rainfall is low and evap-

otranspiration is high (CONNER *et al.*, 1986a). In Verret basin, the bottomland hardwood forest study site was approximately 20-30 cm higher than the surrounding swamp forest site. Flooding occurred during the winter and early spring, but for most of the growing season the forest floor on the ridge was dry during the 1984 measurements. The lower cypress-tupelo zone was flooded for most of the year. Analysis of the forest water levels and water gauge data (Figure 2) yielded regression equations with correlation coefficients of 0.78 and 0.56 for Barataria and Verret, respectively.

Analysis of the yearly average water level in both watersheds shows that there is a significant apparent increase in water levels through time (Figure 3). This similarity is not surprising considering that both basins have undergone similar patterns of geologic development. Apparent water level rise was calculated to be 8.5 and 13.7 mm/yr for Barataria basin and Verret basin, respectively.

Sedimentation

From October 1984 to June 1985 sedimentation averaged 2.7 ($\pm$ 1.2) mm on the bottomland hardwood ridge in Verret basin as compared to 8.8 mm and 6 mm in the more flooded cypress-tupelo forests of Barataria basin and Verret

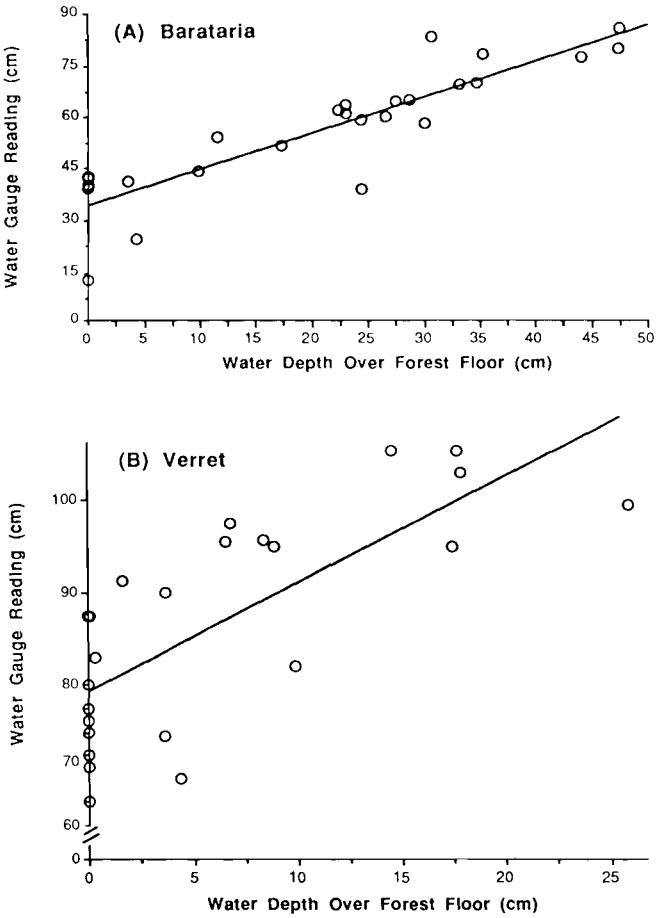

Figure 2. Relationship between forest flooding levels and U.S. Army Corps of Engineer gauges at Chegby (Barataria basin) and Attakapas (Verret basin). No water wells existed in the areas at the time of this study so the group of gauge readings at zero forest water depth is the result of not being able to measure depth to the water table.

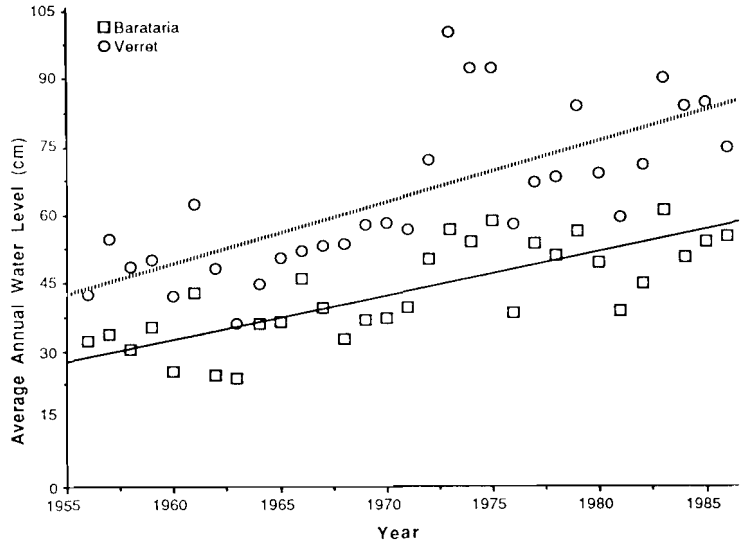

Figure 3. Average yearly water level for U.S. Army Corps of Engineer gauges at Chegby (Barataria basin) and Attakapas (Verret basin).

basin, respectively. This difference is undoubtedly due to the frequency and height of flooding experienced by each basin. There are about ten flooding events each year in Louisiana coastal forests varying in duration. Each flood event transports sediments into the forest areas. Since only the higher floods cover the bottomland ridges, much less sediment is imported and deposited there.

Historical Trends in Water Levels

A comparison of apparent water level rise and sedimentation rates clearly indicates that sedimentation is less than apparent water level rise in these forests. Vertical accretion deficits are 2.5 and 4.9 mm/yr in the swamps of Barataria basin and Verret basin, respectively, and 10.8 mm/yr on the bottomland ridge in Verret basin. Assuming that the apparent water level rise and sedimentation rates have remained constant for the time period 1956-1986, then the days flooded per year are easily calculated (Figure 4).

Both study areas have experienced significant increases in the total number of days flooded per year. The Verret basin bottomland ridge did not experience any major flooding until the 1970's but since then has experienced a steady increase in the number of days flooded/year. Before 1970, the Verret plot was at an elevation to keep the forest floor from flooding. However, the lack of sedimentation in the area combined with apparent water level rise has resulted in the ridge now being at an elevation where flooding occurs frequently.

In Barataria basin, the swamps have always been flooded to some extent (Figure 4), but flooding has increased to where the forests are flooded almost year round. Even during dry periods such as 1981 and 1985-86, these forests were rarely free of standing water although the total days flooded decreased during these years. The history of flooding in the swamp of Verret basin is similar to the bottomland ridge site except that increased flooding is evident by the late 1960's. The high flood years 1973-75 on the Atchafalaya and Mississippi rivers are evident more in the Verret basin because the area is affected by backwater flooding from the Atchafalaya River more than the Barataria basin is by Mississippi floodwaters.

DISCUSSION

Apparent water level rise in coastal Louisiana is rapid, more so than in other coastal areas of the United States. For example, STEVEN-

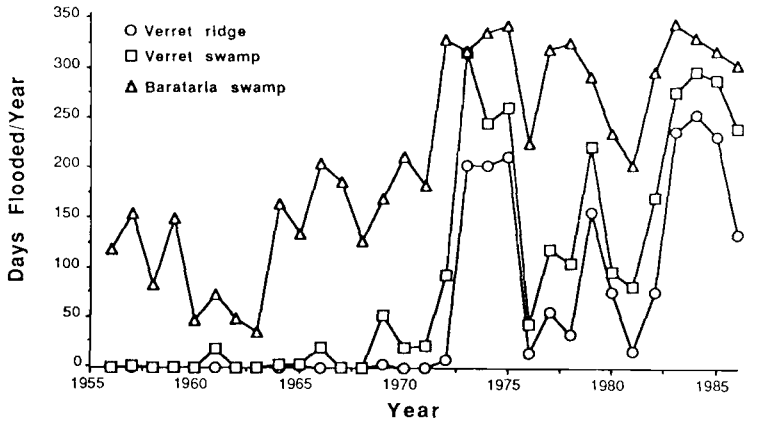

Figure 4. The number of days flooded per year in Barataria and Verret forests.

SON *et al.* (1986) reported that apparent water level rise on the Atlantic coast was 3-4 mm/yr versus the 8-14 mm/yr observed in this study. As water levels continue to rise, the 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 the mortality of these tree species (HALL *et al.*, 1946). Already many of the trees in these areas are showing evidence of severe stress (CONNER and DAY, 1987; CONNER *et al.*, 1981; CONNER *et al.*, 1986b). Even baldcypress and water tupelo, two of the dominant species in Louisiana's coastal forests (CONNER and SASSER, 1985), slowly die when exposed to prolonged, deep flooding (BROWN, 1981; HARMS *et al.*, 1980; PENFOUND, 1949; EGGLER and MOORE, 1961).

Another important factor to be considered in these coastal forests is the recruitment of new individuals into the forest. Only buttonbush (*Cephalanthus occidentalis*), can germinate in standing water. Other tree species including baldcypress and water tupelo must have dry periods for the seed to germinate and establish. In many cases, this is not happening (CONNER *et al.*, 1986a) and if water levels continue to rise, coastal forested areas will eventually be replaced by scrub-shrub stands or open water.

As water levels rise, one would expect that there would be a migration of the forest up the elevation gradient (CLARK, 1986). In many areas, however, coastal forests are confined by man-made obstacles like flood-protection levees or occur on low ridges where the elevation gradient is truncated. Range extensions or shifts in forest areas as CLARK (1986) suggested are not generally possible. Therefore, many of the coastal forests in Louisiana may be facing possible elimination or great reductions in area.

More attention is necessary concerning the possible consequences of sea level rise in forested areas so that techniques can be developed for effective management of this resource for the future. Natural regeneration in these areas has been affected by rising water levels (CONNER *et al.*, 1986b) and planting is difficult because of herbivores (CONNER and TOLIVER, 1987). More work needs to be done on how to ensure adequate survival of planted seedlings. Direct manipulation of water levels is another option that should be considered. In the Mobile, Alabama swamp forests, Scott Paper Company regulates water levels in cutover areas to let natural reproduction take place (Gilbert Sproler, personal communication, Scott Paper Company, Mobile, AL). In Louisiana, the numerous canals and spoil banks in existence in the coastal area could be used to pump out areas for one to two years to let natural regeneration occur. This is not a long-term solution, however, because of the trend of continued water level rise.

The introduction of sediments from the Atchafalaya and Mississippi rivers should also be considered to save these forests. Since the

lack of sediment is what is causing the problem, it would be beneficial to these areas if sediment-laden waters were once again directed through these forests. There have been several suggestions to divert fresh water and sediments into wetlands (TEMPLET and MEYER-ARDENDT, in press; GOSSELINK and GOSSELINK, 1985). For example, TEMPLET and MEYER-ARDENDT (in press) reported that diversion of 11% of the flow of the lower Mississippi during high discharge would offset apparent water level rise.

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☐ RESUMEN ☐

Las costas de las cuencas de Barataria y Verret en la Luisiana contienen extensas áreas de zonas húmedas arboladas.

El análisis de los datos de nivel del agua en cada cuenca revela que el incremento aparente del nivel del agua es de 8.5 mm/año y 13.7 mm/año para Bartaria y Verret respectivamente. Este ascenso relativamente alto del nivel del agua se debe principalmente a una subsidencia regional. La sedimentación en los bosques de cipreses y tupelos de la cuenca de Barataria es de 6 mm/año contra 8 mm/año en los de la cuenca de Verret. En las tierras más altas y secas de cuenca de Verret la sedimentación es de sólo 2.7 mm/año. El ascenso aparente del nivel medio del agua es mayor que la sedimentación en todas las áreas dando lugar a déficits de acrección vertical de 2.5 mm/año y 4.9 mm/año en las marismas de Barataria y Verret y de 10.8 mm/año en la cuenca de Verret. Este déficit es acumulatico lo que está conduciendo a un aumento en el número de dias al año de inundación en cada cuenca. Si esta tendencia actual se mantiene, las tierras húmedas arboladas en estas cuencas se mantendrán en inundación continua impidiendo la reproducción del arbolado.—*Department of Water Sciences, University of Cantrabria, Santander, Spain.*

☐ ZUSAMMENFASSUNG ☐

Die kústennahen Becken von Barataria und Verret in Louisiana beinhalten ausgedehnte bewaldete Sumpfgebiete. Pegelmessungen in beiden Becken haben ergeben, daß offenbar der Wasserspeigel um 8,5 mm pro Jahr im Barataria- und 13,7 mm pro Jahr im Verret-Becken ansteigt. Das ist im wesentlichen auf regionale Senkungserscheinungen zurückzuführen. Die Sedimentationsrate in den Sumpfzypressenwäldern des Barataria-Beckens beträgt 6 mm im Jahr, gegen 8,8 mm/Jahr in den Zypressenwäldern des Verret-Beckens, während sie innerhalb des Verret-Beckens auf einem flachen Wallstück nur 2,7 mm pro Jahr beträgt. Da offenstichlich in allen Gebieten der Wasserspiegelanstieg größer ist als die Sedimentationsrate, ergeben sich Differenzen von 2,5, 8,9 oder gar 10,8 mm pro Jahr. Diese Defizitraten addieren sich von Jahr zu Jahr und führen zu einer immer größeren Anzahl von Überflutungstagen in jedem Becken. Falls dieser Trend anhält, werden die bewaldeten Sumpfgebiete evtl. ständig überflutet werden und sind dann außerstande, sich aus sich selbst heraus zu erhalten.—*Dieter Kelletat, Essen, FRG.*

☐ RÉSUMÉ ☐

Le littoral des dépressions de Barataria et de Verret en Louisiane présente de vastes terres humides plantées en forêt. L'analyse des données de niveau d'eau de chaque dépression montre une élévation apparente de 8,5 mm/an pour la dépression de Barataria et de 13,7 mm/an pour celle de Verret. Cette élévation importante est principalement due à la subsidence régionale. La sédimentation dans les forêts de cyprès et de nyssas de la dépression de Barataria est de 6mm/an, contre 8,8mm/an dans celles de Verret. Au dessus du bourrelet le plus haut et le plus sec de la dépression de Barataria, la sédimentation n'est que de 2,7 mm/an. Partout, la montée apparente du niveau de l'eau est plus importante que la sédimentation, ce qui conduit à des déficits d'accrétion verticale de 2,5 mm/an (marais de Barataria), de 4,9 mm/an (marais de Verret) et de 10,8 mm/an (bourrelet de la dépression de Verret). Ce déficit est cumulatif. Il conduit à une augmentation significative du nombre de jours d'inondation par an dans chaque bassin. Si cette tendance se poursuit, les terres humides plantées en forêt pourront être inondées en permanence et seront inaptes à se reproduire.—*Catherine Bressolier, Labo. de Géomophologie, UA 910, Montrouge, France.*