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A METHOD FOR DETERMINING POND INUNDATION HEIGHT FOR USE IN SALT MARSH MOSQUITO CONTROL

STEVEN S. BALLING AND VINCENT H. RESH

Division of Entomology and Parasitology, University of California, Berkeley, CA 94720

The addition of ditches provides effective long-term mosquito control in salt marsh management programs. However, economic and environmental costs (Resh and Balling 1983) associated with ditching require accurate determination of which ponds produce mosquitoes and should be ditched. Although regular monitoring of ponds for the presence of mosquito larvae is a reliable approach, it is impractical in marshes that contain numerous ponds. A cost-effective alternative is to use environmental factors that are correlated with mosquito presence to predict which ponds will produce mosquitoes. In a study of environmental factors that influence *Aedes dorsalis* (Meigen) and *Aedes squamiger* (Coq.) populations in San Francisco Bay salt marshes, pond inundation height, i.e. the minimum tidal height above mean lower low water (MLLW) necessary to inundate a marsh pond, was significantly correlated with occurrence and abundance of mosquito larvae (Balling and Resh 1983).

The pond inundation height is best determined by using surveying techniques from a nearby tidal benchmark. Unfortunately, there are often no nearby benchmarks, or there is reason to suspect that recorded benchmark elevations are no longer reliable due to land subsidence or mechanical disturbance. In lieu of surveying, an acceptable estimate can be obtained by using the height of a particular high tide (either taken from tide table predictions or, preferably, measured by a nearby tide gauge) as a reference datum from which heights of other ponds can be calibrated. This is possible because differences in inundation height within and between marshes are essentially constant (Marmer 1951). Although the following procedure was used to estimate pond inundation heights in marshes around the San Francisco Bay, this method is applicable in any area with recorded or predicted tidal heights.

DATA COLLECTION. *Marker construction.* Staple a strip of heavy-duty, waterproof tape (e.g. heating-duct tape) vertically, with the adhesive side exposed, to a long stake. Sprinkle potassium dichromate crystals or some other water-soluble, easily visible, non-toxic substance along the length of the tape. Dissolution of the potassium dichromate on the tape will give a measure of the local tidal height.

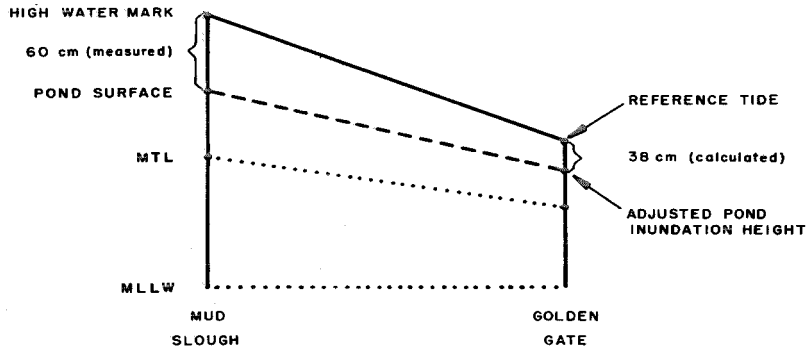
Marker placement. Prior to a series of inundating tides, and at a time when wind speeds are low, implant the stake in the pond; leave the upper portion of the stake sufficiently high above the marsh surface to exceed the height of the expected tide.

Measurements. After the tide has flooded the marsh and receded, allow sufficient time (12–24 hr) for the pond to drain down to, but not evaporate beyond, basin-full level. Then, measure the difference between the pond surface and the high water mark on the stake (the high tide reference datum), which is indicated by the line of undissolved potassium dichromate on the tape.

Replication. This procedure should be repeated for several different high tides to establish the most accurate estimate.

CALCULATION OF POND HEIGHT. The height of the tide (taken from tide tables or a tide gauge) minus the difference between the high water mark on the tape and the level of the pond surface will give an estimate of the pond inundation height equivalent to that obtained from surveying.

If tide tables are used, the inundation height must be adjusted for differences in diurnal tidal ranges (due to systematic differences in bay and channel morphometry) between the tidal reference station and the marsh. As an example, consider that a tide is 186 cm high (above MLLW) at the Golden Gate reference station in San Francisco Bay (where the tidal range is 174 cm) and 60 cm above the surface of a basin-full pond at Mud Slough (where the tidal range is 277 cm; for locations see Balling and Resh 1983, Fig. 1). The difference between the two tidal ranges indicates that the tide is higher at Mud Slough than at the Golden Gate; that is, a 1.0 unit increase in tidal height at the Golden Gate reference station corresponds to a 1.59 (277 cm/174 cm) unit increase at Mud Slough. Therefore, the 60 cm difference between the high water mark on the stake and the pond surface would be equivalent to a 38 cm difference (60 cm/1.59) at the Golden Gate reference station. After subtracting this 38 cm from the known height of the tide at the reference station (in this example, 186 cm), the



DISTANCE FROM HIGH WATER MARK DOWN TO POND SURFACE	÷	TIDAL RANGE CORRECTION	=	HEIGHT CORRECTION	+	TRUE TIDAL HEIGHT AT REFERENCE STATION	=	ADJUSTED POND INUNDATION HEIGHT
-60		(2.77÷1.74)=1.59		-38		186		148

Fig. 1. An example of the calculations used for determining the adjusted pond inundation height based on the method described in this paper; MLLW = mean lower low water, MTL = mean tide level.

adjusted pond inundation height for the pond at Mud Slough is estimated to be 148 cm (Fig. 1). Diurnal tidal ranges for many areas can be obtained from the National Ocean Survey (e.g. 1981, Table 2).

Based on this method, inundation heights for ponds in different marshes around an estuary or along a coastline can be adjusted to the same reference station. Thus, a regional value for the mosquito production threshold can be established (e.g. Balling and Resh 1983).

PRECAUTIONARY MEASURES. The predicted tidal heights reported in tide tables are based upon long term (i.e. 19 yr) data records for reference stations. Therefore, the predictions usually differ from empirical measurements. Differences between actual and predicted values can result from constant winds and a long fetch that push tides higher on the downwind side of an embayment, variations in barometric pressure that depress tides in one area relative to another, and unusually high or low river discharges that affect tidal height. With regard to estimating pond inundation height, these influences can be minimized by using high tides that occur in the late evening or early morning, since wind speeds are generally lowest at these times, and by applying the method during the dry season (in a Mediterranean climate), or after an appropriate post-storm period (which will be different for each estuary).

If empirical tidal data are available for the reference station, or if a tide gauge is used to measure tidal height at the pond, then tide tables are not required. However, tide gauge data must be adjusted to the 19-yr epoch; tide table predictions include this correction and need not be adjusted.

Given appropriate consideration of these precautions, a satisfactory estimate of pond inundation height can be obtained from tide tables, and thus can be included in determining a pond's potential for mosquito production (Balling and Resh 1983).

We thank J. N. Collins for assistance in developing this methodology. Support for this research was provided by the University of California Mosquito Research Funds.

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