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SURVIVAL OF FRESHWATER AND SALTWATER ORGANISMS IN A HETEROGENEOUS FLOOD MODEL EXPERIMENT

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The Noahic flood destroyed all the air breathing animals except those on the ark. No doubt the flood also took a major toll on freshwater and marine organisms due to the turbulance, turbidity, changes in salinity and temperature. Some marine animals probably survived by simply tolerating changes in salinity. Survival of a marine reef fish, Blue Damsel, Abudefduf uniocellatus, was tested at different rates of freshwater dilution. It was found that the salinity where the fish lost the ability to swim was the same when exposed to dilution rates of 15 0/00/hrs (parts per thousand per hour) and 1.5 0/00/hr but was higher with the slow dilution rate of 0.031 0/00/hr. These data suggest that marine organisms could not have survived a homogeneous freshwater deluge.

A heterogeneous flood model was set up in a 55-gallon aquarium. A quantity of saltwater 20 cm deep was overlaid with freshwater and the system was exposed to outdoor summertime weather conditions in western Oklahoma. Marine algae (Phaeophyta and Chlorophyta), brine shrimp (Artemia nauplii), a hermit crab and some marine gastropods were introduced into the saltwater portion. A goldfish (Carassius auratus), two mosquito fish (Gambusia affinis), and freshwater plants were introduced into the surface layer. Although some mixing occurred, all the organisms survived four week exposure to outdoor conditions suggesting that protected pockets of marine organisms may have survived the flood by being overlaid with freshwater.

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Introduction

THE FLOOD AND LIVING ORGANISMS: The flood described in Genesis was a catastrophe of such magnitude that its effects are difficult to grasp. No doubt raging waters during the flood and the receding waters at the end of the flood shaped much of the earth's topography. Many excellent papers dealing with flood geology have been published in this journal.[1-4] Much of the abundant fossil record was deposited during the flood and such a record is testimony to the death and destruction brought by the deluge.[5]

Terrestrial animals, including man, survived by God's provision of the ark. The Biblical account, however, is silent regarding survival of other organisms. Broadly, one may divide other organisms which must have survived the flood into the following three categories: terrestrial plants, aquatic (freshwater) plants and animals, and marine (saltwater) plants and animals.

Howe[6] provided evidence that some kinds of terrestrial plant seeds can survive long periods of soaking in varying concentrations of salt water. Perhaps other plants survived in floating masses and certainly many land plants survived as accidental and planned food stores on the ark.

Freshwater plants and animals were no doubt drastically reduced in numbers by the flood. As the flood developed, turbulence, turbidity and changes in salinity, temperature and dissolved oxygen would destroy most of the organisms living in the water. The decomposing bodies of drowned terrestrial animals and plants would further reduce available oxygen and alter nutrient balance. Nevertheless, it is quite conceivable that most kinds of freshwater organisms could, at least in small protected places, survive and even reproduce during the terrible deluge and repopulate suitable aquatic habitats following the flood. One such example being the freshwater alga, *Lemanae fucina*, which, although being vegetatively stunted and having its sexual development retarded, does withstand short and repeated exposures to saltwater.[7]

Survival of marine plants and animals during the year of the flood is less obvious. Many estuarine and some tidepool species are euryhaline and thus can tolerate marked changes in salinity. Some organisms complete portions of their life cycle in one medium only to reproduce in another. For example, salmon, striped bass and a few other fish spawn in freshwater and mature in saltwater. Eels reproduce in sea water but grow to maturity in freshwater streams and lakes. Such animals (and euryhaline plants as well) could survive, although many individuals would succumb to the stresses inherent in the flood. Even the euryhaline teleost, *Fundulus kansae*, fish require several days to adjust to rapid changes in salinity.[8]

There are, however, many kinds of marine plants and animals that are stenohaline and thus cannot tolerate large changes in salinity. The internal salt balance of marine organisms is precisely regulated and has been studied for over 50 years.[9] Even the breaking of a small dam and subsequent flooding of a marine harbor by freshwater took a heavy toll on marine fauna.[10]

Two models have been suggested for the survival of the flood by stenohaline organisms. Whitcomb and Morris, among others, have suggested that if the changes in salinity were slow enough marine life could survive.[11] Indeed, many organisms can adjust to moderate changes in salinity if the changes are gradual. Young barnacles can withstand exposure to 3 0/00 salinity if reduced slowly.[12] However, many marine organisms seem not able to survive freshwater dilution beyond certain limits no matter how slowly the dilution occurs.[13] Starfish, *Asterios forbesi*, can survive dilution to 16% for two months and survive indefinitely at 18-20%. They survive short exposures to 3% but die after one hour exposure. Attempts to increase the tolerance of starfish to low salinities by slow, gradual changes of salinity failed. An absolute threshold of 16-18% exists for starfish.[14]

A second model, suggested earlier, is that of a heterogeneous flood. In the heterogeneous flood model, preflood seas were thought to have been overlaid with freshwater during the flood. Such a system is, for a time, physically stable due to the greater density of the saltwater. Limited data from an earlier experiment indicated survival of both aquatic and marine organisms in the same small aquarium is possible.[15] Several examples of naturally occurring heterogeneous situations have been described. In the previously mentioned flooding of Newport Bay, freshwater persisted atop saltwater for several days.[16] Wood and Straughan describe a typical situation where freshwater flows into the ocean forming a freshwater wedge riding above saltwater. Hot brines overlaid with freshwater were described in Venezuela.[17] Deep water brines are found in the Red Sea[18] and Gulf of Mexico.[19]

The purpose of this study was to investigate both models experimentally. Marine fish were tested for their tolerance to freshwater dilution at different rates and a two-layer heterogeneous aquarium was established outdoors to test survival of marine and aquatic organisms and to measure the physical stability of such a system.

Experimental Methods

DILUTION TOLERANCE MODEL: Two 10-gallon aquaria were partially filled with 20 liters of artificial seawater, the bottom was covered with crushed oyster shells and brine shrimp were added to each. The water was aerated and the systems were maintained at room temperature (22-23°C) throughout the course of the experiment. Blue Damsel Fish *(Abudefduf uniocellatus)* were placed in both tanks. All the fish were approximately the same size. Fresh water was added to the experimental tank and saltwater removed to maintain a volume of 20 L. In the first rapid dilution experiment, salinity was reduced in twenty 1.5 0/00 increments over time periods of two hours or a rate of dilution of 15 0/00/hr. Two additional experiments (intermediate and slow dilution) were performed and salinity was reduced in twenty 1.5 0/00 increments over a period of 20 hours (1.5 0/00/hr) and 40 days (0.031 0/00/hr). Salinity was measured with a salinity meter (YSI Model 33). Observations were made on the activity level and behavior of the fish periodically between changes, and fish were removed when loss of locomotive ability (ability to right themselves) occurred. Salinity levels were recorded and the fish were placed in a seawater tank to recover. Ten fish were used in each experiment and means of the salinity where loss of locomotive ability occurred for each individual fish were compared by Student's t-test. Means were considered significant if $P < 0.01$.

HETEROGENEOUS MODEL: A 55-gallon glass aquarium was placed on a metal support stand and set up outdoors with the long axis oriented in an east-west direction to minimize the solar heating of the water in the tank. Styrofoam (1½") was attached to all but the north-facing side to reduce light and diurnal temperature changes. Styrofoam also insulated the bottom of the aquarium. An open lattice-roofed shelter was erected over the aquarium to reduce solar heating.

The 55-gallon tank was filled to a depth of 20 cm with artificial seawater from a commercial mix (Instant Ocean), the bottom of the tank covered with a layer of crushed oyster shell to buffer pH. Marine algae from an established seawater aquarium was added and the system was aerated thoroughly for three days. A good growth of algae to provide oxygen was developed and brine shrimp *(Artemia spp.)* were added. Marine organisms were then added to the system including a 6 cm Striped Damsel Fish *(Dascyllus aruanas)* a 5 cm Hermit Crab and sea slugs (Gastropods). These animals were allowed to adapt overnight to conditions in the tank before adding freshwater.

Freshwater was overlaid above the saltwater to a depth of 16 cm above the saltwater level. It was added by pouring it gently onto the surface of a board floating on the surface. This allowed the filling of the tank without greatly mixing the two layers. Two locally collected 2 cm Mosquito Fish *(Gambusia affinis)* and a 4 cm Goldfish *(Carassius auratus)* were then added to the freshwater. Also added were a freshwater snail and duckweed *(Lemma sp.)* collected locally.

Twice daily, on alternate days, at 8:30 AM and 4:30 PM, measurements were taken at 2 cm intervals from the waterline to the bottom of the tank. These measurements included water temperature, dissolved oxygen content, and salinity. Measurements were made using a Dissolved Oxygen Meter (YSI Model 51B) and a Salinity-Conductivity-Temperature Meter (YSI Model 33). Additionally, environmental measurements were taken including wind speed and direction, air temperature, relative humidity and approximate amount of cloud cover. Observations on the conditions and behavior of the organisms and the general state of the system as a whole were also recorded at these times.

Results

DILUTION TOLERANCE: Blue Damsel Fish exposed to dilute saltwater turned dark just prior to loss of locomotive ability. The rapid dilution rate of 15 0/00 salinity/hr loss of locomotive ability was observed at 0.80 ± 0.08 0/00 salinity. Loss of locomotive ability occurred at 0.88 ± 0.36 0/00 salinity for the intermediate dilution rate of 1.5 0/00 salinity/hr. These results are not significantly different even though rates of dilution are different by a factor of 10. At the slow rate of dilution of 0.031 0/00 salinity/hour the fish stopped swimming at 20.3 ± 1.1 0/00 salinity. Slow dilution then resulted in less ($P < 0.01$) tolerance to dilution for fish in this experiment.

HETEROGENEOUS MODEL: The salt and freshwater layers remained relatively distinct in the heterogeneous aquarium flood model for the 30-day duration of the experiment. All the animals and plants survived

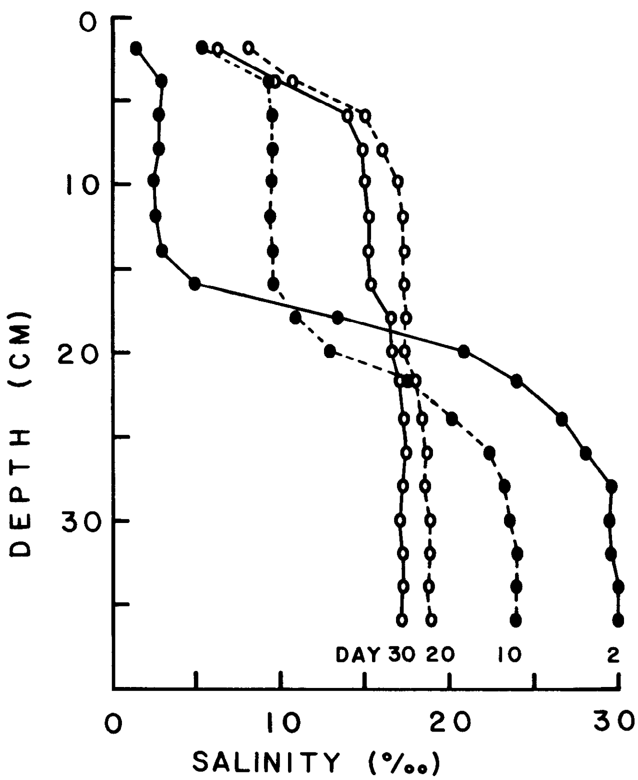

Figure 1. Relation of depth in centimeters from the surface to salinity in parts per thousand (o/oo) during the 30-day experiment.

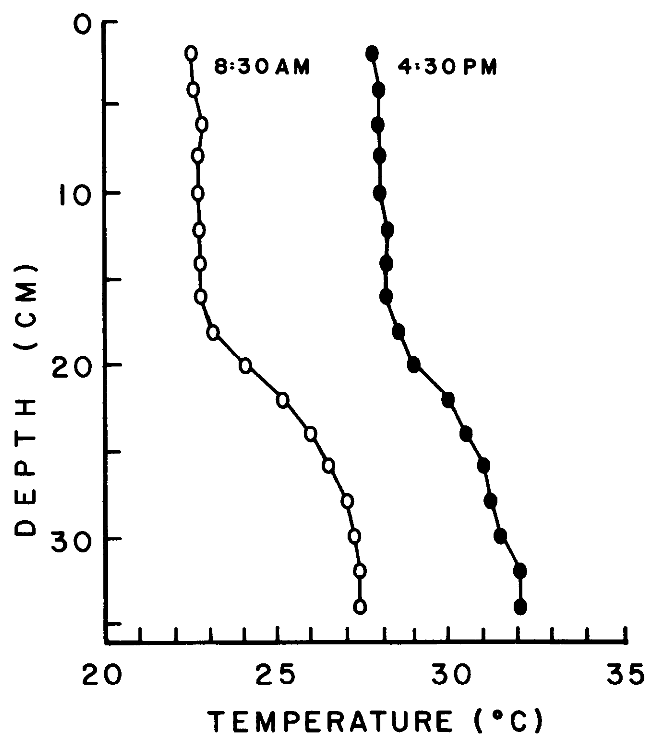

Figure 2. Temperature profile at different depths in the morning and afternoon. Lower saltwater remained warmer especially at night.

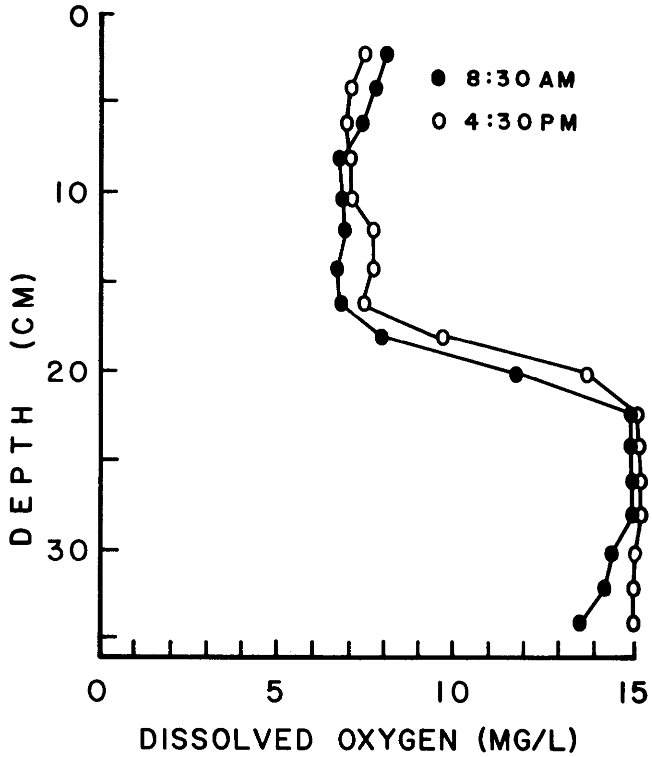

Figure 3. Dissolved oxygen profile at different depths in the morning and afternoon. Lower readings were above 15 mg/L and were off scale on the oxygen meter. The lower saltwater layer consistently contained more oxygen than the upper freshwater due to photosynthesis of marine algae.

even though there was an expansion of the transition layer between salt and freshwater.

Throughout the experiment the goldfish remained in the freshwater layer with only short excursions into the lower saltwater layer during the first few days. Conversely the damsel fish remained in the saltwater layer except for a few feeding excursions into the transition layer and upper region of the freshwater. In contrast the mosquito fish moved freely throughout the aquarium showing no preference for any salinity region. The sea slugs and hermit crabs remained exclusively in the lower portion. Some brown algae were limited to the saltwater and some green algae seemed to do best in the transition layer and increased in area on the glass as the transition layer expanded with time.

Figure 1 shows the salinity changes throughout the experiment. There was some dilution of sea water and salinity increased in the freshwater, however differences were still evident after 30 days. Figure 2 shows morning and afternoon temperature profiles and Figure 3 shows the morning and afternoon dissolved oxygen profiles at mid-experiment. Figure 4 shows changes in isohaline depths during the course of the experiment.

Discussion

Results of the dilution tolerance experiments and much of the literature do not support the suggestion that marine animals can tolerate freshwater dilution. Many organisms have a relatively fixed limit to changes in salinity they can withstand no matter how slow the dilution rate. It is reasonable to expect organisms to withstand a greater salinity shock than that in which they can survive. Such is certainly the case for temperature tolerance. Data from this study suggest less tolerance to dilution at very slow rates. This raises serious questions as to how marine organisms could have tolerated a homogeneously mixed freshwater deluge.

Results from the heterogeneous flood model experiment are more encouraging. All plants and animals did survive and mixing of freshwater and saltwater were incomplete even with exposure to outside environmental conditions (see Figure 4). It is interesting that the highest oxygen levels were found in the lower saltwater layer. This suggests that oxygen would be available for marine life if sufficient light penetrated the overlying freshwater layers. Photosynthesis would therefore provide for the growth of autotrophs and the entire marine food chain. In addition, there no doubt would have been a continual "rain" of nutrients from the upper freshwater layer.

A "natural" system, as occurred during the flood, would obviously be more complex and stable than our miniature model. Increased plant and animal diversity would improve stability. Nutrient reserves would abound and a mixing interface region measured in meters or even tens of meters would still permit stenohaline species to exist above and below.

The vast majority of marine life probably was destroyed during the flood as was true of terrestrial plants

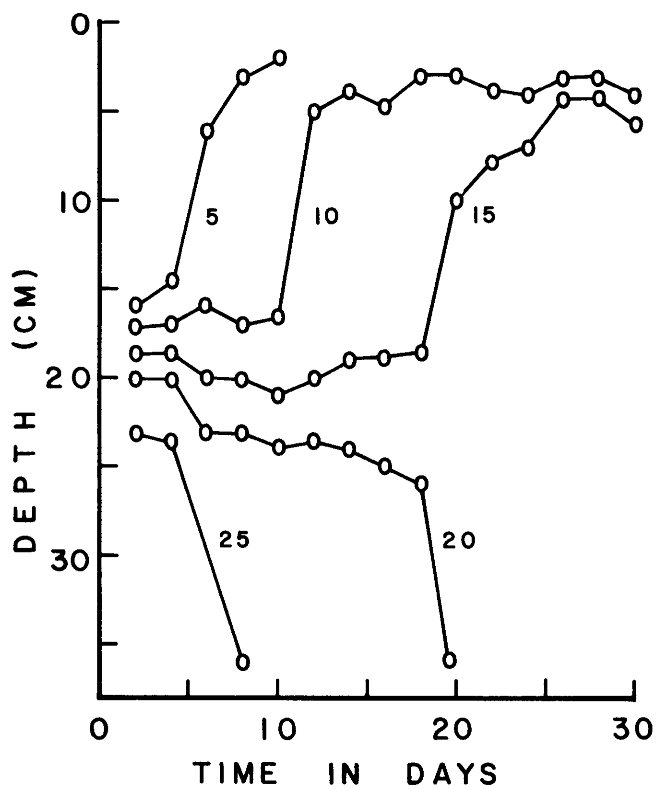

Figure 4. Isohaline depths for different salinities during the 30-day experiment. The thickness of the transition zone separating fresh and saltwater increased during the experiment. Mixing was due to activity of the fish in both regions and wave action (from wind).

and animals and much of the aquatic life. It may be argued, however, that small protected areas of the pre-flood seas were overlaid with freshwater during the flood and marine organisms could have survived. Obviously, additional research is needed, especially regarding the reestablishment of our present seawater salinity at the end of the flood.

Acknowledgements

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DARWIN'S LAST HOURS REVISITED

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The material presented in the tract, Darwin's Last Hours, does not correspond with the facts known about Charles Darwin. It is suggested that Christians not use the tract in any creation-evolution discussions.

Introduction

In 1975 I wrote an article entitled Darwin's Last Hours[1] as an answer to a tract of the same name. Since the appearance of that article, a number of critical references have been made to it in some publications.[2] My original concern was that this tract was being distributed in quantities to high school students for use in biology classes as support for the creationist position. When I was asked to evaluate it, I studied it very carefully. After some research in university graduate libraries, I felt that sufficient reasons had been accumulated to doubt its authenticity and question its proposed use. Apparently wishful thinking dies hard.

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The Darwin Tract

It is true that Darwin's undergraduate degree was a bachelor of divinity. However, he made the Beagle voyage before he could enter the ministry. On his return, he had lost all desire to become a vicar. Later he lost his Christian faith as well. The original tract carried a short account of a lecture, supposedly documenting Darwin's return to the Christian faith. A number of variants have appeared but all agree that the lecturer was a Lady Hope, a consecrated Englishwoman from Northfield, England, according to one version. The location of the delivery of the lecture is not specified.[3] According to another source, the lecture was delivered on August 15, 1915 in Northfield, England. Subsequently it was published in the *Watchman Examiner*,[4] date unspecified. According to yet an-