Table 1. Relative levels of serum proteins, in percentages, in three strains of mice, Tm, Qv, and Wd. All three mutations are simple recessives. Therefore, Tm--, Qv--, and Wd-- indicate normal mice from the Tm, Qv, and Wd strains, and tmtm, qvqv, and wdwd indicate affected mice from the respective strains.

Strains	Genotypes	Sex	No. of determinations	Albumin			Globulin		
				$\bar{x}$	$s_{\bar{x}}$	Difference, P	Alpha	Beta	Gamma
Tm	Tm--	M, F	28	66.95	0.59	<0.001	10.59	14.96	7.50
	tmtm	M, F	14	74.76	1.17		6.22	12.69	6.33
Qv	Qv--	M, F	10	66.36	0.80	<0.05	11.18	14.44	8.02
	qvqv	M, F	10	60.55	1.97		11.46	17.17	10.82
Wd	Wd--	M, F	14	70.45	0.52	<0.05	9.00	12.89	7.66
	wdwd	F	8	73.95	1.49		5.89	11.34	8.82
	wdwd	M	8	70.81	0.76		10.25	11.73	7.21

a constant current of 2.5 ma (75 volts) for 16 hours, by use of the improved techniques described by William, Pickels, and Durrum (*3*). A barbiturate buffer, *p*H 8.6, ionic strength 0.075, was used as electrolyte. The elution technique was adopted for the quantitative determination of the proteins, and a spectrophotometer at a wavelength of 590 mμ was used to read the solution. Bromophenol blue was the dye employed in this procedure. The serum components were labeled as albumin and as alpha, beta, and gamma globulin, in analogy with components of human serum. No effort was made to identify different fractions of each of these components. Both affected and normal mice between 5 and 7 months of age were obtained from strains designated as Quivering (strain symbol, Qv), Waddler (strain symbol, Wd), and Tremulous (strain symbol, Tm) that have been maintained by sib matings for various numbers of generations at Genetics Laboratory of Boston College.

The results of this study are summarized in Table 1. The relative levels of the various components of the serum proteins vary only slightly from strain to strain among normal mice. However, significant changes were observed in the affected animals of all three strains. In the Tm strain, a significant proportional increase in the albumin level and accordingly a proportional decrease of the globulin level were observed. Most of the decrease in the globulin level was accounted for by the sharp decrease in alpha fraction. In the Qv strain, in contrast to the Tm strain, the level of albumin fell considerably in the affected mice and there was an increase in the globulin level. Increased levels were seen in both the beta and gamma fractions, but the alpha fraction remained practically the same as in the normal mice. This is graphically shown in Fig. 1. These differential changes of the serum protein patterns seem to indicate that, although tremulous and quivering mice are strikingly similar in their phenotypic expression, they may result from alterations in different biochemical pathways.

In the Wd strain, the result was more complicated. The affected males showed no significant changes as compared to their normal sibs, but the affected females showed tendencies similar to those observed in the Tm strain. The level of albumin rose and that of the globulin, especially the alpha fraction, dropped. This indicates that the changes in waddler females may be secondary rather than primary effects of this genetic disorder. Since it was observed that the variances in affected mice of all three strains were higher, although statistically not significant, than those in the normal mice, this may be true for tremulous and quivering mice also, if it is assumed that the higher variances are due to gradual changes that take place in the affected mice and that some mice are affected more severely than others at any particular time (*4*).

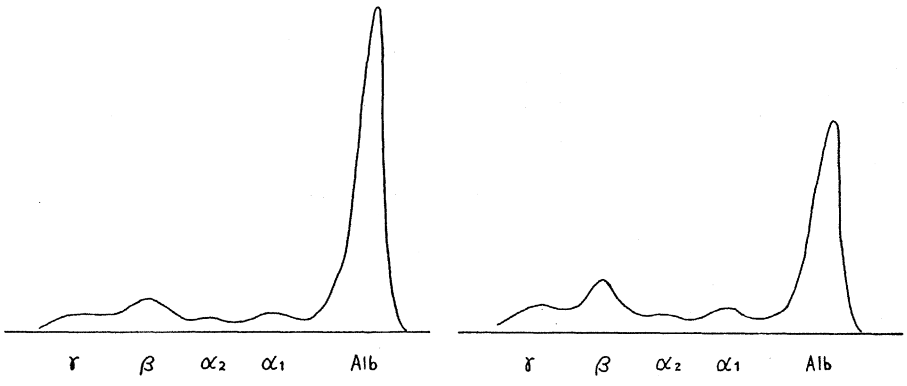

Fig. 1. Electrophoretic patterns of tremulous (left) and quivering (right) mice, showing changes in opposite directions.

CHAI H. YOON

Department of Biology, Boston College, Chestnut Hill, Massachusetts

References and Notes

1. C. H. Yoon, *Am. Naturalist* **94**, 435 (1960).
2. ———, *J. Heredity* **48**, 176 (1957); *ibid.* **50**, 238 (1959); and unpublished data.
3. F. G. Williams, Jr., E. G. Pickels, E. L. Durrum, *Science* **121**, 829 (1955).
4. This work was supported by grant B-2267 from the National Institutes of Health.

11 July 1961

Preliminary Method for Estimating Stability in Plankton

Abstract. The stability of plankton in the York River, Virginia, during the summer of 1960 is computed by a derived empirical stability measure. The communities were indicated to have considerable homeostasis, being over five times more stable than the physical biotope.

In connection with a study of plankton productivity in the York River during the summer of 1960, data were obtained at a station about 300 yards off the pier at the Virginia Institute of Marine Science in 10 consecutive weeks (between 22 June and 25 August) for a number of pertinent variables. In studying these data, it became desirable to know something about the resistance of the communities to change of state.

A number of stability tests are available for linear systems from formal stability theory (*1*), but unfortunately these depend mostly on the nature of the latent roots λ (eigenvalues) of the characteristic equation.

$$\phi(\lambda) = \lambda^n + m_1 \lambda^{n-1} + m_2\lambda^{n-2} + \dots + m_n = 0 \qquad (1)$$

of matrix A in the homogeneous equations

$$(A - \lambda I_n)X = 0 \qquad (2)$$

where A is the coefficient matrix of the canonical representation of the system shown in Eq. 3:

$$
\begin{aligned}
dx_1/dt &= a_{11}x_1 + a_{12}x_2 + \\
&\quad \ldots + a_{1n}x_n + b_1 = 0 \\
dx_2/dt &= a_{21}x_1 + a_{22}x_2 + \\
&\quad \ldots + a_{2n}x_n + b_2 = 0 \\
&\cdots\cdots\cdots\cdots \\
dx_m/dt &= a_{m1}x_1 + a_{m2}x_2 + \\
&\quad \ldots + a_{mn}x_n + b_n = 0 \qquad (3)
\end{aligned}
$$

and X is a column vector whose components are the variables $x_1, x_2, \ldots, x_n$. Since it is usually not possible to obtain sufficient data to represent natural ecosystems canonically and since they are probably not linear, formal stability criteria are not generally available for ecological applications. The only realistic approach is to develop empirical measures. MacArthur (*2*) has provided such a measure for food webs, relating their stability to their entropy. A stability criterion for n variable ecosystems is formulated below and applied to the variables of the York River listed in Table 1. The primary data are fully reported elsewhere (*3*) with details of the methods employed.

In considering the stability of plankton, two basic problems are (i) how stable are they and (ii) are they more stable than their immediate environment? If all the variables of an ecological system were random variables, randomly sampled, then each variable might be regarded as most stable if and when the probability for an increase in value when low and for a decrease when high were unity. Assuming the stability of the whole system to be in direct relation to that of the individual variables (not a sound assumption, technically, but acceptable for first approximation purposes), then a simple stability measure might be

$$\sigma = \frac{1}{n} \sum_{j=1}^{n} s_j \qquad (4)$$

where σ is the stability of the system, and s_j that of the jth of n variables. For stability of the separate variables, consider the matrix of transition probabilities P:

$$P = \begin{bmatrix} p_{id} & p_{ii} \\ p_{dd} & p_{di} \end{bmatrix} \qquad (5)$$

where p_{id} represents the probability for a decrease following an increase, p_{ii} that for an increase following an increase, and so forth. We may associate with P a determinant, and employ it as a stability measure for the jth variable. Thus, Eq. 4 can be written

$$\sigma = \frac{1}{n} \sum_{j=1}^{n} \det P_j \qquad (6)$$

where σ has a range $-1 \leqq \sigma \leqq 1$. Null stability of the system is denoted by $\sigma = 0$, instability by $\sigma < 0$, and stability by $\sigma > 0$.

By separating all the variables of the York River for which data were obtained into two groups, physical and biological stabilities can be computed separately for the environment (σ_E) and for the plankton (σ_P). The calculations are summarized in Table 1. The results, $\sigma_E = 0.12$ and $\sigma_P = 0.65$, indicate that the plankton were 5.4 times more stable than the physical habitat. This degree of homeostasis (0.65 on a scale with maximum value unity) seems quite remarkable considering how loosely integrated plankton communities are usually thought to be (*4*).

B. C. PATTEN

Virginia Institute of Marine Science,
College of William and Mary,
Gloucester Point

References and Notes

1. A. Porter, *Introduction to Servomechanisms* (Methuen, London, 1950); W. R. Ashby, *Design for a Brain* (Wiley, New York, ed. 2, 1960).
2. R. H. MacArthur, *Ecology* **36**, 533 (1957).
3. B. C. Patten, unpublished manuscript.
4. This report is contribution No. 94 from the Virginia Institute of Marine Science.

15 May 1961

Table 1. Stability determinations for plankton in the York River during the summer of 1960. "Trajectory" refers to the line of behavior of each variable (averaged for the whole water column) in terms of whether it increased (*i*) or decreased (*d*) over the preceding observation.

Variables (j)	Trajectory	p_{id}	p_{di}	p_{ii}	p_{dd}	det P_j
	Environment					
Temperature	iiidididd	.60	.67	.40	.33	.27
Chlorinity	iiiiidddi	.20	.33	.80	.67	−.47
Dissolved oxygen	iddiiddid	.75	.50	.25	.50	.25
Nitrate-nitrogen	diidddid	.67	.50	.33	.50	.17
Inorganic phosphorus, dissolved	diiddiidi	.50	.75	.50	.25	.25
Inorganic phosphorus, adsorbed	iddiiiidd	.40	.33	.60	.67	−.27
Organic phosphorus, dissolved	iiddidddd	.67	.20	.33	.80	−.13
Total solids	ididdiidi	.75	.75	.25	.25	.50
Extinction coefficient	ididdiidd	.75	.50	.25	.50	.25
Secchi disc	didiiddii	.50	.67	.50	.33	.17
Light intensity	dddididdd	1.00	.33	.00	.67	.33
$\Sigma\det P_j$						1.32
$\sigma_E = {}^1/_{11}\,\Sigma \det P_j$						0.12
	Plankton					
Total chlorophyll	dididididid	1.00	1.00	.00	.00	1.00
Chlorophyll *a**	idiiidid	.60	1.00	.40	.00	.60
Chlorophyll *b**	didiidid	.75	1.00	.25	.00	.75
Chlorophyll *c**	(none present)					
Carotenoids, astacin*	ididiidi	.75	1.00	.25	.00	.75
Carotenoids, non-astacin*	(none present)					
Organic phosphorus, particulate	iddidiiid	.60	.67	.40	.37	.25
Biomass	ididdiddi	1.00	.60	.00	.40	.60
Cell counts	iidididid	.80	1.00	.20	.00	.80
Number of species	didiididi	.75	1.00	.25	.00	.75
Gross production	iidididid	.80	1.00	.20	.00	.80
Respiration	iddiiidid	.60	.67	.40	.33	.25
Net production	diiididid	.60	1.00	.40	.00	.60
$\Sigma \det P_j$						7.15
$\sigma_P = {}^1/_{11}\,\Sigma\det P_j$						0.65

* Information provided by M. L. Brehmer.

Bow Wave Riding of Dolphins

Abstract. Dolphins riding bow waves were observed through underwater viewing ports. The postures assumed by the dolphins show that they present their bodies rather than the ventral surfaces of their flukes to the propellant forces of the bow wave.

How dolphins ride bow waves is the subject of a current controversy. After observing them performing this feat through underwater viewing ports in a ship's bow, I would like to report the method the dolphins themselves seem to consider proper.

Since Woodcock (*1*) noticed the "motionless" swimming of dolphins and interpreted it as bow wave riding, several proposals attempting to reconcile it with hydrodynamic theory have been advanced. Woodcock and McBride (*2*) concluded that only under conditions of laminar flow and nonbuoyancy could a dolphin sufficiently overcome drag to get a ride. Hayes (*3*) then showed in