**Activated Carbon as a Cause of**
**Head and Lateral Line Erosion (HLLE) in Marine Aquarium fish**

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**Background:**

Head and Lateral Line Erosion (HLLE) is the name for a type of skin erosion that affects some species of marine fishes in captivity. It is occasionally referred to as Marine Head and Lateral Line Erosion (MHLLE) or Head and Lateral Line Erosion Syndrome (HLLES). A similar syndrome occurs in freshwater fishes, but the causes seem to be different, and that is usually termed, "Hole-in-the-Head" disease. HLLE typically begins as small pale pits around the fish's eyes. These may develop into light colored lesions along the fish's lateral line system, finally spreading onto wider areas of the body and sometimes involving the unpaired fins. Fish that develop severe lesions are usually permanently disfigured. At least 20 families of fish have been identified as having developed HLLE in captivity (Table 1). Not all species of fish show the same symptoms, and do not always develop lesions to the same degree (Hemdal 2006). HLLE is not normally seen in fish in the wild, but there are two published photographs that bring this into question; one taken by Rudie Kuiter in the Cook Islands shows HLLE in a large black tang, *Zebrasoma rostratum* and another image taken by Tim Laman in Bali shows minor HLLE pitting in a juvenile emperor angelfish, *Pomacanthus imperator*.

| Family | Common name |
|---|---|
| Acanthuridae | Surgeonfishes |
| Blenniidae | Combtooth blennies |
| Centrarchidae | Sunfishes |
| Ceratodontidae | Australian lungfish |
| Chaetodontidae | Butterflyfishes |
| Cichlidae | New World cichlids |
| Gadidae | Cods |
| Grammatidae | Basslets, Grammas |
| Haemulidae | Grunts |
| Labridae | Wrasses |
| Lutjanidae | Snappers |
| Muraenidae | Moray eels |
| Percichthyidae | Temperate perches |
| Percidae | Perches |
| Plesiopidae | Roundheads |
| Pomacanthidae | Angelfishes |
| Pomacentridae | Damselfishes |
| Protopteridae | African lungfishes |
| Scorpaenidae | Scorpionfishes |
| Serranidae | Sea basses and soapfishes |

**Table I. - Families of fishes with members known to be susceptible to HLLE-like lesions in aquariums (J. Hemdal - personal observation).**

A similar condition, termed "epithelial thinning", has been noted in walleye, grouper and hepatus blue tangs (other species may likely develop this as well). This syndrome is characterized by thinning of the skin on the head, often with a change to a paler color. Sometimes, but not always, this can evolve into classic, deep-pit HLLE. The cause of this issue has not been determined.

**Causes of HLLE:**

To date, the cause(s) of this syndrome have not been identified in aquarium fish through published scientific study, although conjecture and informal studies abound. This report is based in part on a peer-reviewed study that was published in the North American Journal of Aquaculture (Hemdal and Odum 2011). That paper evaluates the relationship between the use of activated carbon in aquariums and the development of HLLE in surgeonfish. The results of an additional dietary study, not part of the original research is included here, but that material is offered only as preliminary results as it was not peer-reviewed.

In 2009, a survey was taken of 100 advanced aquarists who identified twenty-five suspected causes for HLLE in marine fishes. The majority of the survey participants believed that HLLE in marine fishes such as tangs and angelfish is caused by a dietary problem, notably deficiencies in vitamin C or low levels of highly unsaturated fatty acids. General stress caused by captivity also was cited as a major cause of HLLE. Other survey responses included stray electrical current, the use of copper medications, heavy metal toxicity, lack of sunlight, the use of activated carbon or the presence of a variety of chemical pollutants all as possible causes of HLLE. Viral and bacterial infections have also been implicated in causing this syndrome (Varner 1991, Hemdal 1989). In the survey results, 18 treatment methods were reported to have caused remission of HLLE symptoms in fishes. Eighty-four percent of these cases involved moving the fish to a new aquarium as one part of the treatment. This shows that there are conditions in the physical operation of the aquarium itself that can be changed in order to reduce the incidence of HLLE. When the survey results were limited to professional public aquarists, 19% of the respondents found complete reversal of HLLE by discontinuing the use of carbon filtration. In addition, 75% of this sub-group stated that they felt that the use of carbon caused HLLE in at least some cases.

Tom Frakes wrote a report in a 1988 SeaScope about a roundtable discussion at the second International Aquarium Congress where George Blasiola was presenting a paper implicating improper diet as causing HLLE. Towards the end of the article, and with no real discussion, mention is made of a Dr. Dieter Jauch of the Wilhelma Aquarium who expressed his opinion that carbon use caused HLLE. Tom Frakes also performed a small-scale study that was not published, but which implicated carbon use in causing HLLE in some damselfish (Frakes pers. comm. 2010).

**Current study:**

The history of activated carbon use at the Toledo Zoo has shown a correlation between the use of lignite (coal-based) carbon and the formation of HLLE lesions in some fishes.

Moving the fish to aquariums without carbon filtration sometimes caused the lesions to heal without additional treatment. Once carbon use at the facility was curtailed over ten years ago, cases of HLLE greatly diminished.

Based on those preliminary observations, the Toledo Zoo funded this study, the objective of which was to demonstrate the relationship between carbon use and the development of HLLE. In turn, it is hoped that these results will allow marine aquarists to make more informed decisions regarding the use of carbon in their aquariums.

Three 120-gallon marine aquarium systems (two tanks per system) were established using typical home aquarium equipment and synthetic seawater. Live rock was utilized as the basis for biological filtration in all three systems. Thirty-five ocean surgeonfish, (*Acanthurus bahianus*) were evenly distributed among the three systems at the start of the study.

Because there have been so many purported causes of HLLE, it was very important to control variables that relate to any of the suspected causes. For example: The test fish were not exposed to natural sunlight, and light levels were maintained between 54 and 323 Lux. This was to eliminate "sunlight" and other bright light sources that have been reported to reduce the incidence of HLLE. Voltage between the aquariums and a common ground was monitored with a voltmeter, to be very low, ranging between 0.2- and 1-Volt AC. This helped rule out spurious voltage as a cause. The air supply was passed through a HEPA filter, as "dust" has been implicated as an irritant, possibly causing HLLE (more about carbon dust later). The study fish were net-collected by a professional fish collector and not exposed to carbon or copper prior to their arrival. The water quality in all systems was maintained within parameters considered acceptable by Stephen Spotte (Spotte 1979).

| Parameter | Lignite Carbon System | Pelleted Carbon System | Control System | Suitable Range (Spotte, 1979) |
|---|---|---|---|---|
| °C. | 24-28 | 25-28 | 24-28 | Not given |
| Specific gravity | 1.022-1.024 | 1.022-1.025 | 1.022-1.024 | 1.024 |
| pH | 8.0-8.3 | 8.0-8.3 | 8.0-8.3 | 8.0-8.3 |
| DO % sat. | 94-97% | 94-97% | 94-96% | >85% |
| mg/l $NH_3$-N | 0-0.03 | 0-0.04 | 0-0.10 | 0-0.10 |
| mg/l $NO_2^-$N | 0.01-0.04 | 0.003-0.04 | 0.02-0.04 | 0-0.10 |
| mg/l $NO_3^-$N | 3.4-7.9 | 3.0-7.6 | 3.6-9.2 | 0-20.0 |

**Table 2. Range of water quality parameters for each system during the study.**

Water changes were performed on each system at a rate of 45% per month. This maintained nitrate-nitrogen levels below 10 ppm (High nitrate levels are another suspected cause of HLLE). Small amounts of water, (~3 milliliters) were transferred between all three systems on a weekly basis. The intent was to demonstrate that there were no easily communicable fish diseases present in one system and not another. Because a reovirus has been associated with HLLE lesions in marine angelfish (Varner and Lewis 1991), and a possible correlation shown between bacterial diseases and HLLE, (Hemdal 1989) it was important not to restrict the potential transport of disease organisms between the test and control systems. The most difficult variable to control was that of diet. So many people believe that poor diet is the root cause of HLLE, that any study that does not control this variable will be suspect. Because the fish in each of the three systems could be further split into two groups, it was decided to feed half of the fish in each system a premium pelleted diet known not to induce HLLE (Tilghman, et-al 2003) and the other half, a bulk flake food, that was known to at least not prevent HLLE. Once acclimated to these diets, the study fish were not given any other foods or supplements.

One week after the fish arrived, 500 grams of unwashed lignite carbon was placed in a mesh bag and added to the filter sump of the first system. At the same time, 500 g of extruded pellet carbon was placed in a mesh bag and added to the filter sump of the second system. No carbon was added to the control system. Two months later, the carbon in the first and second systems was supplemented with an additional 500 grams of each variety. This carbon usage follows the recommendation made by Spotte (1979), of 1 gram of carbon per liter, changed every two months.

**Study results**

Minor HLLE lesions were noted on two fish 20 days after the lignite carbon was added to the sump of their system. The lesions began to develop on the additional fish in that system, and grew in size until after four months, all of the fish in that system showed severe lesions (Eventually involving over one third of their body surface). One fish of this group died, but this was attributed, (at least in part) to tank mate aggression.

The 12 fish exposed to pelleted carbon did not develop visible symptoms, but microscopic lesions were discovered upon histological examination by an outside laboratory, and two of the fish developed minor lesions a few months after the conclusion of the study. The 11 control fish did not develop any visible or microscopic lesions. Six months after the study was concluded, and the carbon was removed, the HLLE lesions remain on all originally affected fish, and the control fish are all still symptom-free.

The effect of lignite carbon on the fish was swift and involved all of the exposed fish. None of the control fish developed any lesions. **Statistically, the results were definitive that activated carbon use caused HLLE in these fish.**

**Discussion**

The basic hypothesis of this study was that activated carbon causes HLLE in fishes. Originally, it was thought that carbon dust (known as fines) was the causative agent. This was based on observations at the Toledo Zoo where carbon was removed from an aquarium and the water changed, yet HLLE symptoms could still be produced by adding susceptible fish to the aquarium, indicating there was some unknown residual action by the carbon. Carbon fines were frequently discovered in the filter sumps and substrate of these tanks. Changing all of the aquarium’s water, decorations and substrate would then render the aquarium safe for housing susceptible fishes (Assuming no new carbon use). Two public aquariums have reported acute outbreaks of HLLE in systems where carbon had been accidentally ground up and ejected into aquariums by mechanical filtration systems. It has also been reported that aquariums which use foam fractionators (Protein skimmers) do not seem to develop HLLE as frequently, even when carbon is routinely used. Since foam fractionators remove particulate organic carbon from water (including carbon fines), it was thought that this might be why these systems do not cause HLLE as readily. In addition, the hard pelleted carbon used in this study did not cause severe HLLE, while the soft, dusty carbon did. However, no carbon fines were seen in the histological examinations of the lesions of the study fish. This means that the dust causing the effect is either fleeting, the fines were too small for the histologist to see, or that there is some other factor associated with carbon use that causes HLLE in susceptible fishes.

When these results were informally presented to home aquarists, some would mention their own cases that confirmed the relationship between carbon and HLLE, but other aquarists would steadfastly argue against the conclusions. Some of these home aquarists have used carbon filtration products for years with no problem. Public aquarists as a whole are much more familiar with the cause and effect of carbon and HLLE. Why the difference in experiences? It may be due to home aquarists often opting to purchase high quality carbon products, while public aquarists, needing huge amounts of carbon, and often purchase bulk commercial brands. It may also be that home aquarists just never suspected that such a commonly used filtration material could be at the root of the HLLE issue.

**Diet Study:**

After the HLLE project was concluded, a post-study pilot project was undertaken to see what long-term effects severe HLLE lesions might have on the health of the fish. All of the remaining study fish were held in their respective tanks after the carbon was removed. Monthly 45% water changes continued. For ninety-five days, each tank continued to be fed the same diet (premium pellets or basic flakes) and the fish were sedated, measured and weighed four times over three months. All food fed to the fish was weighed, and the fish were fed three to four times per day in appropriate amounts. Feeding amounts were approximately 1.5% of the fish's body weight in food per day. Both foods had the same percentage moisture (10%) so direct comparison was easily made.

Using a formula: $K = \text{fish weight in grams} * 100 / \text{Length in centimeters}^3$ the average condition factor K was determined for each group of fish. Condition factor is used by fisheries scientists to determine how "robust" a particular group of fish is. A lower number indicates a thinner, poor condition fish, while a higher number shows that the fish is healthier, and in better condition. Of course, extremely high numbers can indicate obesity.

Condition factor numbers cannot easily be compared between species, or even between different age fish of the same species, but these numbers can be used to show relative differences in condition between groups of similar fish. The condition factors for surgeonfish in the wild ranges from 3 to around 4. The range of "K" in the study fish was 2.584 to 3.882. The fish fed the premium pelleted food had a higher average condition factor (3.354) than the fish fed the generic flake food (3.047). More importantly, the control fish not exposed to carbon had a higher condition factor (3.280) than the fish with severe HLLE (3.088). The fish exposed to pelleted carbon were intermediate (3.235). This shows that HLLE causes systemic health problems in fish, and is not a purely cosmetic issue. While this does seem intuitive (after all, fish with HLLE do look very sick) it has not been demonstrated before, that HLLE has any direct effect on a fish's health.

**Conclusion:**

The recommendation based on the clear effect that the use of carbon had on the study fish is not to use activated lignite carbon in marine aquariums housing fish species susceptible to HLLE. Other means of water quality management should first be explored; water changes, non-carbon chemical filtration, or foam fractionation. Extruded pelleted carbon may be more suitable, especially if used sparingly. No conclusions can be drawn regarding the use of carbon filtration products that were not tested.

If you do use carbon, rinse it well in reverse osmosis water prior to use, employ a foam fractionator, and do not place the carbon in a high water flow reactor (that might serve to break the carbon granules up into finer particles).

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