AQUACULTURE AND FISHERIES
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THE BANGGAI CARDINALFISH: A 10 YEAR UPDATE

THE AQUARIUM HOBBY'S NEW POSTER CHILD FOR AN ENDANGERED SPECIES

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PHOTOS. BY A. VAGELLI AND A. CALFO

It has been more than 10 years since I first wrote about keeping and breeding the Banggai Cardinal… the beautiful black and silver striped fish found exclusively in the Banggai archipelago. Since then, a lot has happened. In 1995, when Dr. Gerald Allen reported at MACNA (the annual Marine Aquarium Conference of North America) that he rediscovered this unique *Pterapogon* off of a pier in Banggai, little did he know he would unleash the aquarium hobby on this unsuspecting fish. He also did not realize that the aquarium hobby would find this species so fascinating that it would make the fish a "must have" item for many aquarists. With that interest came a huge surge in wild harvesting. A mounting body of evidence from the international scientific community has indicated that the natural populations of this species are under considerable threat with further implications that the aquarium hobby is ultimately responsible for pushing this fish towards extinction. It is no wonder that the aquarium industry has attracted controversy over the sustainability of the fishes it collects.

Yet, a great positive can be gleaned from all of this interest and consumption. We now have a tremendous understanding of this fish's natural habitat, husbandry, and ecological situation. We have also discovered that Banggai cardinals are nearly the reproductive equivalent of freshwater guppies (*Poecilia reticulata*). Most home aquarists are easily successful in their captive breeding efforts with this cardinalfish species. I thought an article that summarized much of what we have learned about the Banggai cardinal (BC) would be fitting on this anniversary. We present to you an outline - a decade later - detailing husbandry and breeding techniques for the BC. We also provide some background and updates on what has and what *is* happening on the conservation and ecological status of the species. Most importantly, we discuss what you can do to help protect, if not produce, this fish.

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Distribution

The Banggai cardinalfish, *Pterapogon kauderni* (Koumans 1933), is a marine species with a very restricted geographic range. BCs appear to be limited to the shallows of approximately 32 islands within the Banggai Archipelago, and in a confined site off of mainland Sulawesi, Indonesia. Two introduced populations exist outside of the archipelago: one in the Lembeh straits, and the other in Secret Bay (Bali). This fish is found in a variety of habitats throughout the islands, including sea grass beds and coral reefs. It is also commonly seen in protected bays. The species' geographic range is approximately 5,500 km^2. However, taking into account its habitat preferences, BC's potential maximum available habitat comprises only about 300 km of coastline where they are associated with a variety of living substrates such as sea urchins, some corals, and anemones. Specific aspects of the reproductive life history of this fish, such as unusually low fecundity (maximum spawn size about 60 eggs), lack of a pelagic larval phase, and a strong site attachment are thought to be the primary reasons for the BC's extremely limited geographic range.

Since its rediscovery by Allen in 1994, *P. kauderni* has become incredibly popular with the aquarium hobby community and, as a result, has been heavily collected from the wild. This species is of no interest to either food fishing or other industries; it is collected solely for the aquarium trade. Starting with surveys in 2002, data showed wild collections of BCs at approximately 200,000-400,000 fish per year (Vagelli & Erdmann 2002). By 2004, a staggering 600,000-700,000 individuals were being collected. A recent census in 2007 indicated that over 1 million fish are now being collected annually [*Ed. note* – these are the numbers of fish collected *before* export before any mortality has been reckoned through the chain of custody to consumer nations… a sobering reality]. Because of the heavy and unregulated trade of this species, Banggai cardinalfish populations are threatened in the wild.

What is CITES?

CITES (**www.cites.org**) is short for the "Convention on International Trade in Endangered Species of Wild Fauna and Flora." It is an international agreement between governments and its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Species of animals placed into CITES are put onto one of 3 lists (known as appendices) depending on the threat of trade to their survival, either currently or in the future.

CITES appendices are divided into: Appendix I, Appendix II and Appendix III. These appendices list species that are protected by international treaties and the degree of their protection. The scale goes from complete abolishment of trade (Appendix I) to regulated trade (Appendix III).

Appendix I species are banned from international trade. There can be no commercial trade in these listed species. Limited non-commercial trade is allowed for scientific and research purposes, for display in zoos, and for import for licensed breeding programs.

Appendix II species are permitted in international trade, but said trade is controlled by a strict system of permits and quotas. In general, the exporting country of origin has to define a yearly quota system based on scientific studies of their exported species' status in the wild and sustainable harvests.

Appendix III species have regulations that are similar to Appendix II species. A main difference is that Appendix III species are not globally threatened, but are listed by participating countries and require monitoring.

Captive Bred/Propagated Specimens: any listed species that is captive bred is still subject to CITES regulations with the following difference: captive bred specimens of Appendix I species originating from an approved CITES breeding facility are treated as CITES II (commercial trade is allowed). Captive bred specimens of Appendix II species are usually exempt from quotas, but this will generally depend on the decision of the source country.

New data from Vagelli (personal communication) also estimates that more than half of all BCs collected die or are discarded due to injury or damage before they reach their final destination. Regarding the total population, from eight censuses taken from 2001 to present, an approximation of the current status for the species remains around 2 million individuals (0.033-0.69 individual fish/m^2). Within a number of island sites, populations unsurprisingly declined from containing some BC (0.07 fish/m^2) to now *zero*, suggesting a few local regions may be entirely fished out. Thus, the combined characteristics of limited BC reproductive strategy and localized distribution, coupled with a high demand by the marine ornamental industry, have led to a dire conservation situation for this species, so few years after its rediscovery. Experts have predicted that if collection pressures continue unabated, the BC could become extinct within a decade.

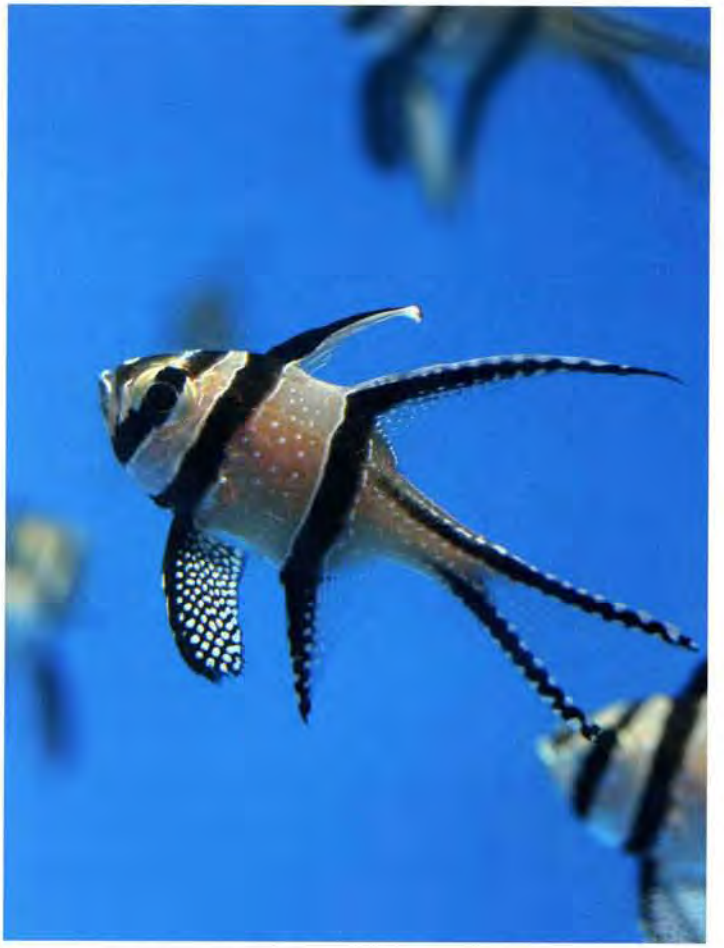
above: baby Banggai cardinalfishes seek protection among the tentacles of certain corals and some anemones. Heliofungia *is a favored host coral.*

Conservation

In 2001, Gerald Allen made an impassioned plea for the international community to protect the Banggai cardinalfish. His initial report suggested that overharvesting of the BC population was unsustainable and that CITES protection would be required to protect its long term future. However, without sufficient field surveys to support his claims, the CITES proposal was never initiated. In 2006, after completing an eighth census and field survey of the Banggai archipelago, Dr. Vagelli felt that the data was complete and most importantly compelling enough for the United States to sponsor the proposal for the Banggai cardinalfish to have CITES II protection. This sponsorship was unique because in most cases the county to which the species is native is usually the one that submits the CITES proposal. However, the United States is the largest consumer of the BC by far and, during many trips to the Banggai archipelago, Dr. Vagelli felt he had the support of Indonesian country members that a US proposal would not be overturned. So, paperwork for CITES II protection was filed and a meeting date was set. During the ensuing months, Dr. Vagelli met with and talked to Indonesian CITES members (March 2007) and other scientific members who felt that he needed strong support from the Indonesian government to ensure the proposal's success. Additionally, Dr. Vagelli also helped to establish a marine sanctuary in Bangkulu, where collecting of Banggai cardinals would be banned and enforced. However, in June 2007 at the Convention of the Parties (CoP) at the Hague (Netherlands), rumblings suggested that opposition from many governments would try to minimize and negate Vagelli's data and block the CITES proposal. To some extent, that is what ultimately happened. Below is an excerpt from the FAO panel:

Banggai cardinalfish: The US introduced its proposal (CoP14 Prop.19) to list Banggai cardinalfish (Pterapogon kauderni) on Appendix II, noting that it is a major importer of this endemic Indonesian species. Vagelli highlighted recent data showing further population decline and unsustainability of current harvest levels (CoP14 Inf.37). Opposing the proposal, INDONESIA underscored: high productivity of the species both in the wild and in captivity; ongoing conservation efforts; and implications of the proposed listing for local livelihoods. Supported by IRAN, he also expressed concern over the legality of recent research. Many others also opposed, with AUSTRALIA stressing national management measures for endemic species, JAPAN saying an Appendix-III listing would be more appropriate, and THAILAND citing the FAO Expert Panel's opposition to the listing. Following these comments, the US withdrew its proposal.

"Experts have predicted that if collection pressures continue unabated, this species could become extinct within the next decade."



above: a healthy adult female Banngai in a species-specific aquaruim

So, in late June 2007, the United States felt it best to withdraw its CITES II proposal for the Banggai cardinalfish, as it met unmanageable opposition from a number of opposing governments. Unfortunately, there is a lot more back story involved here and I would recommend reading the FAO recommendations on the Internet:

ftp://ftp.fao.org/docrep/fao/010/a1143e/a1143e.zip

and the response by Vagelli found here:

http://www.marinebreeder.org/phpbb/viewtopic.php?t=268

Those who wish to know the opposing view about the FAO assessment should go to the CITES website: http://www.cites.org/eng/cop/14/inf/index.shtml and scroll down to # 37 where you will find the rebuttal to the FAO review, entitled, "*Additional Information on biological and trade criteria in support of an Appendix II listing for the Banggai Cardinalfish,* Pterapogon kauderni *(submitted by the United States of America).*" In addition, the CITES secretary recommended the acceptance of the proposal, despite acknowledging FAO's negative review. See:

http://www.cites.org/eng/cop/14/doc/index.shtml
(open Item # 68, then read proposal #19)

above and below: When defining a species, a single fish is preserved as the "typical" of that species, to which other specimens can be compared. This primary, or "name-bearing," specimen - selected by the original author of a name of a species or subspecies - is called th ***holotype*** *for the species. When more than one specimen is collected for this purpose, the specimens are called* **syntypes** *(see images)*

To quote Vagelli,

"At the CoP 14, the science and conservation status was disregarded, and the reasons for opposing to protect this species are rooted in political and economic interests. By ignoring the information provided in the proposal and additional documents, as well as the supporting position of the IUCN and many conservation organizations, CITES choose to give more value to the above economic figure than to the survival of an entire species endangered by the international trade, which is more appropriately what CITES should be focusing on.

This species is truly representative of the Banggai islands. It is found no place else in the world and is unique to a small number of suitable habitat patches within its range. The cultural impact of losing this species would go way beyond the loss of economic activity associated with it. In some ways, this fish defines the identity of the region and, as such, has a very high intrinsic value. In the end, a great opportunity to put in place a long term conservation project has been lost, and consequently the Banggai coral reef ecosystems, which are relentlessly degraded by dynamite and other destructive fishing methods, the Banggai cardinalfish, and the local people, are the big losers. The CITES II listing would have encouraged the development of local aquaculture activities and would have provided needed funding to develop and enforce a sustainable management plan, which would have assured not only the future of the species... but long term economic benefit for the local residents from this species. As it is now, the species is at extreme risk."

Thankfully, in September 2007, The IUCN (see below) instead declared the Banggai cardinalfish as an endangered species. This announcement was based on an objective evaluation of its conservation status, including census and survey data, as well as numerous field studies. Unfortunately, a proclamation of "endangered species" by the IUCN does not restrict international trade or collection.

The remainder of this article is an overview of what is known about BC husbandry and breeding. It has been distilled from the experiences of hobbyists and researchers alike. It is hoped that the information provided will be useful to others to inspire and improve captive production of the BC with the goal of relieving collection pressure on wild populations of the species, if not its very extinction.

What is the IUCN?

The IUCN List of Threatened Species (also known as the IUCN *Red List*, see: www.iucnredlist.org), was created in 1960's with the intent of providing the most comprehensive inventory of the conservation status of animal and plant species. Set forth by the International Union for the Conservation of Nature and Natural Resources, this Red List is considered the world's main authority on the conservation status of species. The IUCN Red List was created based upon precise criteria to evaluate the extinction risk of animal and plants species, and it is relevant to all species and all regions of the world. The IUCN's aim is to convey the urgency of conservation issues to the public and policy makers, as well as to help the international community try to reduce species extinction.

Classifications made by the IUCN are purely recommendations; they are neither wildlife law nor do they impact the trade of these classified species. Being placed on the IUCN Red List is not the same as having CITES protection.

Red listed species are classified in nine groups, measured against a number of criteria, such as rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation, as follows:

Extinct (EX)	Endangered (EN)	Least Concern (LC)
Extinct in the Wild (EW)	Vulnerable (VU)	Data Deficient (DD)
Critically Endangered (CR)	Near Threatened (NT)	

When discussing the IUCN Red List, the official term "threatened" is a grouping of three categories: Critically Endangered, Endangered, and Vulnerable.

Broodstock and General Husbandry

We should begin with how to do identify a healthy Banggai cardinal. I find that healthy specimens are very alert and responsive to outside movements. Their fins are most always kept erect, and the second dorsal fin seemingly waves at all waking moments. A healthy BC remains buoyant and level with minimum movement of the pectoral and anal fins, and appears to be hovering. The large eyes of this species should be clear and plump.

The body coloration should be densely black striped on a silver body, dappled with many white spots. A healthy BC also reacts quickly to food. Contrary to some BC kin, I have found that these fish are very active during the day and do not mind moderately bright aquarium light. Some, however, can be shy, and all are easily frightened. Provide adequate rockwork or other cover for them to hide behind. I find that my BCs do well in the home aquarium between 75-85°F (~ 24-29°C) and with a wide range of water flow conditions from mild to brisk.

A Conversation with Alejandro Vagelli

How bad off are the wild Banggai populations?

There is ample scientific evidence demonstrating that the Banggai cardinalfish is seriously imperiled, primarily due to over-collection for the international aquarium fish trade. No population has been near to what we consider its historical density of about 0.6 ind./ m^2 since we began our field studies, despite fluctuations in collecting efforts at particular sites. The current capture magnitude of at least 900.000 specimens/year is clearly not sustainable, as demonstrated by the severe decline of several populations (three already extinct) and the increased collecting effort of the fishers.

Destructive fishing techniques are destroying the habitat of this fish. Given its biological and ecological characteristics, *Pterapogon kauderni* is not capable of naturally recolonizing vacant habitats. Moreover, as its reef habitat is destroyed, there are fewer areas where sufficient living substrates remain for this species. Combined with its ease of collection and the unsustainable number of fish being collected monthly, the international trade in this species, if not regulated, will deplete many sub-populations and, given their genetic distinctiveness, entire genetic lines will be lost forever. In addition, my finding, during the last survey, of coral fields covered by a fungus-like organism and coral formations being covered by algae add yet another threat to the habitat availability for this species, already being diminished by the rampant dynamite fishing throughout the archipelago.

What do think is next for them in regards to conservation?

Unfortunately, to date, no conservation program involving *Pterapogon kauderni* is underway in the Banggai region. No aquaculture/captive breeding projects are in place... and not a single village in the Banggai Archipelago is considering implementing such a project. Also, MAC (the Marine Aquarium Council) in Indonesia informed me that no certification program is being contemplated for the Banggai cardinalfish. The inclusion of *Pterapogon kauderni* in the IUCN Red List as an "Endangered species" does not restrict international trade or collection, so the Banggai cardinalfish is still in a very precarious situation. The inclusion of *Pterapogon kauderni* under CITES will be the only practical way to ensure the much needed protection for both the Banggai cardinalfish and the ability of local people to sustainably harvest the species over the long term. The regulation of such trade will likely facilitate the restoration of *Pterapogon kauderni*, increase protection for its habitat, and lead to the development of comprehensive management plans for the species throughout the region. In addition, a CITES listing may provide opportunities to seek international funding to conduct additional studies of the species to expedite the implementation of management plans and to establish captive breeding operations.

Feeding

BCs are active hunters that will pursue food items, but they are not overly aggressive feeders. BCs will be out-competed by more aggressive fishes. Gut content analysis of wild caught BCs indicate that this species is a carnivorous planktivore, with the size of their prey items ranging from 0.1 mm (calanoid copepods) to 14 mm (megalop larvae and small fishes). From observations made in captivity, BCs are proficient hunters with juveniles and adults eagerly eating mysid shrimps, amphipods, small to medium sized crustaceans, and small fishes. Initially, I offered my BCs gut-loaded ghost shrimp (Palaemonids), and live brine shrimp (*Artemia*). With some persistence, BCs can be weaned onto prepared or non-living meaty foods of marine origin.

Longevity

Reports from the wild suggest that BCs have an average life span of only 2 years, primarily due to predation. However, in the home aquarium, adult males Banggai can easily live 3-5 years, with reproductive females exhausting after 2 to 3 years. In my experience, female BCs tended to be less hardy, as most of mine have only survived about 2 years. But, I have never kept a female alone and therefore may have shortened their lifespan due to the biological rigors of frequent breeding.

Sex Differences

Back in 1996, I suggested a method to sex Banggai cardinals based on structural jaw line differences observed in my breeding pairs. I thought males had more V-like jaw lines, whereas females were more rounded. While a recent Banggai culture manual (Hopkins 2005) and fish breeding book (Wittenrich 2007) have also referenced the jaw line distinction, it appears that it may not be totally correct. A morphometric analysis of both sexes, however, has revealed that there are *no outward sexual differences* (sexual dimorphism). As such, jaw line anomalies do not appear to be a reliable method to distinguish the sexes. Since then, I have heard or read many anecdotal methods to sex these fish, from longer banner fins (2nd dorsal), number of scales between eyes to operculum, genital papilla counts, thickness of the base of the 2nd dorsal shaft, and more. In all cases, these methods have not withstood rigorous testing. However, once your male is brooding, or if your female is extremely gravid or displaying to a male, then one can easily identify the sex of fish based on such benchmarks.

below: Banngai cardinals will live well in groups, but breeding success is significantly increased by keeping only one adult pair per enclosure

Forming Breeding Pairs

It is possible to match breeding pairs without knowing the sexes of the fish. While it is not known whether pair bonds are permanent in the wild, it appears that in captivity, pair forming is transient with promiscuous females that will mate with several different males (Marini 1996, Vagelli 1999). Nonetheless, finding compatible mates takes time and careful attention. Several approaches have been tried with varying degrees of success, as described below.

Method 1. A group of sub-adults (3 to 5 individuals) can be placed together in a communal tank where they develop pair bonds as they mature. Once pairs are formed and move away from the group, the "outsider" fish should be removed before injury can occur from territorial breeders. It is important to note that any BC seen with dark coloration and/or cowering in a corner must be removed immediately or it will likely die soon.

Method 2. Place a fish of unknown sex with a known sexed fish. Back in 1995, I had a male specimen who was unquestionably sexed correctly and was used as an aide to sex other BCs. When a new Banggai was placed in his tank, he did one of two things: 1) try to beat the snot of out him (new fish = male), or 2) mate with it (new fish = female). This technique often requires a bit of time. Initially, the established known sexed fish may display and present to either sex, but within 30 minutes the displays are over and the fighting or mating starts. What I found useful in such cases was a small breeding net (like those used for freshwater live-bearing fishes) serving as a barrier between the specimens. With the new specimen resting protected in the submerged net, the established fish can view the new BC and respond.

Method 3. Place two unknown BCs in a small quarantine tank and allow them to interact. While I think this may be the least sensible approach, you will discover within an hour if they are compatible. An adult male and female BC will determine pretty quickly whether or not they like each other. Initially, they interact normally, only to suddenly have one fish rush the other or fin nip. If you observe one fish darting towards the other with a coincident retreating by the other fish, they are unlikely to be compatible and you must remove the withdrawing fish. With incompatible pairs, the dominant fish (frequently the larger or more established of the two specimens) will maintain normal coloration and move freely about the tank while the other fish will maintain a stressed dark coloration and soon begin to hide or cower. This occurs even without obvious displays of aggression. Again, the "odd man out" must be removed for its safety and survival. BCs will harass others of their kind to death.

Method 4. Select two specimens from a merchant that has a tank full of like-sized BCs. Purchase the two that are "hanging out" together, frequently away from the other fish

*** My personal recommendation for seeking pairs or broodstock** is to obtain many young (small) BCs and allow them to pair up as they mature in quiet species tanks. Frequently, multiple pairs of BC can be obtained this way.

Sexual Maturity

A report from Vagelli suggests that young BCs, as small as 70mm (~3.5 in./5-6 months old), contain mature oocytes and are capable of reproducing. In the home aquarium, sexual maturity appears, however, to take slightly longer. Most aquarists report BCs spawning at 6-8 months of age, though a few have reported shorter times, especially in males (carrying eggs at just 4 months of age). Sexual maturity, nonetheless, can be delayed to 7-9 months if larger and more mature BCs are present in the same aquarium. Therefore, keeping BC pairs separate from others will ensure the fastest reproductive maturation.

Tank Size: Broodstock can be housed in a variety of tank sizes with various success. In general, 10 g (~ 40 l) is the minimum aquarium size recommended, but use at least a 20 gallon aquarium (~ 80 l) for each breeding pair. Some aquarium hobbyists prefer to farm BCs in larger colonies. I have found that works well too, such as a 55 g (~ 200 l) long tank with opaque partitions for separating pairs. In 1996, I used a 45 gal long tank divided into 3 partitions. More recently I have used 55 gal tanks divided into 4 partitions and a 29 gal divided into two partitions as my smallest brood tanks. You will definitely want partitions to be opaque, as see-thru barriers such as egg crate do not prevent territorial disputes and stress. Male BCs will spend their entire day preoccupied with neighbors invading their territory. In multi-partitioned tanks, please also be sure to ensure adequate oxygenation (airstones or small powerheads per section) and good water flow for better water quality.

Mating and Egg Transfer

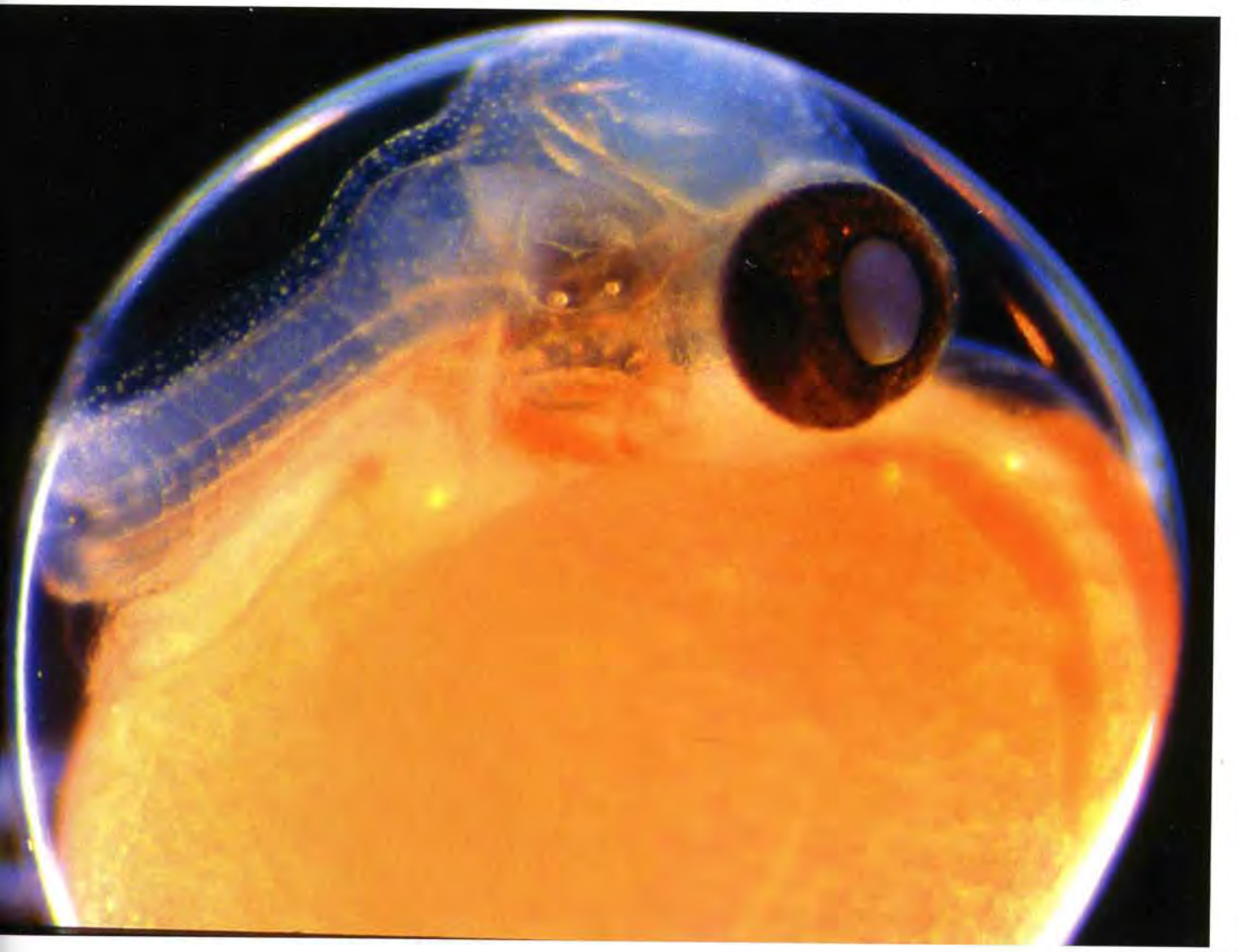
The female initiates the mating dance between BCs, after which time both fish participate in the courtship display. The BC mating dance is composed of the following behaviors: non-injurious fin nipping, side-to-side twitching, and front-to-back swimming. This display can go on for minutes to hours, but it will build in intensity in time. The actual mating occurs when the trembling dance gets frantic and the pair drops to the bottom of the tank.

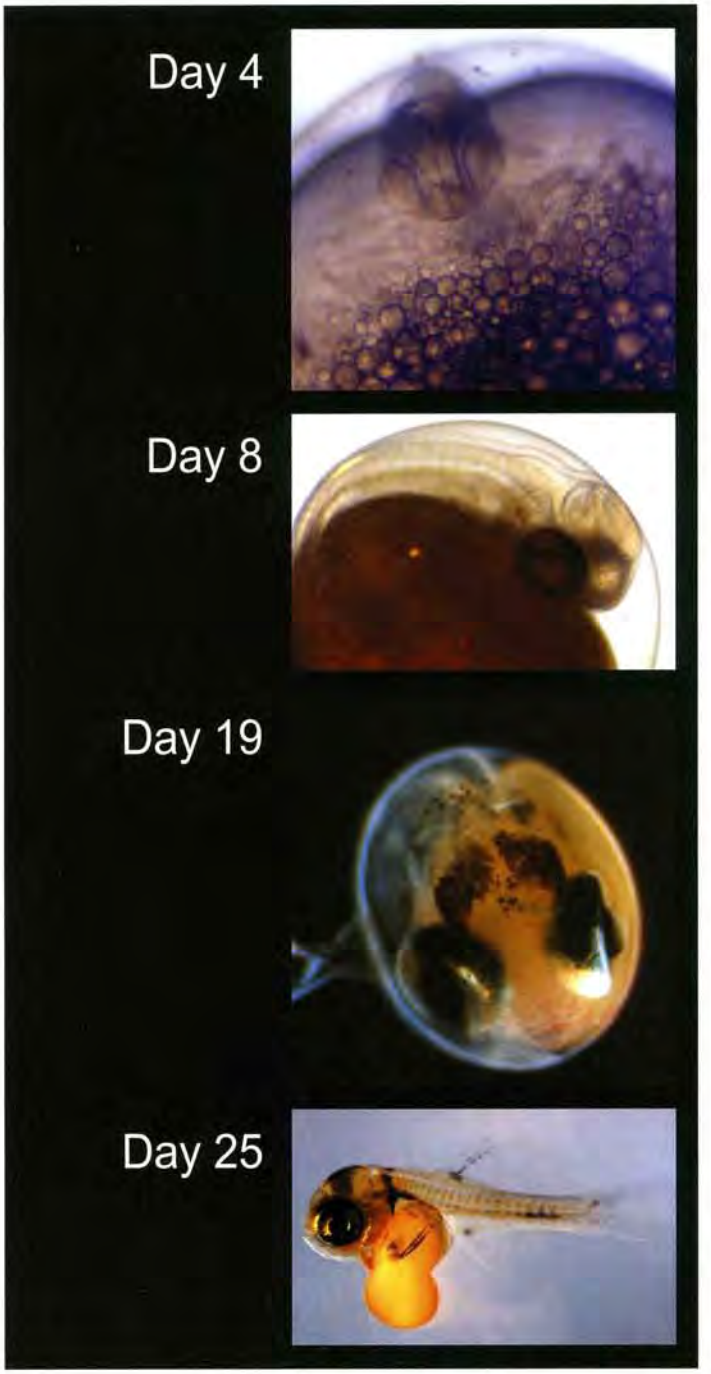
Data from Vagelli suggest that the egg transfer typically occurs in wild BC between noon and 3:00 PM (most commonly at noon). My aquarium specimens, however, would perform their mating dance late in the afternoon and into the evening. I normally find brooding males the next morning.

Regardless of time of day, the mating event is extremely brief. It starts with the female beginning to expel the egg clutch. Once the eggs are exposed at the female's vent, the male quickly fertilizes them and then turns rapidly around and gulps them into his mouth. Seen in a video recording, the transfer occurs in less than 1 second. Unless you are looking at that precise moment, you will not observe egg transfer. The size of the egg mass varies with the individual eggs' size(s), but a 40-egg cluster has been removed from a brooding male. The BC egg clusters also have a strong fibrous attachment matrix (Vagelli, 1999; Vagelli and Volpedo, 2004). This keeps the egg mass intact so that the cluster can be tumbled and stimulated inside the brooder's mouth without dislodging any eggs.

above: the spawn size of Banngai cardinals is significantly smaller than that of other marine fishes, decreasing their ability to rebound from overfishing

below: a Banggai embryo at the ninth day of development. Note the large yolk sac and developing eye and spine at the top of the image





A few additional relevant observations have occurred through the years. I have received reports of female BC grabbing their own eggs and holding them in their mouths for a few days if no male was present. Also, I have watched a video of two BCs transferring eggs with the female BC dropping the egg mass directly to the bottom of the tank (the male did not take them from her vent), only to turn around and scoop them up. I suspect these are most likely captive phenomena, as it has not been reported in the wild. Or, it may just be young or inexperienced breeding behavior. An interesting aside, it seems that in the wild, BC reproduce in synchronization with the lunar cycle, with most spawns occurring during the full moon (Vagelli 2002).

Spawn Size

The size and age of a female BC has the greatest influence on spawn size. Assuming that nutrition and health is optimal, larger females on average will simply produce larger eggs and more of them. However, what really determines the overall size of the *successful* brood (living fry) is the volume of the male's oral cavity. Larger mouthed males can accommodate more eggs. In fact, a report suggests that female seek out larger mouthed males in their attempts to produce larger spawns. However, if you have juvenile males, or small-mouthed males that can't accommodate all the eggs, you will frequently notice stranded eggs on the bottom of the aquarium. Or, you may see females with untaken eggs hanging from their genital papilla. Regardless of what size the male or his mouth is, some eggs will be lost during egg transfer. These factors contribute to the low fertility of this species

Incubation of Eggs

In 1997, I wrote that the average incubation time for BC eggs, sampled from over 24 broodings, was approximately 21 days. Today we have a much better understanding of what is going on inside the mouth of a male BC.

Essentially, during days 1-13, the eggs appear to develop slowly, with eyes and tails appearing around days 10-13. From days 13-18, development occurs more quickly. By day 18-19, fully formed baby Banggais (I have coined the term "banggers" to describe the BC fry) are apparent with yolk sacs. They remain in the mouth of the male for another 8-10 days while they grow and develop more in safety. What is most important to note here is: 1) brooding male Banggai cardinalfish are not much more than living incubators to provide shelter for the eggs (suggesting that the eggs can be removed as early as day 1 and the fry will develop completely), and 2) the direct development from egg to free-embryo (called an eleutheroembryo) frees up any concern for the need of microscopic foods. **There is no planktonic larval stage for this species.** Also, if the BC eggs are kept at a higher temperature (79-82°F/26-28°C), embryonic development will occur faster *[Note:* the water temperature in the Banggai Archipelago can reach 86°F/30°C]. In the wild, there doesn't appear to be a preferred time of day for fry release. One report suggests the it occurring in early morning hours (before sunrise). However, in the home aquarium, males tend to release a few fry at first, as if they are testing the waters, then release the remaining fry in small spurts over a period of days. Some hobbyists have also reported their males releasing all fry soon after the aquarium lights turn off.

Egg Stripping

This technique has been suggested for increasing the number of successfully reared fry and to avoid the male BC's need to hold eggs while fasting for 21 days. Since male Banggai cardinals are most only serving as living incubators after fertilizing spawn, egg stripping is a largely beneficial method for rearing BC fry. Briefly stated, brooding males can be netted, have their mouth gently pried open and robbed of the eggs. A stripped cluster can be placed into an egg tumbler such as those DIY and commercial units used for African cichlids, and provided warm, well-oxygenated moving water to keep the eggs in suspension as they would be in a brooding parent's mouth. You can watch the development of fry *ex vivo,* and the male BC can return sooner to the broodstock tank to resume eating and breeding again.

Prematurely Aborted Spawns

It was initially reported that male BC will, from time to time, spit out or swallow eggs, or even release premature offspring. I postulated that there is a relationship between failure to hold offspring full term to whether or not a brooding male has had sufficient time to regain his strength and nutrition between the release of juveniles and the next spawning event. What I found that works particularly well is if the male BC is fed heavily and/or physically separated from the female for longer periods between spawning events. With conditioning, a male BC is more likely to carry the next spawn to full term. However, juvenile BC males will frequently abort their first brood or first few broods regardless of conditioning, until they better hone their brooding instincts. But once BCs pair up and initiate breeding, they often continue to mate every 21-28 days.

Banggai Fry

Upon release, BC fry are approximately 8 mm in length with most of their yolk consumed (and typically in a sex ratio of 1: 1). Immediately after release, the fry seek protective shelter. In the wild, they prefer safety among the long spines of *Diadema* sea urchins. Aquarists can use surrogate artificial sea urchins in aquaria to attract the offspring and protect them from predation by larger fishes. Alternatively, seaweed-like plastic plants can be placed throughout the fry tanks. As reported in my original Breeders Registry article, I fed the baby BCs with Selcon-enriched brine shrimp nauplii (*Artemia*). This is still one of the best and easiest food sources for new baby cardinalfishes. I believe that it is critical to use HUFA enriched foods to prevent sudden fright syndrome (sidebar on next page). After my observations and proposal on this issue, a scientific study validating the requirement for HUFA in BC fry was completed (Vagelli 2004). Additionally, I recommend coating or feeding *Artemia* nauplii with other vitamins, minerals and lipid complexes, such as Aquafarms *Rotirich* food and Boyd's *Vita-chem*.

Baby BCs should be fed a minimum of five times daily, as much as they can eat in a few minutes. Be sure to siphon out any uneaten food immediately afterwards. Through the years, I have identified other food sources that appear useful, but I have never fully replaced freshly hatched *Artemia* nauplii. The nutritional value of *Artemia* plummets soon after hatching without enrichment. Fish and prawn roe, as well as Argent *Cyclop-eeze*, seems to work well, as some BC fry will strike at non-living items. However these fail to serve as first food items. Only after about ten days of *Artemia* can you begin to mix in other zooplankton substitutes. Increase the ratio of prepared to live food over a period of weeks until the fry are weaned over.

below: fry will seek protection in a variety of corals or anemones if the preferred Diadema *sea urchin is not available*

Once the 'banggers' are feeding wholly on prepared foods, they begin to grow quickly! A 30-day-old Banggai cardinalfish should be approx 1 in./25 mm. By two months of age, juvenile BCs should be about 2 in./50 mm. And after four months, the young fish should have reached adult size at 3-3.5 in./75-88 mm.

* It must be emphasized that BC fry growth rates are largely influenced by food quality and water temperature.

Growout Systems

Both Vagelli and I have used small aquaria (5-10 g/~20-40 l) successfully to grow out BC fry for the first month after release. It is, in fact, important to use smaller aquaria to concentrate feeding opportunities with shy newborns. My fry were fed enriched *Artemia* every few hours, but a recent culture manual has suggested a less-intensive approach to rearing banggers by utilizing pond culture techniques.

Sudden Fright Syndrome

Frequently I'll read or hear breeders report their fry experiencing a "fainting or heartattack-like syndrome." When the Banggai fry receive sudden stimuli, such as turning lights or quickly adding large volumes of food to the grow out tank, they may "freeze" in motion and start drifting motionless to the bottom of the tank. This phenomenon is called Sudden Fright Syndrome (SFS). What actually happens is the stimuli essentially short-circuit (shock) the nervous system and the fish becomes paralyzed. Depending on the severity and frequency of the event(s), it can be lethal. SFS susceptibility is the result of a nutritional insufficiency during development: primarily a lack of highly unsaturated fatty acids during the development of the fry.

All animals require certain polyunsaturated fatty acids in their diet. Two essential fatty acids were noted as critical during Banggaii development: Omega-3 and Omega-6 fatty acids. They are key components of cellular membranes and they are critical in the development of nervous system tissues, such as brains and eyes, as well as heart and the innervations to the heart. Omega-6 fatty acids principally originate from animal sources (such as animal fats), while Omega-3 fatty acids are derived from plants. Notably, Omega-3 fatty acids tend to be lacking in the diet of reef aquarium fishes, since plant based foods are rarely fed. Therefore, since fatty acids are not converted from one type to the other, a proper balance of both classes of fatty acids is important to health and proper development. Important to a fish breeder are the two Omega-3 HUFAs; are DHA (docosahaxaenoic acid: 22:6 n-3) and EPA (eicosapentaenoic acid: 20:5n-3), which are synthesized almost exclusively by marine algae, such as phytoplanktons.

While newly hatched baby brine shrimps (BBS) are the mainstay of first foods, they lack sufficient quantities of EPA & DHA, and most marine fish fed exclusively on baby brine can begin to die soon, due to a lack of HUFAs. The good news is that this situation and a resulting SFS is readily corrected through enrichment of BBS using phytoplanktons (alive or pastes) or, if your using dead or prepared foods, then the use of a liquid HUFA supplement, such as Selco, Selcon, Zoecon, and the like. Feeding the BBS with nutritious phytoplankton overnight, or hours before using them for food, is sufficient. After a week feeding enriched BBS, the fry shouldn't experience SFS.

Common features of HUFA deficiency are:
1) Sudden fright syndrome: shock, convulsion, or death when the animals are frightened
2) High mortality and disease rates, particularly when stressed
3) Worn or eroding fins
4) Poor growth rates
5) Poor vision and reduced ability to locate prey
6) Sudden massive die offs during early development
7) Low egg viability or infertility in adults
8) Inability to heal after being wounded

In this method, a small group of BC fry were released into a small seawater pond, measuring about 130 square ft (12 m^2) with a 3,500 g (~13,000 l) capacity. The pond was well-established with flora and fauna and had no pump intakes or overflows (to protect and promote zooplankton production). According to the authors, 100% of the offspring survived and grew to an appropriate market size in 125 days by eating natural plankton. *[Ed. note:* Anthony Calfo had the same experience in his first coral farming greenhouse in the latter 1990's – his Banggai cardinals spawned, were born and reared unassisted by human hand in otherwise fishless, coral culturing pools]. The key to success using this arrangement was the low fish density and high (microcrustacean) infauna populations. Additionally, this group tested floating mesh cages that were placed in the saltwater pond; these cages were approximately 35 liters (~ 9 g) in size and afforded uncomplicated fish management, feeding, and harvest collection. Adult BCs were fed saltwater-adapted guppies (*Poecilia reticulata*) that were gut-loaded with marine foods rich in HUFAs.

Banggai Genetics

I am frequently asked questions by hobbyists with concerns about inbreeding aquarium BCs. In response, I have to say that I presently do not know the long term consequences of inbreeding this fish. In most species, it is usually bad to continue inbreeding without periodic out-crossing (preferably from a wild source). In the wild, BCs appear to have one of the most diverse population structures (genetic differentiation) among studied marine fishes. Interestingly, populations living along the same island, inhabiting different reefs separated by only a few kilometers, appear genetically distinct enough to be considered different populations with *no significant migrations* of individuals between groups, despite the close proximity. What is especially fascinating is that mitochondrial DNA analysis (samples from 14 islands) demonstrated that specimens were grouped in two well-separated clades (founder populations). One founder population consisted of fish collected at the three southeastern-most sites, from the island of Bangkulu. The other clade included samples collected from the northern site on Bangkulu. A unique genetic haplotype was uncovered in Luwuk Bay, suggesting a separate population. Additionally, the population of BCs collected from Lembeh straits had similar genetics to those BC found off of Banggai Island, clearly demonstrating it was a collected BC population that was released into Lembeh. This means that while BCs may come from only a few founder populations, they have many diverse subgroups. These populations can mix during collection/ holding/transport, but naturally tend to be site-specific as most offspring remain local and mate in close proximity to their parents.

Diseases

In general, Banggai cardinalfish are a hardy, disease resistant fish, aside from the occasional outbreak of common "white spot" type parasites and fungal infections of the lip. However, recent shipments of BCs coming into the hobby trade have had significant to sometimes-dismal rates of mortality. Frequently, the imports are not feeding well or just "up and die" for no apparent reason. In recent conversations with Dr. Vagelli, he stated that he had not seen any signs of disease, virus outbreaks, nor even external parasites in wild BC populations. Having dissected several hundred BC specimens in the lab to complete studies on their feeding habits, reproductive ecology, and population structure, he did not find sick specimens. However, as has occurred with many hobbyists, his recently purchased BCs seemed to die for no reason.

With this mystery affliction occurring soon after acclimation, new BCs first become reluctant to eat, appear distressed (dark coloration), and/or remain hidden or motionless. Then, after just a few days, the fish are simply dead. Dr. Vagelli sent specimens to a pathology lab and the diagnosis was a potential viral infection suspected because of pathology of the liver, spleen and ovaries including poor coloration, inflammation and conspicuous hemorrhages. Unfortunately, the virus is unidentified. Therefore, it appears that BC in the wild are healthy, yet, BCs after collection/holding/transport appear sickly. It would be interesting to determine where the infections occurred, be it at the export centers or the major import wholesalers, since many hobbyists across multiple nations have reported problems. This clearly rules out local pet stores and not surprisingly implicates the early side chain of custody.

I'd like to end this article with a discussion of the potential economics of BC breeding, as this concept may be germane to many potential fish breeders.

Pricing

When Banggai cardinalfish were first introduced to the aquarium trade in 1995, retail prices were at or above 100 USD per fish. Hobbyists and breeders since have suggested that wild caught BCs captured in 1996-2000 were of better quality and health than what has been obtained in the past 4 years, which appear considerably weaker and more sickly on import. Despite warnings about overcollection and declining populations, wild caught BC prices have *declined* steadily since 2000. Currently, the retail price for Banggai cardinalfish is approximately 15-25 USD per each wild caught fish and only approximately 25-35 USD for each captive bred fish. I have recently seen wholesale prices for wild BCs hovering around 5-8 USD each.

If aquarium hobbyists understood the immense advantages in the health and survival of captive bred BCs over wild harvested specimens, the price differences would be a negligible buying factor influence. Sadly, many hobbyists are still purchasing imports while complaining about the cost of captive raised specimens, despite suffering continued mortality in their wild-caught specimens!

The simple reality, however, is that successful, profitable, and easily accomplished domestic reproduction of BCs is within the grasp of small and large scale enterprises. Self-sustained trade of captive bred BCs is a realistic possibility!

Once established, this species requires little space per fish, has a fast cycle of harvest, and incurs minimal operational expenses to produce. The optimal time to market captive bred BCs is between 3 and 4 months of age, when juvenile male BCs have not reached sexual maturity. Once males reach sexual maturity, these fish will fight and cannot be kept in communal holding tanks. But coin-sized specimens (~ 2 in./5 cm) still live together well and they are capable of withstanding the rigors of shipping and transport. They also adapt readily to other fishes in community aquaria.

The average home aquarist, conservation minded or otherwise, can easily make more than a few tens of dollars per month breeding Banggai cardinalfish. It is not without some challenges, of course. If one considers, by comparison, that a single breeding pair of clownfish (*Amphiprion* species) will produce approximately 200 fry per spawn and that Banggai cardinalfish only produce approximately 25 fry, one would need 8 times more broodstock of Banggai to equal clownfish production potential. It is a fair comparison too when clownfish species require similar space per adult as BCs, and the market pricing is similar for both too.

Also keep in mind that each BC pair will require a separate broodstock tank and each batch of fry likely will too. These expenses (the hardware and extra systems' maintenance) need to be factored in when determining the final selling price. A few commercial firms have already limited the sales of male BCs to increasing their production potential. Hopefully, with the new Endangered Species tag associated with Banggai cardinalfish and the understanding that the hobby is truly responsible for the declining population of the species, we – the aquarium hobbyists – will be proactive and demand only captive raised specimens, thereby eliminating the collection pressure on this beautiful little fish.

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