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# Editorial: Fibropapillomatosis Tumors at Honokowai: Underwater Observations with Potential Broad Application

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**Forward.** Decades of research and dozens of science publications have provided useful insights into the tumor-forming disease known as fibropapillomatosis (FP) affecting primarily green turtles, *Chelonia mydas*. Yet the cause, cure, and manner of transmission of this affliction remain substantially unresolved. The leading etiological candidate continues to be an alpha-herpes virus, but how and where is it spread, and under what environmental conditions? The answers to date remain inconclusive and elusive. But might important information available in plain view on the world wide web for the past 20 years have gone unnoticed or ignored? On 17 December 1995 Canadian naturalists Peter Bennett and Ursula Keuper-Bennett composed the following essay based on 8 summers of meticulous underwater observations of green turtles off West Maui in the Hawaiian Islands. Their insightful thought-provoking article was prominently posted where it remains today on one of the world's first web sites devoted exclusively to sea turtles, Turtle Trax (<http://www.turtles.org>). When the essay was written FP seemed to signal the eventual collapse of the Hawaiian green turtle population. Such worries, while fully justified at the time, have failed to come true and likely never will. Indeed, two of the world's most historically FP-afflicted green turtle populations (Hawaii and Florida) have shown phenomenal long-term growth to the present day. This fact lends credibility to the Bennett's observations and parsimonious reasoning. That is, that the spread of FP is exacerbated in dense green turtle populations, and deterred by lower densities. Thus, while some of the material in this essay has become outdated with progress in the research concerning fibropapillomatosis, and also with our own continuing education about the disease, this essay remains valuable.

My congratulations to the Marine Turtle Newsletter for ensuring a place in the published literature so the Bennett's essay can seriously be taken into account by FP historians and researchers of the future. The original essay can be found here: <http://www.turtles.org/tumoursa.htm>

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"Pollution, right?" That is the first reaction of nearly everyone who sees our images of tumored turtles. If only it were that simple.

No one really knows what causes turtle tumors. Although scientists have made progress towards understanding fibropapillomatosis (FP), the cause is still uncertain. Until someone finds the cause, no one can know how tumors spread. This makes it difficult - but not impossible - to know what to do about the disease.

We reached this conclusion after reading many scientific papers, consulting Internet sources, and soliciting information through email from marine turtle specialists, virologists, government officials, and fellow divers.

Note that we did not say fellow scientists. Scientists we are not. We are turtle-watchers. We have eight summers of observations in the waters of Honokowai, West Maui, Hawaii, USA. Over that time, we have done nearly 1000 dives averaging about 75 minutes each, with 35-40 of those minutes spent actually watching turtles. We have made over 90 hours of videotape and taken over 2500 photographs. We have paid close attention to watching and documenting the changes in the environment. We have developed a reliable method of identifying individual turtles (>100 so far) allowing us to track the changes in their condition from year to year.

**Why we wrote this.** Since we first discovered the turtles of Honokowai and their tumors, we have frequently been asked to explain the problem. When we tell people that science is still searching for the answers, we are next pressed for our opinion. Because we now maintain Turtle Trax, a webpage dedicated to spreading information about marine turtles, we felt a need to make sure that whatever opinions we expressed were solidly based.
We have therefore spent considerable time trying to make sense of what we have seen and learned. From our observations and the inquiries they prompted, we think we have a plausible explanation of the dynamics of the disease and its transmission. Certainly it explains our observations and many of the points raised by researchers in the papers we've studied.

We have no doubt that our explanation is incomplete and probably wrong in some areas. Nevertheless, it does fit the facts we have gathered from various papers, as well as our personal observations underwater. We believe that if we are correct, we can identify potential hot-spots, where the incidence of tumors will be exceptionally high (>50%).

In this essay, we show how our thinking arose from our observations and inquiries about our Honokowai dive site, and explain why we believe it can explain aspects of the development of the FP tumors worldwide.

**Some premises:**

- Seaweeds, like any algae, respond to nutrients (Brodie 1995). If you allow extra nutrients into a shallow coastal area, one where they will not be quickly diluted and carried off, you will get increased seaweed growth.

- Sea turtles, like other animals, tend to cluster at places where food is most plentiful. Green sea turtles feed primarily on various seaweeds (Balazs 1980). It seems likely that if you find an area of abundant seaweed, you will find more turtles than you would in areas with less seaweed.

- When the turtle population density increases, there is more contact between individual turtles, and each turtle has contact with a larger number of other turtles. This provides more opportunities for the spread of communicable disease (Herbst 1995). FP tumors are almost certainly spread by a virus. Although the virus has not yet been isolated, FP is virus-induced in other animals (Herbst *et al*. 1995). Herbst (1995) and others have strongly implicated a viral cause and are working towards conclusive proof.

- Viruses can be spread through mechanical vectors (P. Young, pers. comm.). When turtles gather in sufficient numbers, some fish will become cleaners (Losey *et al*. 1994). Each one is a potential vector (Losey *et al*. 1994).

Below we examine how these points apply to the turtles of Honokowai.

**Nutrient input.** Around 500 m to the north of where we watch these turtles, there is the Mahinahina Channel, part of the Honoloua Watershed Project. This is a concrete channel built for flood and erosion control. At roughly the same distance to the south, there is the Honokowai Stream Channel, also concrete. Runoff from pineapple and sugar cane fields collects in these channels and until recently, was discharged right into the ocean.

Just over 1 km south and about 500 m from the shoreline, the Lahaina Wastewater Reclamation Facility uses injection wells to dispose of sewage effluent. Into holes ranging from 55-70 m deep, contained only by concrete casings extending approximately 45% of their depth, Maui County pumps effluent at a rate of 15-25 million liters/day. Maui, of course, is a volcanic island, with plenty of porous rock and lava tubes. Where has this effluent been going? No one knows, but it seems extremely unlikely that none of it ever reached the ocean.

The waters of West Maui near Honokowai are shallow and do not appear to lend themselves readily to self-cleansing. When Tropical Storm Dora passed by on 22 July 1993, about two hours of heavy rain sent countless liters of runoff down the two concrete channels. This runoff was characterized by silt that left a muddy band along the coastline, stretching 100 m and more from the waterline. Despite wave and current action, this band persisted until well into November 1993, providing a graphic demonstration of how long it can take to disperse material that enters the ocean in this area.

No one tested this runoff, but because the channels both reach far back from the shoreline into agricultural areas, it is hard to believe that this mud was not loaded with nutrients above and beyond its natural levels, which already would be high enough to disrupt the underwater environment.

This is only the most obvious example of what has been happening to the waters of Honokowai. In 1989 and 1991, there were enormous blooms of *Cladophora sericea*, a seaweed usually found in deeper water. Since 1989, hooked red *Hypnea musciformis* has been establishing itself in the same area, and now is a permanent feature along Honokowai, piling up on shore and floating in huge mats.

Underwater, a former garden of low corals has become choked and overgrown with seaweeds. The northern portion of our dive site no longer has living corals in the 4-6 m depths. As early as 1985, Balazs *et al*. documented that the southern portion of our dive site already had dense algae growth (Balazs *et al*. 1985). This suggests that the area was already receiving significant nutrient input well before the blooms of 1989 and 1991.

**A bountiful foraging area.** Honokowai has more seaweed in its waters than do the areas both to the north and south. Because there is so much food readily available, turtles should be more common at Honokowai than on the neighbor reefs. This has, in fact, been our experience. Communications with others who dive West Maui tend to confirm this, although no one has undertaken a thorough turtle census.

We might not be able to say exactly how many there are, but by observing the behavior of the Honokowai turtles, we have learned a number of things about them. For example, we know that there is a resident population numbering roughly 30 individuals that can be found year after year. Every summer, we also identify perhaps half a dozen summer visitors, turtles that we see daily but for a single summer only. Finally, each year we identify another ten or so that are probably transient, because we see them once or at most, half a dozen times.

**Turtles get together...** The Honokowai turtles turn out to be social creatures. They seem to like being together. A turtle arriving at a site that is already occupied by another turtle frequently approaches the original occupant. Often, there is physical contact. It is not unusual for the new arrival to settle down so that both turtles are touching in some manner.

**...and are joined by cleaners.** When enough turtles cluster in this way, a symbiosis develops with some of the resident fauna. Fish discover that turtles are a source of food (Losey *et al*. 1994).

Some fishes will groom turtle shells, and others will look for and remove such parasites as small barnacles. Some fishes will even switch to feeding primarily through cleaning. A turtle cleaning station will evolve with several cleaner species, each of which represents a possible mechanical vector for the spread of any FP virus.

In Honokowai, we see more and more species engaging in cleaning. Some of them started because the tumors often host parasites. At Honokowai, we have long observed that saddleback wrasses and Hawaiian spotted tobies bite at FP tumors, presumably because the tumors are infested. In 1995, for the first time, we observed long-nosed butterflies (*Forcipiger flavissimus*) cleaning turtles, a behavior that has continued. We believe it is significant that this cleaner fish targets tumors.

**Suspects for mechanical vectors.** None of the tumor-cleaners at Honokowai bite exclusively at tumors. From the beginning, we have observed this type of cleaner biting at the eyes of turtles. The behavior occurs whether the turtle has tumors or not. One possibility is that the cleaners are attracted to the greyish-white mucous matter in the posterior corners of turtles' eyes.

In other words, cleaners often first bite at tumors, then move on to bite at the eyes of a healthy turtle. If it is possible that the FP virus is spread mechanically, we present some prime suspects, along with some incriminating circumstantial evidence: in almost all of the turtles of Honokowai, we have documented tumors in the posterior corners of the eyes. With rare exception, this location is the first to have visible tumors.

Cleaners that bite tumors often snap at any other prominent white feature on a turtle's body. We have learned to anticipate tumors on any turtle subjected to these cleaning attempts.

**FP is probably caused by a virus.** In Honokowai, over 75% of the turtles we see from year to year have contracted FP. It is hard to find a Honokowai turtle without tumors. Within 5 km north and south of Honokowai, it is hard to find a turtle with tumors. If tumors are caused by a communicable virus, this is the expected pattern (Herbst 1994). Because turtles concentrate at Honokowai, the virus will spread quickly through those turtles.

FP tumors do not appear to be a new phenomenon. Herbst (1994) has reported suggestions that the disease has always been present at some low level. If something encourages turtles to gather at greater densities than before, there is increased opportunity for epidemic patterns to emerge (Herbst 1994). We point out that nutrients introduced in certain types of coastal waters cause increased seaweed growth, an attractor for turtles. We therefore expect to find high tumor rates at this kind of site.

**Applying these premises to other sites.** For example, the Sebastian Inlet area of the Indian River Lagoon system in Florida has also been subjected to high nutrient input and has experienced high seaweed growth (Woodward-Clyde Consultants *et al*. 1994). We are told that it has a dense green turtle population (D.A. Bagley, pers. comm.). We do not think it is a coincidence that it is a site with high tumor rates (Herbst 1994).

When we check environmental data about coastal regions, we find that the kind of nutrient overload seen at Honokowai is becoming common. For example, when writing about the special aspects of Australian eutrophication, Brodie notes that this is a growing problem worldwide (Brodie 1995). As the number of affected areas increases, so should the clustering of turtles. This would lend itself to epidemic outbreaks of a virus anywhere that turtles gather in groups large enough to trigger cleaning symbiosis.

**The effects of site fidelity.** In our experience, Honokowai turtles exhibit extremely high site fidelity. Not only do they remain in the same area year after year, they like to settle in almost precisely the same spot on the reef. Honokowai has turtles that have migrated to the French Frigate Shoals to nest and returned, to be found at the same two or three favorite resting spots - within a meter!

In an area with easily obtained food, turtles also have much more time to spend resting. Our experience is that turtles seek each other out, so they tend to rest close together. This leads to cleaning symbiosis and the possibility of mechanical vectors.

We think this can explain why a high percentage of the residents at an infected site will have tumors, while turtles faithful to sites a few km away will likely be healthy. The cleaner species we suspect of being vectors are all reef fish that do not ordinarily have much range.

Unfortunately, a small percentage of the turtles we see annually turn out to be there for only a single summer. We believe this is long enough to become infected. If these turtles are residing elsewhere the next summer, the potential exists to spread the disease and eventually give rise to another “hot spot.”

**The Honokowai cycle.** When people assume that pollution is causing turtle tumors, we believe they are correct, but probably not in the way they think. In summary, this is the cycle we see:

> A coastal area gets overloaded with nutrients.
> Seaweed growth increases proportionately.
> Turtles are attracted by the excess of food.
> Sooner or later, an infected turtle arrives.
> Turtles like to gather.
> When turtles gather, cleaning symbiosis starts.
> Cleaners learn that tumors host edible parasites.
> Cleaners bite tumors and then healthy turtles (particularly the eyes).
> More turtles become infected.
> More cleaners discover tumors are a food source, an escalating spiral.

This cycle is based primarily on observations at Honokowai and how we fit them into what we have learned from research papers on the disease. We do not know what occurs underwater at Indian River or other tumor sites. We have not, however, found any material that contradicts our thinking, while the concept does seem to fit the sites that we have information from.

This does not mean we are right. We advance this idea in hope that someone can either show us where it is wrong, or supplement it with additional information.

**The value of the Honokowai observations.** We have tried to assemble a reasonable explanation that is not in conflict with known facts, while offering explanations for our observations and those of researchers examining this problem.

If this explanation can withstand scrutiny, we can use it as a powerful argument in favor of reducing and even eliminating nutrient input into oceans that are home to green turtles. It is important to understand that even if there are no turtles in an area, it does harm to let nutrients into the water, since the area will soon begin to attract turtles. Areas with a low population density and healthy turtles will become depleted. The nutrient-heavy area will see a population density increase with a high potential for a local tumor epidemic.

At the 15th Annual Sea Turtle Symposium, Balazs (1995) reported that numerous Hawaiian green turtles had recently begun foraging at a site on the Kona Coast that had not previously been heavily populated. He reported that park personnel observed scores of turtles feeding, an obvious indication that the area has abundant seaweed growth. This is a strong indicator for eutrophication. Regardless of the cause of the ample food source, we believe it has a high potential to be another tumor "hot-spot." If the food supply holds, the turtles will remain in the area, the population density will increase, and there will be a tumor epidemic.

Right now, we can say, "Don't put nutrients in the ocean, it's probably not good for the turtles." We'd like to be able to say with confidence, "Don't put nutrients in the ocean, it's definitely not good for the turtles."

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<http://www.sjrwmd.com/indianriverlagoon>

**Figure 1.** Turtles Clustering: This picture shows the end of Hilu's return from a trip to the surface for air. He could have picked an empty spot anywhere in the area, but he chose instead to land literally on top of two other turtles. This emphasizes the affinity turtles have for the company of other turtles, and the resulting close contact. It is this social nature that we believe ultimately leads to a much higher potential for the spread of FP tumors.

**Figure 2.** Suspected Mechanical Vectors: The cleaners in this image, goldring surgeons (*Ctenochaetus strigosus*), are clearly grazing on the tumors. Much more likely suspects, however, are saddleback wrasses (*Thalassoma duperrey*), such as the one in the upper left portion of the photo. Four Spot, the turtle in this picture, was free of tumors in 1992.

**Figure 3.** This picture was taken at a place we call The Graveyard. It is a long finger-like depression that drops about 1.5 m below the surrounding floor, bottoming out at about 8 m below the surface. Most of the time there is a mat of algae accumulating here, nearly deep enough to cover a 75 cm turtle. In this mat, we usually see two or three turtles. Every year, they are among the worst tumor cases we see, hence the reason for choosing its name. We speculate that the sickest turtles gather here because the area has abundant seaweeds and is shallow, so they expend as little energy as possible to get food and air.

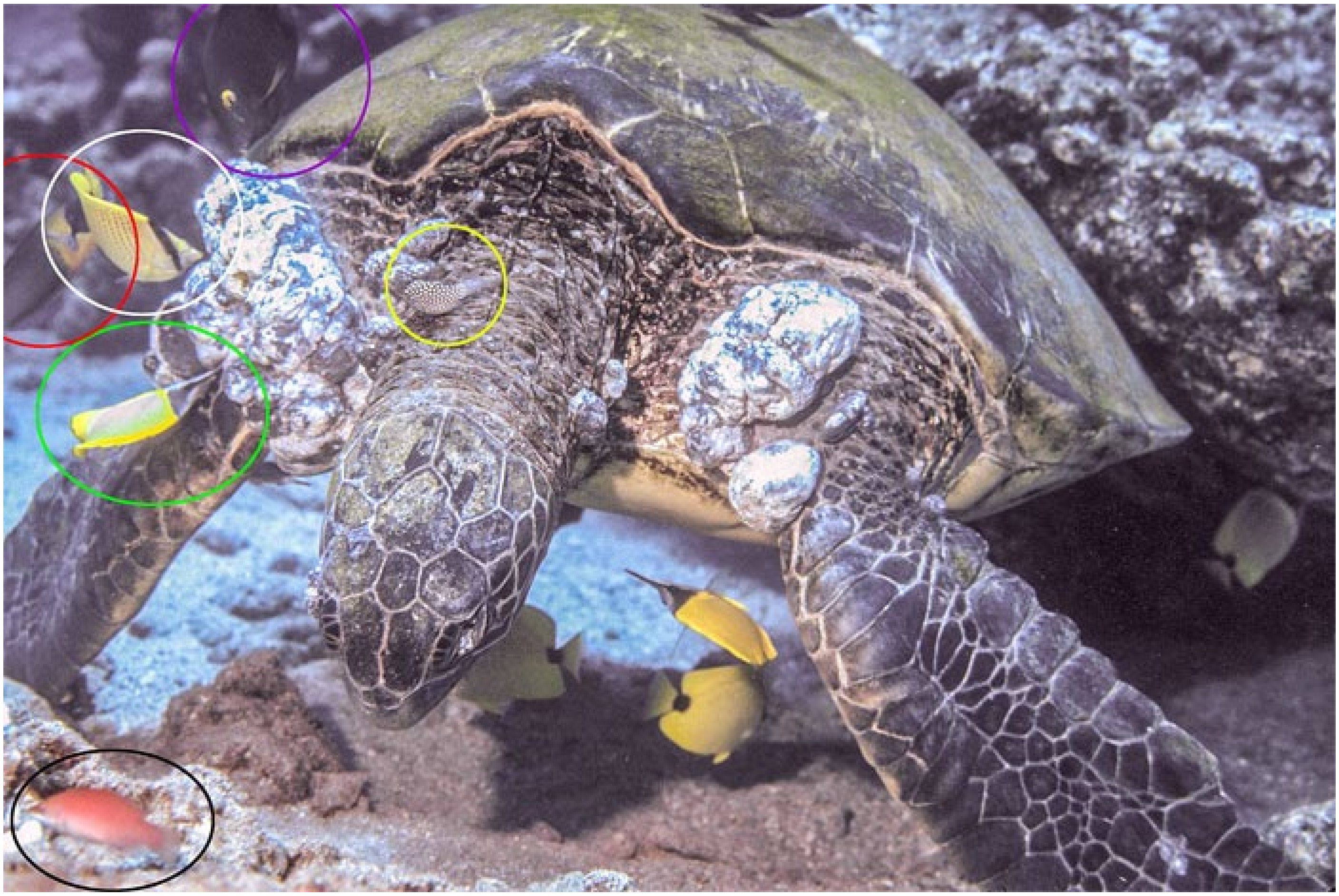

**Figure 4.** When we first began watching turtles in 1989, we observed that goldring surgeons (*C. strigosus*), saddleback wrasses (*T. duperrey*), and whitespotted tobies (*Canthigaster jactator*), were the cleaners. By 1991, we began seeing eight-lined wrasses (*Pseudocheilinus octoaenia*) in black ring and millet seed butterfly fish (*Chaetodon miliaris*) participating in cleaning. This summer (1995), for the first time we saw long-nosed butterflies (*Forcipiger flavissimus*), engaged in cleaning activity. Unlike the other cleaner species, which we noticed at work no matter where the turtles were resting, we saw this change in the long-nosed butterflies at only one specific site. About half a dozen of these fish concentrated almost exclusively on tumors whenever the opportunity arose. They clearly preferred tumors over their usual foraging among the corals. This picture is interesting because all six of the most common cleaners are present, each circled in a different color.
**Purple ring** = goldring surgeons (*C. strigosus*); **Red ring** = saddleback wrasses (*T. duperrey*); **Yellow ring** = whitespotted tobies (*Canthigaster jactator*); **Black ring** = eight-lined wrasses (*Pseudocheilinus octoaenia*); **White ring** = millet seed butterfly fish (*Chaetodon miliaris*); **Green ring** = long-nosed butterflies (*Forcipiger flavissimus*)