LETTERS AND COMMENTS/LETTRES ET COMMENTAIRES

Comment on Unionid Growth Curves Derived from Annual Rings: A Baseline Model for Long Point Bay, Lake Erie

Comment

McCuaig and Green (1983) described how the growth of freshwater clam shells might be of practical use in detecting long-term limnological change. They described clam growth from a number of sites in Inner Long Point Bay, Lake Erie, using the well-known Walford method, in which length at age t + 1 is regressed against length at age t for all growth rings on all clams. They then illustrated how an average growth equation can be used as a baseline model for comparison with future clam growth data. Significant changes from the baseline model would be evidence for environmental changes in the bay.

We applaud McCuaig and Green's efforts to utilize clam growth as a limnological monitor, but our own experience in a similar project suggests that development of baseline models using clams will, in general, require more extensive sampling than that performed by McCuaig and Green. Specifically, there is a substantial possibility that the specific model they derived for Inner Long Point Bay is both innacurate and unrealistically precise; therefore, it may not be a suitable reference for measuring environmental change.

Our skepticism about the baseline model arises primarily from McCuaig and Green's decision to eliminate data from one of their four sites (site LRB) before pooling the data for Walford analysis. This decision was based primarily on the finding that growth at the LRB site was significantly different from the pooled (statistically homogeneous) growth data from the other three sites. Because site LRB was also closest to the main shoreline (although there were other sites as close to island shores), was in the shallowest water, and the proportion of *Anodonta grandis* there differed from that at the other sites, McCuaig and Green concluded that growth at site LRB was not representative of the bay.

Our own data on variation in clam growth at different sites within 10 southeastern Ontario lakes (Fig. 1) suggest that significant among-site variation is common, even in water bodies much smaller than Inner Long Point Bay. Although our data are for *Elliptio complanata*, while McCuaig and Green's analyses are for *Anodonta grandis* and *Lampsilis radiata*, we have no reason to believe that our unionid clam provides an atypical picture of among-site variation within lakes. Even though our three sites in each lake were almost all in closer proximity than those of McCuaig and Green, 20% of our lakes had ranges in Walford slopes greater than the range for all four sites in Inner Long Point Bay; 70% of our lakes had ranges greater than that for the three sites finally used in McCuaig and Green's analyses (Fig. 1, upper panel). The equivalent figures for our Walford intercept values are 10 and 40%, respectively (Fig. 1, lower panel). Therefore, the variability encountered among the four sites in Long Point Bay may not be particularly unusual. Based on this larger data set, we suggest that it is no longer appropriate to conclude that site LRB is outside the range of normal growth variability of clams at Inner Long Point Bay, without a more thorough examination of spatial variation in growth than McCuaig and Green's four sites allow.

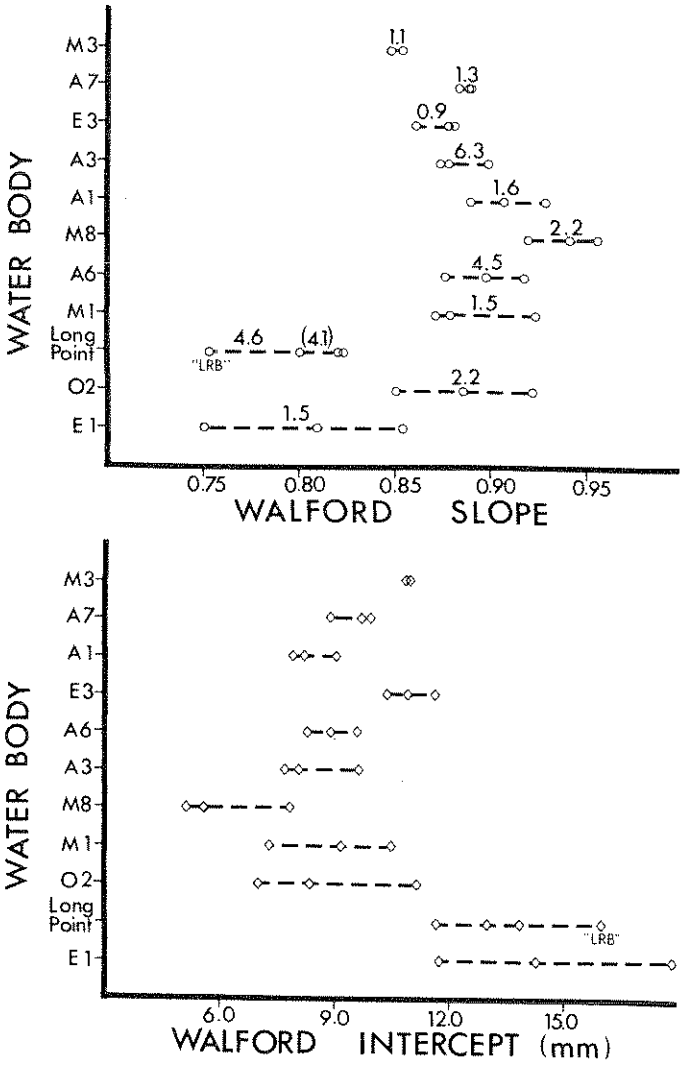

FIG. 1. Walford growth parameters for *Elliptio complanata* from 10 southeastern Ontario lakes (our data) compared with those for *Anodonta grandis* from four sites in Inner Long Point Bay, Lake Erie (McCuaig and Green 1983). Each point in our data set arises from ring measurements on about 100 clams collected at a single site in 1.5–3.0 m of water. Numbers above the points for each lake are the maximum distances (km) between any two of the sampling points. The second distance (in parentheses) for Long Point Bay is that separating the three sites eventually combined by McCuaig and Green (1983).

Frequent occurrence of among-site differences in clam growth (Fig. 1) suggests that it may exhibit the patchiness frequently characteristic of other parts of the benthic community. Furthermore, clam growth is much more spatially variable in some water bodies than in others. At present we are not aware of

data in the literature that would allow us to determine the spatial scale over which clam growth in lakes might be assumed to be uniform. Therefore, we do not know how precisely a sampling site need be relocated in order to obtain a replicate sample of clams from a population that was previously sampled. If spatial variations in growth occur on a small scale, then significant differences from a baseline model of growth might arise, even in the absence of environmental changes, from failure to exactly replicate the site locations of the baseline model.

To summarize, we feel there is a significant possibility that the three sites selected for use by McCuaig and Green are a biased sample of growth responses in the bay. We are also concerned that the precision of the parameter estimates of the baseline model was enhanced by the elimination of site LRB and by the assumption that the individual growth ring widths of single clams are independent data points. Based on the frequency of significant among-site variation in our growth data, we suggest a more conservative approach to the construction of baseline models: growth measurements for clams within each site should be summarized by regression, with the regressions for each site given equal weight in constructing an average baseline model. Models constructed in this way will likely exhibit higher error variance and many fewer degrees of freedom than the model derived by McCuaig and Green. Both these differences will reduce the precision of growth parameter estimates, so that small changes in clam growth will not be as readily detectable as McCuaig and Green depicted. Of course, in cases where sampling shows that growth is really spatially uniform, a less conservative approach, like that of McCuaig and Green, will still be appropriate.

We encourage further use of clam growth measurements as environmental indicators in freshwaters. Reliable, precise, baseline growth models will require (1) statistically acceptable numbers of sample sites distributed over the habitat under study and (2) measures of the reliability of parameter estimates when a site is sampled repeatedly in the absence of environmental change — H. M. Mitchell and N. C. Collins, *Department of Zoology and Erindale College, University of Toronto, Mississauga, Ont. L5L 1C6.*

References

McCuaig, J. M., and R. H. Green. 1983. Unionid growth curves derived from annual rings: a baseline model for Long Point Bay, Lake Erie. Can. J. Fish. Aquat. Sci. 40: 436–442.

Reply

In replying to Mitchell and Collins, it is necessary to clarify what this baseline model was intended to accomplish. In our view, any baseline model is for use to powerfully and robustly detect future change in environmental state. The change we had in mind was some kind of deterioration in water quality that would be pervasive and fairly homogeneous throughout Inner Long Point Bay. Therefore, inclusion of natural spatial variation in the sampling design would only add noise, inflate the error term, reduce power, and contribute nothing to the objective. *One* station would suffice. It makes sense to use more than one station only if it can be shown that the stations are arrayed within a spatially homogeneous region, regarding biological response. We deleted station LRB because it introduced natural environmental spatial heterogeneity into a design that, without station LRB, describes a homogeneous pattern of growth for the flat 2–4 m depth south-central bottom area of Inner Long Point Bay. Sampling in future, to estimate these growth parameters for comparison with the 1981 baseline estimates, should ideally be done at the same stations or at least within the same area of Inner Long Point Bay and within the same range of environmental parameters.

Certainly we did not intend to imply that our purpose was to present a model that described, or predicted, "the range of normal growth variability of clams at Inner Long Point Bay." That was not our purpose, and we apologize if we did not make that clear. We *are* interested in building such "spatial variation" models and have planned further studies in the Long Point Bay area and elsewhere for that purpose. The data provided by Mitchell and Collins are interesting in this regard. See also Green (1972) for results of a study on variation of *Lampsilis radiata* shell morphology as a function of spatial variation in environmental variables.

As for adequacy of sample size, we would emphasize that our paper was primarily an illustration of how a baseline model for growth rate parameters of bivalve molluscs could be created and used. We were not arguing that the sample size we used is generally desirable. As we showed, it was adequate for us to detect as statistically significant the changes in growth rate parameters that we simulated, and those were not large changes. However, we would reemphasize the point (McCuaig and Green 1983, p. 439) that sample size should be sufficient for robustness, and beyond that it should be adequate for detection of the magnitude of change one wants to be able to detect (a low type II error rate). Excessive replication beyond those needs would result in statistical significance of trivially small and environmentally unexplainable changes in growth rate parameters. The importance of preliminary sampling to estimate variation in growth rate among individuals from the same station should be obvious. Field observations or experiments to determine the magnitude of change in growth rate caused by particular kinds and degrees of pollution would also be of great importance in this regard.

Sample size is only one of the factors that affects the power and the robustness of the test against the H_0: "No biologically important change in the environment." The choice of error term to be used in the test is also important. Given a nested design (pairs of annual rings within clams and clams within stations), we would now recommend using variation among clams within stations, pooled over stations that are not significantly different, as the error term in the test of the H_0. Thus, change will be judged against among-clam variation within a given place and time — J. M. McCuaig and R. H. Green, *Department of Zoology, University of Western Ontario, London, Ont. N6A 5B7.*

References

Green, R. H. 1972. Distribution and morphological variation of *Lampsilis radiata* (Pelecypoda, Unionidae) in some central Canadian lakes: a multivariate statistical approach. J. Fish. Res. Board Can. 29: 1565–1570.

McCuaig, J. M., and R. H. Green. 1983. Unionid growth curves derived from annual rings: a baseline model for Long Point Bay, Lake Erie. Can. J. Fish. Aquat. Sci. 40: 436–442.