Estimating the age of marsh soils over the past ~50 -100 years

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SUMMARY

The most popular methods for estimating the ages of recently formed marsh soils are ^{137}Cesium (^{137}Cs) and ^{210}Lead (^{210}Pb) dating. Elevated concentrations of ^{137}Cs first appeared in the early 1950's, with peaks detected in 1963, just prior to the banning of atmospheric nuclear testing. The sediment/peat layer from 1963 can be identified based on the maximum activity of ^{137}Cs and subsequent dates are estimated assuming a constant rate of accretion (deLaune et al. 1978). ^{210}Pb is a naturally occurring isotope in the ^{238}U series, which has a half-life of 22.3 years. Sedimentation rates are calculated based on the rate at which unsupported ^{210}Pb (the ^{210}Pb that is deposited from the atmosphere) disappears from deeper sediments as it decays to ^{210}Po (Appleby and Oldfield 1983).

In order to estimate the age profile of peat/sediment, researchers collect cores of a particular depth (e.g. 50 cm) across a transect(s) in the marsh. Cores are then sectioned into 2- or 3-cm slices, dried, and ground. The ground samples are then placed in a low background germanium detector to measure activity using gamma ray spectroscopy. Analysis costs for both ^{137}Cs and ^{210}Pb are about $100/sample.

The data are then used to determine sediment/peat age by applying one of the following models: (1) constant flux-constant sedimentation rate, (2) constant rate of supply (CRS), (3) constant initial concentration, and (4) constant rate of supply minimum variance (Turetsky et al. 2004). For marsh soils, the CRS model and the constant initial concentration model have been applied most commonly.

Age profiles can vary greatly among marshes within an Estuary. Within the San Francisco Estuary, marsh soil profiles have recently been dated at Browns Island, Rush Ranch, Coon Island, Whale's Tail, Newark Slough, and the Petaluma River. More estimates are needed, particularly in less studied areas such as the Delta.

CORE COLLECTION

Figure 1. From top right clockwise: (a) Hargis corer (with RTK GPS in background) ready for coring, (b) coring with the Hargis, (c) close-up of gray reduced marsh sediment, and (d) capping collected core in tube.

PROCESSING MARSH CORES

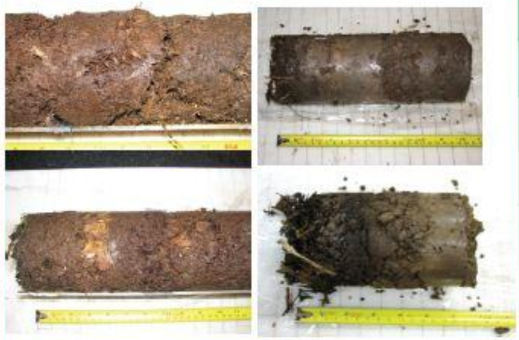

Figure 2. Marsh cores contain both organic material and inorganic sediment. The ^{137}Cs and ^{210}Pb are mainly held in the inorganic fraction. Cores are sliced, dried, and ground in order to prepare for analysis by gamma spectroscopy.

210Pb and 137Cs Activity

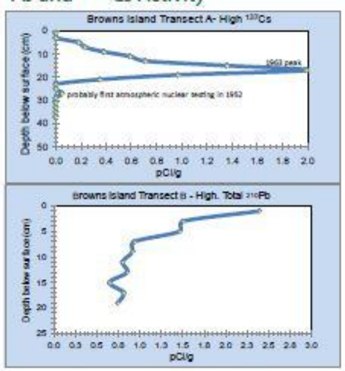

Figure 3. Activities of both ^{210}Pb and ^{137}Cs are reported in pCi/g (picocuries/gram or 2.2 disintegrations/g; Bequerels are the SI unit, but are used less frequently.) Top panel shows ^{137}Cs activity with depth. The bottom panel shows that ^{210}Pb decreases with depth in the profile. For ^{210}Pb dating, the unsupported ^{210}Pb (not total) is what is used for determining the age of the sediment. This is the fraction that rains down on the land surface vs. the fraction that remains in situ, (the supported ^{210}Pb).

CRS MODEL

$$A = A_0 e^{-\lambda t}$$

where λ is the radioactive decay constant of ^{210}Pb(0.0307), A is the cumulative residual unsupported ^{210}Pb beneath a specified surface area to particular depth interval of age *t* within a core, and A_0 is the total residual unsupported ^{210}Pb in the entire peat core (Appleby and Oldfield 1983). The sedimentation rate (r) can be determined from the following equation:

$$r = \lambda(A/C)$$

where C is the total unsupported ^{210}Pb inventory, calculated by subtracting the supported amount from the total amount of ^{210}Pb for each depth interval through the peat core and summing across all depths.

ESTIMATING MAR AND VERTICAL ACCRETION RATE

CRS Model: Example of Results for Browns Island Transect B -High Core

Mid interval depth (cm)	Vertical accretion rate (cm/yr)	Mass accumulation rate (g/cm²/yr)	Mid interval date	Estimated error
1		0.03	2010.22	5.39
3	0.27	0.04	2002.69	4.48
5	0.25	0.04	1994.62	6.58
7	0.27	0.05	1987.09	6.93
9	0.33	0.07	1981.06	9.27
11	0.29	0.04	1974.21	13.76
13	0.20	0.03	1964.44	18.46
15	0.14	0.03	1949.70	23.62
17	0.08	0.01	1923.92	63.52
19	0.04	0.01	1874.99	333.60
	mean =0.249	mean =0.041		

Table 1. The results after using the CRS model to determine peat age in a core from Browns Island. It is critical to consider which model (CRS or CIC or another model) is the best fit for the site under study as the models each have different underlying assumptions. For modeling purposes the mean mass accumulation is of most interest. The orange shading indicates that error is too great for these estimates to be used (based on Van Metre and Fuller 2009).

DATED MARSH PROFILES

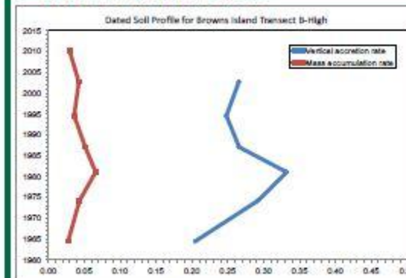

Figure 4. Marsh soil profile showing vertical accretion (cm/yr) and mass accumulation (g/cm²/yr) rates with time. Mass accumulation rates can vary greatly between marshes or even within marshes. These values are important with respect to modeling. A mean value for the whole soil profile may be used or a mean for a certain time range may be more appropriate if significant change has occurred over time.

TAKE-HOME MESSAGES

(1) Dating marsh soils requires field work and lab work, which is expensive.

(2) Care must be taken to choose the right model with appropriate underlying assumptions for the study site.

(3) ***Soil dating produces age estimates, not definitive ages.*** In theory ^{210}Pb can date soils up to ~100 years old, but, due to error, the period of time is usually much less.

(4) Soil age profiles can vary greatly between marshes. Within the SF Estuary, soil profiles have recently been dated at Browns Island, Rush Ranch, China Camp, Coon Island, Whale's Tail, Greco Island, Newark Slough, and the Petaluma River.

(5) Such data need to be better shared. More estimates are needed for understudied areas such as the Delta.

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