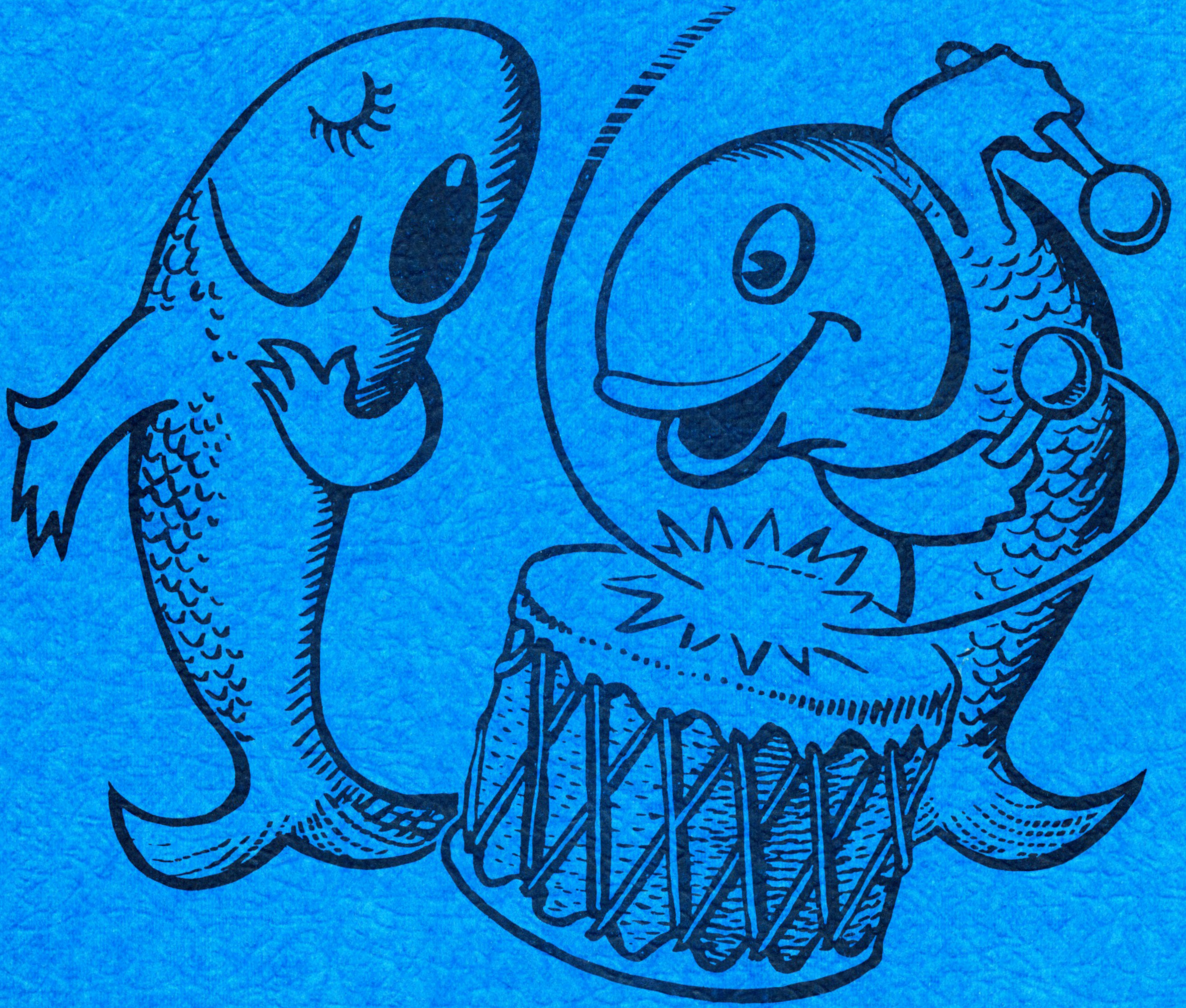
The DRUM and CROAKER

A Highly Irregular Journal for the Public Aquarist



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DRUM AND CROAKER

The Informal Organ

for

Aquarists

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1200 South Lake Shore Drive
Chicago, Illinois 60605

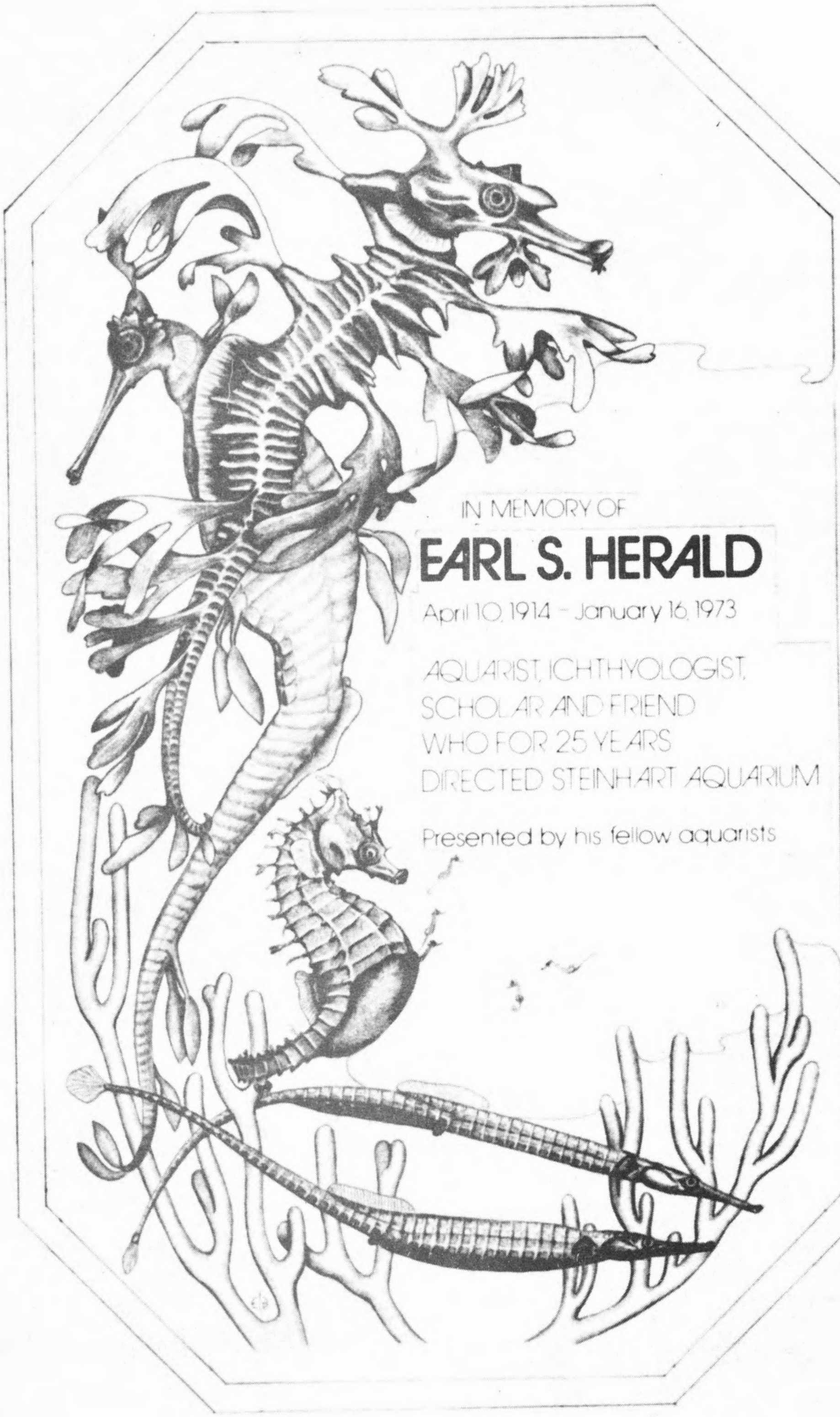
This issue of DRUM AND CROAKER compiled by Kim J. Marggraf, Secretary to the Director, John G. Shedd Aquarium.

Prepared by the John G. Shedd Aquarium; 1200 South Lake Shore Drive; Chicago, Illinois as a service to aquariums generally.

This issue of DRUM & CROAKER is dedicated to

Earl S. Herald

April 10, 1914 - January 16, 1973



Design of plaque in memory of Earl Herald, to be displayed in the Steinhart Aquarium, and made possible through the generosity of his friends and colleagues.

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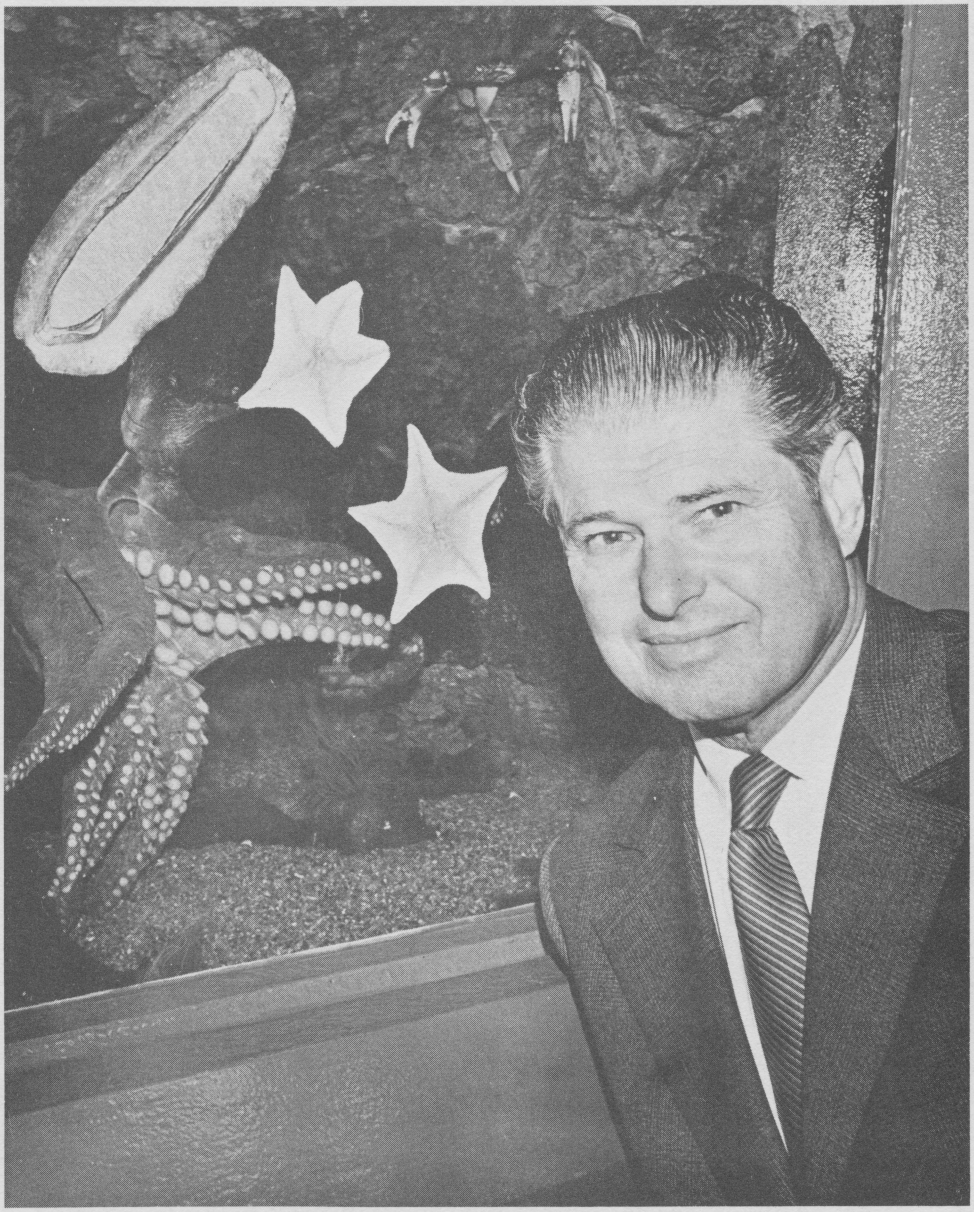


Earl Stannard Herald

EARL S. HERALD

April 10, 1914 - January 16, 1973

Dr. Earl Stannard Herald was the most outstanding professional aquarist of the U.S.A. and, perhaps, the entire world. This evaluation is not based on his absolute preeminence in any particular field of endeavor, but on his excellence in every one of the disparate activities that sooner or later involve the director of any large, public aquarium. No one aquarium man ever did so much for his institution and at the same time so much for his profession, his public, and his science as did Earl Herald during his astoundingly diversified career as institutional director, public relations expert, educator, author, and ichthyologist.

Too small ever to house the largest collection of aquatic animals in the world and too old-fashioned ever to permit it to be the most novel or advanced, the Steinhart Aquarium nevertheless became, under Earl's leadership, the home of what was probably the New World's finest collection of living fishes as well as some of the most important recent technical advances in aquariology. Prophylaxis and treatment of disease with copper and water sterilization by means of ultraviolet are but two of our present-day techniques that were developed largely by Earl and his staff. Earl dreamed of the day when the operation of public aquariums would be both fully automated and foolproof, and he took the first steps to make Steinhart work that way. He never stopped searching for new and spectacular exhibits for his institution, and it was typical of his audacious optimism, tempered by practical showmanship, that the renovated Steinhart included a tank expecially designed for that greatest of all finny rarities, the coelacanth, but a tank which could also hold other worthwhile exhibits until an expedition to the far-off Comoro Islands could be launched.

Earl never lost an opportunity to boost the aquarium profession, and he constantly preached and consistently practiced inter-institutional cooperation. In 1957 he founded "Drum and Croaker" and served as the editor for the journal's first two issues. He was one of the nine original "Trustees" of the Aquarium Research Science Endeavor (A.R.S.E.) and through the years, a leading participant in aquarium symposia, including the First International Congress of Aquariology, held in Monaco in 1960. Beginning in 1963, he also served prominently as a member of the study team for the National Fisheries Center and Aquarium.

For more than a dozen years, Earl starred in an award-winning television show called "Science in Action". Hundreds of thousands of people got the message that Science is interesting and worthwhile by watching Earl interview prominent scientists, introduce the Animal of the Week, or show off some new development in the aquarium world. With this popular weekly program and his two widely disseminated books, Earl undoubtedly reached a greater audience than has any public aquarist, before or since. His Living Fishes of the World (Doubleday, 1961) is the most complete and accurate non-technical survey of the world's fishes that has ever been written, at least in the English language. It was the best illustrated, too, until his second book, Fishes of North America (Doubleday, 1972) appeared.

In all, from 1939 until 1973, Earl Herald wrote nearly one hundred scientific and popular articles. He was the world's authority on the Family Syngnathidae, the seahorses and pipefishes. One result of his studies on these fishes was that he was able to recognize and describe 21 new species of pipefishes and 4 new subspecies as well. He was an expert fish collector and captured thousands of specimens as a member of the George Vanderbilt Pacific Equatorial Expedition (1951), the Philippine Fishery Program of the Fish and Wildlife Service (1947), and Operations Crossroads (1946) which studied the life of Bikini Atoll just before the atom-bomb tests were carried out.

Earl Herald was convinced that science and aquarium management are intimately connected and that their relationship is most definitely a two-way street. Many of the observations he made in Steinhart's tanks found their way into scientific reports--for example, the discovery that the blind dolphin of the Indian subcontinent habitually swims on its side. Earl always tried to apply scientific methods to the solution of aquarium problems. It was no accident that the authoritative account of the white-flag dolphin from Tung Lake in mainland China, published by the American Society of Mammalogists in 1972, was written by Earl (with Robert L. Brownell, Jr.). As soon as the Bamboo Curtain was lifted, Earl has set his sights on that mysterious cetacean, and he began his preparations by systematically finding out everything he could about the creature.

White-flag dolphins and coelacanths should rest a bit easier now that Earl will not be able to carry out his designs on them. But the entire aquarium world, as well as all people who believe that Science must play a vital role in man's future, can only grieve his untimely death.

James W. Atz
The American Museum of Natural History

EARL S. HERALD

DIRECTOR, STEINHART AQUARIUM

1948 - 1973

The death of Earl Herald while diving off Cabo San Lucas on January 16, 1973 cut short the ebullient career of an outstanding aquarist.

For a quarter of a century Earl was in charge of the California Academy of Sciences' Steinhart Aquarium, which in a way is a monument to his industry, infectious enthusiasm, and determination to make it the best with the resources available. He was never satisfied with the status quo--he knew things could be better.

Steinhart had reached the venerable age of twenty-five years when Earl Herald was charged with its direction in 1948. A major renovation was needed, and he convinced the Trustees of the Academy and the citizens of San Francisco of that need. A bond issue of $1,500,000 was passed to accomplish the improvements he wanted and they were completed in 1964. At the same time Earl envisioned and planned other substantial expansions of the aquarium. One of these, a doughnut shaped tank sixty feet in diameter and resembling those at Kashikojima and Aburatsubo in Japan, appealed to Academy Trustee Wilson Meyer, who arranged for a grant for its construction from the G.H.C. Meyer Family Foundation. Since Earl's death the plans have been completed, the environmental approvals won, the contract let, and construction of the $1,050,000 tank is underway.

These are some of the accomplishments of the man, but others were of greater importance for his profession. As a scientist and writer and television personality he was indefatigable in his efforts to improve the status of aquarium people. The City of San Francisco is obligated to provide support for Steinhart Aquarium, and Earl's friendship and rapport with several mayors and many supervisors led to their better understanding and appreciation of his aquarium, and their approval of realistic compensation for its employees when its budgets were reviewed. the direct benefit was for Steinhart but the indirect benefit was for the whole profession.

Earl was demanding of his employees, who were expected to share his enthusiasm, ambition, and dedication. He was also solicitous of their welfare, and protective and appreciative. "Graduates" of Steinhart hold many important aquarium positions in many places.

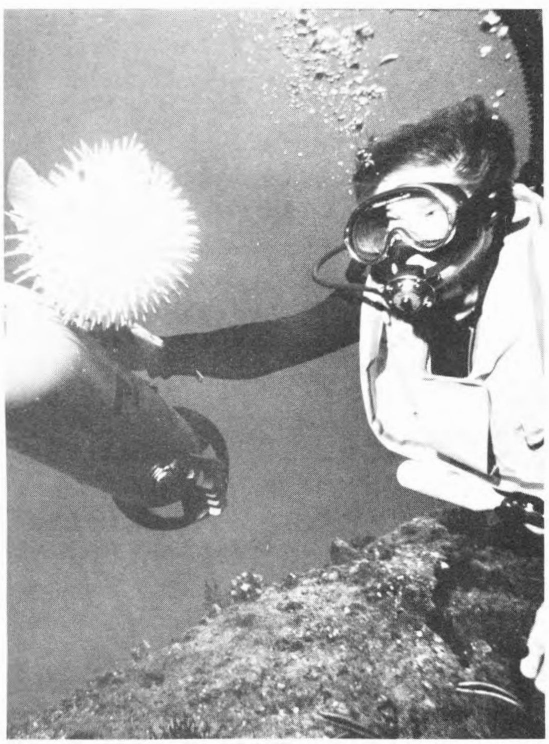
Earl Herald died before his time, and he is missed--but he has left his mark on the aquarium world.

George E. Lindsay
Director

Earl Herald visited me on several occasions. I took this portrait in my hatchery about 1961 or '62. Earl had come on this trip to inspect my photo files for his coming book, Living Fishes of the World.

Knowing him as I did, his loss was felt most deeply by me. I doubt there is another person to grace the world of ichthyology as Earl Herald did.

Gene Wolfsheimer



Earl S. Herald
Photo taken by Jeffery W. Meyer at Cabo San Lucas, January 16, 1973

I have known Earl Herald as a professional colleague and friend for thirty years. He was a well-respected ichthyologist who worked hard and was highly co-operative. It is the general opinion of all of his professional associates that he was a good bit more amiable than the average biologist.

It is such a terrible pity that he was cut down in the prime of his life when he had so many good years in front of him. Mankind is the loser for that.

Gordon Gunter

Earl S. Herald, long respected as a leader in the aquarium field, is missed by his colleagues in the zoo field as well.

Earl was a founder member of the San Francisco Zoological Society, which was established to assist the San Francisco Zoo. He played a leading and significant role in the development of both institutions, and his support will be missed.

Earl was also a member of the International Union of Directors of Zoological Gardens until his retirement.

We join with many others on this occasion to honor Earl.

Ronald T. Reuther

Earl Stannard Herald   Photo by Jeffery W. Meyer

THYROID TUMORS IN INBRED GUPPIES (Poecilia reticulata)

Dr. Sylvan Cohen
Kaiser Foundation Hospital

Thyroid tumors in fishes have been previously described by a number of different authors.[1-6] The same authors have mentioned the known difficulty in separating thyroid hyperplasias from benign and malignant tumors. Both tumors and hyperplasias may respond to treatment with iodine and thyroid hormone, and no clear cut differentiation may be possible in some cases. The problem is made even more difficult by the fact that the thyroid is not an encapsulated or well demarcated organ in teleost fishes but is loosely mixed with adjacent tissues in the floor of the mouth (Figure 1). The degree of differentiation of the thyroid tissue in question may be a useful criterion for separating tumors from hyperplasias as suggested by Nigrelli,[5] and as is the case in dealing with human thyroid tumors to some degree. Schlumberger & Lucke's extensive review of the literature involving tumors of fishes, amphibians, and reptiles,[1] refers to several previous studies of such tumors, most of them, however, concerning various species of trout and salmon, and none referring to the guppy Poecilia reticulata. Relatively few other fishes have been known to develop thyroid tumors.

The best previously studied of these fishes appears to be the swordtail Xiphophorus montezumae.[2,4] Thyroid tumors were found in multiple inbred laboratory-raised fish, while none were found upon examination of the original wild stock.[4] Several additional fish, including the guppy, were kept under identical conditions and did not develop thyroid tumors.

A specific discussion of "Tumors of the Thyroid Gland in Teleost Fishes",[6] includes a review of the literature in which one reference to a tumor in the guppy is cited in the French literature.

The current informal study was undertaken when a hobbyist and friend of the author noted that some of his guppies were behaving abnormally. They appeared to have trouble with gill movements, and their opercula were flared out away from their body. Several of these fish were placed in Bouin's solution for fixation and decalcification and were studied histologically. Sections reveal papillary thyroid tissue infiltrating the floor of the mouth and extending into adjacent gill structures. (Figure 2) In one fish the tumor was so large it completely filled the oral cavity. (Figure 3). The histologic

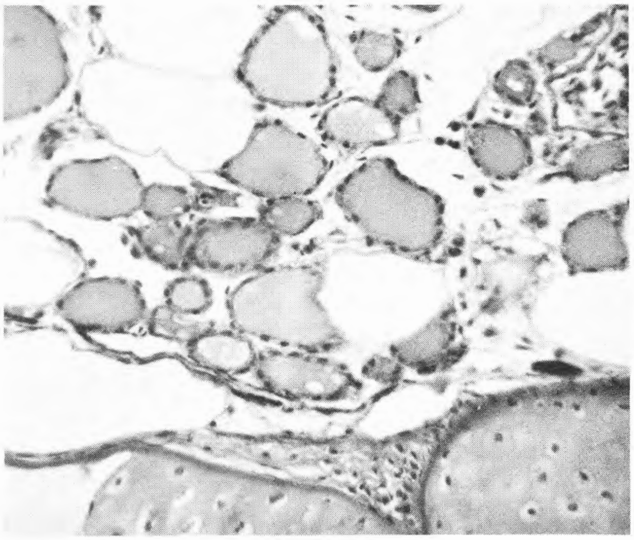


Figure 1. Normal thyroid tissue in the guppy Poecilia reticulata. 450X

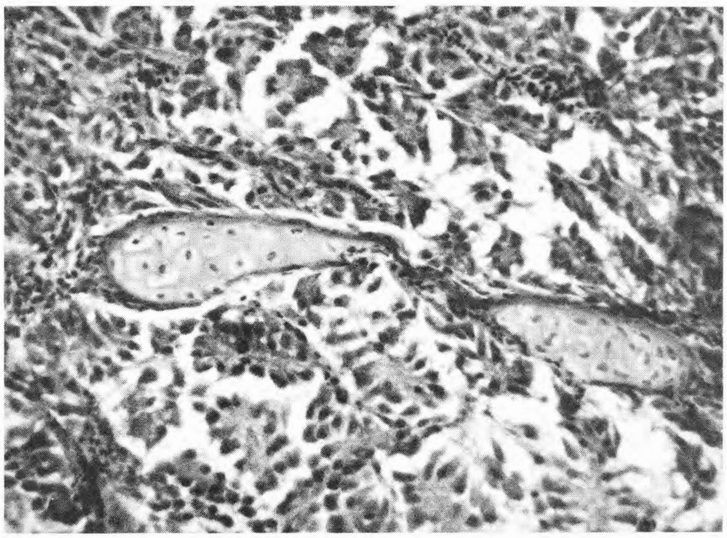


Figure 2. Papillary thyroid tumor eroding bone. 450X

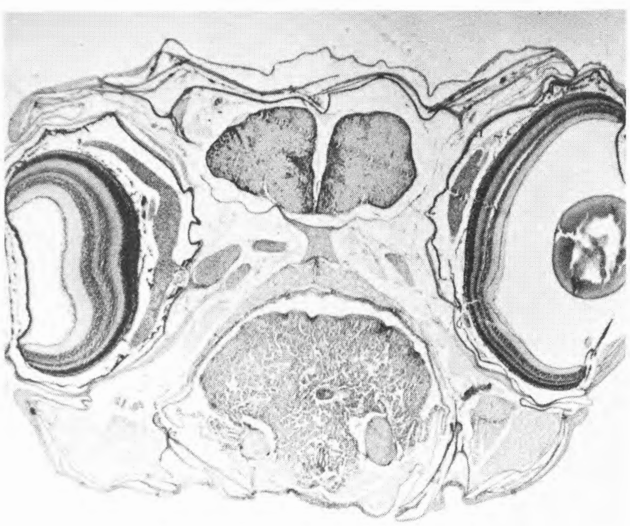


Figure 3. Papillary thyroid tumor in the guppy, filling the oral cavity. 40X

appearance of the tumor is identical to that previously illustrated in the Montezuma swordtail.[4] All of these fish were from the same strain of guppies, from the same aquarium, and had been allowed to inbreed freely. They had been maintained almost exclusively on a good quality dried food (Tetra-min growth food). Fishes in many other aquariums had been fed the same food without developing thyroid tumors.

DISCUSSION:

The situation described here is similar to that previously described with an inbred strain of Montezuma swordtails,[2,4] Pure dietary causes of the tumor are doubtful, since other fishes of the same species (although not of the same strain) were fed identical diets without developing similar tumors. However, the possibility does exist that this particular inbred strain, in addition to inheriting obvious common characteristic features of color and fin shape, may also have inherited an abnormality in iodine metabolism or a tendency to develop thyroid tumors unrelated to iodine metabolism. In any event, the development of thyroid tumors in the guppy Poecilia reticulata is very rare.

The author would like to thank Dr. Sheldon Springer for the guppy specimens on which this article is based.

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SHIFTING DOLPHINS

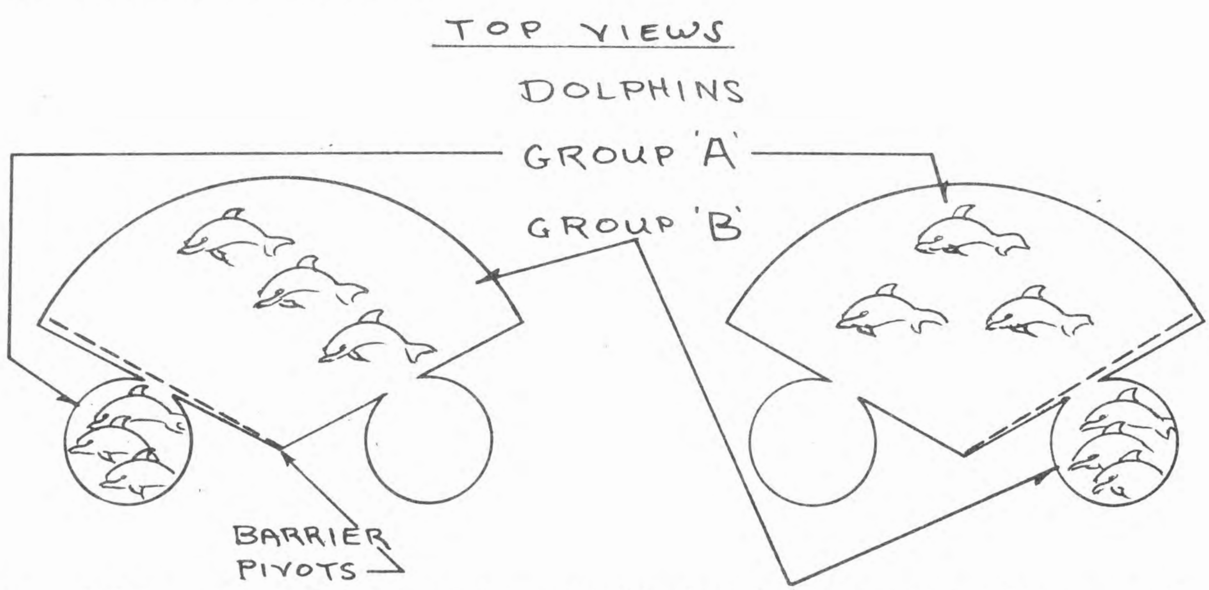
Herman Buttron, Senior Lead Keeper
Seven Seas Panorama, Brookfield Zoo

Providing positive control of the movement and separation of dolphins and other marine mammals can be extremelv useful. Within groups of dolphins, hierarchies are readily developed and even juveniles quickly establish patterns of dominance. The associated aggressiveness interferes with normal conditioning procedures--unless we're only concerned with the dominant animal. Usually this is not the case and progress with the subordinates is impaired.

Isolating an animal eliminates the competition and he becomes relaxed and tractable.

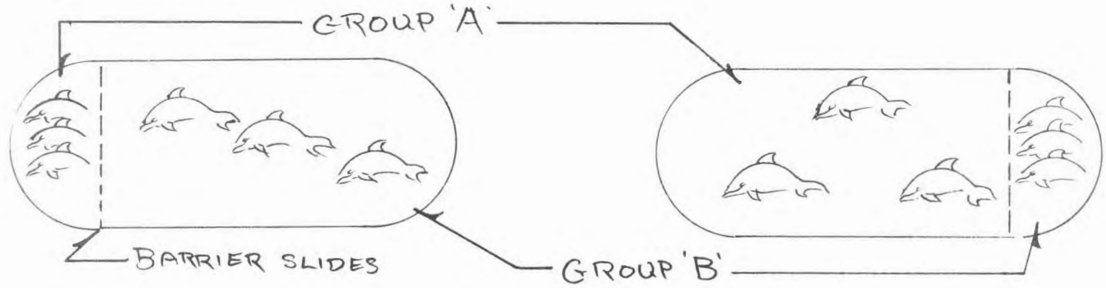
Some dolphinaria have pens or separate pools that animals are conditioned to enter in exchange for a reinforcer, usually food or play activity.

Unfortunately, there are a number of variables which can alter the dolphin's inclination about swimming into a pool. Sexual interest, loss of appetite, disliking a smaller area, can all be a problem. A problem, especially, is the sick animal who is not interested in food or play and prefers to stay with the others. This is precisely when he should be in a holding tank for treatment or observation.

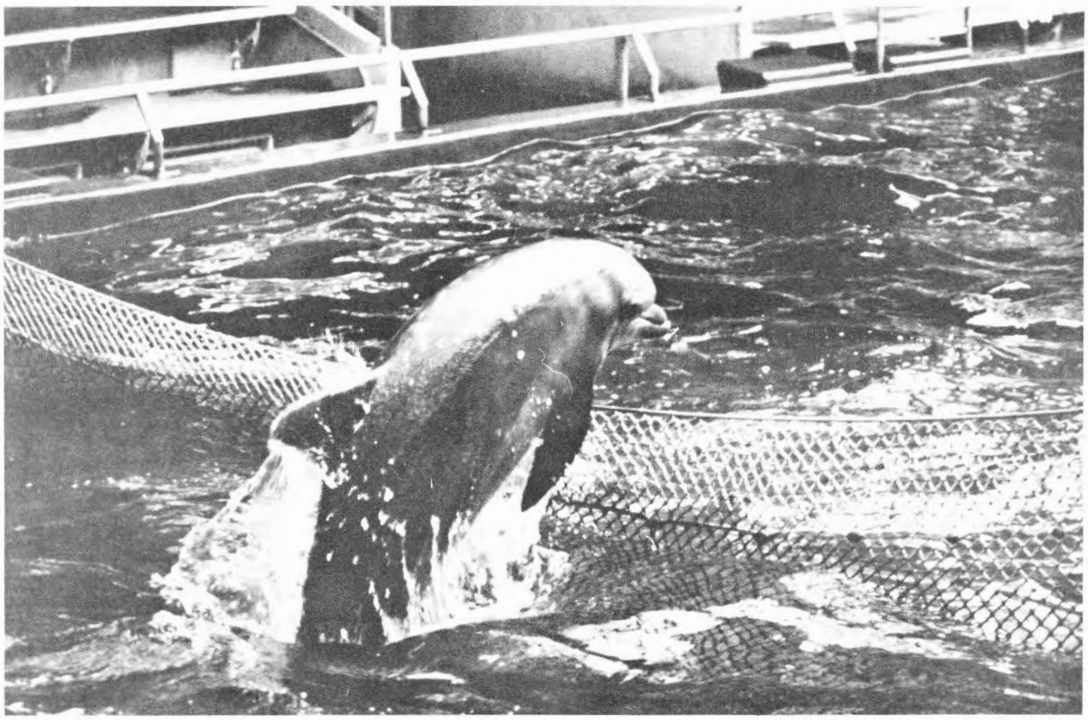


A positive control system can be a movable barrier arranged so its operation gives the dolphin no alternative but to swim into the desired area.

Aside from the beneficial effect on training programs, positive control may also allow team capability. Depending on the situation, this may allow more performances per day, a backup group or utilizing incompatible species.



Generally, even trained jumpers will not leap over things they have not been conditioned for. Even so, it has happened and any design for a controlling mechanism must be planned to eliminate that possibility. The above water part of the barrier must be imposing enough to discourage thoughts of jumping it.



The mechanical aspects of positive control may not always be needed. After X number of times the animals may cooperate by swimming freely into their designated areas. This is fine--it's faster and more "professional". However, when there is a problem, the system should be available.

THE SAN JUAN AQUARIUM

Robert A. Martin and Ernest Bodner

Ocean Life Park Aquarium is situated atop a rise some thirty feet from sea level in the beautiful Boca de Cangrejos ("mouth of the crab") area which is just outside San Juan, Puerto Rico. It is surrounded on three sides by water: on the north by the sea, to the east by an inlet and to the south by Boca de Cangrejos Bay. This was the original site of the Battery Lancaster used in World War II, much of which still stands but has been incorporated into the aquarium. The aquarium building itself is actually the main building of the battery: munition chambers have been converted into large display tanks, the former machine room is an alcove where the small gallery tanks are located, and the base of the anti-aircraft gun emplacement is now the base of our dolphin tank. The aquarium is owned and operated by Sea Aquarium, Inc. of Puerto Rico and has been in operation since May 1971. Members of the Board of Directors include Robert E. Pile, Ernest Bodner, Robert H. Rout and Chiri Vassallo. Plans are now underway for future expansion and the inclusion of a dolphin-sea lion show and arena.

The aquarium building houses ten large corridor tanks ranging from 1000 to 10,000 gallons in capacity, nine small gallery tanks (600 to 1200 gallons) and eight aisle tanks (15 to 45 gallons). With the exception of two colorful south Pacific reef tanks, all of the fishes displayed here come from Puerto Rican waters (an estimated 97 fish species). Outside the main building, there is a circular dolphin tank (14,000 gallons) which houses our young 4 year old female bottlenose 'delfi'; a kidney-shaped sea lion tank (20,000 gallons) and stage with four sea lions; a circular lagoon with a diameter of 60 ft. containing native fishes and turtles; the tropical bird enclosure housing 4 flamingoes, 3 wood ducks, 6 native domestic ducks, 2 mallards, 1 peacock, 3 cattle egrets, and 2 domestic geese; the alligator pool with two alligators; and the Japanese deer park with 17 deer. Other animals displayed throughout the premises include items that children enjoy such as pigeons, rabbits, guinea pigs, iguanas and spider monkeys. We hope to include a children's zoo in the near future.

Water for the aquarium system is taken near shore from a point just below the low tide level. This raw water is pumped some 30 feet up to the aquarium grounds and is fed to two sand and gravel filters (12' x 22'). Three lift pumps (two 7.5 h.p. and a 10 h.p.) supply the raw water, while each filter is supplied with a 5 h.p. pump that feeds water to the aquarium building and outdoor pools. The system supplies about 1800 gallons per minute when the entire system

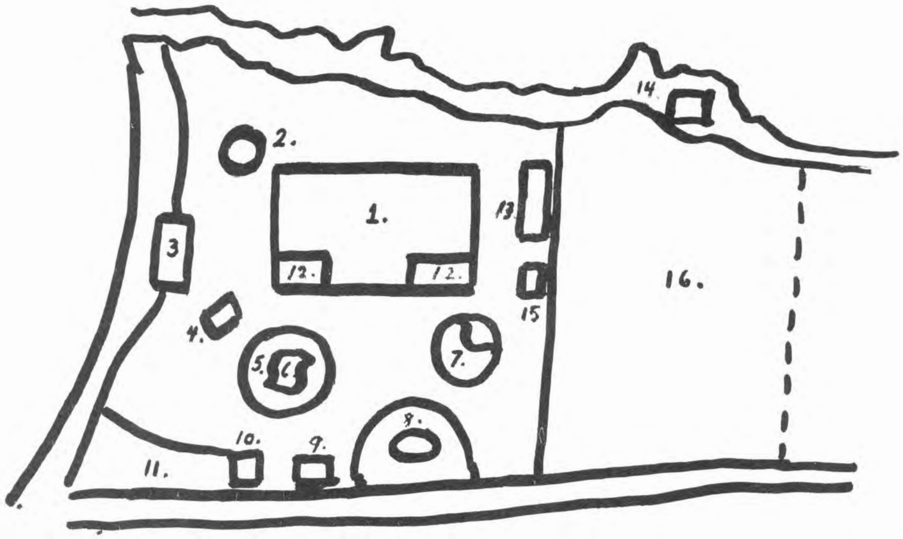


Plate I. Aerial Diagram of Ocean Life Park Aquarium
1. Main aquarium building; 2. Dolphin tank; 3. Administration building; 4. Wishing well; 5. Lagoon; 6. Island with spider monkeys; 7. Sea lion pool; 8. Bird enclosure and pool; 9. Alligator pool; 10. Deer house; 11. Deer park; 12. Filter beds; 13. Warehouse; 14. Beach pump house; 15. Apartment for guests; 16. Additional land leased for expansion

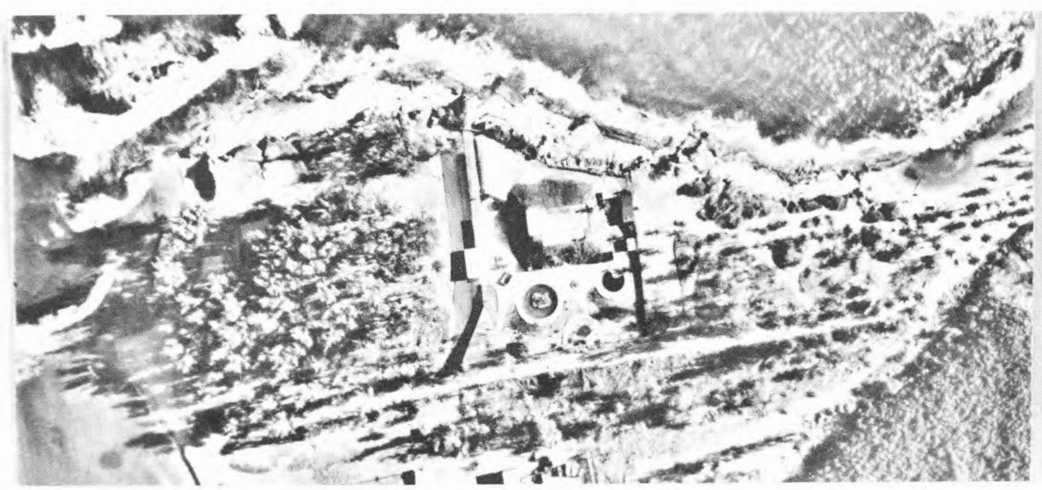


Plate II. An aerial view of Ocean Life Park Aquarium

is operating. However, it is possible to operate the complete system using but one or two life pumps and one filter bed when this is necessary.

Plans for the future include the further conversion of indoor display tanks to recirculation units with subsand filters and carbon compactors, addition of extra holding tanks for storing fish and disease treatment, drilling for a good salt water source to circumvent difficulties involved in filtering surf water, and the construction of a dolphin-sea lion performance tank.

SEA WORLD OF OHIO ANNOUNCES "WORLD OF THE SEA" TRIQUARIUM

The newest of Sea World of Ohio's fifteen exhibits is the $1 million "World of the Sea" triquarium. The new three roof complex which sets out over Geauga Lake features many of nature's highly unusual marine species.

Supported by 111 sixty-foot long pilings, the 10,000 square foot building is services by multiple entrances and exits to accommodate free traffic flow and provide good ventilation. The dramatic roof of the structure is composed of a series of intersecting triangles of redwood rising thirty feet above the adjacent lake with wood deck seating around the exterior of the building providing a dramatic view of the lake.

On the inside, the walls of the ultra-modern structure will be decorated with radiogram graphics. These graphics will incorporate the use of black lights to highlight many exciting aspects and animals of the sea. In addition to the many colorful graphics, the triquarium will also utilize beautiful visual displays along with audio presentations at each tank to further dramatize life in the aquatic environment.

Marine game fishes, tropical and fresh water species will be featured in the three large display tanks. The walls of these huge six-sided tanks are constructed of concrete eight inches thick. In the sides of each tank five windows will provide excellent viewing, and at the same time are able to withstand the internal pressure in the tanks. The windows of these tanks are constructed of two-inch thick Plexiglas sandwiched with quarter-inch plate glass on the outside. They stand seven feet high.

The huge 10,000 gallon Marine Game Fish tank will feature numerous exciting species, including leopard sharks, guitarfish and giant sea bass. The tank's emphasis will be on fish that play a predator role in the sea environment.

In the second 10,000 gallon tank, fresh water fish will be featured in their unique environment. Here, red tail catfish and alligator gars will be but two of a wide variety of species swimming in this exciting tank.

The third 10,000 gallon tank will feature tropical fish swimming in highly colorful surroundings. Spadefish, blue angels and yellowtail snappers will be but a few of the many exotic species in the tank. In addition, guests at the marine-life park will see Sea World's lovely Sea Maids dive to the depths of this tank and feed the multi-colored species.

In the center of the triquarium, visitors will find five 300 gallon tanks. These tanks will display some of the world's most unusual fish and also emphasize some of the different biological relationships of fish, such as symbiosis. Sea horses, turkeyfish and scorpion fish will be but a few of the fish in this display.

In keeping with Sea World's "See, Touch and Feed" concept of public education, the Pacific tide pool display will provide the visitor with the opportunity to touch and observe animals such as starfish and spiny sea urchins. Sea World is one of the few places today where the visitor can actually get this close to the animals they are observing. Sea Maids will also be on hand to answer any questions in the display area.

With the opening of the triquarium, Sea World of Ohio will realize one of its long-range goals. This closed system triquarium will be a complete self-contained unit. Each tank will possess its own filtration and temperature control system.

The artificial sea water for the exhibit will be specially formulated through the addition of 32 different chemical salts. This artificial sea water will then go through a month-long curing process before any fish are put into the tanks. The water in each tank will be filtered and completely recycled every hour.

Ohio's weather was a major consideration in the design of the triquarium facility, which will remain operational throughout the year.

The World of the Sea triquarium's design is the end product of cooperation between Sea World's technical staff, and numerous teams of consultants including William Driess of Los Angeles, Sea World's master planner; James M. Montgomery of San Diego, consulting mechanical engineer; Richard Wheeler and Associates of San Diego; and Dunlop and Johnston of Cleveland, Ohio, general contractors.

DEMONSTRATIONS OF ECOLOGICAL CONCEPTS BY THE ALEWIFE IN LAKE MICHIGAN

Beverly Serrell, Shedd Aquarium

Introduction

The history of the alewife, Alosa pseudoharengus (Wilson), in Lake Michigan is a striking demonstration of several major ecological concepts. Real data support the principles of population growth, succession through competition and predation, and adaptation. The current situation in the lake calls for conscientious application of these principles in planning for the continued utilization of Lake Michigan as a natural resource.

The following information is a survey of the available literature on what is known about the alewife. What is shown here particularly is how one animal, familiar to most people around the Great Lakes and East Coast, has followed some very important and basic laws of ecology within the limits of the Lake Michigan ecosystem.

The alewife is not native to Lake Michigan (Hubbs and Lagler, 1957). It is an anadromous fish occurring from Nova Scotia to Florida. Its distribution is a function of temperature as it follows warmer waters south in the winter, extends northward in summer months, and moves inshore to river and stream waters to spawn in the early spring (Bigelow and Schroeder, 1953; Hay, 1959).

Prior to 1949 there are no records of its occurrence in Lake Michigan. The alewife entered Lake Michigan and became established by 1954 after migrating through Lakes Huron and Erie, the Welland Canal, and Lake Ontario (Miller, 1957) (Figure 1). How it came to be in Lake Ontario in the first place is a matter of speculation. Most likely it arrived on its own through the St. Lawrence River or the Erie Canal (Miller, 1957). But it may have been introduced inadvertently along with shad, Alosa sapidissima (Wilson), or it may have remained in Lake Ontario after the last glacial epoch.

The alewife is a landlocked fish in the Great Lakes. Yearly mass mortalities have been occurring for the last 80 years since its establishment in Lake Ontario (Graham, 1956). Similar mortalities have been recorded in Lake Michigan since the mid 1950's in the spring as the alewife moves inshore to spawn. The extremes of temperature experienced by the alewife confined to fresh water has been cited as a major factor contributing to the die-offs (Colby, 1971).

By 1956, the alewife was well distributed throughout Lake Michigan, and in 1966 it reached peak densities. The classic exponential rise in numbers of alewives from 1954 to 1966, and the accompanying and immediately following events had a tremendous environmental impact on Lake Michigan.

Conditions Prior to Establishment

The events which led to the phenomenal success of the alewife are twofold. Commercial fishing prior to 1930 and the invasion of the sea lamprey, Petromyzon marinus Linnaeus, into the Great Lakes helped set the stage for the alewife. Exploitation of the native species of trout, walleye and burbot by commercial fisheries depleted the stocks of these species. The use of particularly effective nets and other gear enabled fishermen to take more than the maximum allowable catch and some species were slow to replenish themselves (Crossman, 1969).

The spread of the sea lamprey into Lake Michigan was followed by the collapse of the lake trout populations. This large deep water fish was excellent prey for the unchallenged lamprey parasite. When the numbers of trout had been reduced, the lamprey turned to other large fish prey and depleted the stocks of burbot, large chubs and whitefish, suckers and walleyes as well (Smith, 1968b).

These events gave the alewife a tremendous competitive advantage. With few predators, an abundant food supply and plenty of space, a species can fully realize its reproductive potential, i.e. the ability to reproduce at a given rate. While efforts to control the lamprey became effective, the niches and food supplies abandoned by various native species were left wide open. While the appearance of the alewife in the early 1950's did not go unnoticed, its subsequent spread and incredible success was not predicted (Figure 2).

Influence on Other Fishes and Invertebrates

In the past, the fishes of Lake Michigan made up a multiple species complex. Utilization of space and food was shared by a number of differently adapted species. This situation was replaced by a numerous, widely distributed, singly dominant fish--the alewife (Smith, 1970).

The alewife is a small, active fish which moves throughout the lake in large concentrations on a seasonal basis (Wells, 1968). As the abundance of alewives increased, there was a decline in the numbers of native planktivores and other changes in fish stocks (Smith, 1968b). Because of its numbers and migratory habits, the alewife has managed to displace those species with more restricted ranges (Figure3). Productivity formerly shared efficiently by consumers of different trophic levels is now going unused in portions of the lake abandoned

Figure 1. This map shows the layout of the Great Lakes and the date when alewives were first noted and the year they were established as abundant. The time between first noted and abundant was the shortest in Lake Michigan. The failure of the alewife to become established in Lake Superior is likely due to the cold water and the presence of lake trout and salmon populations not decimated by the lamprey as they were in Lake Michigan.

seasonally by the alewife. Given the competitive advantages of large numbers, no major predators, and a wide range of distribution, one species can work to the detriment of several other species simultaneously.

The alewife feeds by swimming about rapidly with jaws hinged to open wide and scoop up the small but clearly visible organisms (Brooks, 1965). It prefers zooplankton, but will take invertebrates and some algae along with selected copepods, amphipods and cladocerans (Morsell and Norden, 1968). The gill rakers are closely placed, acting as a plankton sieve, catching the zooplankton and allowing diatoms to pass through (Figure 4). As the alewife population exploded selective predation of the larger forms of copepods and cladocerans caused a change in the composition of the zooplankton (Wells, 1970) (Figure 5).

Population Biology

A species will continue to reproduce at its capacity until some limiting forces take effect. By 1966 and early 1967 it was evident that alewives were exceeding the carrying capacity of the lake. Carrying capacity is the stable number of healthy individuals able to be supported by the system and is usually maintained by limiting factors such as the depletion of the food supply or other adverse effects of crowding. The numbers of alewives had been rapidly climbing and the individuals were not as healthy as in previous years. Just prior to 1966 and the peak abundance, the average body weight was less per individual fish than in years when the density was not as great (Brown, 1972a). Intraspecific competion for food probably shortened the attainable growth and the life span of the adults.

Commercial production for 1966 was 29 million pounds, and in 1967 it reached 42 million pounds. These figures are derived from commercial catches for those years, so actual numbers of fish are estimated to be far greater. That the peak had been reached and the carrying capacity of the lake exceeded was confirmed in 1967 when at least 100 million pounds of dead alewives washed up on the beaches of Lake Michigan in the spring (Woods, personal communication). Spring die-offs and the familiar stench in April or May had become an established pattern prior to 1967, and some years were much lighter than others. But the abundance of that year's dead was catastrophic and received national attention (Time, July 7, 1967).

The reasons for the annual mortalities are complex. The normally anadromous alewife restricted to Lake Michigan is confronted with different problems of osmoregulation than it would experience if it could get back to the Atlantic Ocean. While it is a good osmoregulator under both salt and fresh water conditions (Stanley and Colby, 1971), continuous exposure to fresh water may contribute to its ultimate demise. The lack of iodine in fresh water and the thyroid stress

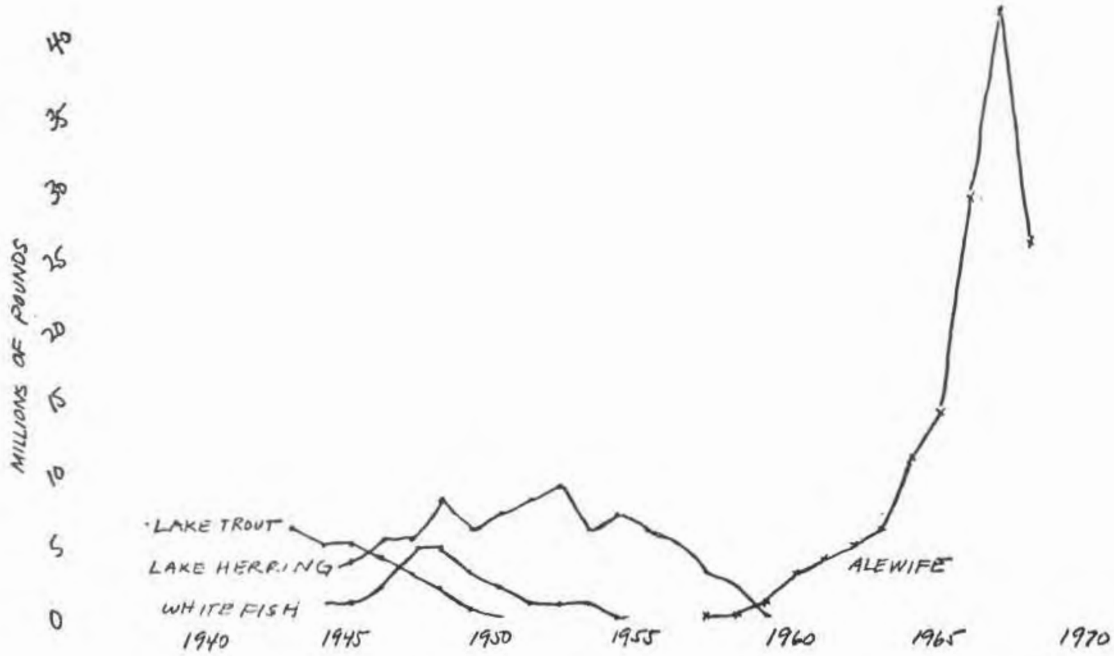


Figure 2. The rise in the alewife population was preceded by the decline of three major native species which were potential competitors and predators of the alewife. Graph based on data from Smith, 1970, derived from commercial production figures--which may reflect effort rather than relative availability. See Figure 7 for data based on experimental samples.

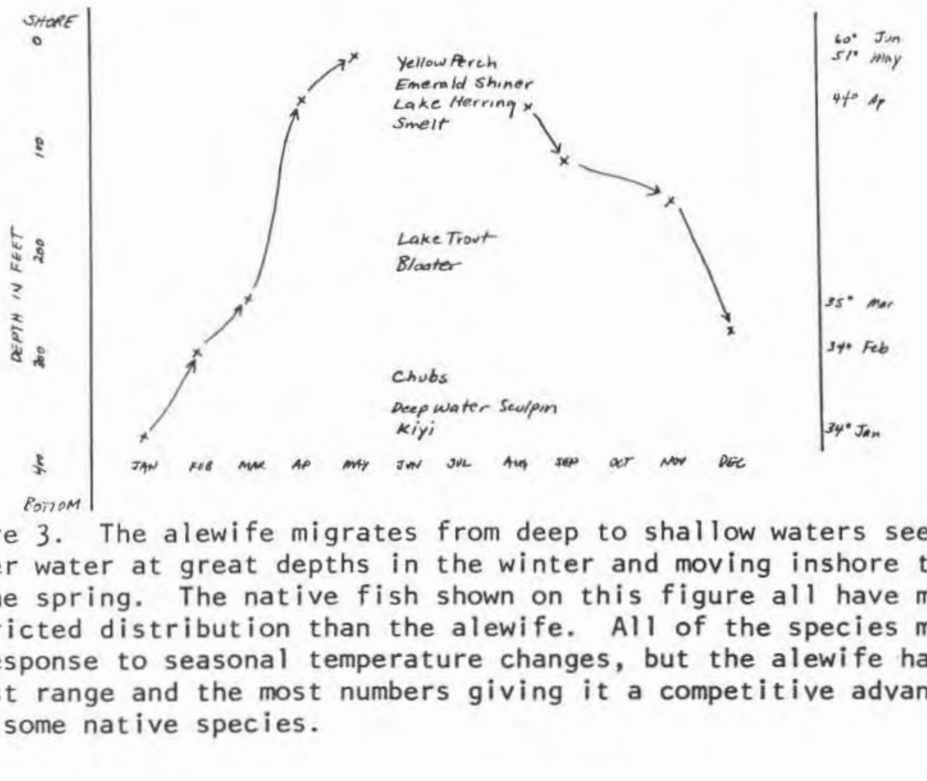


Figure 3. The alewife migrates from deep to shallow waters seeking warmer water at great depths in the winter and moving inshore to spawn in the spring. The native fish shown on this figure all have more restricted distribution than the alewife. All of the species move in response to seasonal temperature changes, but the alewife has the widest range and the most numbers giving it a competitive advantage over some native species.

due to different conditions of metabolism demands may also be a factor (Hoar, 1952). A major factor implicated by field observations and laboratory tests seems to be the changes in temperature experienced by the alewife (Colby, 1971; Graham, 1956).

Atlantic-run alewives are able to migrate to warmer waters in the sea during the winter, but the Lake Michigan alewife is forced to endure temperatures of 34°F for the winter months. Seeking the warmest waters, the alewives move to the depths of the lake during the winter and remain there (Wells, 1968). In early spring they migrate inshore to spawn, and in doing so, are exposed to various gradients in water temperature. Laboratory experiments have shown that cold-adapted fish can be "shocked" by rapid changes in temperature (Colby, 1971). Field observations of fish dying near river mouth or shoal warmer temperature gradients suggest that the exposure to fluctuating temperatures is lethal to the alewife (Smith, 1968a).

The years of the biggest die-offs in Lake Michigan, 1965 and 1967, were characterized by extended low water temperatures (1965) and by more rapid than usual change in April/May warming of lake temperature (1967) (Figure 6).

Spring die-offs are not partial to age, sex or spawning condition (Brown, 1968). What may be occurring is a seasonal selection against those fishes failing to adapt to the natural stresses. One researcher has suggested that natural selection is occurring in favor of larger headed alewives in Lake Ontario (Graham, 1956). Larger heads would better equip an alewife with osmoregulatory surfaces in the gills to adapt to the stresses of landlocked life. Changes in the nature of the physical environment of a species will exert natural selection pressure on that population for those individuals better adapted to the new conditions. Even though an adaptation might be very slight it may be enough to give that animal, and subsequent generations, an advantage.

The Future of the Alewife in Lake Michigan

Considering the successful invasion of the alewife into Lake Michigan, its subsequent displacement and disruption of the native fishes, its over-population and decimation, what lies ahead?

Numerous suggestions have been made throughout the years to utilize the alewife as a food resource (Mather, 1881; Miller, 1956). However, commercial exploitation for industrial purposes has failed to be developed on a large scale. As lake residents, alewives are small, bony, unpalatable fish, and because they move about seasonally, they are difficult to fish on a yearly, regular basis. Overabundant supply and low demand bring scanty rewards for a fisherman, and the distaste they inspire in most people rank the alewives as undesirable. Another reason for the alewife's unpopularity as a food resource is that it contains thiaminase and when fed as a regular diet to other animals

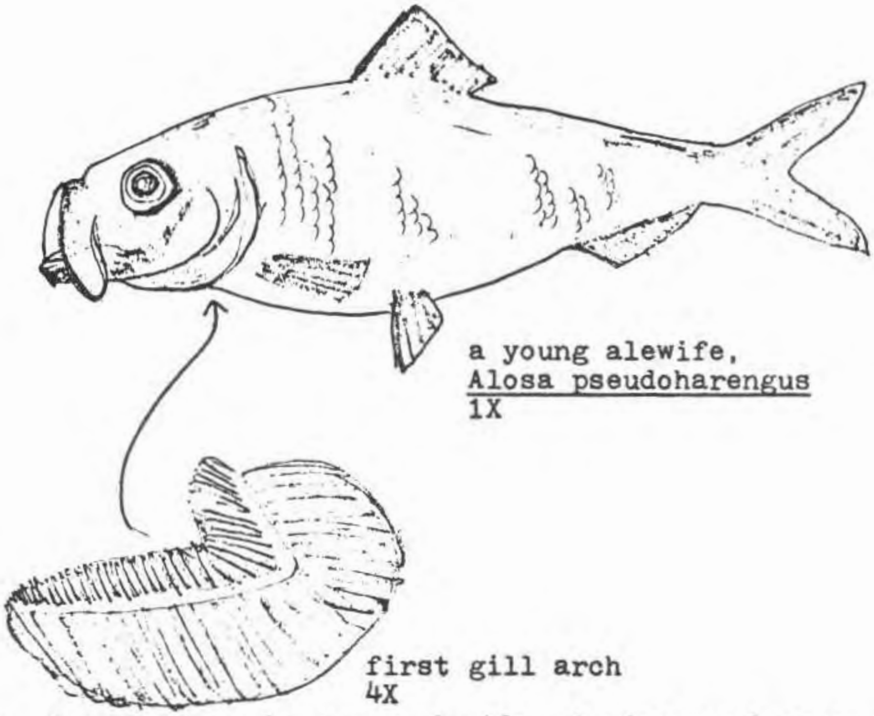


Figure 4. Actual size of a young alewife, showing mouth open, and a diagram of the first gill arch showing the closely spaced gill rakers.

A 15 mm gill arch from a 100 mm alewife has approximately 54 gill rakers. The space between the rakers is approximately 0.17 mm. Common components of the selected zooplankton diet include size ranges from 0.4 mm (Bosmina); 1.5 mm (Daphnia); 2.5 mm (Limnocalanus); to 10.0 mm (Pontoporeia). The gill raker space enables the alewife to be selective in a wide range of available zooplankton.

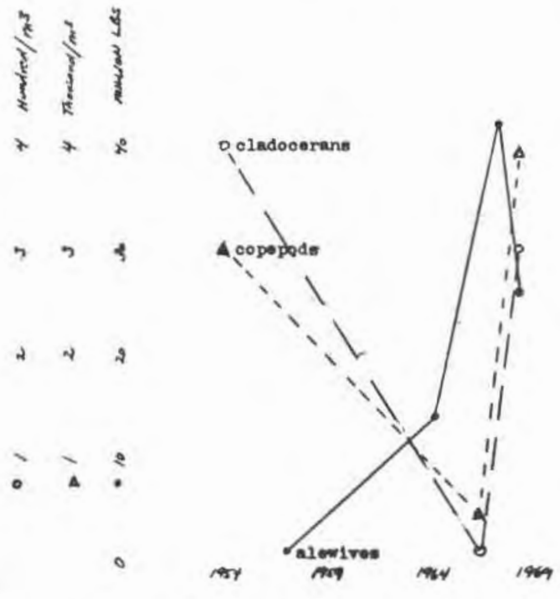


Figure 5. As the number of alewives increased certain species of zooplankton decreased. Selective predation by the alewife put pressure on the three largest species of copepods and cladocerans. As the numbers of larger copepods and cladocerans decreased, the alewives ate the available smaller species. After the 1967 alewife die-off, some of the zooplankton species recovered their populations. Graph based on data from Smith, 1970, and Wells, 1970.

will cause those animals to lose their Vitamin B_1 (Gnaedinger and Krzeczkowski, 1966). Cooking the alewife destroys the thiaminase but makes commercial production more complex.

The biggest thrust to reestablish some semblance of balance to the fisheries of Lake Michigan has been through the efforts of the Michigan Department of Natural Resources. The introduction of coho and chinook salmon as predators to forage on the alewife populations and provide sport fishing in the lake has been a major possibility of controlling alewife numbers (Smith, 1970). If four-state cooperation in the management of the fisheries is possible, perhaps the multiple species complex can become an ecological reality again, but it is highly unlikely that a natural situation can be restored. So far, the coho and other introduced species seem to be growing rapidly and eating alewives readily, but continued yearly restocking will be necessary to maintain their numbers (Wells, personal communication; Woods, personal communication).

What the possibilities are for a come-back of native species, or the success of introduced species, depends on the ability of people to recognize a necessary priority in dealing with the ecology of Lake Michigan. Funds must be spent to clean up spawning grounds both in the lake and tributaries, and to maintain the water quality of the entire lake. Continued restocking and careful watch and regulation of introduced species must be scientifically undertaken to avoid a repeat of the catastrophic events such as the lamprey and the alewife. By regular experimental trawling and other sampling methods the different populations can be surveyed.

Typically, the true and full impact of environmental change is not felt until years after the change. There is often a delayed effect (Aron and Smith, 1971). Modification of the physical or biological factors of the environment will cause subsequent modifications of the preexisting populations. How severe these results are, in terms of extinction of one species or radical changes economically important to man, depends on how sensitive the existing system is to that type of modification. We must learn to predict environmental sensitivity and take steps to deal with problems before they reach disastrous proportions.

Lake Michigan was once presumably a self-regulating system with species interacting to control each other's populations (Smigh, 1968). The system is no longer self-regulating. Changes in the numbers of fish through man's exploitive fishing or accidental introduction of new species have led to the present imbalance. Physical alteration of tributaries, shores and shallows and the degradation of spawning grounds has been going on since man first settled the banks of Lake Michigan. Now, the threats of chemical changes to the lake are becoming problematic. Eutrophication of shore waters due to locally polluting sources, municipal and industrial, is evident. Phosphorus, oils, DDT, mercury, other

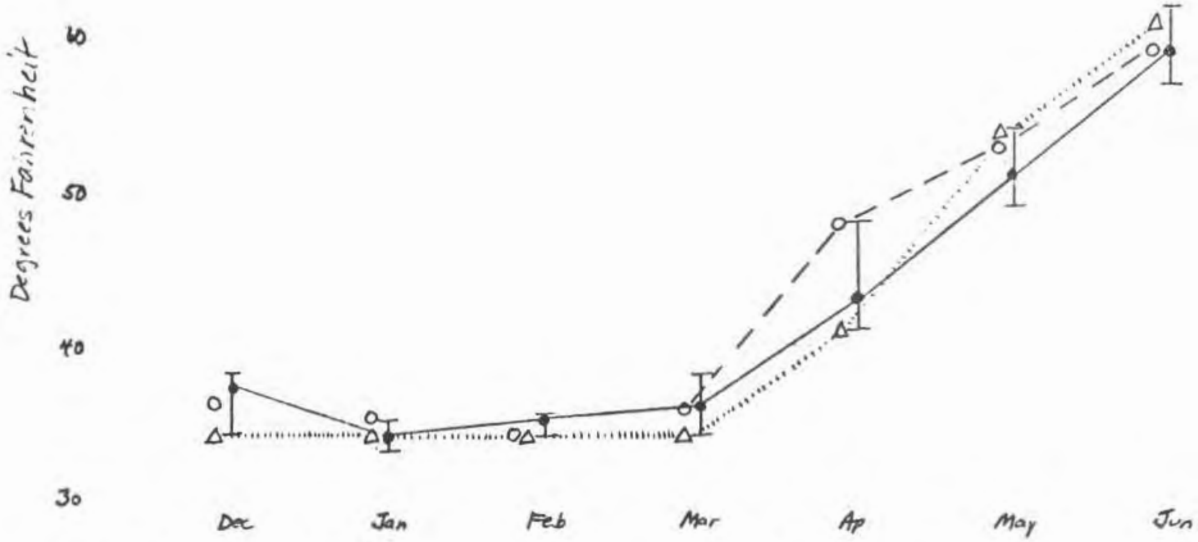


Figure 6. Lake Michigan water temperatures from December to June over a seven year period average coldest during December to February and warm up by June. The solid line shows the average monthly water temperature from 1960 to 1967 including the highest and lowest recorded temperature for that month. In the years of the largest die-offs, the temperature pattern was unusual. The dotted line shows 1965 when the winter temperatures were lower longer. The broken line shows the more rapid warm up of water temperatures in 1967. Data collected from the Central Water Filtration Plant intake in Chicago. Dever Crib intake is located 2 1/2 miles off shore from the plant, at a depth of 34 feet.

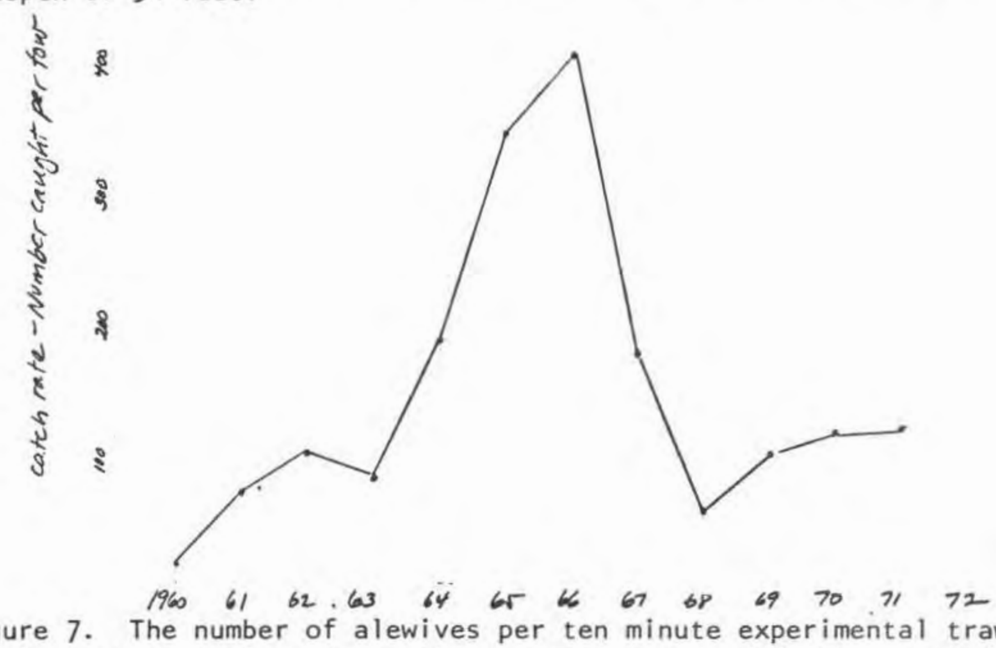


Figure 7. The number of alewives per ten minute experimental trawl showing exponential curve as the population expanded, the rapid decline with the 1967 mass mortality, and the apparent leveling off in recent years, perhaps indicating the alewife carrying capacity of Lake Michigan. Data from Brown, 1972, and personal communication.

metals and radioactive wastes dumped into the lake can cause changes in the biological properties of the water and in turn influence the kinds of species that survive. Physical modification through warming of lake waters near heated effluents will also change the types of organisms living nearby. Alewives and other fish seeking warm waters in the winter months will probably be attracted to the outfalls. If any spawning occurs in these warmer waters, incubation time will likely be shortened and might have serious consequences for larval forms (Edsall, 1970).

The future of the alewife in Lake Michigan depends on management. The population of alewives seems to have leveled off in the past four years (Brown, 1972b) (Figure 7). It is doubtful they will ever reach enormous proportions again, but they will continue to live in Lake Michigan and go through yearly die-offs as they are pressured by the physical environment. If the numbers of alewives drops in the future, the population could be allowed to expand by decreasing the number of introduced predators. Man can direct the lake system by controlling the numbers of fish, but we are only just beginning to understand the complexities involved.

The most serious damage done to Lake Michigan has occurred in the last 50 years, and some of those damages cannot be repaired. To undertake the management of those 22,000 square miles will be a vast and important task. Improvement of water quality and wise management of the fisheries requires much additional research and time. The comprehensive evaluation of present condition, possible trends, and desired outcomes or objectives is difficult, complex and necessary if we are to preserve the lake, or any other naturally productive system, as a resource. If we can learn to use the concepts of ecology to predict and anticipate, we can regulate and encourage the productivity of Lake Michigan.

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ALEWIVES AT SHEDD AQUARIUM

Harry Cook
Trinity Christian College - Palos Heights, Illinois

The John G. Shedd Aquarium in Chicago has played an important role in research into several aspects of alewife (Alose pseudoharengus) biology. The alewife is notorious for the massive die-offs which have occurred along the shores of several Great Lakes in the midwestern United States and Canada (Brown, 1972). The Great Lake alewives, unlike their Atlantic counterparts, remain in fresh water during all phases of the life cycle.

The facilities of Shedd Aquarium have been used to keep alewives by investigators from the University of Wisconsin-Milwaukee, Drs. Jon G. Stanley, Eldon Warner and others, as well as by ourselves. Fish were kept in fresh and marine water, and served the useful function of eliminating some of the effects of differences in water temperature, specimen size, and other geographical factors that are encountered when fish are collected in Lake Michigan and Maine. Thus it was gratifying for us that the Shedd fish corroborated the observations on fish obtained from the lake and the ocean. Adult fish transferred from the lake into aquarium tanks have a poor survival rate but juveniles were found to survive much better.

In our study (Cook, Rusthoven, and Vogelzang, 1973) the effects of salinity on the cells in the pituitary gland that secrete prolactin were investigated. An interesting morphological characteristic of Alosa, and other Clupied fishes also, is the persistence of the oro-hypophyseal duct. This duct is believed to be a derivative of Rathke's pouch, the pharyngeal invagination that produces the pars distalis, of the pituitary gland. In adult alewives the duct can be followed from the buccal cavity through the parasphenoid bone to the anterior end of the pituitary gland. In adult fish the portion of the duct adjacent to the buccal cavity degenerates into a cord of connective tissue. Olsson (1968) has discussed the implications of the duct's persistence in several teleosts in an interesting paper.

In the alewife the prolactin cells are located around bifurcations of the oro-hypophyseal duct. While the mode of secretion of prolactin granules is still not determined in several teleosts, the electron microscopic evidence suggests that in the alewife the prolactin granules, along with other cell contents, are released in to the branches of the duct. This was of interest to us not only because the release of the hormone was probably in response to salinity conditions, but also because the method of hormone release was different from that described for other teleosts.

The prolactin cells showed marked differences in response to environmental salinity. In fresh water specimens these cells were heavily granulated, while in marine specimens they were less heavily granulated. This was true for the specimens obtained from the aquarium as well as the ones from the lake and ocean.

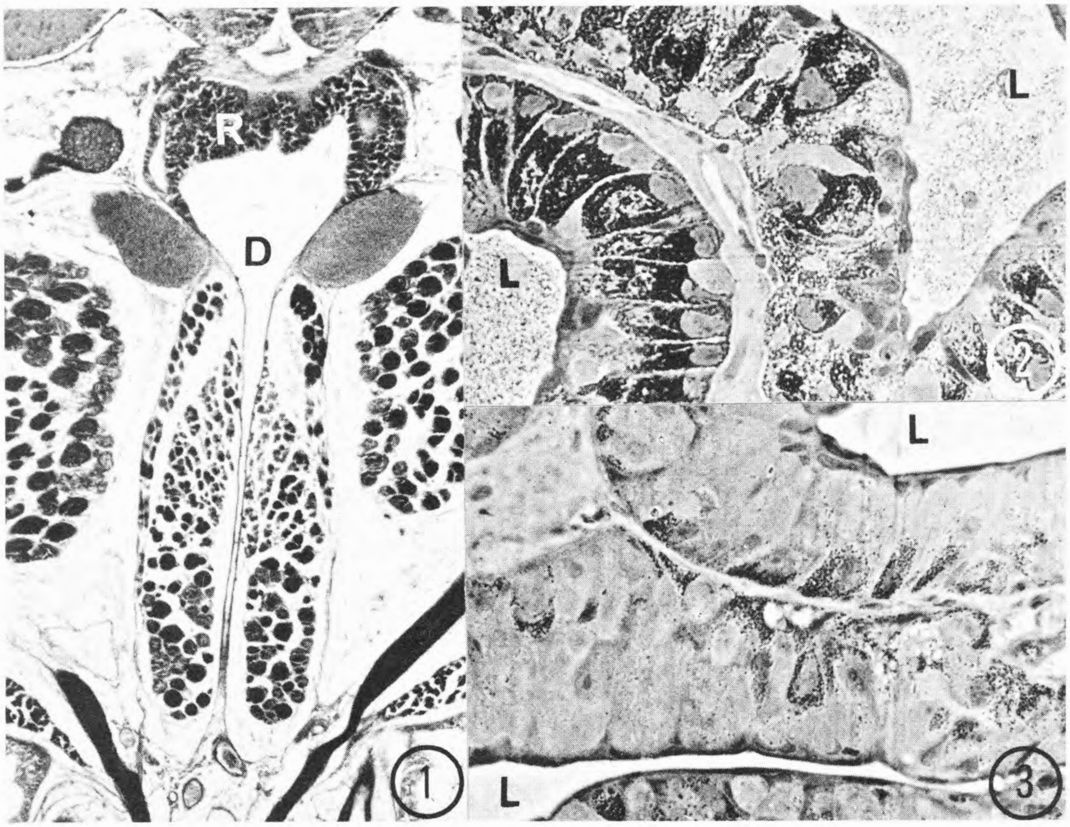

Figure 1. The orohypophyseal duct (D) of a juvenile alewife extends from the rostral pars distalis (R) toward the pharyngeal region. X60

Figures 2 and 3. Micrographs showing differences in granulation between a freshwater fish (Lake Michigan - Fig. 2) and a fish entering fresh water from the sea (Fig. 3). L, lumen of orohypophyseal duct branches. Phase contrast, X475

One of the advantages of doing research on some fish kept at a public aquarium is that it brings you past the display tanks on a regular basis. At Shedd, seeing the new reef tank for the first time was a major event. As an old Vancouverite I was also struck when I saw a whole tank supplied by Vancouver Aquarium, full of pacific marine life. Recently I have been impressed by the beautiful invertebrates in the cold marine tanks (I understand copper sulfate used to do them in!). Thus one learns to see Shedd not only as an excellent aquarium, but as a constantly changing, constantly improving display.

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# # # #

NOTE FROM NATIONAL AQUARIUM:

A slide program of the nesting of the Loggerhead Sea Turtle is available, complete with script, through the Education and Information Department; National Aquarium; Bureau of Sport Fisheries and Wildlife; Washington, D.C.; 20240.

TRACE ELEMENTS - AND A PROPOSITION

Richard M. Segedi
Pittsburgh Aquazoo

In the years since closed system marine aquaria have become numerous, there has been much discussion over changes in water quality as these systems age. One theme which invariably emerges in discussions concerning water quality is that of the fate of the various trace elements in the sea water systems.

I think everyone who has dealt with the problem of captive systems will agree that the quantity of the various trace elements in a closed system changes with time. But are we sure that there is a loss of trace elements, or could there be a gain? Let's take a look at some of the factors affecting trace element concentration.

Dr. James Atz was kind enough to suggest some references to me concerning the subject last year. One very interesting article appeared in Analytica Chimica Acta 42(3): 533-537 and another in Chemical Oceanography, vol.II, Riley and Skirrow pg. 303 concerning trace element losses. The authors state that losses occur through absorption of ions onto suspended particles in the water and also onto container walls.

> "Glass and plastics are supercooled liquids, which, because of their broken and distorted bonds have greater surface energy than crystalline substances. This leads to the absorption of ions from solution and to the formation of bonds between the surface and the absorbed ions."
> (Chemical Oceanography)

The authors found that sea water in polyethylene lost 75% of its gold in three weeks. In pyrex containers 5 to 10% cobalt was lost in 20 days. Also, in pyrex, 10% rubidium was lost in 10 days. Some loss occurred of zinc, cesium, strontium, and antimony. Iron lost 50% of its concentration to the glass in 30 days. (Note; none of the containers held animals.)

Other factors concerning trace element loss are absorption and storage by the life forms within the system. However, unless these life forms are continually harvested, an equilibrium will eventually be reached (dead cells returning substances to the water), and loss rates should level off. An actual loss to the system occurs if algae are regularly removed from the system and whenever dead specimens are taken out.

Some trace elements react with others to form insolubles which precipitate out. An example is copper which forms a carbonate, precipitates and is thus removed from the system.

Some creatures, such as sharks, show symptoms of a deficiency of iodine after a period of time. They exhibit goiter-like growths which decrease with addition of iodine to the water or to their diets.

On the other side of the balance sheet are the sources of trace element gain. Tap water for topping off systems is one source of elements, but by far the most important is the food put into the system. The food creatures are themselves storehouses of trace elements, and what is not retained in the bodies of the animals which receive these food creatures, passes into the water of the system to accumulate.

Almost all of the trace substances which aquarists regularly check show a buildup. Nitrate, a trace element in sea water, shows a buildup. Ammonia and nitrite are oxidized to nitrate and thus build up in the system. Phosphate and chlorides are other examples of this buildup.

With the exception of iodine and copper I know of no other substances which regularly disappear from closed systems from which no organic matter is harvested. It seems to me that there should be a buildup resulting mostly from the waste products of feeding.

Some of you may be monitoring other substances in closed systems. If so, I would be interested in seeing your data. Ultimately, I would like to put together a summary dealing with trace (or for that matter, gross) elements in closed captive systems.

Likewise, if anyone knows of other papers dealing with the subject, I would very much appreciate receiving their titles. Perhaps a number of us could get together, pool our data and put out a joint report on the subject.

I'll put my money on a buildup of most substances. How about you?

A FORMULA FOR A CALCULATED SALINITY CHANGE

By Louis Garibaldi and Bruce Poole

For many years aquarists have used various home recipes for accomplishing the conversion of fish from salt to fresh water or vice versa. Many have just used old rules of thumb such as "just run a trickle of salt water into the freshwater tank or just run a trickle of fresh water into a salt water tank" or change "X" percent of water per day until you get where you want to be. Some have just taken anadromous fish and simply thrown them into salt water from fresh water. It appears that some of these fish have survived this treatment, but experience has shown that it does not always work with all fish.

In June 1971 the National Aquarium in Washington, D.C. received 200 Beluga sturgeon fry from the Soviet Union as part of a fish trade between the United States (Bureau of Sport Fisheries and Wildlife) and the U.S.S.R. These youngsters averaged only about 4" long at the time of arrival and many were distributed to various aquariums around the country as they reached 6-8" in length. Being the voracious eaters they turned out to be, in less than a year most had reached 12-18" in size, all in fresh water.

At about this time, various aquariums decided it would be an advantage to switch their Beluga sturgeons to salt water (a natural sequence, but one that usually occurs earlier in their life cycle). However, almost without exception all fish were lost during this procedure. It soon became apparent that there was an unusual problem to be faced. These sturgeon were not responding like striped bass or most salmonids. The normal procedures used by these aquariums ran into total defeat.

At the New England Aquarium we decided to try a more prolonged and gradual change that we hoped would succeed where other had failed. We wanted to make the water change over a 60-day period (chosen at random) by a measured daily addition of salt water. The problem was: how much water to change daily to achieve a consistent rate that would take 60 days to accomplish the total change. However, every day that you add a certain amount of salt water, you displace an equal amount of an unknown salinity after the first day.

The problem reminded us of classical calculus problems involving a rocket ship whose mass is variable because its mass is fuel, therefore the amount of propulsion needed varies as the mass decreases with consumption of the fuel.

This problem was turned over to a co-op student at the aquarium, Bruce Poole, who, with the assistance of professor Gene Saleton of the Physics Department, Northeastern University, came up with the following formula:

$$R = \frac{V}{t} 4.6 \quad *$$

In which R = the rate of addition (e.g. gallons)
V = the volume of the tank (e.g. gallons)
t = time for change (e.g. days)
4.6 = a constant expressing the curve of the changing salinity.

Therefore $R = \frac{1754}{60} \times 4.6 = 134.32$ gal/day

Using this formula we arrived at a flow rate of 5.5 - 5.6 gal/hour or 134 gal/day in a tank with a total volume of 1750 gal. With this constant flow rate we successfully changed the Beluga sturgeon from 0 ppt to 30 ppt salinity in 60 days. We also lowered the water temperature of their tank before and during the conversion. They had previously been kept at approximately 73 - 75°F or room temperature. The temperature was lowered to 53°F (our lower limit capability for their tank) as there is some evidence that lowered temperatures allow some freshwater fishes to enter salt water. With these apparently delicate fish it was felt that all measures should be taken to attempt an easy conversion.

The four animals we converted were between 2 and 3 feet in length and a little over 2 years old. They averaged .28 kg of food consumption/day at 53°F. Ammonia, pH and salinity were measured constantly. At 6 ppt, we lost the freshwater bacteria in the filter; a resultant rise in NH_3 readings was remedied by reseeding the filter with salt water bacteria. The salinity rose rapidly from 0-24 ppt within the first month, then more slowly. It reached 30 ppt by the end of the designated time period. pH started at 7.5 and rose to 7.8.

This formula can be used in any freshwater to salt water (or vice versa) change by merely using different volumes and times as desired. Mathematically and in practical application it has proven itself.

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* See appendix for derivation of formula

APPENDIX

The derivation of the formula for salinity change use is as follows:

tank of volume V at salinity C
incoming volume R at salinity P
leaving volume R at salinity C

The water entering and leaving the system is at equal amounts but differing salinities. The fractional salt concentration in the tank at any time is a function of the time that R amount has been entering at P salinity -- represented as C9(t).

Solution:

$$C(t) = \frac{S(t)}{V}$$

S(t) = Volume of salt water in tank

then $$\frac{dC}{dt} = \frac{1}{V}\frac{ds}{dt}$$

but obviously: $$\frac{ds}{dt} = PR-CR = (P-C)R$$

Thus, $$\frac{dC}{dt} = \frac{R}{V}(P-C), \text{ or } \frac{d}{dt}(C-P) = \frac{-R}{V}(C-P)$$

Solve the differential:

$$C(t) = P + e^{-Rt/V}$$

where A is arbitrary, since C(0) = f freshwater

A can be rounded to

$$C(t) = P + (f-P)e^{-Rt/V}$$

and since f = 0 (no salinity)

$$C(t) = P(1 - e^{-Rt/V})$$

since $(1 - e^{-Rt/V})$ is always less than one, C will always be less than P. Theoretically you will never get to P, but close, .99P.* But solving the last equation for R(rate):

---

* P = .03 (30 ppt)
C = .99

$$R = \frac{V}{t} \ln\left(\frac{P}{P-C}\right)$$

or $$R = \frac{V}{t} \ln \frac{P}{P(1-.99)}$$

$$R = \frac{V}{t} \ln \left(\frac{P}{.01P}\right) = \frac{V}{t} \ln 100$$

$$\ln 100 = \frac{\log 100}{\log e}$$

$$\ln 100 = 2.303 \log 100$$

$$\log 100 = 2 \ ; \ 2 \times 2.3 = 4.6$$

$$(\ln 100 = 4.6)$$

Thus $R = 4.6\frac{V}{t}$

R = rate of inflow salt water

V = volume of system

t = time for change

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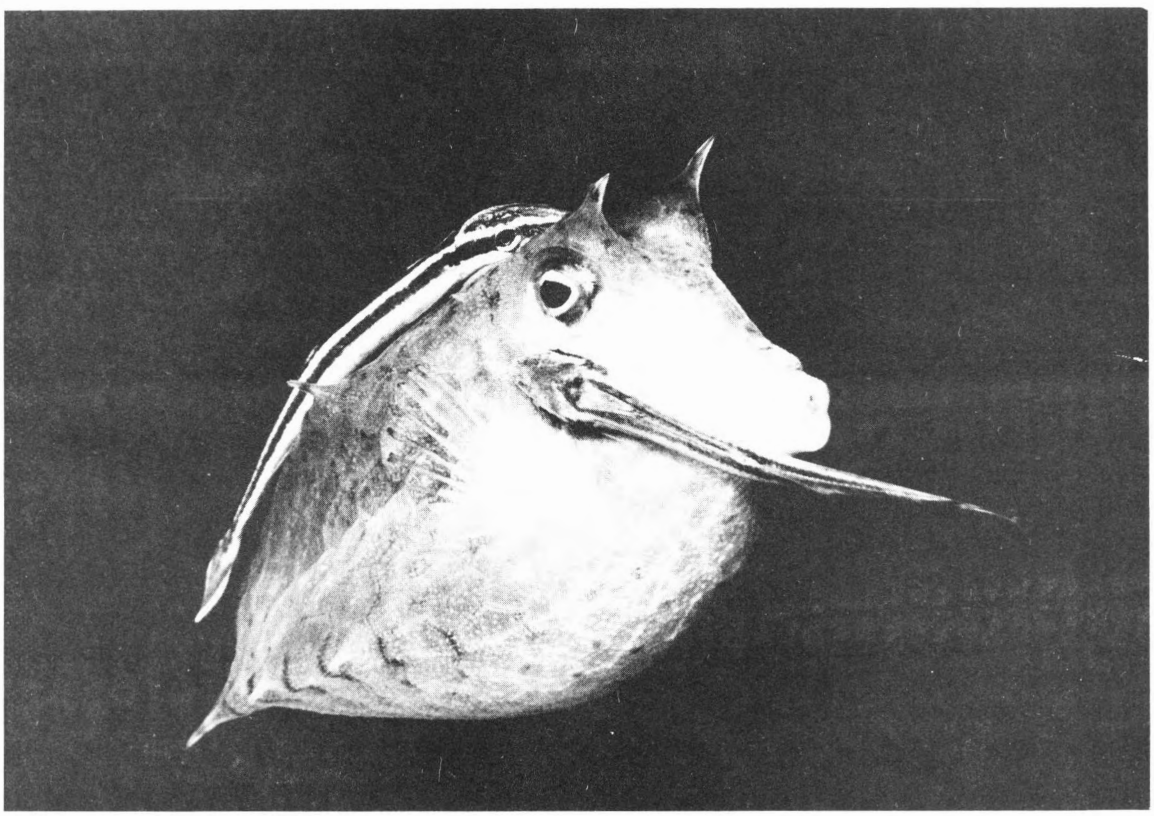

Photo by Phil S. Lobel

The Hawaiian cowfish, Lactoria diapanus, with two ramoras attached. The "group" was collected off Makua Beach; Oahu, Hawaii on July 18, 1973 at 60 feet on a small patch reef. The cowfish is approximately 4 1/2" long.

PRELIMINARY FISH TAGGING INVESTIGATIONS ON THE MISSISSIPPI RIVER

Brad Latvaitis
Associate Scientist, Fisheries Division
Industrial Bio-Test Laboratories, Inc.

Introduction

Tagging investigations are being carried out during the operational phase of the Quad-Cities Nuclear Power Plant on Pool 14 of the Mississippi River. Fishes are being tagged to determine how endemic certain species are to particular habitat locations. Movements are recorded to ascertain whether fishes will pass through the slight temperature differential created by operation of the diffuser pipe system.

The tagging investigation is only a part of the extensive environmental impact study. Areas of the fish community under investigation are: a) species composition; b) population density; c) age and size distribution; d) food habits; e) temperature and river flow; f) external parasitism; and g) fish impingements on intake screens. In addition, extensive studies involving water chemistry, water temperature monitoring, pesticide analysis and benthos, periphyton and zooplankton communities are under study.

Operation of the diffuser system disperses a heated effluent that results in increased temperatures at locations downstream from its operation. The increased temperatures are slight, with the location most affected (Location 6T) having an average temperature increase of 0.6°C over shoreline temperatures. Figure 1 indicates sampling locations. Often upstream locations are as warm or warmer than locations downstream from the diffuser. Temperature differences between the main channel upstream from the diffuser and Location 6T during sampling dates, ranged from +1.5°C to -0.2°C. This variance is greatly exceeded by natural temperature differences caused by solar radiation as seen in shallow slough areas. These locations are often the warmest areas sampled. In these areas, ranges of temperature variances between upstream and downstream locations were +4.8°C to -1.3°C.

Methods

Fishes were captured by electroshocking. Habitats immediately upstream (Locations 4 and 5) and downstream (Locations 8 and 9) from the heated

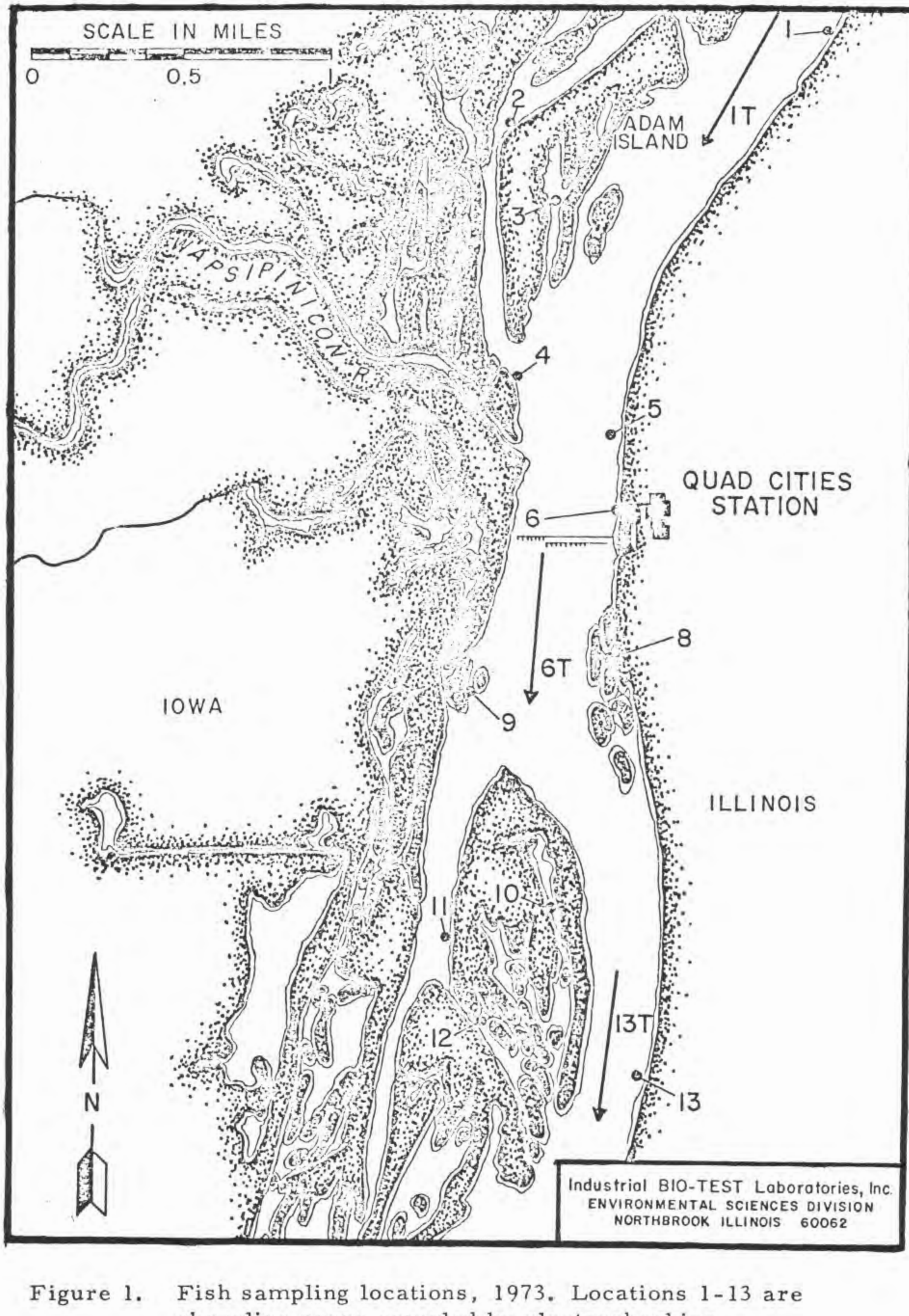

Figure 1. Fish sampling locations, 1973. Locations 1-13 are shoreline areas sampled by electroshocking. Locations 1T, 6T, and 13T are mid-channel areas sampled by bottom trawling and drifting trammel nets.

discharge were each sampled for 60 minute periods twice a month. In addition, fishes of adequate size collected at all locations during regular 20 minute twice a month electroshockings were tagged. Data collected on fishes tagged included species, size, location of capture, and scale sample collection.

Discussion

Of 1,323 fishes tagged during 1973, only 60 were recaptured. In addition, 14 of 1,092 fishes tagged during 1972 were recaptured during 1973, indicating good tag retention. The 1973 return is much greater than during 1972, when 39 fishes were recaptured of 1,092 tagged. The difference between 1972 and 1973 in numbers recaptured could be attributed to differences in sampling effectiveness, the increased concentration of tagging and recapturing at four locations rather than sparse tagging at all sampling locations, and greater returns from sport and commercial fishermen. As indicated in Table 1, an increase in tagging effort resulted in increased recaptures. (An exception would be Location 6, the Station's intake bay which offered a rocky habitat, easily sampled by electroshocking.)

There is no indication that the heated effluent presents an impassible barrier to fish movements (Table 2). Even though only a small amount of movement information has been accumulated, two tagged black crappie, two white crappie, two sauger and individual largemouth bass and channel catfish have traveled across the diffuser pipe system. The tagged black crappie, channel catfish and saugers traveled upstream across the diffuser, while the largemouth bass and white crappie traveled downstream.

Results of recovery of tagged fishes are presented in Table 2. Most largemouth bass, bluegill and white crappie were recaptured near their tagging locations. These species appear to reside in particular habitats and when movement did occur, it was less than three miles. Sauger, channel catfish and carp may not inhabit an exclusive location, since none have been recaptured where tagged. The recaptured channel catfish had traveled seven miles each. Sauger can apparently travel long distances since one tagged during 1972 was subsequently recaptured during 1973 at Lock and Dam 12, fifty miles away. Although over 200 carp were tagged, none were recaptured. This is apparently due to their great abundance, possible poor tag retention, or excessive movement. According to an investigation by Funk (1957) carp may range in excess of 200 miles.

There has not been a substantial amount of literature concerning movements of particular species of fishes in various bodies of water. It is probable that the amount of movement varies with the situation. Movements of a species may be determined by a number of variables, including species abundance, population density, food abundance, available niches, habitat type available, and water current.

Table 1. Number of fishes tagged and recaptured at each location, 1973.

	Location													
	1	1T	2	3	4	5	6	6T	8	9	10	11	13	13T
Number tagged	11	29	78	83	254	53	85	35	240	178	162	42	8	45
Number recaptured	1	0	2	1	8	1	10	0	17	7	9	2	0	0
Known movement across diffuser	1	0	0	0	0	0	0	0	1	1	0	0	0	0

Table 2. Number of fishes tagged and recaptured and occurrence of movement during 1973.

Species	Number Tagged	Number Recaptured	Movement	Movement Across Diffuser
Shovelnose sturgeon	26	0	--	--
Carp	221	0	--	--
Bowfin	16	2	--	--
Northern pike	9	1	--	--
Channel catfish	142	2	2	1
Bluegill	283	11	1	--
Largemouth bass	214	30	1	1
White crappie	153	6	1	1
Black crappie	153	7	4	2
Walleye	10	1	1	--
Sauger	37	0	--	--

Conclusions

1. The increased temperatures resulting from diffuser pipe discharge are very small.

2. There is no indication that the heated effluent presents an impassible barrier to fish movements.

3. Largemouth bass, bluegill and white crappie appear to reside in particular locations, ranging short distances only.

4. Sauger, channel catfish and carp appear to be more mobile in nature.

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REPRODUCTION IN THE GIANT OCTOPUS OF THE NORTH PACIFIC

Susan Gabe
Vancouver Public Aquarium

In March of 1973, the Vancouver Aquarium had in its possession both a mature male and a mature female of the Giant Pacific Octopus, Octopus dofleini. The female had not yet released her eggs, and so the two were mated in a large 735-gallon tank. The female was placed in the tank first and left there overnight; the following morning the male was transferred into the tank. Immediately the male approached the female, rose above her and then alighted, pinning her beneath him. They remained together and almost motionless for nearly four hours. The spermatophores, long, narrow and cylindrically shaped, were later recovered from the tank, each measuring approximately 45 cm. The spermatophores of smaller cephalopods are considerably shorter. Although both animals remained in the tank for 24 hours, no further mating was observed. After that period, the female was transferred to a 70 gallon tank.

The mating had taken place on March 15. On the morning of April 27, four clusters of rice-shaped eggs were discovered fastened to the back of the tank, each cluster containing a few hundred eggs. The female continued to deposit eggs for about 15 days until finally they covered more than two square feet of space on the tank wall. The egg-laying always took place at night and was not observed. Water temperature during the spawning ranged from 9.2° to 10.3°C.

As is usual among brooding octopuses, the female took exceptional care of her eggs, continuously agitating them with the tips of her arms. Such brooding behaviour is described in the literature for a number of species, including O. vulgaris (Vevers, 1961), O. bimaculatus (Fox, 1938) and O. Luteus (Arakawa, 1962). She also siphoned streams of water onto the eggs - although less often than is reported. Her respiratory rate during brooding remained the same as before that period. Also contrary to what has been reported, she never lost her appetite during the brooding period.

Unfortunately, both parents eventually died. The male died from unknown causes on May 8. During the first days of the hatching period, the female had an accident. She pulled the plug out of the drain; she was found the next morning with one arm deep in the drain. This action saved her eggs as it prevented the water from escaping from the tank. However, half of her arm had broken off, and the remainder was badly infected and had to be amputated. Two days later she was dead. An autopsy performed by Dr. Eric Hochberg of the Santa Barbara Museum of Natural History failed to pinpoint the cause of death, although it did confirm that her digestive system was healthy (unlike the condition found in many brooding octopuses). It is believed that she died as a consequence of the accident - possibly from shock, loss of blood or infection.

The young, numbering in the tens of thousands, began to hatch during the first week of October when the water temperature was between 12.2° and 12.8°C. During brooding the temperature had reached 13.9°C. The hatching continued for 68 days, during which period, the temperature dropped gradually to 10°C. During the early stages of development, the yolk sac is situated at the wide end of the egg away from the stalk. By the time the young octopuses are ready to emerge, almost 80%** of them have rotated 180°. Consequently, during hatching, it is the posterior end that, 80% of the time, emerges first. From the base of its arms to the posterior end of the mantle, the young octopus measures approximately 2.5mm. On each arm are 13 to 14 suckers.

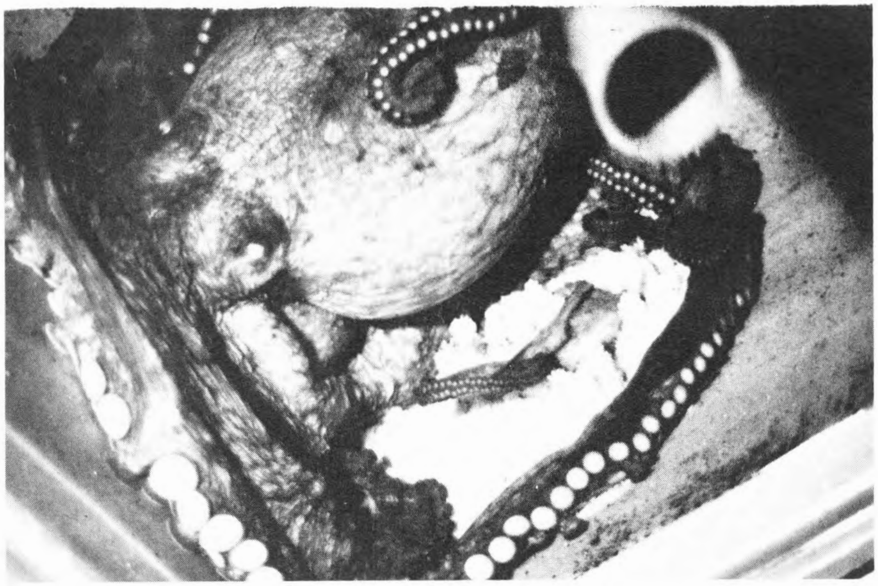
After hatching, the young were removed and placed in tanks ranging from 10 to 30 gallons. The mouth of the outflow tube was expanded by adding a styrofoam cup with a 70 mm. diameter. Plankton netting (mesh size approximately 3/4 mm.) was stretched around the mouth of the cup to prevent the larvae (and their food) from being swept through the outflow. The inflow tube directed water past the mouth of the cup, thereby preventing the animals from becoming enmeshed in the netting. The water flow was approximately one litre per minute.

A variety of foods was offered the young octopuses. These included egg yolk, ground shrimp and mussel, live gammarids, live brine shrimp (both young and adult stages) and fry of the Red Irish Lord sculpin (*Hemilepidotus hemilepidotus*). Of these, only the fry and the adult brine shrimp were accepted and these only when offered in sufficient quantities. Brine shrimp - the food more often taken - were added to the tank in densities of approximately 100 per litre. If supplied in small quantities, neither the fry nor the brine shrimp were eaten. Thus, it seems that prey density is a key factor. However, by the time the best food and its optimal density had finally been determined very few larvae remained (about 50). Over one weekend their numbers were halved, but for the first time, there were no remains. Could it be that they were becoming cannibalistic? Earlier I had observed young octopuses breeding on dead siblings. Of those larvae that lived over a month (up to 6 weeks), some reached a length of 6 mm.

The Giant Pacific Octopus is once again breeding*** and this year I am hoping not only to mate a pair at the Aquarium, but also to find and observe a breeding pair in the wild. It would be interesting to compare the brooding behavior and the egg development in the two situations.

** (a percentage based on a sampling taken throughout the developmental period).

***To summarize, the mature animals mated in March. The eggs were laid 42 days later and were brooded for 160 days at temperatures ranging from 9.2° to 13.9°C. Hatching continued for 68 days at temperatures ranging from 10° to 12.8°C.



1. The mother octopus takes meticulous care of her eggs; her arms continuously wave through the clusters agitating the eggs. Photo by S. Gabe

2. A young octopus is about to free itself from its egg. The ink gland is visible through the mantle. Photo by F. Larsen

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"WHITE WATER, BLUE DEATH"

By Kym Murphy, Technical Director
Sea World, Inc.

At Sea World we find it advantageous to use the "break point" chlorination process in both marine mammal and aquarium systems.

With this process we can lower a volumes B.O.D., ammonia level, chloramine level, and bacterial counts. This ability is obviously advantageous when recycling water, subjected to an organic load.

Whenever we employ this process, we normally dechlorinate with sodium thiosulphate. We had never noted any adverse affects while using this process on our marine mammal systems (primarily at Sea World of Ohio) except for periodic clouding after the process was employed. We attributed this to residual flocculant.

Not until we used the "break point" process on a fish system did we realize the gravity of our over zealous dechlorination practices.

Due to the relatively "non-toxic" nature of sodium thiosulphate, we had always employed the "better safe than sorry" method. In other words if one pound is adequate, a pound and a half would be safer. This philosophy proved to be our undoing.

At Sea World of Ohio we planned to use "break point" chlorination if the ammonia or nitrite levels in the aquarium systems approached dangerous levels.

As expected the chlorination procedure eliminated the nitrogen containing compounds from the water. (An isolated volume).

We first tried this process on a 10,000 gallon system containing Carribean Tropicals. Everything appeared to go smoothly (e.g. ammonia, nitrites, and nitrites = 0, water clear and colorless). Then suddenly (at 3:00 A.M. - S.O.P. for aquarium emergencies) I received a call from the maintenance personnel stating that the exhibit had turned white and everything appeared to be dead (except for one loggerhead with a grunt in his mouth).

After trying unsuccessfully to cut my throat with a Tract II razor, I came into Sea World to find that the report was unfortunately accurate.

The water looked as though a bag of D.E. had been dumped into it, and ALL the fish lay on the bottom with their gill plates extended.

On the spot, tests showed that the ph was 6.0 and the dissolved oxygen was less than 1 ppm. All other tests were within acceptable limits.

Three hours later another 10,000 display started to become cloudy and the inhabitants respiratory rate increased at an alarming rate.

Assuming that the fishes in the first tank died of asphyziation, we placed two large conde-compressors equipped with allundum aerators into service. The D.O., which had plummeted to 2.8 ppm climbed above 5 ppm and held.

All the fish in this second exhibit survived.

Our efforts to determine the cause of this catastrophy were initially frustrating. A phone call to Rhodes Trussel (water chemist for Montgomery Engineers) confirmed our original hypothesis, that "break point" chlorination should have no detrimental effect on the water or ultimately on the specimens.

Another variable that came to mind was our 4th of July fire works display, which produced great clouds of sulphur dioxide gas, that engulfed the aquarium building repeatedly.

Our suspicions were reinforced during a conversation with Rick Segedi (Curator of the Pittsburgh Aquarium). Rick felt that the highly soluble SO_2 might be combining with the dissolved oxygen forming SO_3 and depleting the system of oxygen.

Though many questions remained unanswered we settled for this answer and discounted any possible roll played by the chlorination-dechlorination process.

A few weeks later a similar fish kill occurred in one of our Koi ponds in San Diego.

The fish had been isolated while the pond was chlorinated and dechlorinated with sodium thiosulphate. Approximately 48 hours after the fish were placed back in the pond, the water became hazy white and the fish started dying.

Tests revealed similar conditions to the Ohio tragedy (low ph & low D.O.) I loaned Dave Powell my Track II, but he too failed.

Our next step proved to be a lucky one. We contacted Bill Shipman, Senior Research Chemist, for the Naval Under Sea Center. One of Bill Shipman's specialties just happened to be the chemistry of sodium thiosulphate.

Bill explained to us that in a system where accessive sodium thiosulphate comes in contact with "acidic pockets" a self-perpetuating series of reactions may occur.

Briefly, the sodium thiosulphate ions reacts with hydrogen ions to form SO_2 gas and elemental sulfur. The elemental sulfur colloid causing the system to turn white. The sulphur dioxide gas, in solution, then reacts with water molecules to form H_2SO_3. The H_2SO_3 then combines with the dissolved oxygen in the system, bringing about the death of the inhabitants by asphyxiation.

The H_2SO_3 plus oxygen gives rise to sulphuric acid thus perpetuating the reaction until all of the sodium thiosulphate or the oxygen is consumed.

$$S_2O_3^{=} + 4OCl^- + H_2O \qquad 2SO_4^{=} + 4Cl^- + 2H^+$$

$$\text{(excess) } S_2O_3^{=} + 2H^+ \longrightarrow SO_2 + S + H_2O$$

$$\downarrow$$

$$SO_2 + H_2O + H_2SO_3^{=}$$

$$2H_2SO_3^{=} + O_2 \qquad 2H_2SO_4$$

In conclusion, the dechlorination process for the removal of organic substances, in both fresh or salt water systems, remains a very valuable tool.

Our thanks to Rick Segedi and Bill Shipman for helping us solve this mystery. Our thanks to Gillette for saving our lives.

"THEMATIC DISPLAYS: AQUARIUM"*

Mr. U. E. Friese
Curator of Aquarium, Taronga Zoo.

Although a few zoos include major public aquaria of recognised excellence the traditional zoo aquarium is often only an insignificant building with about two dozen tanks, situated somewhere between the giraffe house and the seal pool. Usually such an "aquarium" houses a random collection of fishes in displays which are of little biological significance and of even less interest to the general public. Despite the fact that most zoos are slowly outgrowing their early role as mere animal repositories, the zoo aquarium usually still comprises a totally unplanned collection of mediocre exhibits, which - more often than not - consists for the largest part of specimens donated by the general public after having outgrown the home aquarium of their original owners.

That money is only too often the limiting factor in the design and development of a large and modern zoo aquarium, everyone here will no doubt agree to. But does it always have to be the limiting factor for meaningful individual aquatic exhibits on a smaller scale - even within the framework of a modest zoo aquarium? I would say definitely not!

If it is not money which prevents the creation of such meaningful aquatic exhibits (and I shall elaborate on the term, "meaningful aquatic exhibits" later) it must then be the lack of know-how or interest on the part of the person in charge of such an aquarium. Let us look for a moment at the average professional aquarist working in a public aquarium. Usually his interest in fishes dates back to his childhood days when he caught his first fish in a local pond or spent his pocket money on some of those "pretty fishes" in a local pet shop. If the budding aquarist then did not become discouraged by the sudden demise of some of his pets within a few days, he would gradually learn, "the hard way", a great deal about fishes and the maintenance of home aquaria. As time goes on he may develop special interest in certain types of fishes or confine his interest to such unusual animals as aquatic invertebrates. Others may go on to deepen their knowledge of fishes and their environment by taking up studies at university level. However, irrespective of their particular pathways, whether they remain amateur aquarists or become professionals in a public aquarium, most of these people are characterized by a distinctive trait; they have become collectors.

Thus either their interest is focused upon certain specific types of fishes with others being of little interest to them, or they have become random collectors whose collections reflect the availability of funds and are little more than matters of prestige or status symbols.

* REPRINTED from "Bulletin of Zoo Management", Vol. 5, No. 1, November 1973.

Unfortunately, the collecting syndrome is still symptomatic of many people in charge of public aquaria, a trend which tends to be somewhat more obvious the smaller the aquarium. The reason for this correlation seems to be that those people without special training in aquatic biology or fisheries science tend to foster their own ichthyological interests rather than offer to the public aquatic exhibits which are educational and on a wider and more general scale. (This is not to say that there is anything inherently wrong with a specialist aquarium, provided that it is recognized and utilised as such.)

In recent years a fresh wind appears to be blowing in the aquarium world. The trend of unplanned collections of aquatic exhibits is changing gradually so that they are becoming more relevant to the modern zoo's function in education, research and wildlife conservation. There is no doubt that this is in response to an increasing public awareness of the aquatic environment. There is ample daily evidence of a rapidly growing ecological conscience among the public, manifested by many amateur and professional conservation pressure groups, and further supplemented by a constant exposure to underwater films, television adventures, news reports of environmental destruction by pollution, and other more direct effects of man's presence on this earth.

Furthermore, there is a gradual acceptance by the public and the aquarium people alike that educational aquatic exhibits need not be dull. In fact, as evidences by such zoos as London, Frankfurt, Berlin, New York and Tokyo, a large aquarium can be a very popular attraction. As I have indicated above, the public is seeking more and more insight into basic biological concepts and deserves to be served by meaningful displays. It is simply not enough to display animals in rows of rectangular barred cages with little signs giving the countries of origin and the Latin names of species. Nor is it sufficient to offer the aquarium visitor an arbitrary exhibit of fish species A, B and C in one tank and X, Y and Z in the next. The aquarium curator does not dispose of his responsibilities by putting the label, Paracheirodon innesi, on a tank of Neon Tetras; visitors would like to know why these fishes are so brilliantly coloured or, more generally, what produces the colouration - an enquiry which can easily lead into general and far-reaching explanations of the functions of chromatophores and the processes of Natural Selection.

Now, let us examine some of the basic considerations which go into the creation and development of thematic displays. In setting up any exhibit in an aquarium, the aquarist should ask himself, "What can a visitor learn from this?" This is not to say that beautiful or uncommon aquatic creatures should be excluded from display; but these qualities are not sufficient in themselves to merit the exhibition of certain creatures.

There is virtually no limit to the range of biological topics that can be demonstrated or commented upon in relation to any exhibit - a point well made by Conway (1968) in his provocative essay on the display of a Bullfrog. However, a properly planned aquarium might well begin by providing exhibits that illuminate the implications of pollution and destruction of the environment, the structure of animal communities, animal societies, aggression, and the ways in which species are adapted to their environments, and cope - or fail to cope - with natural or man-made changes in their habitats. It would also be pertinent to provide insight into the principles involved in the wise utilizations and management of populations of commercially exploited aquatic species. The concept of the maximum sustainable yield of a mullet, tuna or lobster fishery should be made clear to the visitor before he passes through the exit of a zoo aquarium. By following this line of approach to the display of aquatic specimens one can also make a good case for going beyond the normal macroscopic level of display and observation. An aquarium is concerned with water, and a visitor could well be introduced to the concept of the hydrological cycle; from its atmospheric origin, via the soil to rivers, into the oceans, and back again to the atmosphere. For such an exhibit, where parts are reduced to microscopic levels, it would be appropriate to utilize optical and television microscopes and projection equipment to extend the view of the visitor.

So much for the theoretical consideration of the various possibilities of thematic aquarium displays. Now the question comes up, what have we done here at Taronga to implement such philosophies? At this time it may be pertinent to point out that money is very much the limiting factor for the development of a new Taronga Aquarium. Furthermore it would not have been wise to invest a substantial amount of money in the remodelling of our fifty-year-old facility. Consequently, we have concentrated our efforts on that part of the aquarium which, by its structural soundness, merits a modest remodelling programme, incorporating some of the concepts of thematic aquatic displays outlined above. About three years ago this programme was initiated by the removal of a series of antiquated fish tanks cluttering up the upper floor of the public viewing area of the aquarium. These tanks were replaced by an octagonal unit. Eight 60 gallon all-glass tanks of identical size were constructed, to be serviced by a small door leading to a service gallery. The basic step was from several widely scattered individual fish tanks to one solid structural unit. The next step was to create an overriding theme for this exhibit. It was decided to create an exhibit which demonstrated various adaptations of fishes to various environments.

1. <u>Production of electricity</u>

   This particular tank features three mormyrids (Elephantnose fishes). These fishes give off minute electrical currents (about .01 volt) which are amplified and projected over a loud speaker to the public viewing area, and they are also visually demonstrated on an oscilloscope screen. An illuminated sign explains in about 140 words the reason for such electrical currents generated by fishes; how such currents are produced, and how these fishes have adapted to use these currents in their environment.

2. Air-breathing fishes

Few people are aware of the fact that fishes can actually drown. The next exhibit contains some anabantids (Labyrinth fishes). A special feature of this group is an accessory respiratory organ which enables the fish to breathe atmospheric air. Again a large explanatory sign elaborates on the anatomical details of such a mechanism and the implication which such a unique organ has to the fishes in making adjustments to extreme environmental conditions. (pollution).

3. Ovo-viviparity

The concept of live-bearing fishes is strange to most people; with a tank of Guppies, Swordtails and Black Mollies we demonstrate dimorphism of these species and their unusual reproduction. The accompanying sign discusses this, for fishes, rather unique reproductive process.

4. Adaptive colouration

The effects of concealment and disguise as adaptive colouration are demonstrated with a tank of angelfishes. Their vertical black bands are a perfect match against the long and narrow leaves of water plants, supplemented by a series of upright bamboo sticks embedded into the bottom of the tank.

5. Mouth breeders

Another fascinating reproductive mechanism is that exhibited in certain cichlid fishes from Africa. The fertilized eggs are carried in the mouth of the female, and once the young have hatched they will seek refuge in the mouth of their mother in the event of danger. One of these new tanks demonstrates this with an exhibit of Tilapia.

6. Semi-terrestrial fishes

There appears to be considerable doubt in the mind of many visitors when they see mudskippers as to whether these are fishes or amphibians. In a tank with shallow water and ample rock space for these fishes to climb out of the water several Queensland mudskippers are exhibited. Again a large explanatory sign discusses the adaptations of such a fish to life in and out of the water and what this means to the survival of the species.

7. Blind fishes

Another fascinating group of fishes are those without eyes, a characteristic of certain cave-dwelling species. One tank within the octagonal unit features a group of blind cave fishes from Mexico. The accompanying sign explains why some fishes were first attracted to caves and how they subsequently lost their eyes through the process of evolution.

8. Colour in fishes

Visitors to a public aquarium are usually greatly intrigued by the often brilliant colours of fishes. One tank with a school of brightly coloured Neon Tetras demonstrates the principle of absorbed and reflected lightwaves and how these "colour" fishes. Chromatophores are defined and their function is explained.

A group of animals which in the past has always been greatly neglected by aquarists are the invertebrates. These animals are, of course, inherently difficult to keep in an aquarium. In an open-system type of aquarium operation the most serious problem is an adequate food supply, since most of these animals are filter feeders or rather specific herbivores. Predatory invertebrates are much easier to keep in an aquarium. However, the maintenance problems of invertebrates are greatly compounded in closed systems where the loss of water quality due to a build-up of metabolic waste produced is usually fatal within a rather short period of time.

Sydney harbour is well known for its abundance of colourful invertebrate life. It is for this reason that we have taken the initiative of creating a comprehensive marine invertebrate exhibit on the upper floor of the Taronga Aquarium. In order to have structural balance in this part of the Aquarium, we have designed another octagonal unit very much similar to the previously discussed one. Again we have eight tanks of identical size, with a large water volume, and most of these are connected to our open sea water system. These are specially designed with oblique walls creating an impression of considerable depth. The overriding theme is a systematic presentation of local invertebrates. The approach is towards the identification of distinct groups of invertebrates. A descriptive sign explains some of the more pertinent details of each group of animals, and the overall emphasis is on external morphology, things which can be readily observed on all display specimens.

Currently the following groups of invertebrates are on display in this new exhibit.

Sea Anemones

One of the most frequent questions asked by visitors in all aquaria I have ever been associated with is: "Are sea anemones animals or plants", a somewhat understandable question in view of the "flowery" appearance of these creatures. The descriptive signs identify these specimens to their correct phyletic group, and the rather unspecialized body structure is briefly explained, and the presence of potent stinging cells - peculiar to all coelenterate animals - is pointed out.

Crustacea

The point made in this exhibit is the fact that here is a group of animals which virtually has a skeleton on the outside of the body. It is pointed out that such a "skeleton" has to be shed in order for the animal to grow.

Mollusca

This very general exhibit permits the use of a great variety of similar animals, which are essentially characterised by the presence of a full or partial limestone shell. The degree of such a limestone shell in various types of molluscs is mentioned, and then supplemented by the appropriate display specimens.

Sea Squirts

Few visitors are aware that these primitive-looking creatures are animals, let alone that they are related to vertebrates. Since the viewers have to accept the fact that these specimens are highly developed, this exhibit essentially relies solely on visual impact to demonstrate this very important point.

Crown-of-thorns Sea Stars

Not all exhibits have to be of purely academic interest. In fact, often the most popular thematic exhibits are of a topical nature. Crown-of-thorns sea stars have been in the news for a number of years, and when visitors to the Taronga Aquarium see our display of these unusual animals there is often a genuine expression of interest and indirect association. After all, everybody has heard of these "dreadful" animals, but few have actually ever seen one.

Murray River Crayfish

One of the more recent fields of active freshwater aqua-culture is yabbie farming. With this Murray River crayfish exhibit we are featuring one of the more unusual native Australian crayfish species, and one which is also currently under culture by the New South Wales Fisheries Department.

Corals of Sydney Harbour

Most people tend to associate corals and coral polyps with tropical waters, especially with the Great Barrier Reef. In one tank of our new invertebrate exhibit we feature a rather attractive type of coral from Sydney Harbour. The accompanying explanatory sign discusses the anatomical details of coral polyps, their feeding and their reef-building characteristics.

Echinoderms

While this is a rather generalised display, it permits us, depending on seasonal variations in the availability of certain display specimens, to exhibit a wide range of these spiny-skinned animals, from sea urchins to sea stars and sea cucumbers.

The upper floor of the aquarium also includes a few other individual thematic displays, such as a tank with clownfishes (Family Pomacentridae) together with large tropical sea anemones where the theme is "symbiosis", a Barrier Reef tank, a poisonous fishes tank, and a sea horse tank; all thematic displays.

So much for our current efforts in the Taronga Aquarium. Now what are our plans for the future? Although at this time we do not have the money for a new aquarium, we have spent a considerable amount of time in preliminary design work on general concepts to be included in a new Taronga Aquarium. Apart from the previously discussed smaller types of thematic exhibits, it is most desirable to include substantially larger types of exhibits. Essentially this type of exhibit could be called participatory exhibits of which there are two major groups. Firstly, there would be the walk-through type of exhibit. As an example this could involve the entire water cycle, where visitors walk through large scale exhibits from mountains with their trout streams, through the more sluggish water flowing areas of the lower streams, through the mangrove swamps of a typical estuary and finally to the open sea shore. There could be large wave-action exhibits as well as a series of tide pools with fluctuating water levels. Secondly, any new aquarium should have certain "contact" areas very much similar to children's zoos. Here various inter-tidal invertebrates could, under strict supervision, be handled by visitors. The inherent loss of species of such exhibits is well offset by the tremendous gain in appreciation and specific knowledge of such creatures.

Incorporated in the overall concept of a new aquarium there should be complementary exhibits touching upon such specific subjects as pollution control methods and devices, fisheries work showing efforts in aquaculture and fisheries technology as well as oceanography.

Conclusions

As I have demonstrated above there are no absolute prescriptions or definite limitations to thematic aquarium displays. Zoos have lagged behind museums in formulating a reason for their existence. Zoo aquariums have similarly lagged behind their parent zoos for lack of an acceptably defined motivation. It is obvious that technological progress over the past decade has brought about a revolution in aquarium hardware but it must be admitted that the software of our profession is still very much in its infancy.