Aquaria: needs and aspirations[1]

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ABSTRACT

The major changes taking place in captive bodies of seawater are decreases in alkaline reserve, pH, and dissolved oxygen. Inorganic nitrogen compounds, carbon dioxide, phosphates, dissolved organic compounds, and bacteria increase in concentration. Methods which have been applied to reduce the rates of these changes include nitrification by bacteria, adsorptive filtration, ozonation, ultraviolet light, protein foaming, ion-exchange resins, autotrophic buffering systems, and dilution of the culture medium. Improvements in aquaria are dependent on behavioral studies, direct transfer of deep-water forms, increased knowledge of organic fractions in the culture medium, selective means for removal of inhibitory compounds, and improved artificial media. A computer-controlled system is envisioned as a developmental goal.—GOLDIZEN, V. C. Aquaria: needs and aspirations. *Federation Proc.* 32: 2209–2211 1973.

Investigators working with marine invertebrates were for many years limited to seashore laboratories, and in temperate zones to those months of the year in which weather conditions allowed collecting. The desirability of maintaining animals continuously and independently of the sea has prompted a number of investigations into the chemistry and biology of captive bodies of water and the development of techniques to reduce the rates of changes which take place in a delimited volume of seawater containing animals. While the major changes have been reviewed elsewhere, notably by Atz (1) and King (11), they may be summarized as follows: *1)* Dissolved oxygen decreases while carbon dioxide increases. *2)* Inorganic nitrogen compounds increase. *3)* The alkaline reserve of the seawater decreases with an associated drop in pH. *4)* The concentration of phosphate, sulfate, calcium, and potassium ions increases. *5)* The total organic content of the water increases. *6)* Bacterial numbers increase, but species diversity decreases.

Changes in the partial pressures of the named gases and in pH first become critical to the survival of captive animals.

STATE OF THE ART

Techniques for maintenance of marine animals in captivity have been discussed by Clark and Clark (2) and Spotte (15) for large-scale systems, and recently by Hauenschild (4) for laboratory aquaria.

The simplest method of maintaining water quality in aquaria consists of constant replacement of the medium, but an unlimited supply of seawater is required, and the investigator must consider variations in temperature, salinity, turbidity, and the possible introduction of toxins in the seawater supply. Use of a large culture medium: animal–load ratio as employed by Lickey et al. (12) delays the rate of alteration of the culture medium, but few laboratories can afford the space required for large volume storage. The body of water becomes common to all aquaria, with the probability of cross-contamination between experiments. Individual aquaria of appropriate size thus become the choice remaining to the investigator. At this level the subgravel filter (a misnomer, as filtration takes place in gravel or other medium providing a large surface) is widely used. Filters of this type provide some mechanical filtration but, more importantly, serve as substrate for aerobic microorganisms which oxidize metabolites and degradation products produced in aquaria. Hirayama (6–9) has quantified the design of such filters in relation to the load of marine fishes present, and Goldizen (3) suggested criteria for several invertebrates. A lag period for development of the microflora is necessary, and the oxidative products, e.g., nitrate ion, may also be toxic in the high concentrations obtained in time. Partial replacement of the culture medium on a routine basis will reduce levels of the higher oxides, but rarely to the concentrations found in the sea. Nevertheless, the subgravel filter in several modifications is in wide use and is available in several commercial units which also provide temperature control and aeration. It is likely that the majority of the marine invertebrate biomass being maintained in laboratories today is held in systems of this type.

Modifications to subgravel filter systems, or substitutes for them in situations in which no mechanical filtration is desired or the presence of aerobic bacteria would interfere with an experiment, have been developed. Adsorptive filters are successfully used to remove organic compounds, provided that the filtrant is regularly replaced and does not itself introduce toxic materials to the system. Ozone can be used to oxidize organic compounds containing unsaturated double bonds, and is effective in inhibiting bacteria. Ozone is toxic to marine animals, however, and must be introduced into the system in such manner that it has been reduced to molecular oxygen before the water is returned to the main culture sys-

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tem. In view of the danger of ozone to humans, its use in invertebrate culture is not recommended by King (11).

Ultraviolet radiation offers an alternate means to bacteriostasis in culture systems, and was first employed on a large scale by Herald et al. (5). Total removal of suspended bacteria is not achieved, but counts remain in the order of those found in nearshore unpolluted seawater. Units guaranteeing 98% removal of bacteria at up to 10,000 gallons/min flow are now commercially available, and smaller units can be obtained for the limited aquarist.

Wallace and Wilson (16) have suggested foam fractionation as a useful tool. Also called protein skimmers, these units depend on the electrostatic charge produced on small bubbles to attract and carry off charged particles. They are effective in removing proteins, amino acids, and other surface-active compounds, but are less effective in removing carbohydrates. Suspensoids become entrapped in the foam and are partially removed by protein skimming, but partial water changes and the introduction of food would serve to ameliorate these losses. Our own experience with this technique indicates that it can be useful as an emergency measure after the death of an animal, if replacement medium is not immediately available.

Ion exchange resins are on the market that are claimed to selectively remove inorganic nitrogen compounds from culture media. The selectivity of these resins has not as yet reached this point (I. Zabin, personal communication), so that classes of compounds are retained rather than specific ions. These resins are therefore not recommended as specific treatments at this time.

Sorokin (14) described the effects of growing algal cultures on the pH and buffering capacity of culture media. Plant systems have been employed to take up nutrients from circulating systems, and we are currently employing seaweeds to scavenge residual nutrients from a tertiary sewage treatment-oyster culture system. The plants must be furnished with light of appropriate spectral distribution, intensity, and duration to achieve optimum uptake of nutrients, and frequent cropping is necessary, but these systems show promise for those having the space and time to operate them.

Artificial seawaters have become commercially available in several formulations over the past decade. Several of these will support many species of invertebrates in properly designed culture systems and are therefore convenient to use in inland areas. None of the formulations has yet been found to equal natural seawater in all applications, but reports of failures may in part be the result of improper management of the culture medium after it has been made up to specifications.

NEEDS AND ASPIRATIONS

The conformation of aquaria has tended to fit the space available. A standard aquarium is a rectangular solid which sits neatly on a bench or aquarium room shelf. Extensive in situ behavioral studies on species of interest are needed in order that laboratory habitats can, within our capabilities, closely mimic the habitat from which the animal is removed. Cover, current, light intensity, and tidal variations are among the factors which can be controlled if we know what patterns are appropriate to the animal which interests us.

Animals retrieved from deep waters have typically been exposed to traumatic pressure reductions before they are brought to a ship- or land-based pressure facility and repressurized for study. To avoid this hypobaric insult to experimental animals, the Harbor Branch Foundation Laboratory is now installing the first phase of a system which is expected to avoid any significant pressure changes between point of capture and the experimental chamber (R. P. Meek, personal communication). Organisms are hand-captured by divers working from a lock-out submarine, or are collected in traps deployed and recovered by the submarine. Individual specimens will be placed in small transport chambers sealed at depth, and then be transported to the laboratory after the submersible resurfaces. The transport container will be mated to a 230-liter spherical chamber whose internal pressure is equalized with the transport chamber prior to transfer of the specimen. The current design allows for visual observations and dissolved oxygen monitoring. A second phase of this project will provide a recirculating system that entails depressurization of the medium leaving the pressure chamber, water treatment, pO_2 adjustment, and repressurization before the medium is again pumped into the main chamber.

Artificial media will more closely approximate seawater as demand increases, but special formulations will be required for particular applications such as replication of brackish environments. Where possible, results obtained in artificial media should still be compared with those obtained in natural seawater until the investigator can demonstrate that no significant difference obtains.

A better understanding of the organic compounds present in aquaria, and their derivation, should enable closer control of their levels, if indeed such control is necessary. Selective removal of inhibitory compounds could markedly extend the support capability of an aquarium.

As to aspirations, a totally controlled environment, reminiscent of Moore and Gray's (13) automatic salinity control system, may one day be available to us all through our nearest computer terminal. FP

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