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Differences Between Cultured or Captured *Kāhala* in Hawai‘i

Clyde S. Tamaru, Ruth Ellen Klinger-Bowen, and Harry Ako
University of Hawai‘i at Mānoa
College of Tropical Agriculture and Human Resources
Department of Molecular Biosciences and Bioengineering

Cara Empey Campora
Biolintec Consulting LLC

Kazuo Ogawa and Takashi Iwaki
Meguro Parasitological Museum

Akira Kurashima
University of Tokyo
Graduate School of Science
Department of Biological Sciences

Naoki Itoh
Tohoku University
Graduate School of Agricultural Science
Laboratory of Aquacultural Biology

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INTRODUCTION

In 1995, a multi-year project entitled "Hawaiian Fisheries Development" supported by the National Oceanic and Atmospheric Administration (NOAA) began to systematically address development of hatchery technologies for species having the greatest potential for aquaculture and stock enhancement (Ostrowski, 1997). The amberjack more commonly known as *kāhala* was identified as being a good candidate for culture because of its rapid growth rate, high commercial value, adaptability to sea cages and tanks, and tolerance to handling. Although initially fed fresh fish, they have since been shown to readily adapt to commercial pelleted feeds. The *kāhala* and in particular, the Almaco Jack, *Seriola rivoliana,* are commercially cultivated at aquaculture facilities in Hawai'i and are target species for the expansion and diversification of the open ocean aquaculture activities that started in Hawai'i (e.g., what was Kona Blue Water Farms (KBWF) is now known as Blue Ocean Mariculture http://www.bofish.com/).

Two species of amberjack are found in Hawaiian waters, the Greater amberjack, *S. dumerili* and the Almaco Jack, *S. rivoliana*, both of which are commonly known in Hawai'i as *kāhala*. Historically, they were very important commercial species and an excellent food fish taken from the deeper coastal waters between 40-100 fathoms. Although popular as a food fish, the *kāhala* is known to be ciguatoxic in some areas of the Pacific and continues to be a primary source of ciguatera poisoning in Hawai'i (Anderson et al., 1983; Myers, 1991; Randall, 1996). Subsequently, retailers have excluded amberjacks from commercial markets and restaurants, resulting in a dramatic decrease in total commercial landings and for those that are caught that actually are marketed (Figure 1).

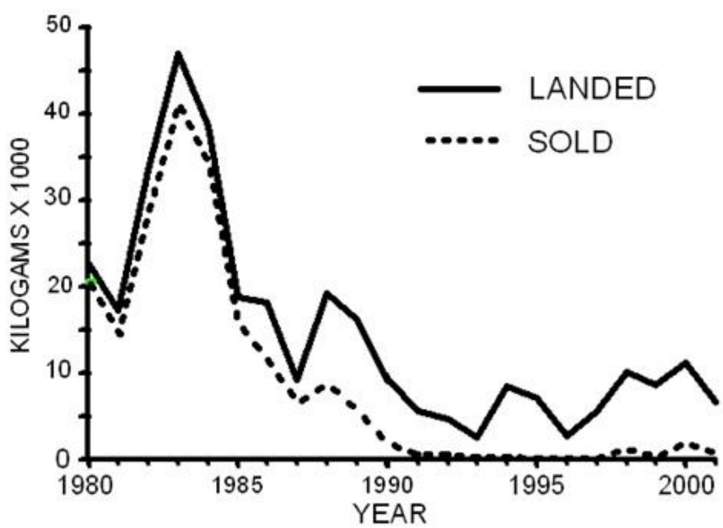

Figure 1. Commercial *kāhala* landings in Hawaii

This publication was completed by research and extension personnel at the University of Hawaii at Manoa (along with their collaborative partners) and summarizes decades of research that underscores the advantages of cultured versus wild caught *kāhala*. It also provides a glimpse of the research and extension activities that will be needed to support the continued growth of this new industry.

FATTY ACID ANALYSIS OF AQUACULTURED AND WILD KAHALA
Collaborative Authors: Harry Ako, Vanessa Sim and Dawn Ueda

This analysis was done with faculty member Dr. Harry Ako providing guidance to students Vanessa Sim and Dawn Ueda, who received an award for their presentation made at CTAHR's 2003 Student Research Symposium.

A prime example of the kinds of data that can be obtained using this strategy is seen in Table 1, where the fatty acid profiles from fillets of ten cultured individuals and ten wild-caught specimens were analyzed. The values of the fatty acids when totaled show a highly significant difference between cultured and wild caught samples. It is well known that the fat content is the Number one factor that affects price of the tuna sashimi market in the fabled Tsukiji fish market in Japan (Blanc, 2002), and in all likelihood plays an important role in the marketing of the cultured kahala. The large difference gives a clear advantage to cultured *kāhala* as opposed to those caught from the wild.

Table 1. Means of the fatty acid profile of fillets from aquacultured and wild *kāhala* (mg/100 mg dry).

Name of fatty acid	Chemical name	Aquacultured	Wild
Myristate	14:0	1.53	0.09
Palmitate	16:0	5.23	0.8
Palmitoleate	16:1n7	2.00	0.12
Stearate	18:0	1.04	0.52
Oleate	18:1n9	6.06	1.01
Linoleate	18:2n6	2.05	0.12
Linolenate	18:3n3	0.57	0.09
Octadecatetraenoate	18:4n3	0.74	0.11
Eicosenoate	20:1n11	0.48	0.04
Arachidonate	20:4n6	0.35	0.23
Eicosapentaeonate	20:5n3	3.96	0.47
Docosahexaenoate	22:6n3	3.43	0.91
Total fatty acids		27.8	4.28

The data can be broken down even further, as the contributions made by specific fatty acids were also assessed. A case in point are Eicosapentaeonate (EPA) and Docosahexaenoate (DHA); these particular fatty acids are the well known omega-3 fats that have been shown to be essential, playing a role in the health of the human cardiovascular system, growth, and intellectual development. The large difference in amounts of both fatty acids in cultured versus captured *kāhala* indicate a superior cultured product, nutritionally speaking.

CIGUATERA FISH POISONING

Collaborative Authors: Cara Empey Campora, Yoshitsugi Hokama, Bruce Anderson and Douglas Vincent.

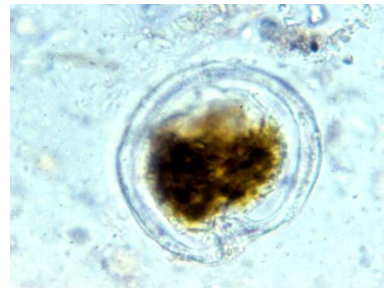

Figure 2. Photomicrograph

Dr. Cara Empey Campora received her PhD in 2008 for her work on the illness Ciguatera Fish Poisoning (CFP), which occurs in humans and is caused by ingestion of subtropical and tropical fish species that have accumulated toxins, called ciguatoxins, through macroalgae in their natural diets. The toxins, which exhibit no apparent harm to the fish, are known to originate from several marine dinoflagellates associated with coral reefs, including *Gambierdiscus toxicus* (Figure 2). Ciguatoxins, which are retained in the muscle and liver of fish and bioaccumulate through the food chain, are heat stable, colorless, odorless, and cannot be inactivated through cooking, canning, drying, freezing, smoking, salting or pickling. They ultimately cause neurological, gastrointestinal, and cardiovascular symptoms in humans and mammals who have eaten affected fish, regardless of any methods of cooking or storage precaution.

CFP is the most common marine toxin disease worldwide with an estimated 50,000 cases reported each year (Lehane and Lewis, 2000; Ting and Brown, 2001). However, it is difficult to track and is thought to be highly underreported. Most CFP cases in the United States occur in Hawai´i and Florida, although tourists may develop symptoms after returning home, and global marketing of tropical fish has been responsible for several outbreaks across the U.S. mainland.

In Hawai´i, a total of 126 incidents of ciguatera fish poisoning were reported to the Hawai‘i State Department of Health during a four-year period ending in 2001, with an average of 25 cases per year. The leeward coasts of the main Hawai´i Islands often report the majority of cases, with west Oahu, the north shore of Kauai, west Maui, and the Kona and north Kohala coasts on the Island of Hawai‘i leading the statistics (Anderson et al., 1983). While the number of cases reported in Hawai‘i is considered low, it is a major concern for both commercial and recreational fishermen in tropical and subtropical waters, and of particular interest to those involved in raising various species of fish at environmentally susceptible open ocean aquaculture facilities.

More than 400 species of fish have been known to cause ciguatera fish poisoning. Herbivorous species that feed on algae and detritus around tropical reefs such as surgeonfish (*Acanthuridae*) and parrotfish (*Scaridae*), and carnivores including snappers (*Lutjanidae*), jacks and amberjacks (*Carangidae*), wrasses (*Labridae*), groupers, sea bass, rock cod (*Serranidae*), moray eels (*Muraenidae*), triggerfish (*Balistidae*), and barracudas (*Sphyraenidae*) are commonly implicated in ciguatera fish poisoning events (Table 2) (Hokama, 2004).

During the 1970s, the almaco jack, *Seriola rivoliana*, and the greater amberjack, *S.dumerili*, collectively known as *kāhala*, were the fish most frequently associated with ciguatera fish poisoning in Hawaii, responsible for 21% of ciguatera incidents reported to the State Department of Health between 1975 and 1981 (Anderson et al. 1983).

Table 2. Fishes most commonly implicated in ciguatera fish poisoning in Hawaii.

Fish Species	**Regional Name**
Jack (Carangoides)	Ulua
Amberjack (*Seriola dumerili*)	Kāhala
Wrasse (*Cheilinus rhodochrous*)	Po'ou
Surgeonfish (*Ctenochaetus strigosus*)	Kole
Grouper (*Cephalopholis argus*)	Roi
Black snapper (*Aphareus furca*)	Wahanui
Parrotfish (*Scarus*)	Uhu
Goatfish (*Mulloidichthys*)	Weke
Moray eel (*Gymnothorax*)	Puhi
Mullet (*Mugil cephalus*)	Ama'ama
Barracuda (*Sphyraena barracuda)*	Kaku

Despite the banning of wild-caught *kāhala* for sale on the open market due to concerns over ciguatoxin, there is renewed interest from restaurants and retailers in the farmed *kāhala* product, which is currently being cultivated as a result of the introduction of open ocean grow-out aquaculture facilities raising reef fishes. *Kāhala* grown in open ocean aquaculture facilities off of the Kona Coast on the Big Island of Hawaii have been assessed for the presence of the marine benthic dinoflagellate, *G. toxicus,* which is known to produce the toxin. While the dinoflagellate was detected on one open ocean cage at extremely low levels averaging 2.51 cells *G. toxicus*/gram algae, a total of 60 individual cultured *kāhala* (*Seriola rivoliana*) were tested using the ELISA method and a highly sensitive neuroblastoma cell bioassay, and none of the cultured fish were found to contain ciguatoxin (Campora et al., 2010). Conversely, 85 wild-caught *kāhala* from around the Hawaiian Islands were examined using the same methods, yielded an outcome of 4.7% positive for ciguatoxin. In addition, there have been no reports of a CFP event from the consumption of cultured *kāhala*, despite the hundreds of thousands of pounds already produced. These findings indicate that ciguatoxin is prevented from entering the culture process for *S. rivoliana* raised in open ocean aquaculture facilities even when *G. toxicus* is present.

THE IDENTITY OF A PARASITE IN WILD-CAUGHT AND CULTURED KAHALA

Collaborative Authors: Ruth Ellen Klinger-Bowen, Bruce Anderson, Douglas Vincent, Kazuo Ogawa, Takashi Iwaki, Akira Kurashima and Naoki Itoh

Research on this topic has lasted as long as the inception of the "Hawaiian Fisheries Development" project and reflects the challenges of depending on peer reviewed research results for the science-based information that is necessary to make informed decisions. However, with the recent acceptance of the research results on this topic (Tamaru et al., 2015), the rationale and justification for the production of this summary is to provide the kinds of science-based information needed to make informed decisions.

Consumers of raw fish (e.g., sashimi) in Hawai‘i have expressed concerns about the occurrence of worms, which have the appearance of cooked spaghetti noodles (Figure 3) that permeate the musculature of the *kāhala*. These worms are the larval plerocercoid stage of an aquatic tape worm (Cestoda) belonging to the order Trypanorhynca and are known to infest the flesh of *kāhala* and possibly other members of the family Carangidae caught from the wild. While they do not pose as a threat to human health, the worms clearly impact the aesthetics of fresh fillets and the culinary presentations expected of sashimi dishes. Heavy infestations of cestodes found in other fish species have reportedly reduced the market value of the infected fish to the level of fish meal or pet food.

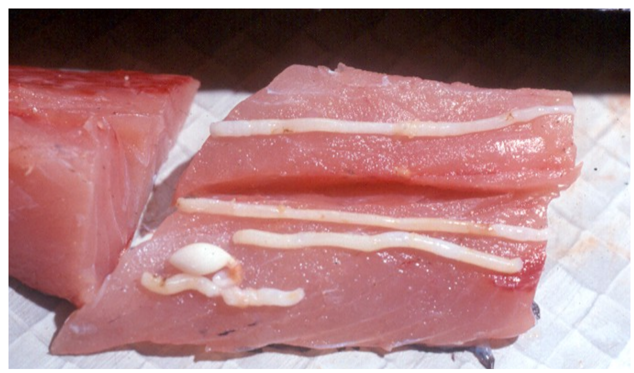

Figure 3. A parasitic worm that is commonly found in wild *kāhala.*

The species of worm has been recently described to be *Protogrillotia zerbiae*; it would require an international team utilizing a combination of classical morphological, as well as state of the art, molecular techniques (i.e., PCR) to complete its final description (Tamaru et al., 2015). One of the interesting findings is that the geographic distribution of this species of tapeworm extends from the waters surrounding Hawai´i all the way to Japan. This is possibly due to the complex lifecycle of the tapeworm and distribution by a host shark(s) that remains to be identified.

The results of the investigation show that 6 out of 11 (54.5%) of the wild-caught specimens from Hawai´i in which plerocercoid larvae were present were below 4 kg in body weight (Figure 4). Using this ratio of infected *kāhala*, the number of cultured *kāhala* that would be expected to be infected would be 22 of 40 individuals (54.5%), if the life cycle of this particular tapeworm were not disrupted. However, the pleroceroid stage was not found in any of the 40 individuals of the cultured *kāhala* examined. This differs significantly ($P<0.001$, Chi Square = 12) from the expected number of infected individuals. These results are consistent with the hypothesis that the life cycle of this tapeworm has been broken by the culture process.

Although cultured *S. dumerili* in Kagoshima and Miyazaki prefectures in Japan were recently found with the same larval cestode infection in skeletal musculature (Ogawa et al. 2012), the prevalence of the infestation is extremely rare, with only two individual *S. dumerili* (total body weight = 3 kg each) infections reported to date in the first report of this parasite in *S. dumerili* in Japan (Ogawa et al. 2012). While no data is being obtained to determine prevalence, the size of the parasite makes it easy to detect when an individual fish is filleted. With the thousands of kilograms of *S. dumerili* being processed it would have surely been noticed, suggesting that its recent detection may be an emerging issue. It is still unclear as to how the cultured individuals in Japan became infected, whether through consumption of an infected copepod or an infected fish; this remains a topic for future research.

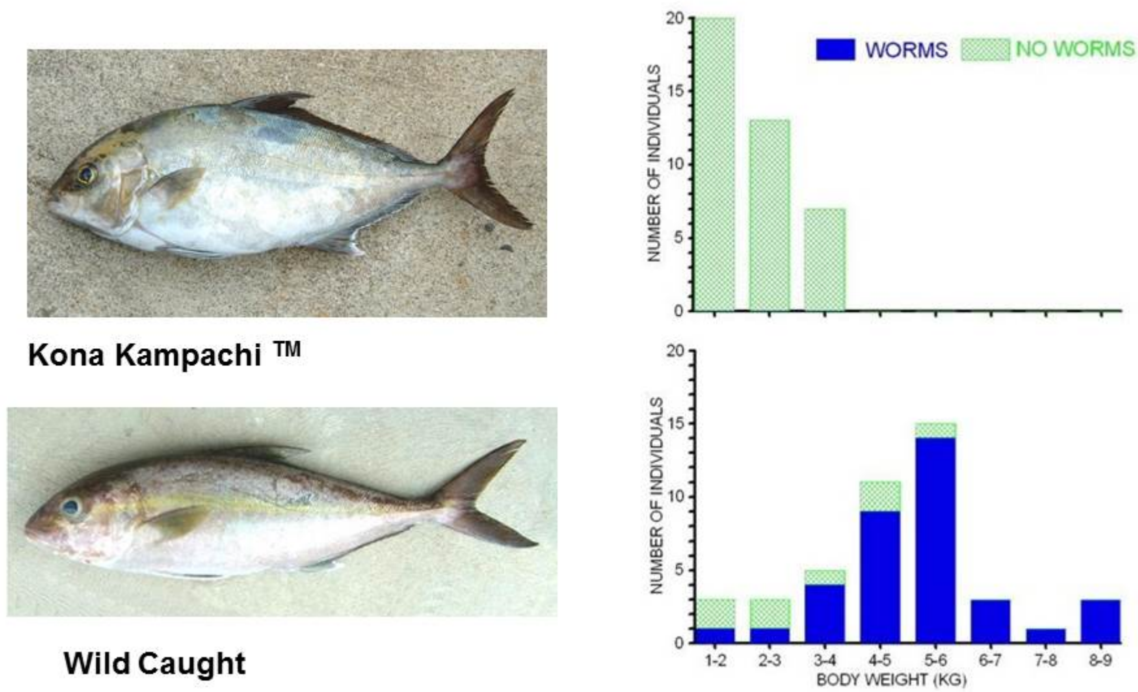

Figure 4. Size frequency distribution of Hawaii cultured and wild caught S. rivoliana infected with trypanorynch plerocerci.

Food safety and nutrition in agriculture, including aquaculture, has become a very important topic in the news and among public and political and scientific circles (Tacon, 2004). As global distribution of aquaculture products increases, quality and safety issues will become even more important. Although the larval tapeworm that infects wild *kāhala* is not a human health hazard, it still significantly depreciates the value of the *kāhala*. From the information obtained during the current investigation it would appear that the technology for the artificial propagation of the *kāhala*, particularly the species *S. rivoliana*, has eliminated this particular larval tapeworm in the farmed product by breaking its exposure to intermediate hosts during its life cycle. Given that much of the market for the farmed *kāhala* is targeted for the fresh sashimi market, these results should be welcome news to producers and also boost consumer confidence for this newly farmed product.

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