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NOTES ON CULTIVATION OF MULLET IN HAWAIIAN FISH PONDS

by

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ABSTRACT

Ancient Hawaiian people built and operated fish ponds along the shores of all the principal Hawaiian Islands. Mullet, mugil cephalus, and milkfish, Chanos chanos, were the fish usually cultivated in these ponds, although many other species were resident in the ponds. Ponds destroyed by natural causes have been rebuilt and their ecology is now being investigated by the Oceanic Institute. Some ponds are now stocked with mullet.

INTRODUCTION

The Oceanic Institute is rebuilding some of the ancient fish ponds used over the centuries by the Hawaiian people who inhabited the Islands. The work is going forward on the Island of Molokai where leases have been obtained from the State of Hawaii. The ponds have been neglected for many years and most of the pond walls, which were built of basalt rock and coral, have been destroyed by the attrition of time and nature. Tidal waves have occurred which were very destructive but fortunately, if one can use the word, pushed the walls inward and most of the rocks are nearby. Rebuilding has consisted mostly of picking the rocks out of the water at low tide and setting them back in place.

Original walls were constructed by enclosing a natural indentation of the shore line usually in an area where fresh water springs made an appearance. Springs are found along most of the coast where they occur above the high water mark or may come up in the littoral zone, or just below the low water mark. Pond waters are slightly brackish; salinities will vary between 20‰ to 30 or 32‰. Most ponds have an area that is exposed at low water. These mud flats are covered with a microbenthos composed of diatoms, unicellular algae, protozoans, nematodes, etc. As the waters rise and flood these littoral zones, mullet come in and feed on the diatoms. Most of the other constituents of the microbenthos are rejected as diatoms appear to be the preferred food. Diatoms grow in more abundance on muddy bottoms or muddy-sandy bottoms. Very few are found on clean sand or bare rock or coral, at least within these ponds.

POND WALL CONSTRUCTION

Ponds as stated above were built around fresh-water spring areas to provide brackish water for the mullet. While mullet are euryhaline and can be found oftentimes in salt-water, they seem to prefer brackish water. It must have been evident to the ancient Hawaiians that brackish water would be better for mullet culture and they located their ponds accordingly.

Walls were constructed of basalt rock brought down from the hills where it is found in great abundance, so material was no problem. Chunks of coral are often found in the walls and coraline algae has cemented and helped to hold the pond walls together. One or two ponds were built entirely of coral. Little attempt was made to construct a water-tight wall. Rather, the rocks were placed loosely in position and water could enter and leave the pond freely.

Not all ponds enclosed a bay or natural indentation of the shore line as some were built out beyond the low water mark or attached to the walls of an inshore pond. However, most ponds were constructed in water not over 3 or 4 feet deep.

What determined the size of a pond is not clear but perhaps it was related to the number of people available for work or the need for fish to feed the people. Most Hawaiians lived in separate communities whose local chief or Alii was sole dictator over the affairs of the land and sea and people and he probably detailed the pond dimensions. Ponds vary in size from 1 to 525 acres and pond walls could be up to 3,000 feet long. Most of the Molokai ponds were built along the shore or offshore but on Oahu many large productive ponds were built inshore such as those at Pearl Harbour, Waikiki and Kuapa Pond near Koko Head, now partially being filled in for a housing development. The width of a pond wall could be anywhere from 3 to 6 feet and would not necessarily be of uniform width for its full length.

The height of the wall would also depend on the location but most walls would stand a foot or two above high water.

A part of some of the walls of the ponds that the Institute has leased have remained intact. Reconstruction is relatively simple as most of the dislocated rocks have been found close to the original wall. One pond was rebuilt for some 1000 feet with 10 men in a three-month period. Some of the rock for this wall was barged in. Another wall was rebuilt with three men who repaired 600 feet in about three months.

Silt from the mountainsides has filled most of the ponds, sometimes completely. Others have been partially filled or decreased in size by the buildup of silt at one end. Molokai offshore waters are subjected to strong currents and strong trade winds which keep the silt that has come down from the land suspended in the water. Waters entering the pond from the sea carry a small amount of silt in and some undoubtedly settles out to add to the silt carried in by floodwaters from the mountains. Siltation is a problem in that it decreases the productive area of a pond. It also makes work in a pond difficult especially during seining operations. Furthermore it provides a habitat for many burrowing organisms, some of which are competitors for food and some are predators.

On the plus side some authorities believe that this type of substrate provides the nutrients essential for growth of primary producers as well as diatoms, algae, and the rest of the benthic community.

MULLET CULTIVATION

Mature mullet have not been domesticated to the point where it is now possible to spawn them, hatch the eggs and raise the larvae. Therefore stocking of a pond must be from natural sources. Most pond walls are pervious and so some larvae could conceivably enter through the walls. Usually a wide opening called a makaka is built into the wall and juvenile mullet could enter through this gate. At best this would not provide stock with any certainty. And an unknown number could enter the pond. If some control of the population size is desirable, then manual stocking must take place. After estimating the swim in population, further stocking is done by catching the juveniles when they are from 25 mm. in length up to 70 or 80 mm. Actually a fingerling of about 60 mm. or larger is best for stocking for they have attained a size where predation would not decimate the population as badly as in smaller sized fish. Furthermore, the aholehole, Kuhlia sandwicensis, is found in close association with smaller mullet. So that if a school of what appears to be mullet is seined up along the shore up to 50% of the school may consist of aholehole. Separation is difficult below 40 mm. - 50 mm. in length.

Mullet begin to scatter and become much harder to catch after reaching a length of 100 mm. so it becomes imperative to catch them at the 50-80 mm. size.

Small scoop nets operated by one man can be used but a net of 1/8" mesh about 12 feet long operated by two men is better. For the larger sizes, ¼" mesh is much easier and faster to pull through the water and the length can be increased due to less water resistance on the larger mesh.

Young mullet are found usually in shallow water within 10 feet of the shore. Many are caught along the water's edge. Mullet prefer warmer waters and show a laboratory preference for water of around 85°F. (Watters, 1968). Under natural conditions they are seldom found in waters of less than 70°F., at least here in Hawaii. Cold water doesn't happen in Hawaii but near the mouth of rivers and some spring areas, cool spots can be found, usually without mullet.

Mullet fingerlings are transported by truck to the pond where they are weighed and total numbers interpolated or hand counted. Ponds are stocked with 50,000 fish per 25 acres.

PREDATION

Mullet ponds in Hawaii contain many species of fish some of which are carnivorous and are potentially dangerous to mullet populations. Because the walls are porous, larval forms of predators can enter into the ponds. The rather large gates are screened with 1/4" or 1/8" hardware cloth (galvanized screen) but small barracude up to 1" long and other species can and do enter.

That these predaceous fish do not feed on mullet is probably due to their feeding on the large population of gobies, Oxyurichthys lonchotus, which are found in one pond at a density of 10.9 individuals per square metre (Van Heukelem, 1968). Since these fish constitute the largest biomass in the ponds and are more easily caught, it is only natural that they would be the fish found most often in stomach samples. If this goby were not present, mullet populations might suffer.

Sphyraena barracuda, the barracuda, is at least by reputation the most dangerous fish in the ponds. However, these fish prefer the goby for food rather than mullet. In 137 stomach samples, the goby represented 72% of the identifiable fish remains and 66% of all the prey consumed which included other fish and crustaceans. Only one mullet was found in a stomach but barracuda do attempt to catch mullet and do, on occasion, catch them (Van Heukelem, 1968).

Caranx ignobilis, the jack or papio, is present in the pond but apparently also takes the goby for food. Because of its deep body it seems doubtful that it could enter the shallow areas to feed on mullet.

Elops hawaiensis, the Ten Pounder, or Ladyfish, is reported by Hiatt (1947) to inhabit the mullet ponds. Presently, however, these fish are not in large numbers. They feed on Molliensis latipima, Leander debilis and Gambusia affinis according to Hiatt, but Van Heukelem finds that the goby, O. lonchotus, constitutes 38% of the diet (by number) and Leander debilis 61%. Apparently mullet are not the prey of Elops.

Saurida gracilis, the lizard fish, because of its ability to swallow fish half its size, is considered to be quite dangerous to young mullet. One specimen 117 mm. long was found with a 60 mm. mullet in its stomach. Of eight specimens examined, 79% of the food was O. lonchotus and 20% M. cephalus.

Hiatt reports that in 50 specimens of S. gracilis 57% of the food volume was Leander debilis and 30% Molliensis latipinna. Time and place and availability of food produce different results in surveys of this nature. Fish are opportunistic and feed on what is in front of them.

Abula vulpes, the bonefish, or oio, apparently is not a mullet-eating fish although it is present in the ponds. Its diet consists of O. lonchotus, the crustaceans Leander debilis and Crangon crassimanus, and small crabs.

Strongyleura gigantea, the needle fish, is present but does not feed on mullet although they do eat other fish.

Upeneus arge, the goatfish, is piscivorous but mullet are not found in stomach samples; O. lonchotus is, however.

Scomberoides sancti-petri, the lai, is found in more brackish water ponds and it feeds on the goby and shrimp. It may be an important predator.

Eleotris sandwicensis, opu akupa, has been found with mullet in the stomach and are carnivores.

Bathygobius fuscus, a small goby, feeds on amphipods, polychaets and crustaceans.

Apogon brachygrammus, cardinal fish, eat small fish, shrimp and crabs.

Bothus pantherinus, a flatfish, feeds on shrimp and amphipods.

All of the piscivorous fishes mentioned above are presumably capable of eating small mullet. Whether they do or not is not known.

BIRDS

There may be other fish-eating birds that feed in mullet ponds, but the one most commonly seen and the only species examined was the black crowned night heron Nycticorax nycticorax. Stomach samples yield Leander debilis, Oxyurichthys lonchotus, and Mugil cephalus, and remains of crabs. They are voracious feeders and can cause very serious losses.

In order to prevent heavy losses of juvenile mullet due to predation, if this is a problem, one can raise the fish in smaller fingerling ponds over which predator control is absolute. However, unless the fingerling ponds were sufficiently large enough to provide adequate amounts of forage supplemental feeding would be necessary.

One private operator on Molokai brings water in a ditch from the sea and from this ditch water enters the main pond through screened gates, and is also used to supply water to fingerling ponds some 20 x 50 feet in size. Bakery bread is used to supplement the natural diet. Ellis (1968) has noted the refusal of bread by aquaria-raised fish and believes that better and less expensive feeds are more acceptable to mullet.

Fingerling ponds constructed of boards or concrete might be economically feasible and might offer even more positive environmental control. Some difficulty in getting fish to feed on artificial food has been experienced in shallow wooden walled ponds due in part to a thin growth of diatoms which the fish preferentially feed on, not enough to sustain them but sufficient to interfere with acceptance of other food. Disease in these small ponds is difficult to control particularly those which are caused by internal pathogens as treatment with drugs in the food is not effective.

COMPETITORS

The goby has been mentioned as the prey of carnivorous fishes in the ponds but it is also a competitor of the mullet for the food in the pond. If a goby population is quite large (10.9 individuals per square metre in one pond), it can restrict the number of mullet which can be raised in a pond. Van Heukelem estimates that in one 25 acre pond gobies consume 136,650 lbs. of diatoms which theoretically could produce 13,651 lbs. of mullet over a 300 day period.

DISEASE

In a large pond of 25 acres or so, disease may cause some mortalities without indication of its presence. This is especially true where birds or carnivorous fish may eat the moribund fishes. In some ponds crabs may be able to catch the slower moving sick fish and eat it, leaving no trace of its demise. Many ponds are sometimes overgrown with mangrove and other vegetation which can tolerate salt water. Sick fish will seek shelter among the roots and limbs of such and may die and not be noticed.

In Molokai ponds a disease caused by a monogenectic trematode worm has caused large losses. The worm very closely resembles the fresh-water trematode, Gyrodactylus elegans and may in fact be the same. It occurs seasonally during the early summer period and may persist for several weeks during which time heavy losses may occur. No attempt at control has been undertaken although the worm can be controlled with low level (.26 to .58 pp.) concentrations of Dylox.

Some bacterial diseases have also caused heavy losses more particularly in the confinement of aquaria and small fingerling ponds. The etiological agents have not been identified. Antibiotics such as neomycin and tetracycline have proved effective providing the fish will accept artificial food in which the antibiotic can be incorporated.

Heterophyid Cysts

Of some importance is the infestation of mullet fingerling with the metacercarial stage of a heterophyid trematode.

Four species of these trematodes are found in Hawaii (Martin, 1958). The metacercariae of Stellantchamus falcatus (Onje and Uishio, 1924) incyst on mullet fingerling in great numbers. The mullet serves as the second intermediate host with the snails, Stenomelania newcombi and Tarebia granifera as first intermediate hosts, and the night heron Nycticorax nycticorax, or the common rat or the mongoose, or man, as the final or definitive host. The worm develops in the digestive gland of the snail, the cercariae leave the snail and swim about in the water. If they encounter a mullet or other fish they shed their tails, penetrate and encyst in the muscles or mucous of the fish. If the fish is eaten by a heron, or by man, or other warm blooded animal, the metacercariae develop into the adult worm which will eventually shed eggs. These can in turn be eaten by the snail to complete the cycle.

Metacercarial cysts can be found in substantial numbers on some mullet fingerling from all areas of Oahu and Molokai. They may be seen as a translucent oval body just under the mucoid covering of the scales. They are found on the caudal peduncle just at the base of the caudal fin. Occasionally encystment occurs along the body. Many mullet have cysts embedded in the gill filaments. A favourite spot is the area under the opercle where it joins the head. This protected area seems to be a preferred encystment location. They may also be found in adjacent areas of the opercle or cleithrum or any portion of the gill cavity. Martin (1958) says cysts may b found in the eye and this seems likely although none have been found by Institute personnel.

It may be debatable whether cysts can cause mortalities in the mullet fingerling although it was losses among a group of fish that led to discovery of the infestation. If sufficient numbers were present on the gills, the proliferation of the epithelium might lead to oxygen starvation. Certainly the cysts under the opercle and on the caudal area must be very disturbing.

Hawaiian people love to eat raw fingerling mullet. In fact, under the heading of Predators, man, Homo sapiens (Hawaiiencis) should be included. Many mullet are stolen from mullet ponds and sold as a delicacy - 1968 price, 50¢ for a cupful. People who eat raw mullet fingerling may accumulate these worms which can cause cardiac arrest and death.

SUPPLEMENTAL FEEDING

Because of the large populations in some of the ponds, supplemental feeding has been tried. Only a commercially available pelleted feed was used and not in any large quantity. The feed was broadcast over the shallow water where fish usually feed. Apparently they do ingest it but if anything is gained by this it is not known. Other foodstuffs such as rice bran, wheat milling by-products, etc., may contribute to the nutrition of pond mullet.

FERTILIZATION

No major fertilization programme has been initiated in the Molokai ponds. Some experimentation on a small scale demonstrated the possibility of using several different combinations to increase diatom growth. Nitrates seem to be required more than phosphates. Studies to further delineate the inorganic requirements of the benthic community are still in progress.

SUMMARY

Mullet can be raised in Hawaiian mullet ponds. Stocking must at this time be accomplished from natural sources rather than through artificial breeding. Most profitable in terms of survival when stocking a pond are the larger juveniles above 50 mm. in length. Ponds are presently constructed of basalt and coral walls. Depth of the pond may vary from two to four feet deep on the outer wall edge next to the sea, down to no depth as the water runs out with the tidal change. Diatoms grow well on the tide flats exposed at low tide, and since diatoms provide most of the mullet's feed in these ponds, the physical contour of the pond bottom would seem to be suitable. Silt may be too deep in some ponds restricting the total possible water volume and occluding light as it is stirred up by the winds. It also harbours burrowing organisms which, while competitors for food with the mullet, may be consumed as feed for carnivores rather than mullet.

Predation on mullet is only occasionally by fish and birds and does not present a serious problem under the present ecological setup.

Disease may cause serious losses and chemical control of ectoparasites may be necessary. Benefits of supplemental feeding are not clear and should be further investigated.

Fertilization studies indicate the need for nitrates to improve the diatom crop.

No attempt has been made to determine the cost of raising mullet and whether or not a profitable return could be realized would depend on how well the pond was managed, the mortalities incurred, the market price of fish, etc. Here in Hawaii where the price of mullet is comparatively high, such a venture might be worthwhile.

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