A GUIDE TO KEEPING KILLIFISH

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Contents

Chapter 1

Forward

Why have I written this book?

This book developed in the time between handing in my M.Sc. thesis, and receiving it back for revision. I was in a writing mood, and taking a former English teacher's advice, I wrote about something I knew—which just so happens to be something about killifish.

I still consider myself a beginner in the killifish hobby, and have a lot of correspondence with other beginners. There is a vast store of knowledge concerning the keeping and breeding of killifish that is scattered over numerous websites, books and articles. Seemingly, an even greater store of knowledge is reserved as experience and recollection, and passed down mainly by word of mouth (or email). Spending a lot of time waiting for the lab centrifuge to stop spinning, allowed me lots of time to search out many of these scattered bits of information.

So it was, that I decided to try and bring all this information together, into one volume, that could serve as a comprehensive guide to starting in the killifish hobby. My many correspondences with other beginners and experts, had the advantage of filling my mind with the important questions that beginners need answered. So, armed with the questions and answers, I decided I would not only bring together all the various lore and ritual, but also discuss the reasoning and logic.

Since, I began work on this book, I have revised it innumerable times, particularly after giving the manuscript to others for evaluation. I made many modifications to various parts, and added various factoids and hypotheses. I suspect this book will never be complete, as each year some new discoveries are made, many old discoveries rediscovered, and some old ideas shown to be wholly false. The marvelous variability in behavior and physiology that exists in all living organisms, gives rise to the realization that there are many ways to arrive at the same end. More disturbing, is that the means often employed in one instance, will not yield the desired result—even if for all pretense and purposes, the instances are identical. This makes any store of knowledge about any group of living organisms impossible to incomplete. It is perhaps, this that makes the keeping of live animals so exciting a past time.

Many a killifish “expert” has struggled with a particular fish, only to have a total novice have unbridled success with that same fish. In most cases, the reason for this success is totally unknown. Was it just pot-luck with the genetics? Was it the way the fish was raised? Did he or she add a little something to the water? Many of these mysteries remain mysteries as very few hobbyists keep detailed records. For this reason alone, fishkeeping in general, cannot be called a science.

Science is doubting what man-supplied knowledge has come before you. In doubting, you must devise a test else you cannot rely on what you think you know. But if you have not kept records, by which you can generate an hypothesis, what do you really know? And if you do not know anything, there is nothing to test and hence no science. While many of the ideas in this book draw on scientifically tested or derived theories and observation, these ideas are hardly scientific. They only become scientific if you, the hobbyist, tests them.

As you read this book I would like for you to undertake to do two things. Firstly, take nothing in this book as certain; do not believe any theories as fact. There is no guarantee any of it will work for you. You have to take what knowledge is here, and test its applicability in your setup. Secondly, I would like for you get a note book, and make detailed records of just what you are doing. Only by doing so, can we really learn anything. I encourage you to publish your observations!

You are not just keeping fish. You are managing an experiment. All you need do to become the scientist, is take notes about what you do, and test your findings, or share your information so others can test your findings. No one needs a fancy degree to be able to learn something about the world, and share it with others.

The secret to success with killifish is careful observation.

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in the production of this book, he was very kind enough to point out errors, supply further insight into some issues and suggest changes.

I must also thank the members of the Killies.com Forum (www.killies.com/forum) who were often the guinea pigs to test some of the ideas in this book. The members also (unwittingly) contributed many of the ideas through their rich exchange of ideas. They were also supremely tolerant of daft ideas.

The South American Annual, British Killifish Association and American Killifish Association Killietalk email lists were also very fruitful in bringing to light many useful killi-keeping pieces of information.

Also, a debt of gratitude is owed to Jui-Pin Paul Wu of Taiwan, who encouraged me to publish the book in print rather than simply dumping it on the internet. (This book developed between submitting my M.Sc thesis for revision and receiving it back as a collection of Q&As to be placed on my website: http://tgenade.freeshell.org)

The text will be sparingly adorned with individual references to those who have given us some bit of useful information through their dedicated observation and experiment. For the most part however, much of the content is unreferenced and has been transferred by word of mouth from killiphile to killiphile, and today by means of the internet and email. To those people who have given us this vast mass of information a great debt is owed.

Finally, to GOD must go the glory for these splendid fish that seem made almost totally to ensnare man with their beauty. It is an unimaginable privilege to discover these fish at this point in their many splendid evolution of color and biology.

Part I

Biology, Maintenance and Breeding of
156
Killifish

Chapter 2

Introduction to killifish

A Killiphile is someone who keeps killifish and collects killifish to the point where he has a killifish in every room in the house or is threatening to do so. A Killiphile can never have enough killifish. He or she also never has enough tanks, nor time. Another term used is “Killinut” which may be more descriptive of the overall pathology of the killifish keeper. Once you begin to dabble in killifish it is very difficult to prevent them from colonizing every facet of your living space—so be warned!

In this book, the various killifish species-groups will be discussed in Part II, with the intent to dispense a few general tips to point you in the correct direction. It is not possible to give an account of every species without turning this book into an encyclopedia. Among the various groups the basic care can be generalized. It is then up to the individual to vary the maintenance conditions, discussed in Chapter 3, to arrive at the best results. As you will read in Chapter 5, there are many ways to arrive at success.

Perhaps more critical to the budding killiphile, there will be a whole chapter on how to come by killifish.

All temperatures and measurements will be in the metric system. Appendix A details the various conversion factors and also why this conformation was adopted for this book. For convenience some passing mention of gallons will be used in the main text where it is most practical to do so.

Killifish are no different to other fish. They require the same amount of care and attention to details. While there are “easy” and “difficult” to maintain killifish, the best success is had by caring for them all the same: with dedication.

Just what exactly is a killifish is a matter of debate.

2.1 What is a killifish?

The word killifish is a modification of the Dutch term “kil vissen” that literally means “stream fish”. The first killifish was the mumichog *Fundulus heteroclitus*, which was discovered in a stream near New Amsterdam (modern day New York). This word, killifish, is now widely applied to all egg-laying members of the order Cyprinodontiformes.

Also belonging to the order Cyprinodontiformes are the American livebears such as guppies, mollies, platies and swords—and the least killifish *Heterandria formosa*. The ricefish (*Oryzias* species) are today placed in the order Beloniformes but is afforded honorary killifish status for old times sake. Both orders are regarded to be closely related to the Atheriniformes (rainbow fish and blue-eyes). As evidence of this, is the potential for eggs of the blue-eyes *Pseudomugil* species (of the order Atheriniformes) to enter a delayed state of development akin to diapause. Eggs of *Pseudomugil gertrudae* and *mellis* are able to extend their incubation 100% (from two to four weeks) when incubated in damp peat instead of water. The eggs of *Pseudomugil cyanodorsalis* can remain undeveloped for extended periods of time in full strength sea water, only beginning to develop in the presence of fresh or brackish water. The eggs of killifish, while not normally tolerating sea water, react similarly to an increase in salinity.

Previously all the killifish fell under the family Cyprinodontidae but have since been split up into several diverse families. The lamp-eyes now fall under the family Poeciliidae along with the guppies and mollies. The *Aphyosemion*, *Epiplatys*, *Aplocheilus* and *Nothobranchius* are now of the family Aplocheilinae and the *Rivulus* and the former “*Cynolebias*” species now under Rivulinae. The various *Fundulus* types of North America fall into their own family Fundulinae. Then there are the families that include the pupfish and *Aphanius* etc…

There are approximately 700 species of Cyprinodont. Where in the past the taxonomy represented the morphological and meristic similarities, today it represents the hypothesized evolutionary lineages. This implies that all fish belonging to the same genus share a common biology that is more closely like each other than any other species group. While not to claim that the science is unimportant, the real issue for us as fishkeepers is that if we know something about the care of one member of the genus we can reasonably assume the same characters are possessed by a species you know nothing about within that genus. When beginning to experiment with a new species these assumptions are invaluable in approaching the question of how to care for your new charge.

Another conformation adopted by the author, is to where ever possible, use the currently accepted sub-generic name for a group of fish. While some ichthyologists reject the genus name *Chromaphyosemion*[1] as a valid genus name for the fish that were the *bivittatum*-group of the genus *Aphyosemion*, this author does recognize the validity of this name. The reasoning is simple: the fish of the *genus Chromaphyosemion* resemble each other more closely in form and physiology, than they do other members of the super-genus *Aphyosemion*. Likewise, the names *Diapteron*, *Kathyetys* and *Mesoaphyosemion* will be used to descriptively group those particular members of *Aphyosemion*.

In summation, to the hobbyist's mind a killifish is a Cyprinodont that lays eggs. That lamp-eyes are more closely related to livebearers than *Aphyosemion* doesn't make them any less a killifish.

2.2 Killifish biology, ecology and survival in the wild

Killifish have evolved to fill a diverse range of habitats; and have evolved equally diverse reproductive strategies. They have also evolved different feeding requirements. The only thing in common between all killifish habitats is water—and in the case of some *Rivulus* that may mean a mere puddle on top of a stone in a tropical forest. Due to this, there is no one general killifish keeping recipe. Each species group will possess a unique combination of characters that render it fit enough to survive in a selection of habitat types.

The majority of killifish come from small streams, rivers and ponds. They are mostly of a non-annual nature. They lay their large eggs in the mud or on plants, and the eggs hatch out in the water to produce large fry that have a competitive advantage over the smaller fry of other species. To the contrary there are species that lay thousands of tiny eggs that survive no less efficiently.

All these seemingly non-annual fish have eggs that can be forced into a diapause—a resting state—in which the eggs do not develop until triggered to do so by an internal clock and/or environmental signals. For some, this buys only an extra week while for others it can be several weeks or months.

[1] I adopt this name based on the work by Rainer Sonnenberg: The distribution of *Chromaphyosemion* Radda, 1971 (Teleosti: Cyprinodontiformes) on the coastal plains of West and Central Africa. In: Isolated Vertebrate Communities in the Tropics, G. Rheinwald, ed., *Bonn Zool. Monogr.* (46):79–94

This enables these fish to survive short dry periods and fluctuations in pond water level better than other fish.

This has also lead to the evolution of annual fish, who have escaped competition with most other fish by being able to survive in temporary environments where other fish cannot survive. These fish produce eggs that can be stimulated to enter into a long diapause of several weeks to months. The temporary ponds or flood plains where they live, fill with water once or twice a year. In the interim they are dry for several months. When the rainy season arrives, the pans fill and the rivers flood, filling floodplains and swamps wherein the fish live. The resting eggs hatch out to produce large strong fry that quickly grow and reach sexual maturity.

In the Gonarezhou National Park in Zimbabwe there is the annual fish *Nothobranchius furzeri* (that was the focus of the author's research) that is so adapted to the yearly cycle of rain and drought that even under perfect conditions the fish will not live longer than three to four months. The fish has adapted so well to the three to four months wet window, that it invests little energy into body maintenance, instead channeling all its resources into explosive growth and reproduction. In very good years, when the rains come in October, the pans fill and the fry hatch. By November the fish are spawning and by January they are dead if the pan has not dried up already.

Built into this is a safety measure in case the rains come and go before the fish can complete their cycle. (Often the first wet season—of which there are two spanning from South Africa up into Kenya—is very short and erratic.) Not all the eggs will have developed and be ready to hatch with the first rains. The eggs do not all develop at the same pace and after several months they can still be in the same state as when first laid. Only on wetting the eggs, or changes in climate will the eggs be triggered to develop. By this method, eggs are able to survive for at least three years! This process is well reviewed by Jaroslav & Kadlec (see Suggested Reading Chapter C, page 91).

Again using the example of *N. furzeri* Gonarezhou: In February or March the second wet season will begin and fish will again appear out of the mud. By the end of March or April, the rain has finished and the ponds are drying up. For the next six to nine months the ponds are dry.

The safety measure of differential development also enables the fish to enjoy two generations per year. A collection in March 2004 in inland southern Mozambique discovered both adults and juveniles in the same ponds. That the juveniles were of the previous year's spawning or this year is impossible to say. What is clear is that by staggering the development of the eggs it is possible to have more than one generation per year hatch, mature and spawn. This can be facilitated by fluctuation in water levels of the ponds.

There is some evidence from the laboratory, that the eggs, under suitable conditions, may develop from egg to fry in three to six weeks in water and yield healthy fry. This water incubaton of annual eggs will be explained in Chapter 5.

The South American killifish expert, Wilson Costa, prefers the term “seasonal fish” for those fish that lay long-resting eggs in the substrate of temporary water bodies. This is in reference to the fact, that in one year multiple generations can be had in response to the availability of rains and droughts.

While not all killifish are short lived they are all racing against the clock. They want to mature and lay as many eggs as they can. For this reason it is not difficult spawning killifish, and in the aquarium they can keep spawning all their lives, which for some species can be as much as five years. Very few killifish die of old age, they get spawned to death or jump out of the tank.

Killifish are active predators. They are always on the lookout for something to eat. In the seasonal pools of South America the diet, for the most part, is small crustaceans, and insect larvae. But there also exists monster killifish (e.g. *Megalebias wolterstorffi*) in the pools that predate the other killifish (e.g. *Cynopoecilus melanotaenia*). This is mirrored in the African pools where the giant *Nothobranchius ocellatus* preys on the diminuative *Nothobranchius luekei* and several other species that inhabit its pool.

In the wilds of West Africa the various *Aphyosemion*, *Archaphyosemion* and *Scriptaphyosemion* species live in the shallow water at the head of streams and creeks away from cichlid predators such as *Hemichromis elongatus*. These fish have adapted to this predation by evolving narrow, long bodies that are able to move easily through dense plant matter or shallow water to evade predation. Likewise, the *Aphyobranchius* subgenus of *Nothobranchius*, such as *N. luekei* have developed the same sleek body profile to evade capture by the predatory larger *Nothobranchius*. This enables the fish to escape among the tall dense grass along the borders of the ponds. The eggs of these fish are also more drought tolerant and erratic in incubation time. It is tempting to speculate that this is an evolutionary adaptation, in response to spending so much more time (spawning) in the shallows of a pond which may not get fully filled each wet season. Alternatively the drought resistance of the eggs could be due to the small size, and hence large volume to surface area ratio preventing dessication of the eggs. Others, such as Ruud Wildekamp, speculate the similar body profile of *Aphybranchius* hints towards a closer relationship to *Aphyosemion*. The author does not share this opinion, choosing to prefer the concept of form following function.

For many of the pupfish—such as *Cyprinodon diabolis*—the staple diet is algae. The *Cyprinodon* species have had to adapt to very isolated water bodies with total dissolved solid measures that may oscillate drastically with the seasons.

Rivulus go mad for fruit flies and other insects, climbing out of the water to catch them. So adapted are *Rivulus* to their diet that many only need to be kept damp to live, and may spend more time out of the water hunting (sometimes “crawling” through grass alongside the water in the case of *Rivulus hartii*) for insects or sun-bathing. *Aphyosemion* and *Epiplatys* seem to feed heavily on mosquito larvae. The killifish collector Rudolf Koubek has observed in his travels through Gabon, that in streams where casava are soaked and rinsed of their toxic alkaloids, there are no killifish to be found. Along these streams there is a higher incidence in malaria.

This is not a new nor unique observation. Professor Raymond Ramond of the Blaise Pascal Institute, France, has long been doing research in West Africa as regards using the indigenous killifish in mosquito control programs. During the 60s and 70s there was work by Walford, Markofsky and others on employing annual killifish in mosquito control. The general observation was that the mosquito fish *Gambusia* were wholly inadequate at mosquito control, and in all cases the indigenous species were much better adapted to the task. What was not known at their time is that annual fish require a specific soil type (vertisols developed over alluvial deposits)[2] for their eggs to survive. On the other hand, experiments performed with *Austrolebias bellottii* proved them to be too invasive, with the eggs being very resistant to dessication in all soil types!

Killifish inhabit a large variety of habitats and most are very generalist in what they feed on. Many are able to tolerate a broad range of temperatures in the wild. In captivity this tolerance is even more remarkable as is the adaptability of the fish to aquarium conditions.

Before addressing the topics of basic care (Chapter 3), it may be prudent to introduce the reader to some basic physiology, that will help the reader to understands the demands of the environment on the organism, and will be the topic of the next section.

[2] WILDEKAMP, R. (2004) *A World of Killies, Volume IV.* American Killifish Association.

2.3 Basic physiology: a response to the environment

[3]All life is an active response against the assault of an unforgiving environment. To survive, organisms need to adapt to their ever changing environment. This adaptation can occur over the course of generations to long-term environmental trends by the process we call evolution; or adaptation can occur at the level of the individuals in the form of physiological plasticity. This section will focus on the latter form of adaptation: plasticity. The best examples are that of learning: where nervous connections in the brain are reorganized to remember some activity or concept; and changes in cellular protein expression to regulate metabolism towards a particular task (such as boosting mitochondrial activity in fatty tissue to burn more fat and so generate more heat in cold weather). This plasticity, is a coping mechanism in a changing world, where the environment forces an immediate adaptation to avoid death.

The scope of physiological plasticity is largely restricted by the hereditary material of the individual[4]. This hereditary material, is what is altered over the long time course of evolution, but such long-term solutions in no way help an organism to cope with the here and now. With evolution, some hereditary material may be shed, other portions may accumulate, or even just be reshuffled into new functional units. What ever the products of evolution the organism has a defined set of tools with which to irk out a living. The important idea is that each organism will be adapted to operate within a certain range of environmental boundries that its ancestors were able to survive under. If we maintain the fish within those boundries it will survive and probably thrive.

If the organism's physiology can be viewed as a well oiled bureaucracy, composed of many departments with their own functions, all integrated and aimed at keeping the organism alive. In this example, the organism's enzymes are the busy bureaucrats, working tirelessly to build, respond and repair. Some of the bureaucrats, and systems they form a part of, may be more efficient under certain conditions, while others may only be efficient

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[3]General references for this section: Garret, R.H. & Grisham, C.M. (1995) *Biochemistry*, Saunders College Publishing; Miller, S.A. & Harley, J.P. (1996) *Zoology*, 3rd edition, Wm. C. Brown Publishers.

[4]An organism's DNA also possesses a form of adaptive plasticity by means of the process of DNA methylation, where the DNA is chemically modified, serving as a road-block for gene expression. These transient road-blocks can be transferred from one generation to the immediate next generation, where after the road-block may be removed if the original trigger for it (e.g. famine) has passed.

under others. Some processes may only work optimally at a specific water parameters and so on. . . The various systems and processes of the organism will have a general optimum within a narrow range of maximal efficiency. For some species, this may be only two or three degrees around 24°C, while other organisms may be able to tolerate as much as 30°C variation but be very sensitive to salinity. Each organism will be different, with its own life-sculpting evolutionary history.

As an implication of evolutionary theory, it can be assumed that related species with a similar life history will express the same range of physiological plasticity. As form generally follows function, organisms within the same habitat will most likely also have evolved the same basic physiology. This basic physiology—from the author's view point of biochemistry—is metabolism, particularly energy metabolism. It is chemical energy that fuels the bureaucrats in our metaphor above.

The fish needs energy to accomplish three main activities: physiological maintenance, growth and reproduction. The fish must grow to reproduce, and to develop and maintain its various systems. The fish is able to regulate its metabolism to meet its immediate needs, but there are limitations to how efficiently it can adapt its metabolism to meet its needs.

Let us examine an example of temperature. For a fish, the environment is the major source of heat, and consequently the fish's ancestors will have adapted to its environmental temperature range. With an increase in temperature, the activity of its enzymes will be effected. Some may become more efficient, and other less so. The fish will have to regulate itself to meet the new environmental needs. But the necessary adaptation may not be allowed by its genetics. This will place strain on its energy budget. It may have to invest more energy into maintenance than it ordinarily would, and this energy would have to come from that allotted to reproduction and/or growth. Feeding more food may help, but there is only so much the fish can eat at any one time, and it could be that its digestive enzymes work suboptimally at the current temperature. As a result the fish may be stunted, or even wither and die. The consequence of such a physiological disturbance may be different at different stages of the fish's development.

Now there is another problem. Enzymes work at a maximal rate dictated by their structure, which is temperature sensitive. Those chemical reactions that normally cause damage in the cell (and need to be repaired) occur spontaneously, and are not limited by an enzyme and its temperature sensitivity. In fact, these reactions may increase in speed and ferocity many times more than the activity of the enzymatic reactions needed to affect repair. As consequence, the fish's physiology is constantly playing catch-up in a game it cannot win. The result: eventually the damage adds up, and the fish dies prematurely.

In reality, this game of catch-up is always being played, and is assumed by many biologists studying the phenomenon of aging to be the cause behind aging. The important point, is that this game has been optimized over many generations under specific conditions to produce a favorable relationship between reproduction efficiency and life-cycle. Changing the conditions of the game beyond the ability of the organism to adapt, can see the organism lagging further behind than it normally would. This results in premature death—perhaps before it has had the chance to reproduce. As most of us want to breed our fish, this is something very important to keep in mind.

The above is speculative, but in the author's opinion is a better approximation of the nature of accelerated demise in response to increased temperature when it comes to fish. Previously, longevity was tied directly to metabolism, with the idea that the faster the metabolism, the shorter the lifespan. This correlation has been shown to be erroneous. Small dogs have a much faster metabolism than big dogs, but small dogs live longer. Also, research by Walford and Liu, showed that the metabolism of *Austrolebias bellottii* was faster in cool water, as opposed to warm water, but that it lived longer under such cool conditions.

Changing such a critical parameter as temperature can greatly disturb the energy budget of a fish. Changing the water quality also cause problems.

Fish need to maintain a specific osmotic pressure in their cells to retain proper enzymatic and physiological functions. Osmotic pressure is a term used to describe the ability of water to move from a area of low osmotic pressure (low total dissolved solids, tds), to an area of high osmotic pressure (high tds).

Osmosis is an example of the universal trend to balance two different states, in this case it is two solution concentrations, but living processes need a unbalanced state to function and generate the energy needed to keep such balance at bay. The osmotic pressure is dependent on the interactions between water and those substances the water molecules are in contact with.

A high osmotic pressure comes about due to the ability of the various compounds in the water to interact with the water so as to increase the viscosity of the solution. This effects the way how proteins and fatty acids organize themselves in the solution, and that in turn, effects how the proteins and fatty acids interact with each other and other compounds in solution. For enzymatic proteins, these changes in the viscosity of the water, can alter the rate of biochemical reactions. For the stringently regulated biochemistry in a cell, and physiology of an organism, any change in the internal osmotic pressures can be a fatal problem. For this reason, each cell is equipped with a myriad of pumps that pump some compounds out and others in (because different compounds interact with water and the other compounds differently). This creates a chemical/osmotic potential across the individual cells and the blood or lymph, which drives various physiological processes (such as nervous impulses or muscle contractions).

In turn, the organism strictly regulates the osmotic pressure of the blood via the kidneys that filter and pump out undesired compounds from the blood, and retain others, to maintain a constant blood osmotic pressure, and in so doing, a constant osmotic potential between the blood and cells. This is call osmoregulation, and osmoregulation takes up a big chunk of the energy budget.

In physiology, these compounds involved in physiological reactions are termed electrolytes, and the proportions of them to each other, as well as their individual concentrations, are very important. Most organisms will strive to accumulate potassium (important for nerve and muscle function), calcium and magnesium (for muscle coordination); while sodium will be excreted—due to its small size, it is able to slip through the cell membranes and plays havoc with osmotic pressure in the cells as well as blood. On the other hand, too much potassium relative to sodium in the blood stream can impair proper nervous function, while too much blood calcium relative to sodium can trigger muscle spasms. The goal is to maintain a constant difference between the cellular environment and blood or lymph.

For land animals the task of osmoregulation and electrolyte balance is easier as the relatively dry atmosphere does not affect their internal osmotic balance, nor allow salts to simply escape into the environment. For the freshwater fish there is a problem, in that the internal environment of the fish (the blood) is directly linked to the external environment by the gills via a very thin membrane. This membrane allows the free motion of water across it (osmosis), as well as the diffusion of salts from high to low concentration. This means that when a fish, with an ideal and near constantly maintained osmotic pressure, is placed into water with a different osmotic pressure/mineral concentration, water can rapidly move in or out of the fish, dangerously disturbing the physiological state of the fish.

In an environment with high osmotic pressure (similar to that inside the fish's cells) the fish needs to spend less energy (by way of its kidneys and cellular pumps) to retain its osmotic balance, as there is less of a difference between the two, meaning less energy is needed to retain that difference. A rapid change in the external environment creates havoc inside the fish, because water (and salts) rapidly diffuse across the fish's gills. If the change is very large the fish's internal environment may not adapt fast enough leading to cellular damage (particularly of the gills) due to a rapid influx of water, bursting the cells or derailing metabolism.

For fish hailing from saline or stable hard water, the capacity to adapt to mineral poor water may be very poor to non-existent, as the fish has evolved in an environment where the kidneys and molecular pumps have not needed to work so hard. The fish's physiology is not aware of this, and will still try to adapt. These adaptations will waste large amounts of energy at the expense of other needs. As consequence, the energy metabolism is disturbed, and the fish slowly succumbs as it burns-out. For fully marine fish, this change can be fatal in minutes, rather than weeks or months.

The threat of osmotic chaos is less if the fish is moved from soft to harder water, as fish maintain an internal environment with a high mineral composition ($\approx$ 6.5–9 g/L) that fresh waters are unlikely to equal. Such a move will mean the kidneys would have to work less to retain valuable minerals (such as calcium), that would ordinarily seep from the fish's gills into the soft, mineral deficient water. For these reasons, fish can generally tolerate a move from softer to harder water, much better than the reverse.

To keep water accumulation and mineral loss to a minimum, freshwater fish do not drink. All water enters passively via the gut and gills, while minerals are ingested and absorbed from the gut, or actively taken up by the gills. Water is prevented from entering fish, and salts exiting, by hard scales and a mucus coat. Any damage to the skin will create a point for water to rush into the fish, and salts out of the fish. This places the fish under severe osmotic stress. For these reasons, adding salt to sick or injured fish's water, is often suggested to ease the burden on the kidneys to maintain proper osmotic balance inside the fish. 8 g/L (or about 2 teaspoons/L) of table salt (NaCl) is the suggested dose, but it must be remembered that osmotic pressure is not the sole factor. Electrolyte balance is also important. Such a high table salt concentration can quickly kill many soft water fish, as the sodium rushes into the fish, creating biochemical and physiological problems. The simple addition of some potassium and calcium salts (in the form of a propriety salt mix) can counter this problem.

Another important aspect that could be of use in understanding stress in fish, is the site of the damage linked to the 'burn out' mentioned four paragraphs earlier. It is suspected (based on volumes of data), that the source of much of the cellular damage caused by stress comes from free radicals. These radicals, are highly energized molecules that react with the fats, proteins and DNA of the cell and surrounding tissues. They are byproducts of energy metabolism. When an organism is stressed, the organism will normally elevate its energy production to rally its resources to correct for any short-term problem. In the short-term, this can save the life of the organism, but over the long-term, damage can accumulate to such an extent that compensatory measures (such as DNA proof-reading and repair enzymes) can no longer cope—as discussed for changes in temperature.

Changes in temperature can also increase the amounts of free radicals produced. The processes that generate the free radicals as by-products in the mitochondria, are regulated by the fluidity of the fatty acid membranes and component enzyme activities that are temperature sensitive. Changes in enzyme activity and membrane fluidity will increase the level of inefficiency that allows the free radicals to be created by the 'leaking' of energy from the mitochondria.

Key targets of these radicals are compounds with double bonds, unstable unshared electrons in them such as for certain amino acids (tyrosine and cysteine), and unsaturated fatty acids. Amino acids such as tyrosine and cysteine play very important roles in enzymatic function. Unsaturated fatty acids are employed in cell membranes to retain fluidity and functionality, as well as synthesize certain hormones involved in proper immune function.

While we may be yesterday's potatoes, our fish are yesterday's frozen bloodworm, flake food or what not. The fish's intake of tyrosine, cysteine and unstaturated fatty acids (highly unstaturated fatty acids, commonly referred to as HUFA in the health food trade) can be boosted by feeding foods rich in these. This influx of undamaged essential amino and fatty acids may serve to remedy the immediate effects of the 'burn-out' situation, allowing the fish to reproduce. To illustrate this, we turn to an example.

Our example is the *Diapteron* breeding experiences of Monty Lehmann (AKA). Monty raised the temperature of his *Diapteron abacinum* tank from 22 to 27°C (80°F) resulting in a massive increase in eggs, but the fish grew weaker as the higher temperature burnt them out. The solution was to feed them the correct food. In this case it was *Cyclops*. *Cyclops*, along with other freshwater aquatic arthropods, seemingly have the correct ratio of protein and fats, as well as the correct types, needed to keep such small forest killifish in good health. While Monty's fish died at a very young age, they proved more productive in their short lifespan than fish that lived the normal duration of several years. More important for our purposes, they also lived longer and were more productive than *Diapteron* maintained at high temperatures and fed only brine shrimp nauplii and other less suitable foods.

As it turns out, *Cyclops* have high levels of unsaturated fatty acids and essential amino acids.

Another important thing to note, is the fact that in spite of the metabolic stress, reproduction was not affected. Killifish in general seem to have a very strong reproductive drive. So strong, that the fish may be ill and near death but still spawn. In most cases, raising the temperature will boost reproductive metabolism, but this in turn can destabilize the energy budget of the fish, if this increase in temperature is unnatural to the fish.

The first physiological casualty is normally the immune system, which is why burning-out fish normally first manifest with health problems such as gut or bacterial infections of the skin, lesions etc. . .

The temperature stress explained above is not unique to killifish. The cichlids coming from the same habitats manifest the same symptoms when kept at high temperatures[5].

In summation, killifish can adapt to their environment, but only so much, and then they begin to suffer. Their physiology can be manipulated, and corrective measures can be taken to help the fish cope with unsatisfactory conditions. Diet and feeding is the front line to killifish health and proper physiological activity. With that, we turn our attention to the matter of keeping killifish in the aquarium.

[5] LAMBOJ, A. (2004) *The Cichlid Fishes of West Africa*. Birgit Schmettkamp Verlag, Bornheim Germany.

Chapter 3

Killifish in the aquarium

Killifish require the same general tank conditions as do other aquarium fish. The water needs to be low in organic pollutants and of a proper temperature. The only special concern is that for a tight fitting lid free of cracks and gaps through which a killifish can propel itself.

In this chapter the author will deal with the topics of water quality, tank setup, maintenance and disease. Ordinarily these topics would be separated into distinct chapters, but this I feel gives a false impression that the topics can be separated, when in fact they are tightly inter-related.

3.1 Killifish in the community

A question asked time and time again is whether killifish can be kept in community aquariums. The answer is yes, but you will have to be selective.

Most species are unable to compete with other active aquarium fish (e.g. danios and barbs), while others can. Some may be aggressive towards other fish in general, while others may only be aggressive towards others of the same or similar species. Some have no problem with tanks with a strong water current, while others will waste away under such stress. Some can be shy and retreating under some conditions (sparsely planted tanks), while being very active under other conditions. Some experimentation may be needed to find out exactly what a particular killifish needs to do well under your conditions. Some basic guidelines follow.

For *Aphyosemion*-like fish, a community of small peaceful fishes (e.g. cherry barbs *Capoeta titteya*, white clouds *Tanichthys albonubes*, neon tetras *Paracheirodon innesi*, *Nannostomus* pencilfish etc…) could work well. For

Aplocheilus, *Epiplatys* and lamp-eyes a rougher crowd should pose little problem. Fish like *Fundulopanchax gardneri* have no problem sharing a tank with kribs *Pelvicachromis pulcher*.

Display tanks composed of all males work well, but the general community rules should be adhered to: don't put one fish with another that it can swallow. Keeping *Fp. sjoestedti* with neons or *Aplocheilichthys normani* would not be smart. Keeping an aggressive little fish like *Aphyosemion joergenscheeli* with similar colored fish would also be silly. Nice displays can be made of excess male *Nothos*.

A killifish community can be built up of *Epiplatys chaperi* or *dageti*, *Chromaphyosemion bitaeniatum* and *Aphyosemion striatum*. *Aphyosemion australe* can be put in the place of *striatum*. The important thing is not to mix similar looking fish. Mixing *Fp. gardneri* with *australe* would not work as the females are very similar in appearance. Mixing *gardneri* and *dageti* works well.

Some fish are also more assertive over territory than others. Male *Fp. gardneri* will dominate the smaller and weaker *Aphyosemion australe* in a mixed tank. *Epiplatys* are in general more assertive than *Aphyosemion*.

It is the coloration of the females that is important when mixing species. Males will chase anything that they recognize as a female, and may even spawn with it. While *Fp. spoorenbergi* and *sjoestedti* look very different in colour and size, the females are very similar and they will crossbreed. Suspect progeny should be discarded, or at least **never** sold or distributed in the hobby.

For ideas on what species one can mix, one need only examine the data at www.killi-data.org to see which species or species groups live together in the wild. In one stream in Cameroon you may find *Aphyosemion raddai*, *A. obscurum*, *Chromaphyosemion loennbergii* and *Epiplatys* sp. and perhaps *Lacustricola camerunensis*. You may also find *Pelvicachromis* species as well as small tetras and barbs. Diverse and interesting communities can be put together with the help of some research and good judgement.

Lamp-eyes make good general community fish as do *Aplocheilus*. The more sedate *Aphyosmeion* and *Rivulus* do not. *Nothobranchius* and "*Cynolebias*" are normally unable to compete for food with general community fish and slowly die.

3.2 Water quality

3.2.1 Water parameters

When it comes to water quality the primary criterion is *clean* water. Killifish can survive and even breed in water they are not really suited to. Many *Aphyosemion* will fare well in hard alkaline water. *Nothobranchius* fare much better in hard alkaline water in captivity instead of the soft water that constitutes the ponds they come from in the wild.

The fish that suffer most are the hard and/or brackish water fish such as pupfish and *Aphanius*. These fish do not survive well in soft water nor do they readily adapt to it. They rapidly develop infections and kidney problems manifest as a gradual decline in health.

The soft water fish from Central Africa and South America can be maintained in hard water. Jorgen Scheel (see suggested reading, Appendix C) found that this was the only way to keep many of his fish alive. In soft water they would be ravaged by Mycobacteriosis (fish TB). While soft water *Aphyosemion* and *Rivulus* can thrive in hard water, soft acidic water is needed to breed many of them successfully. It is hypothesized that high calcium and magnesium levels in hard water causes the egg chorion (shell) to harden faster than normal impairing fertilization and hatching.

Jorgen Scheel also believed that having some peat extract in the water to be beneficial to breeding, development and overall health. There is a resurgence of this belief among modern killifish keepers. The British routinely add tea (presumably Ceylone teas but the author has found South African Rooibos tea to work well) to the tank water to encourage breeding and fertility. In Asia, the leaves of the Sea Almond *Terminalia catappa* are used to improve egg viability and reduce infection. There is published research indicating that extracts from this plant can deter bacterial and fungal growth.

A pH between 6 and 7.5 is fine for most killifish. Jorgen Scheel demonstrated that many killifish can tolerate drastic pH swings from 6 to 8 without any detriment to their health *as long* as there was very little change in tds content of the water.

Tds can be defined as any compounds or minerals in the water that interact with the water. This interaction has an effect on osmoregulation, as previously discussed (see section 2.3, page 8).

Traditionally tds was only considered in respect to general hardness (GH) and today as conductivity, but it must be remembered that while a substance such as sugar has no conductivity in water it does have an effect on the osmotic pressure of the environment, and in so doing, the osmoregulation of the fish as it interacts with the water. Likewise, the various tanins and other compounds that stain peat-water or the black waters of the Rio Negro also effect the environmental osmotic pressure. While such water can be very soft with negligible conductivity, taking fish living in such water and dumping them into pure, very soft water will kill them due to the sudden change in osmotic pressures. Scheel found that the fish he worked with (mainly *Aphyosemion*-like fish) were able to tolerate a 50% change in tds without harm.

3.2.2 Temperature

Many of the non-annual highland West African and South American killifish species prefer cooler temperatures. Constant temperatures exceeding 24°C will cause many highland *Aphyosemion* and *Austrolebias* species to burn-out. Their metabolisms are unable to keep up with the physiological demands of the environment. Fish may be able to breed under these conditions with adequate feedings of protein and lipid rich food, but the cellular damage caused by high temperature living is irreversible, greatly shortening life-span. This is not an observation unique to killifish, the same is observed for the small cichlids coming from the same environments[1].

The killifish from the Gabon highlands require temperatures between 18 and 22°C. The collector, Rudolf Koubek, while collecting *Diapteron* in Gabon registered water temperatures as low as 13°C!

More extreme are the habitats of the *Austrolebias* species of Argentina and Uruguay that may be covered by ice—making it difficult to collect them. Further north, some of the species of the genus *Simpsonichthys* require more tropical conditions to prosper, and seem unable to do well at temperatures much below 22°C. *Nothobranchius* species in Africa inhabit ponds that may peak at 40°C. Some of the pupfish inhabit warm water springs or ponds with temperatures exceeding 40°C, but may drop below 10°Cin winter.

For the most commonly available killifish a temperature of 24°C is suggested. This may seem contradictory to the earlier statement but in general, the commonly available species are of old aquarium strains which only got established because they could stand these high temperatures. You may have to lower or raise the temperature for successful breeding depending on the species in question. Similarly, you may have to alter the water hardness.

Such old aquarium strains, in response to often vigorous selection, should also have evolved to be more tolerant of captive conditions than wild fish making them better beginners fish.

[1] LAMBOJ, A. (2004) *The Cichlid Fishes of West Africa*. Birgit Schmettkamp Verlag, Bornheim Germany.

3.3 Tank setup

What type of tank do you need to keep killifish in? One with a hood. Killifish are notorious jumpers. Some species are so adept that they will launch themselves through gaps no wider than they are. Many are also very panicky and may leap (unnoticed) to their deaths while you are performing routine maintenance.

If you have problems with fish jumping you should start by checking your pH (which can affect the toxicity of certain metals in solution[2]) and other water parameters. In the case of *Rivulus*, it is not unusual to catch the fish sun-bathing out of the water—often stuck up on the sides of the tank above the water line. However, should the fish begin to spend more time out of the water than in it, this can be interpreted as a sign of unacceptable water quality.

Many killifish will jump from the water in the wild in an attempt to reach new habitats. Another cause may be fright. The passing of legs in front of the tank may scare the fish. One trick that often helps with jumping is the addition of more surface plants and other hiding places.

What size tank you will need depends on what you want to do. A serious Killiphile will have tanks ranging in size from one to 30 gallons[3].

Smaller tanks are used for concerted breeding efforts while larger tanks are used for holding fish. The average killifish tank is between four and ten gallons in capacity[4]. These tanks are large enough to hold one to several pairs or trios of fish.

The best and often most productive setups are the "permanent" setups. These can also look the most appealing. A 30 gallon tank with shallow sand or soil/peat substrate that is richly planted with vallis, crypts, Amazon swords, Java fern and moss etc. . . can look very attractive as well as provide ample hiding places for fry. In such a setup a pair of killifish can rapidly fill the tank with fry that will grow up into healthy young fish. *Fundulopanchax gardneri*,*Chromaphyosemion* species and *Aphyosemion striatum* are very productive in this type of setup.

Lighting is a hotly debated issue. Some Killiphiles will object to bright lighting while others (such as the author) prefer a well lit tank. Surface and savannah fish like bright overhead lighting while many of the forest killifish prefer darker tanks.

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[2]Walstad, D. (1999) *Ecology of the planted aquarium.* Echinodorus Publishing, Chapel Hill, North Carolina, USA.

[3]A 1 gallon tank will typically have the dimensions of approximately $20\times15\times15$ cm while a 30 gallon tank will be approximately $91\times32\times38$ cm

[4]$30 \times 22 \times 22$ to $40 \times 30 \times 30$ cm

Colour is a good way to estimate lighting needs, if one assumes the following factors: Fish with lots of yellow will prefer bright lighting while those with contrasting blue/green and red striping/barring prefer softer lighting. Under low light conditions found in forests the blue/green shows up very well in contrast to the red which can appear almost black as the canopy filters out all the red light. If the fish has yellow it needs bright light to use it to its full effect. Using the same logic, fish with iridescent coloring will also need good lighting.

An example of this is *Kathetys elberti*[5]. All strains of these fish have blue bodies with red barring. Those that live in the forest have only blue and red in the unpaired fins while those that live in the savannah have bright yellow in the unpaired fins. These savannah strains also tolerate higher temperatures.

Fish reared in darkness will only feel comfortable in dark tanks. Similarly fish that are raised in well lit tanks will not be bothered by bright lighting. The use of small dither fish can help calm such light-terrified fish.

Logic fails in the case of many of the annual fishes. *Nothos* (Slang for *Nothobranchius*) often inhabit muddy pools where light does not really matter. Light still remains an important trigger for spawning. Many *Nothos* have bright red tails that are important in attracting females in the murky water—where red light penetrates better than blue. In the reed filled waters of South America, dark bodies with contrasting blue spots or bars are common and presumably aid in signaling to females in the murky shaded waters as well as affording camouflage from the predatory neighbors—that are often bigger annual killifish.

(The above information and reasoning may seem sound but are scientifically lacking. The assertions are difficult to test and the data is not as clear cut as reported. Most importantly, it is impossible to generalize when it comes to living organisms, as each has evolved under different conditions causing similarities to often be nothing more than coincidence.)

The author likes well lit tanks with dense plants (as he relies largely on plants for filtration) and shaded corners. If the fish prefer the darker corners then they have that option. Most fish will adjust to the lighting and will appear more relaxed in a well lit tank where they can see everything.

Heating is a problem for many devoted killiphiles as individual heaters are inconvenient with many small tanks. Some hobbyists overcome this by heating only a few small tanks per row and sandwich tanks between the heated ones. The fish are then distributed according to their heating needs.

[5] The September/December issue of the Journal of the American Killifish Association (Vol. 34, number 5 & 6), compiled by master breeder Monty Lehmann (AKA), is an excellent source of information on this and related fish and is the source for this information.

Others employ space heating with small fans or wall mounted heaters in a well insulated room. The use of heated closets, that can hold an assortment of egg and fry tubs, are not uncommon and a practical solution to the problem. In some instances, the heat from incandescent light bulbs above the tank can supply adequate heating as long as there is proper insulation. The author used to position small tanks on top of wood boards (without styrofoam mats beneath the tanks) under which the fluorescent light ballasts were fitted. This resulted in fluctuating night/day temperatures, but the fish did not seem to suffer. (There is well founded evidence, that for *Austrofundulus limnaeus*, this will extend lifespan. There is anecdotal evidence for life extension with fluctuating temperature for *Nothos* as well courtesy of the National Australian Killifish Association member Mark Staiger.) The use of reptile heating mats has also been suggested, but it must be remembered that the above suggestions are only really feasible in a well insulated environment.

The choice of substrate is up to the individual. Gravel or fine sand can be safely used with most fish where it will not get in the way of spawning. Jorgen Scheel used to use a layer of peat on the bottom of the tank. He rooted plants into this by placing small stones on top of the roots. Alternatively the plants can be planted in small pots, or solely floating plants can be used. The author prefers bare bottom tanks and floating plants, or ferns and moss attached to stones or drift wood, as this facilitates easier maintenance. With any substrate, care must be taken that it does not turn anaerobic and begin to produce lethal quantities of hydrogen sulfide and ammonia gas. This can be remedied by frequent stirring, or by rich planting, as the plants transport oxygen into the roots and so into the substrate.

If peat is used it must first be treated as described in Section 5.2.1, page 43.

3.4 Maintenance

Killifish need their tank's water changed just like other fish. The more fish in the tank the larger and more frequent the water change needed. Always use the same water source to avoid osmotic shock due to changes in osmotic potential as explained above in section 2.3.

A good conductivity/tds (total dissolved solids) meter is more valuable in a busy fishroom than an entire arsenal of test kits.

Find out if your municipality adds chlorine or chloramine to the water. Chlorine will dissipate in 24 hours while chloramine is stable for several weeks. Chloramine is far more toxic than chlorine; and there is anecdotal evidence that in small amounts it can impair fish fertility. Obtain the correct chemical to neutralize this compound (some only split the chlorine-ammonio bond, liberating lethal quantities of ammonia!), or filter all water through activated carbon before adding it to the tank.

Some fish require cleaner conditions than others. Lamp-eyes are such fish. Keep mulm and detritus to a minimum to avoid bacterial infections such as dropsy. Keep filters clean. *Nothos* can survive in the worst conditions imaginable—and even breed better—but will not live nearly as long as when kept in a clean tank.

Having lots of healthy growing plants in the tank will stabilize the environment and reduce the need for water changes. A large well planted permanent setup tank with low population density can go without a water change for a long period of time. Jorgen Scheel, using a tank substrate of peat and lush plantings of *Hygrophilia difformis*, was able to go two years without a water change for some tanks. He was able to overcome the carbon dioxide limitation on plant growth by dosing his tanks with 1 mL per liter of a 50 g/L sugar solution. This method may cause the pH to decline due to the fermentation of the sugar. Buffering with some lime or calcium carbonate would be essential to keep the pH from crashing to dangerous levels. Lush plant growth, will in any case cause the pH to fluctuate wildly between acid (at night) and alkaline (during the day) as the plants extract the carbon dioxide from the water. There is also the possibility of hydrogen sulfide gas production, which can be countered by preventing the substrate becoming anaerobic.

Duckweed is a fast grower and a nitrate sponge, whereas Java moss is alleged to rapidly sequests any ammonia/ammonium in the water in its tissues. They are perfect killi-tank plants.

The best filters are sponge and box filters. These can be filled with the normal filter floss. For fish that fair better under alkaline conditions, the addition of some crushed sea shells or coral into the box filter can go a long way towards maintaining good water quality by buffering pH crashes .

It is a good idea adding some crushed coral/sea shells or dolomite to filters when working with very soft water that is prone to rapid (and often fatal) pH crashes that can cause acidosis and fatal gill damage. At low pH, filter bacteria will cease to work causing dangerous spikes in ammonium and nitrite levels.

At high concentrations of nitrite, the nitrite will oxidize the hemoglobin in the fish blood, rendering it unable to bind and carry oxygen, effectively suffocating the fish. This can be remedied by adding salt (sodium chloride) or methylene blue to the water. Nitrate concentrations need to greatly exceed

300 ppm[6] before they become toxic. At these levels, enough of the nitrate may be converted back to nitrite by the bacteria in the fish's gut to cause problems (often exhibited as dark flecks in the fins). Fish can fully recover from nitrite poisoning if corrective measures (large water changes) are taken swiftly.

At low pH values, virtually all the ammonia is in the form of harmless ammonium ions. A pH change from 7 to 8 can cause a ten times increase in the concentration of free ammonia. Ammonia can become toxic from 0.05 ppm for some fish species, but can be causing damage at much lower concentrations before the toxic effects become obvious. For fry an ammonia concentration of 0.005 ppb[7] can already cause gill damage and stunt growth[8][9].

For this reason the accumulation of relatively harmless ammonium at low pH (where bacteria cannot convert it to nitrite and nitrate) can be very dangerous. A water change meant to correct a low pH can rapidly turn into an ammonia poisoning episode.

For maintaining a low pH in water with high carbonate hardness (KH), a stocking full of peat will do the trick. The addition of sodium or potassium bicarbonate to the water at regular intervals can be used to raise/buffer pH but can lead to osmotic shock and gill damage after water changes due to the difference in salt content between the old water and new water. The use of lime (CaO and $CaOH_2$) or calcium carbonate are safer options. The simple presence of sodium salt in soft water can greatly upset the osmoregulation inside fish, causing health problems. Ian Sainthouse (BKA), reports that *Nothos* maintained in soft water with added salt live shorter, less productive lives than those maintained without salt. Plants and other organisms also cannot function if the level of salt is greatly out of proportion with other electrolytes (particularly potassium).

Lime can also be used to soften water. By adding lime to hard water, the pH will spike and the bicarbonates present in the water will be converted to carbonate that will precipitate out with calcium and magnesium ions. Once this precipitate settles, the clear water (now with greatly reduced calcium and magnesium levels) can be poured off and used for the fish tank once the pH has been lowered by, for instance, peat filtering. The water may need to be hardened to buffer for pH crashes.

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[6] ppm = parts per million or mg/L

[7] ppb = parts per billion (US) or mg/1000 L

[8] BURROWS, R. E. (1964) Effects of accumulated excretory products on hatchery reared salmonids. *U. S. Dept. of Interior, Bureau of Sport Fisheries and Wildlife. Res. Rept.* 66 12p.

[9] SPOTTE, S. H. (1970) *Fish and Invertebrate Culture*, chapter 7: Water Management in Closed Systems. Wiley, USA.

pH greatly effects the solublity of the compounds in it. Lead oxide is virtually insoluble, but at low pH it can dissolve and poison fish. Lead is just one mineral to be concerned about. There are very few metals that are not toxic at a high enough concentration. This includes iron. For such toxic metal compounds to dissolve, the pH must normally be below 4 or above 10.

Regarding water movement, the current should not be too strong. Few killifish come from raging rivers. *Nothos* will quickly perish in a tank with a strong water current. They are not built to endure currents and quickly tire and burn out—wasting away. In many of the author's tanks there is no filter at all. There is only a small airstone facilitating water movement. Filtration is by plants. Weekly 30% water changes are performed and stocking kept low.

On the opposite end of the spectrum, lamp-eyes relish a strong current to swim against.

Chapter 4

Foods and feeding and disease

There is a direct correlation between diet and health. These inseparable subjects are the focus of this important chapter.

Killifish need copious feedings of protein rich foods to grow properly, as well as maintain themselves. Vitamins and essential fatty acids (HUFAs) are critical to maintaining good health and proper growth. Healthy fish do not generally get sick. But when they do, healthy fish are far more likely to respond to treatment and survive.

4.1 Feeding

In the killifish hobby, brine shrimp nauplii (bbs), *Artemia* species, is the staple diet. Due to its ease of preparation and high nutritional profile at the earliest stages of life, this food has been shown to be a great asset in aquaculture for newly free-swimming fry.

However, as fry grow and become fish, their nutritional demands change, as it does for human babies. During growth there is a high demand for amino-acids from protein; as well as lipids to construct cell walls. Of particular importance are highly unsaturated fatty acids (HUFAs) such as DHA and EHA, which are essential vitamins in the development and maintenance of the nervous and immune systems. Aquaculture researches long ago found bbs to be deficient in these fats and certain amino acids during the rapid growth phase of young fry. Supplementation of these fats greatly boosted survivability of broods. Today, products can be bought to enrich bbs with HUFAs and essential amino acids.

Feeding a varied diet may be a better way to supply such important vitamins. *Cyclops* is rich in HUFAs, as is *Spirulina*. Bloodworm and other insect larvae are very rich in protein—essential for fast growing killifish. *Daphnia* are another excellent food source. Being filter feeders, they will gut load themselves on algae and other microorganisms in the water, that are themselves, rich in vitamins.

A symptom of HUFA deficiency is "panic attacks", where fish will dart frantically about the tank injuring themselves, in response to normally harmless stimuli such as turning on the fishtank light. Immune dysfunction characterized by imflamation or lesions are also symptomatic of HUFA deficiency. The culture of grindal and white worms can be useful here, as they have a high lipid content that can be manipulated by feeding. If fed items such as peanuts (with a high unsaturated fat content) or spirulina, the worms will assimilate the fats (and amino acids if fed spirulina). When the fish eat the worms they in turn assimilate the fats and amino acids.

Fatty acids also play a part in cell membrane fluidity. This fluidity effects the ability of the cell to communicate with surrounding cells and the body as a whole. Inside the cell, in the mitochondria, such problems with membrane fluidity can result in energy metabolism running amok, and generating too many free radicals, that damage DNA, lipids and protein. This can result in premature aging of the fish, and related health problems such as immune system dysfunction and reproductive decline. Membrane fluidity is also affected by temperature. HUFAs are more fluid than saturated fatty acids. So, for cool killifish, HUFAs are may be very important to keep the cells functioning normally. At warmer temperatures there is greater demand for high energy fuel to mediate cellular repair, growth and reproduction. HUFAs, are more energy rich than saturated fatty acids.

Fresh live food is always better than frozen. Alas many of us do not have access to fresh live food and have to rely on frozen foods. The author's choices are frozen *Cyclops* and blood worm. The diet is supplemented with feeding of bbs, and dried food where possible. Dried food has the entire array of essential vitamins and minerals. Most killies can be tempted to take flake and small pellet foods. Most adult killies will also not turn up their nose to bbs. Jorgen Scheel reported that fish fed on a mixed diet of live and dried food faired better than those only fed live food.

It has been asserted that fish fed only on bbs can develop a nervous disorder where they dart about the tank in a panic injuring themselves. This may be due to a HUFA shortage. Also, in the author's opinion, fish fed only bbs do not grow as well as fish fry fed a more varied diet. This is not a new observation. The master killifish breeder A. van der Nieuwenhuizen observed the same the same phenomenon[1], and when ever hobbyists complained to him that their fish grew slowly he always determined the cause to be that they fed only one type of food from hatching.

For *Nothos* the author also feeds frozen beef heart imported from Europe[2] with added garlic. A high saturated fat food such a beef heart must be fed with care. Cool water killies (such as some *Aphyosemion* and Cynolebias types) would soon succumb from such a high saturated fat diet. It is hypothesized that this is due to the higher melting temperature of the saturated fats which render them less soluble and able to be digested and metabolized. Cool water fish, would only possess enzymes capable of metabolizing fats that would be fluid at the temperatures they live at. At these cooler temperatures, only HUFAs would be able to be metabolized. The undigested fat would either cause bowl obstructions (that can lead to dropsy)[3] or, if taken up by the fish, will be deposited around the organs (particularly the gonads) and cause organ failure as the saturated fats cannot be mobilized and metabolized.

Nothos need lots of protein and fat for growth and reproduction. As they tolerate warmer temperatures they suffer less from the threat of the fat accumulating around the internal organs killing the fish or causing bowl obstructions. (They also live too short a life for fat deposition to be a problem worth worrying about.) Such a rich food is fed sparingly and not every day! All uneaten food must be removed from the tank lest it rot and poison the fish. Dr Robert Golstein reports that beef heart gives the highest growth rate of any “commercial” fish food offered to fish.

In training killies to take a new food the first step is to have them associate you with food. If you are feeding bbs with a pipette or turkey baster, let the fish associate the pipette with food. Once the fish respond to the pipette, change the diet to what you want the fish to take. Feeding different foods mixed with the regular food is also a means of introducing fish to new foods.

Using these techniques, the author, has conditioned many fish to take foods that are convenient to feed. This includes picky wild *Nothos*.

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[1] V. D. Neiwenhuizen, A. (August 1963) Fishes of the Congo, Part III. *Aquarium Journal* 34(8):344–350.

[2] Europe has some of the highest standards for beef. No artificial steroids are allowed to be given to the cattle to bulk them up as in some other countries. In the USA, Jack Wattley suggested the use of second grade beef heart, as these have less fat—that can store unwanted steroids and other harmful compounds.

[3] Johnson, A. (Jan/Feb 2002) First South American Annual Killifish Roundtable: feeding. Edited by Harper, L. *JAKA* 35:18–32.

Feeding too much of some foods can cause health problems. It is best to alternate feeding of blood worm with other foods. Letting the fish fast for a day or two each week is also a good idea. In feeding large quantities of rich food, such as beef heart or bloodworm, there will be faster accumulation of waste products, thus requiring more maintenance.

In general, killifish do best being fed small foods such as bbs, *Daphnia* and *Cyclops*—and white/grindal worms sporadically. The large predatory species prefer live fish and big earthworms.

4.2 Culturing your own fish food

There is no substitute for live food. Today's dried foods, while being a comprehensive diet, lack that extra special goodness live foods have. You can choose to buy *Daphnia* from your LFS if you have no qualms of where it comes from, or you can culture your own. This chapter will deal with the topic of culturing your own fish food for those special occasions and fish.

4.2.1 Worms

All fish love earthworms. Earthworms can be cultured in compost heaps and bins in loose soil supplemented with organic matter like kitchen vegetable scraps (free of pesticides). The worms can be collected by milling through the soil and picking out the worms. They will also gather under objects such as tiles left on the surface of the culture.

Nematode worms are a good treat for small to medium size fish and can form a stable food for small fry. The grindal and white worms are for medium size fish. These worms can reach over 2 cm in length. They can be cultured in tubs filled with moist, loose soil or peat that has been treated to remove excess acid. The addition of shell grit or coral chips will help buffer the pH drop that is associated with a growing worm culture. The worms will eat almost anything. The best food is crushed peanuts. Peanuts are rich in vitamins, protein and HUFAs. As you are what you eat, peanuts will turn the worms from fish heart disease packages to something far more nutritious. The worms should still only be fed sparingly. *Spirulina* flake is also a good food that can be used to gut-load the worms with vitamins and essential amino acids. The grindal worms will prosper between 18 and 24°C. White worms need to be kept below 18°C. To collect the worms place a sheet of glass or stiff plastic on top of the substrate. Place the food under the sheet, and all the worms will congregate under the glass around the food. They can then simply be scraped off the glass and fed to the fish. The culture should be kept in the dark.

Microworms are a very good food for young fish. They too can be fed on crushed peanuts and *Spirulina* flake. Traditionally they have been cultured in jars or tubs on a mix of oats and a little bit of milk with some brewers yeast. These cultures stink and need to be replaced periodically. It is best to culture the worms in small air tight jars. The worms will climb up the sides of the jar and can then be removed with a brush and fed to the fish. Microworms can also be grown in soil/peat that is kept moister than for grindal and white worms. The worms' lipid profile can be improved by adding some olive oil to the culture medium. This will only be effective if the culture container dose not allow light in, as the light will destroy the delicate HUFAs in the olive oil.

Vinegar eels are minute nematode worms that inhabit wine/vinegar mixtures. They are cultured in jars filled with one part vinegar and one part water. To this is added several slices of apple (or any other fruit). The culture is left in the sun for a day or two till the mixture turns milky. At this stage the worms are added and the culture placed in the dark. Collecting the worms can be a challenge. Some people culture them in old wine bottles with narrow necks. Filter floss is stuffed down the neck of the bottle, to the level of the culture, and fresh water is then placed on top of the floss. The worms will congregate above this floss in the neck of the bottle. They can then be siphoned off and filtered or fed directly to the fish if your water is well buffered as the vinegar will rapidly acidify soft water. Some people place strips of scouring pads into the culture. The worms congregate in the pads. The pads are then removed and rinsed into fresh water.

While the first three types of worm will die in water after a time the vinegar eels will not. For this reason vinegar eels are a good food choice for small fry.

Tubifex and blackworms are good fish food provided they are clean and healthy when fed. *Tubifex* that are not eaten will effortlessly start a colony in any tank they are put in. Care must be taken to prevent their numbers from reaching plague proportions. The killifish in the tank should help in this regard. Rampaging colonies can be a serious problem. Should some disaster befall the worms they may die and poison the entire tank. Frozen *Tubifex* is not accepted by fish. The live worms can be kept indefinitely by placing them in a bucket or tub in a cool place, and letting water slowly run through the tub.

4.2.2 Insect larvae

Bloodworms, glassworms and mosquito larvae are excellent fish foods. All can be cultured very easily. Simply leave a vat of water with some organic matter in it outside in semi-shade and eventually it will be filled with water born insect larvae. These can be removed by net or siphoned up to feed to fish.

There is some debate about the safety of culturing mosquito larvae near one's home due to West Nile Virus. In reality the risks are very low. As long as you capture and feed all the mosquito larvae to your fish the risk of your mosquitoes infecting you with the West Nile Virus is zero. One also requires infected birds to be in the vicinity to infect the mosquitoes.

For obvious reasons, aquatic insect larvae will only be able to be cultured during the warmer months when temperatures are above freezing.

Some care must be exercised to prevent introducing aquatic predators such as dragonfly larvae into your fish tanks.

4.2.3 Crustaceans

Blessed is the man with a productive *Daphnia* culture. These little crustaceans can be cultured without too much fuss in large tubs both indoors and outdoors as long as there is enough light and nutrients to stimulate the growth of algae and other micro-organisms. To setup the culture, fill a container with water and add some organic nutrients (such a manure or leaf litter) to the container and let the water turn green. Then add your *Daphnia* starter. Setup several tubs in this manner. When the water is teaming with *Daphnia* begin to collect by swirling a net through the tub. You will have to keep adding nutrients to the tub to maintain the culture. Adding 1 mL per liter of a 5% sugar solution is one method; another is to add bakers yeast for the *Daphnia* to feed on.

Cyclops can be cultured in much the same way as *Daphnia*. *Moina* is very similar to *Daphnia* but much smaller—almost the same size of brine shrimp nauplii (if not smaller)—making it good food for fry.

Brine shrimp (*Artemia* sp.) are also crustaceans. They can be cultured in sea water. If the salinity is maintained just below that of sea water the shrimp will not lay eggs but produce many live nauplii that will grow up and replace the adults. The culture will need lots of light to grow the algae the shrimp feed on. Some aeration is also important for the shrimp. These shrimp can be enriched with *Spirulina* or HUFA mixes.

Brine shrimp eggs (bse) are easily obtained (often at astronomical prices) and can be hatched in a saline solution. The saline solution will need to have a specific gravity of 1.022 to 1.026 (or simply 20 to mbox35 g/L[4] of sodium chloride salt for the Utah shrimp). Russian brine shrimp eggs may require a weaker salt solution. If you live near the sea, you can collect sea water and use that. If you are unlucky enough to live far away from a source of sea water you will have to make your own brine. A solution of plain salt (sodium chloride) is fine but it is a good idea to add small quantities of potassium chloride, epson salts ($MgSO_4$) and calcium carbonate or sodium bicarbonate ($NaHCO_3$) to buffer the pH and yield a better hatch. Propriety marine salt mixes yield more consistent results.

There are several methods used to hatch the shrimp. The first is to take a plastic soda bottle, cut off the bottom and invert the bottle. Fill it with brine and about half a teaspoon of brine shrimp eggs. Aerate vigorously. After 24 hours (if you are using 90% hatch quality eggs) the aeration can be turned down. The nauplli will mass at the bottom of the bottle and the eggs will float to the surface (in a perfect world). The nauplii are simply siphoned out with a tube. They can then be washed or fed directly to the fish and fry or be used to grow up adult shrimp for feeding.

Presoaking the bse in fresh water can improve the hatch rate and separation of the bbs and empty cysts. Excess live bbs can be stored for at least 72 hours in the fridge without any effect to the nutritional quality or health of the shrimps.

Another method (the one the author employs), is to fill shallow trays with brine and add enough bse to form a thin film on top of the brine. The next day start another culture. After 24 hours the first tray will have bbs congregating in the best lit corner of the tray. These bbs can be siphoned out and fed to fish. You will have to setup a new culture every day as long as you need bbs. Each tray should yield bbs for two or three days before all the eggs have hatched. Several trays per day may be needed depending on the size of your fish collection.

Freshwater shrimp can also be cultured and fed to fish but these shrimp are often larger and less productive in culture.

4.2.4 Fruit flies

Examination of the gut of wild killifish reveals that many will consume any small insects unlucky enough to enter the water. Ants are a staple of the forest killifish of West Africa. Of course ants are not what you want to be culturing at home.

[4]Handy hint: one teaspoon of salt is about 4.5 g.

Some aquarists culture fruit flies for their killifish. For this purpose the wingless varieties are easier to manage and feed to the fish. These flies would need to be obtained from other killifish keepers or from research labs. The genetics department of your local university should be able to help you find these flies.

The flies will thrive on a mashed banana or oat meal mix. Some mold inhibitor will need to be added. Commercial mixes are available from biological supply houses. Both the flies and their larvae can be fed to the fish. The flies are easy to propagate; and can be harvested by placing a culture in the fridge to chill the flies. The chilled and immobile flies are then collected by tipping them into a net and added to the fish tanks.

Microworm cultures tend to get infested with fruit flies. The fruit fly maggots can be safely fed to killifish in moderation.

4.2.5 Culturing Infusoria

Infusoria are easy to culture for feeding to fry. You will need several glass jars that have been thoroughly rinsed to be free of detergents. Take some banana skins, lettuce or spinach leaves and put them in the jars. You do not need to stuff the jar full of material. To this add some boiling water. Allow the jars to cool then add some fish tank water to each jar. Put the jars in a well lit spot and wait. In a few days the jar will appear hazy and on closer examination you will see the haze is composed of many tiny specks that seem to move of their own accord. These are infusoria: a mix of single and multicelled micro-organisms. In place of adding fish tank water, a piece of Java moss can be used.

A piece of meat can be used in place of plant matter, but must be removed no less than one day after being added, else it will foul the culture.

To feed from the culture, simply pour portions of the culture into the fry tub/tank. Then refill the culture using water free of chlorine or chloramine. Over time the culture will loose vitality. To keep it going add a drop of condensed milk to it.

There is a product on the market composed of dried rotifers. These products contain millions of rotifer cysts and are good starters for your own rotifer cultures.

4.2.6 Artificial food mixes

Killifish can be trained to take artificial foods such as the paste food recipe of Julian Haffagee[5]. This recipe is as follows:

- whole prawns (shell on) (40-50%)
- other shellfish (10-20%) (e.g. shrimp, muscles. . .)
- fish meat (10-20%)
- heart/liver (10-20%) (remove excess fat)
- A mix of vegetable matter (20%) (peas, carrots etc. . .)
- vitamin supplements
- fennel seeds—for flavour
- garlic—for flavour, but also allegedly good for preventing intestinal worms, and generally promoting good health
- teaspoon brewers yeast—full of B vitamins
- 1/2 teaspoon anstaxanthin—colour enhancer, derived from an algae, brings out the red in your fish. Young fish colour-up earlier, and adult fish look great!
- trace of Cod liver oil—full of good things, especially if youŠre a fish!
- old flake/pellet foods—any commercial fish food, that they will not eat on its own.

Mix the above in a blender and add water if needed to form a thick paste. Boil a cup of water with two packets of gelatine and when cooled add to the food mix. Put the mix into flat bags laid flat in the refrigerator to set and then freeze. Putting the mix into ice-cube trays would also work. Defrost just enough of the food to feed your fish, or the frozen block can be grated over the tanks, the frozen chips being fed to the fish.

The use of second grade meat for the heart or liver would be better, as it will contain less fat (and so less fat soluble toxins that accumulate over time in large animals).

[5] http://www.thebomb.clara.co.uk/paste.html

4.3 Disease: prevention and cure

Contrary to popular belief killifish are not so short lived. Many can out-live the average guppy. Even the so-called annual fish can live for two years under optimal conditions.

The primary killifish diseases are velvet, bacterial infections and worms. The first two go hand in hand with poor aquarium maintenance. The latter is due to getting infected fish that then spread the disease because of poor quarantine procedures.

Killies should not be kept with weak or diseased fish. Commercial guppy strains are a good example of a weak fish. The common commercially bred aquarium strains are not as robust and fit as the old wild or selectively bred strains. They tend to pick up infections very easily. These infections can rapidly spread and reach plaque proportions. Keeping killies with young angels is also not very smart. Angelfish are notorious worm carriers (as are mass produced livebearers). This is the same reason why angels are not kept with discus. While the large angels can tolerate the worms the smaller killies cannot, and perish prematurely or never mature properly.

Velvet is prevented by maintaining a permanent salt concentration of half to one teaspoon per gallon. In the event of a velvet outbreak the first remedy is to raise the pH with bicarbonate of soda and then push up the salinity to 3 teaspoons per gallon. For those who prefer chemicals, any medication with quinine in works by far the best. The suggested concentration is 10 mg/L per day for three days, where after the water must be changed. Beware of medications that include copper. Many species are very sensitive to copper. Acriflavine also works well at about 5–10 mg/L.

If you are growing plants in the tank, the addition of some calcium and magnesium salt will help the plants resist the hydroscopic effects of the salt.

Velvet epidemics generally only occur in crowded, poorly maintained tanks. Velvet also has to be carried into your setup on an ill fish, so be vigilant.

Bacterial infections normally take the form of clamped fins, shimmying and slimy skin. The latter can be caused by the protozoan parasite *Costia*. The most common bacterial pathogens are *Flexibacter columnaris* and *Pseudomonas* species. Thanks to the fish farm practices of treating their fish prophylacticly with antibiotics such as Furan, these bacteria are now resistant to most fish store antibiotics. *Pseudomonas* are simply antibiotic resistant, and for human infections, the first course of action is a treatment with a cocktail of three antibiotics of different classes. Aquarium bought antibiotics are unlikely to do the job, and any ad hoc combination of them is likely to cause more harm than good (it will certainly kill your filter bacteria). The best course of treatment is either adding salt to a concentration of 3 teaspoons per gallon or a mix of malachite green and/or acriflavine with methylene blue.

Malachite green should be added to a final concentration of 0.05–0.15 mg/L[6]. If this has no effect the dose can be doubled and then further increased to 5 mg/L (a which concentration the fish have probably succumbed to the medication). Malachite green is a very strong medication that can prove fatal to fish as well as pathogens if used at too strong a dose. If the fish appear very unhappy after dosing, do a 50% water change and try a different treatment. During the course of treatment it is a good idea to do between 30 and 50% water changes in any event. Malachite green must never come into contact with galvanized metal in the fishtank as it can catalyze the release of zinc, causing zinc poisoning.

Acriflavine should be added to a final concentration of 0.02 mg/L to begin with (some sources state 5 mg/L). This dose can be increased incrementally to 10 mg/L. Keep notes as to what concentrations work best for you. Acriflavine is also effective against ***Costia***.

Malachite green is effective against **white spot**—another protozoan parasite—and **fungus**, as is acriflavine.

Acriflavine is a powerful antibiotic that can have serious side effects. Acriflavine is listed as an irritant on material safety data sheets and can interfere with DNA, and thus a potential mutagen/carcinogen.

These dyes will interact with any organic material in the water. Large amounts of mulm, organic material, bog wood and filter carbon will rapidly decrease the concentration of these dyes. Some plants (such as hornwort), may suffer as the dyes are toxic to them.

Dropsy is a bacterial infection that is easily prevented by proper house keeping. Do more water changes and keep the tank clean! Diet may also be the problem. Some SAAs do not do well on a high protein diet like bloodworm. They need more roughage in the diet to help clear the gut of bacterial and protozoan build-up, and are best fed small arthropods. Fed rich foods with little roughage their guts get blocked and bacteria proliferate resulting in dropsy. Regular fasting may be of help. (At least this was the consensus from a group discussion on the now defunct AUNZZA killifish email list.)

Intestinal parasites such as worms can be a serious problem. The drug of choice is Flubendazole. The dosage is 2 mg/L. The drug is available as a 5% powder. Of this powder you would have to add 40 mg to 1 L. A dose is added each day for three days with a 50% water change the next day. Fluben-

[6]See http://aquascienceresearch.com/APInfo/DrugDose.htm for a list of recommended doses of various compounds for fishtanks.

dazole is also effective at killing *Hydra*, protozoan and bacterial parasites at much lower doses. Impure flubendazole preparations can cause irreversible swim bladder problems. For this reason metronidazole (sold at your local pharmacist as Flagyl®) is the drug of choice for **flagelate infections** of the gut such as what causes hole-in-the-head disease. The first sign of an intestinal infection is the refusal of the fish to eat and a trail of stringy clear feces. The dose is 5 mg/L. This dose is added on day one. On day two a 50% water change is performed and the dose again added. On the third day the 50% water change is repeated with the addition of another dose. On day four a 50% water change is performed. Alternatively the course can run over seven days with a water change and dose every third day.

Hollow bellies are also a sign of a intestinal parasite infection. The fish have got stressed (perhaps too strong a water current?) and a formally benign infection has gotten out of hand. If the feces is clear and stringy treat with metronidazole. If red worms are seen to be hanging from the anus treat with flubendazole. Also do more water changes to improve water quality and turn down the filtration to reduce water movement.

Nothos are very sensitive to such infections. In *Nothos* this is termed *Notho*-fade-away. SAA and non-annuals are also susceptible. For *Notho*-fade-away a treatment of 40 mg of 5% flubendazole powder per liter is effective.

Glugea is another notorius internal parasite. For many the first sign of disease are white nodules on their flanks and massive fish deaths. Sometimes they will waste away for a time before they show the nodules. In cases involving very young fish the nodules never show, the fish just die before maturing.

The first course of action is to send live fish to a veterinary pathologist to confirm the diagnosis. This is important as the only sure-fire way to deal with the parasite is to cull **all** suspect stock and sterilize all suspect tanks and equipment. It is best to be certain with what you are dealing with.

Sterilize the tanks the ill fish were in and throw away all consumables the fish may of been in contact with. Quarantine all your tanks and inform everyone your have sold fish to that you may have *Glugea* in your fishroom. *Glugea* is a **BIG** deal. It is very difficult to get rid of, and will be the death of all your annual killifish and many non-annuals unless drastic quarantine measures are instituted.

Suspect eggs can be rescued by washing them. Marc Bellemans[7] developed a procedure where small lots of eggs were removed from tainted peat and washed by taking the eggs and emersing them in clean fresh water and

[7] Marc Bellemans (1999) BKA Killi-News

then removing the eggs to another container of clean fresh water. This procedure was repeated many times till any threat of *Glugea* is so diluted it can be ignored. The eggs are then hatched with the addition of some clean fresh peat. The fry are raised in quarantine and spread over several tubs to reduce the risk of all the fish being infected should one fry be infected.

An experimental treatment with Flubendazole[8] has been shown to be successful in treating the disease. The dose is 53 mg of 5% flubendazole per liter of water. The tank is dosed thrice over three consecutive days with a 90% water change per day. This treatment, while saving infected fish, does not cure the fish but only drives the parasite into remission. This should allow the opportunity to obtain some clean eggs.

Quarantine and sterilization would still need to be applied. The treatment is extreme and risky and is only really warranted on special rare fish.

[8] This treatment was developed by Barry Cooper (AKA) and Robert Goldstein (AKA).

Chapter 5

Breeding killifish

Killifish are not difficult to breed. All you need do is discover the water conditions the fish require (often it is a matter of simply keeping the fish wet). Spawning killifish can be labor intensive, as it can entail a lot of egg picking and fry sorting.

The least labor intensive method is the permanent setup method, where a pair or trio (or rather a small group) is added to a relatively large (20 gallon), well planted tank where the fish spawn freely, and the eggs and fry are left to develop in the tank. Alternatively the fry can be fished out—as with guppies—to be raised separately. As with guppies, the fry rise to the surface to feed and can be scooped out from between the plants. Floating plants like *Riccia* and hornwort work well.

If you want to raise large numbers of fry you will have to work at it by harvesting eggs or setting up special tanks for spawning.

5.1 Non-annuals

Pairs, trios or small groups are conditioned and setup to breed. They can be spawned on mops, over peat or gravel, or on plants. The eggs can be removed to be incubated in small dishes or tubs with whatever treatment; or be left untouched in the spawning tank or on the spawning substrate. The basic spawning substrate is the “spawning mop”. It is the first breeding technique tried to gather eggs of a particular species. Lets begin by discussing the construction and use of spawning mops:

5.1.1 Constructing a spawning mop

Acrylic yawn is best. Obtain a book (Herbert Axelrod's hardcover version of Community Aquariums works well with its dimensions of 23×13×1.5 cm, although his other title, Breeding Aquarium Fishes, may be more appropriate) and wrap the yawn around it about 50 to 100 times. Tie one end with another piece of yawn, and cut the other end so you have the threads of yawn tied together in the middle. Fold the threads so that the tied part (the top) is opposite to the loose ends (the bottom). Now take another thread and tie all the threads together about 2 cm from the top. Tie the threads together again about 1 cm lower than the second tying. Now you can attach the flotation device: a bottle cork or piece of styrofoam. Take a piece of thread, attach it to the top of the mop and tie it to the cork etc... Or, you can just toss in the mop, where it will sink to the bottom of the tank, where the fish will spawn in it all the same.

Before using the mop, boil it with some bicarbonate of soda to get rid of the excess dye. This may not be necessary with today's colour-fast dyes but it is better to be safe than sorry.

When choosing the colour of the yarn you are going to use, get two colours rather than one. The author has observed that a combination of dark and light threads work the best. Dark blue or green wool in combination with tan or cream yarn works well.

Some fish may be devious and turn back to eat their eggs, or prefer to spawn against a more rigid spawning structure. The solutions for both problems is to tie additional threads down the mop. For a 20 cm mop: one tying in the middle and one at the bottom will work to deter egg predation while three ties may be needed for fish like *Procatopus* species that like something firm to spawn against.

5.1.2 Tackling spawning problems

A common complaint is "I see my fish spawn but I never get any eggs." The answer to this is often obvious: your fish are eating their eggs. If you have a trio or group, not all the fish are spawning at once. The fish not spawning will be looking for food, and fish eggs are good food. Eating your neighbor's eggs also has the advantage that your progeny will not have to compete with theirs for food and space. The solution is to setup only one pair to spawn at any one time, regularly checking the mop for eggs. The fish may only spawn at a particular time of day and spend the rest of the time feeding (on their eggs), so checking the mop at different times of the day and collecting the eggs may be prudent.

Often, in spite of all you try, the fish will still not spawn or yield infertile eggs. This may be due to sexual incompatibility. Some males are not compatible with certain females and will not spawn or only produce a few eggs. The solution is to replace the male or female with another fish and see if the new pair is more productive. The mates may need to be swopped many times. The breeder/collector Rudolf Koubek reports exactly this problem with his *Diapteron* killies . One pair of *D. fulgens* may not lay any eggs, but change the male and you get a sudden explosion of eggs. For this reason group spawning is suggested for these fish.

Another way to try boost the number of eggs surviving after spawning (in the case of egg predation),is to try spawning the fish in plants, or over gravel or peat (fibrous peat is best). Condition the sexes separately and the place a single pair over the substrate for a day or two without any feeding. Then remove the fish and wait for fry. Spawning the fish over peat, collecting it and wetting it several weeks down the line can yield many fry. For a peat substrate left in the spawning vessel, it is important to stir it at regular intervals to prevent the peat bed becoming anaerobic. This stirring motion can also stimulate eggs to hatch.

Conditioning the sexes separately, and then bringing them together, has the added advantage that the pair will produce a large number of eggs in a short space of time. These eggs will also all develop uniformly.

A common problem, very often overlooked, is immaturity. Immature fish will not spawn; or if they do, they may only yield infertile eggs as the male is not yet potent. The only solution is time—and a trick learnt from Jorgen Scheel: adding peat extract to the water. The British use tea. Often, a short while after generous dosing with the peat extract, the males will suddenly mature and begin to take an interest in the females. Jorgen Scheel was able to show that prior to this, the gonads had not yet developed, and that they developed in response to mysterious compounds in the peat extract (and tea). Fish not dosed with peat extract and of the same age did not show development of the gonads.

Water level can also be important to spawning. It has been observed by more than one person, that a lowering of the water level seems to promote spawning. In the case of *Rivulus siegfriedi*, lowering the water level boosted egg production from three eggs per week to 15 eggs per day. Low water level has been implicated in spawning many *Aphyosemion* and *Fundulopanchax*. *Fp. sjoestedti* go wild with sexual desire in response to a lowering of the water level and water changes.

Many *Aphyosemion* will only spawn well after a water change. The author observed, that after performing a 25% water change on his *Aphyosemion* *punctatum*, the fish would spawn more vigorously. The difference was large. Egg production would go from three or four eggs to 12 or 16 per day. Cool fresh water seems to trigger spawning.

5.1.3 Collecting and incubating eggs

In the case of mops, to collect the eggs, remove the mop from the tank. Check to make sure no fish are in the mop and then gently squeeze the excess water from the mop. Let the damp mop lie for about 15 minutes and then pick the eggs off with your *clean* fingers or some other blunt implement.

You can choose to incubate the eggs in water or on peat or even in peat. Alternatively you can leave the eggs on the mop and simply store the mop in a plastic bag till the eggs have developed, or leave the mop and eggs in a tray of water and watch for fry. Another method employed is to cut the mop strands with eggs on from the mop and incubate those separately. It is not recommended that one handle the eggs, as this may damage them or transfer bacteria to the eggs that will kill them.

Water incubation offers the most problems but the fastest results. It also offers more control. The biggest problem is infertile eggs and fungus.

Fungus and infertility go hand in hand. Healthy eggs do not fungus, but may be killed from pollution from dead and fungusing eggs. For this reason infertile and fungused eggs are best removed from the incubation dish. Spotting infertile and dead eggs can be difficult. The dye methylene blue can help in this regard. While methylene blue has mild anitbacterial properties, it cannot kill fungus. Methylene blue has another function: that of an oxygen carrier. The addition of methylene blue to the water will increase the oxygen capacity of the water. As eggs are very sensitive to oxygen deprivation, the addition of methylene blue can have a tremendous advantage, especially for the incubation of the eggs of cool water species[1]. The methylene blue is prepared as a 10 mg/mL stock solution. Of this 0.2 ml ($\approx$ 3 drops) are added per liter. Infertile or dead eggs rapidly turn blue (because the dead eggs cannot pump the die out) and can be removed. Too much methylene blue will turn all the eggs blue making it impossible to tell good from bad eggs.

The late master killifish breeder, Ed Warner, used to use an incubation solution composed of half a teaspoon of salt per four liters, plus five drops (0.33 mL) of methylene blue (presumably a 50 g/L solution), and one drop of Aquari-Sol. The author has used a similar solution but with Tetra General

[1]Cooler water has more oxygen dissolved in it, and hence cool water fish are adapted (or rather restricted, because evolutionary speaking "adaptations" are positive traits) to high oxygen conditions and are best maintained under such conditions. The same applies to their eggs.

Tonic used at a quarter to half the recommended dose in place of the methylene blue and Aquari-Sol. A plain solution of one teaspoon of salt per gallon has also been shown to be of benefit.

Even with such precautions the eggs may still disintegrate or fungus. If you are picking the eggs by hand, you may be the reason. The eggs of some species do not like to be handled in the slightest. Your fingers, as well as perhaps structurally damaging the eggs, may also be transferring bacteria onto the eggs. Peat extract has compounds in it that impair bacterial growth and can be used to great effect in this regard. The leaves of the Sea Almond *Terminalia catappa* have similar properties. Extracts can be prepared from the peat or leaves, by simply letting them soak in clean water, and the resulting extract added to the egg tubs. Avoid touching the eggs at all. Collect the egg laden mops and transfer them to a tank with 1 tsp of salt per gallon in the water, and allow the eggs to incubate on the mop. Alternatively cut the strands of mop off which have eggs attached and incubate those.

Infertility and oxygen demands have been discussed above. Another method is transferring the eggs to a makeshift egg bubbler. An inverted cool drink bottle with airline reaching to the bottom would suffice. Remove all eggs that fungus and do small regular water changes. If problems persist vary the temperature in the breeding tank. Male fertility is linked to temperature. You may also want to try using softer water as excess calcium and magnesium in the water could harden the chorion (egg shell) before the sperm can reach it. Change only one variable at a time as only a specific combination of factors may yield the desired result. Such fiddling with the variables can result in a step by step improvement.

A carefree method of incubation is to take a tub, fill it with tank water and java moss. Drop each egg onto the moss where it will incubate surrounded by the fauna of the moss that will keep bacteria in check. The fry are gently scooped from the tub on hatching. The addition of some small shrimp (*Caradina* and *Asellus* species) also helps, as they eat the dead and fungused eggs but ignore the good eggs. Some shrimp species may eat the eggs too, so some experimentation may be needed.

In experimenting with breeding parameters, starting with water hardness is a good place, followed by temperature, pH and then try additives such as peat etc... If changing one factor has no visible effect (which can only be known by keeping good records) then revert to the original state and alter another variable. If that fails try again changing one variable at a time, and then two at a time etc... Perform such experiments over several days, and avoid large rapid changes—especially of tds.

It is best to keep the eggs at a constant temperature. Place the incubation tub on top of a tank where it can remain at a constant temperature; or better yet float the tub in a fish tank. This is often the critical “trick” to incubating the eggs of “difficult” species. Embryological development is strictly regulated by enzymatic processes. Any perturbation in temperature can have large and fatal consequences. For the author, this trick proved to be the crucial factor in successfully incubating the eggs of *Epiplatys bifasciatus*.

The eggs can also be put onto damp peat to incubate. This does not work with all species. Pick up the eggs and gently flick them onto the damp peat and seal the container tightly to retain humidity. The peat should be well washed and alkali treated to prevent it from becoming too acidic. Do not press the eggs down onto or into the peat.

What the author has found effective is collecting the eggs, mixing fine peat moss with the eggs and then drying the peat to a damp-but-not-wet consistency. The peat is then incubated for between two and four weeks. You will need to experiment to see what incubation period works best. This method has the benefit that all the fry will hatch at the same time. The same can be accomplished by pulling the egg laden mops from the tanks, wringing out the extra water and storing the damp mop in a plastic bag till the eggs have incubated.

Non-annual eggs generally take 10 to 21 days to develop in water; and 17 to 28 days on/in peat. The best way to find what incubation routine works for you is by experimentation.

5.2 Annuals

Annual fish are a lot less work. All you need do is prepare the peat, make the spawning container, sink the peat and spawning container and then harvest the peat a week or two later.

5.2.1 Preparation of peat and the spawning container

Always use peat with no added fertilizer. Fine peats such as peat moss are best. The peat moss from Michigan and Canada are considered the best quality but can drop the pH of soft water to 4 in a short time. To prepare the peat, take a portion of the peat and boil it. If the peat is very acidic boil the peat along with some bicarbonate of soda, shells, dolimite chips etc… Save the peat extract. It can be used to retard bacterial growth on water incubated eggs or induce hatching of annual eggs (and reportedly reduce the incidence of belly-sliders among annual fry).

After boiling, rinse the peat and then store the peat in a plastic bag till used. Do not prepare too much—only as much as you can use in a week or two.

Wide shallow spawning containers work best, i.e. the fish find the tub easier. The author uses tubs of a diameter of 15 cm and a depth of 5 cm. If you are spawning the fish in a deep tank, a deeper tub can be used. Likewise, for bigger fish a wider container can be used. The container, here described, works well for most *Nothos*. You will need a 1 to 2 cm layer of peat on the bottom of the tub. For South American annuals that like to dive into the peat a much deeper layer of peat and container must be used (at least as deep as the fish is long). Some people use deep jars or soda bottles.

The container needs to be weighted with a stone to make it sink (if it is not glass). It will also need a lid. The lid will need a whole cut into it of no less than twice the size of the fish. For young fish not used to the container it is best to leave the lid off at first. Once the fish accept the tub as a spawning site, it can be changed for a smaller, more economical container. The learning curve varies from species to species.

Sometimes the fish will insist on spawning outside the tub. This is very common with fish that are in tanks with dark bottoms. The fish have been behaviorally programed to spawn over a dark substrate. The use of wider spawning tubs with white sides and lid can be used to train the fish to spawn in the tub. Sometimes this will fail and the only option is to separate the sexes and put them together over a substrate of peat for short periods of time after conditioning. This is a particular problem with *Nothobranchius rosenstocki* (the former *N.* sp. Mansa and Kasanka). Charles Nunziata[2] (AKA), has observed that female *Nothos* only begin to spawn three hours after first light.

Another problem is that the fish may spawn in the tub and lay hundreds of eggs that simply vanish. There are three possibilities for this. The first is that the water is not the right temperature and/or the male is not fertile. The third reason may be that the peat is too acidic and may be killing the eggs during incubation. The annual fish from the Sao Fransisco drainage in Brazil have eggs which are very sensitive to acidic peat. The German killiphiles solved the problem by adding some alkaline clay to the peat. The best course of action without really knowing what the problem is is to raise the water temperature to 24°C and boil the peat several times with bicarbonate of soda.

An alternative to peat is sand. Fine sand can be used to spawn the fish. It can later be stirred up and the eggs collected by a sweeping figure eight motion as the sand (being denser) sinks faster than the eggs. If the sand is fine enough, it can simply be sieved and the eggs left behind in the sieve can

[2] KATZ, D. (2003) The Convention Seminars. *JAKA*, 36:132–134.

be collected. The eggs can then be incubated in peat or in water.

The eggs are denser than the peat fibers. This allows one to separate the eggs from the peat through a similar process. The peat and eggs are put in a bucket and stirred. With the water swirling the top layer is gently poured off. This is repeated till all or most of the peat is gone and only the eggs remain. The peat can then be recollected and placed back with the spawning fish. The collected eggs can then be stored on peat or incubated in water (see section 5.3).

Mops can also be used to spawn annual fish[3]. The fish are programed to seek out the darkest substrate over which to spawn. By using dark mops stuffed into spawning containers the fish will spawn in the mops. The mops are then removed and the eggs picked from the mops. The eggs can then be incubated in peat or in water as will be described below. This method works excellently with South American annuals that are very messy spawners.

For tropical annuals, an egg incubation temperature of 23°C is adequate. For annuals from southern South America, cooler temperatures may be more appropriate.

5.3 Water incubation and hatching hints for annuals

Annual eggs can be incubated in water. The eggs are collected as described above. They are then laid in a shallow dish without the addition of any antifungals or bacterials. The eggs will develop to the hatching stage but will usually not hatch. To trigger hatching add fresh peat and cool water. It is important not to hatch all the eyed-up eggs at once. Often the eggs look ready to hatch but are not. By hatching only a portion of the eggs you can correct for bad hatches where the eggs yield only belly-sliders. This applies to eggs incubated in peat as well.

Belly-sliders are the result of immature eggs hatching too soon, or old eggs hatching too late. Another theory is that hatching the eggs in water that is too cold prevents them from filling their swim-bladders. Yet another theory states exactly the opposite... It could be that too cold or too warm hatching water may be a problem for particular species. Similarly, too warm or too cool incubation temperatures are implicated in causing belly-sliding. There is strong evidence for this in case of many *Austrolebias*[4]. The same author

[3] V. D. NIEUWENHUIZEN, A. (August 1963) Fishes of the Congo, Part III. *Aquarium Journal*, **34**(8):344–350

[4] MORENSKI, R. (2005) Peat Moss Pot Pouri: Cool Killies. *JAKA* 38:139–141.

implicates temperature in belly-slider problems in *Nothos* [5] but the run-away success of *Notho* fanatics in tropical Asia suggest he could be mistaken. The moisture of the peat could also be a big factor.

If you are getting belly-sliders from most of the eggs then you can try experimenting with the incubation duration. Another idea is to try adding an "oxygen" tablet to the water. The fish belly-slide because they have not been able to fill their swim bladders. By increasing the oxygen supply in the water the swim bladders can be more easily filled. This technique has been successful for both African and South American annuals. Again the addition of peat extract has shown to be of use. The oxygen tablet is added to the peat and eggs which have been placed into a tub that can be sealed air-tight. The tub with peat extract, oxygen tablet and eggs is sealed until the eggs have hatched and the fry are free swimming. The author hatches his eggs in the evening, and returns to them in the morning for the first feeding. The water should be cooler than what the fish were incubated at.

Most books and articles will list a collection of incubation times for annual fish. These lists can be more misleading than helpful[6]. The incubation time of annual eggs is temperature, oxygen supply and moisture dependent. Water incubated eggs will develop much faster than peat incubated eggs. Temperature will also accelerate incubation, as does an ample supply of oxygen. The best process to determine the correct incubation time is by experimentation: hatching portion by portion of eyed-up eggs.

In general South American annuals and African semi-annuals need damper peat than *Nothos*.

Non-annual eggs rarely require any effort in inducing hatching. Eggs that do not hatch as per normal can be induced to hatch by the addition of some microworms or other food to the container with the eggs. It is best to transfer the eggs over to a small vial for hatching in this case. Other methods are to bubble carbon dioxide into the vial (i.e. exhale through a straw) or by simply walking about with the vial in your pocket. Another method is to do a water change with fresh cool water. Even a simple stirring of the eggs/water can trigger eggs to hatch.

Another method used, is to put the eggs with some fresh peat into a small jar or plastic bag and sink it into a deep tank. The extra pressure is supposed to not only stimulate hatching but filling of the swim bladder. (This method

[5] MORENSKI, R. (2006) Nurturing skills to be a successful *Nothobranchius* breeder. *JAKA* 39:3–5. It is a good idea for you to get hold of this article if you are all interested in breeding *Nothos*.

[6] *Nothobranchius eggersi* eggs take three to four months to develop under "normal" conditions (24°C). In Singapore the eggs take only four weeks! If you had to wait the four months in Singapore all the eggs would of perished while you waited.

is attributed to Mr. Morenski.)

Annual eggs should be wet in shallow tubs for ease of removing the fry for rearing. Shallow water also promotes gaseous exchange and distribution in the water. Take a portion of the peat when the eggs are eyed-up and add fresh water to the peat. Eyed-up eggs will have clearly defined eyes with a gold ring around them visible in the egg. The eyes may be seen to wink, or the fry wiggle on close examination. The peat is best submerged about 5 cm deep for hatching. The addition of peat extract will encourage hatching for both annual and non-annuals.

Sometimes the eggs will not hatch immediately. If the eggs have been left to incubate too long it may take some hours or even days before the eggs hatch (perhaps because the fry need bacteria to break down the chorion for them in their weakened state). The author knows of one case involving *Nothobranchius fuscotaeniatus* eggs that took two weeks to hatch after being wet. These eggs were almost two months past the suggested wetting time.

In the case of semi-annuals such as *Fundulopanchax filamentosus* the eggs may hatch over several days rather a once off hatch. In one instance the author collected *Fp. filamentosus* fry from the hatching tub over the course of a week.

5.4 Rearing fry

Fry should be gently removed from the hatching container to another container for rearing, so that in the case of annual killifish, the peat can be redried free of pollutants. You want about 10–20 fry per liter of water initially. As they grow reduce the bio-load to about 5–10 fry per liter. You will need to do 50% water changes at least every second day on the tubs. The author uses 2 L ice-cream tubs for fry rearing and aims to have at most 10 fry per tub with daily water changes and generous feeding for maximal growth. When the fry are about 1 cm they are moved on to a tank with a filter. Having 2 L per fry seems to offer the best compromise between growth and space efficiency.

With a constant flow through system, the fry can be packed denser, but remember that some fish cannot tolerate current. In one instance, the author had both show guppies and extremely fast growing *N. furzeri* fry (adult and colored up in only three weeks!) in separate tanks of a flow through centrally filtered system with UV sterilizer. The guppies thrived while the *Notho* fry languished, never approaching their potential size of 8 cm in total length. Slowing the refill rate, made a tremendous improvement in growth in another experiment, but the stocking density again approached one fish per 2 L.

The reason why the fry are initially raised in small tubs is to cut down on feeding. A squirt of bbs into a small tub will see more fry satisfactory fed than three squirts of bbs into a four gallon tank. The fish will also expend more energy in a larger tank hunting down the bbs than they would in a smaller container. Microworms, vinegar eels and sifted *Daphnia* also make good first foods.

Sometimes the fry will grow up with bent backs. This is most likely due to malnutrition. Fast growing fish such as *Aplocheilus* and *Epiplatys* are prone to this. Some of the faster growing SAAs such as *Simpsonichthys whitei* are also prone to this malady. Cull the deformed fish, vary the diet and feed generously. This condition can also be brought on by parasitic intestinal infections or be of genetic origin.

Killi fry are very sensitive to velvet. The addition of one teaspoon of salt per gallon is a good prophylactic against velvet, but could just as well kill them if there are not enough other salts in the water. Using a comprehensive salt mix with other minerals (such as potassium, calcium and magnesium) is a better option.

If your fry have velvet you are in trouble. Do a 50% water change. To the fresh water add salt to a concentration of one teaspoon per gallon and half a teaspoon of bicarbonate of soda per gallon to raise the pH. The next day repeat the bicarbonate dose and increase the salt to two teaspoons per gallon. The next day raise it to three teaspoons per gallon. Maintain this concentration till the velvet disappears and then slowly return the water to one teaspoon per gallon. Do not stop feeding the fish. Instead feed more as if the fish weaken they will die.

If the velvet will not go away add acriflavine as prescribed in Chapter 4.3.

Velvet outbreaks are due to poor water quality. Add some shell grit or dolomite chips to the filter to keep the pH from falling below 6.5. Always have some plants (particularly Java moss) in the tanks or tubs to assimilate the ammonia.

5.5 Skewed sex ratios

This is a common problem. Observation and research[7] have shown that by raising smaller groups of fry together, a more balanced sex ratio is achieved. By raising fish in sets of two, matched pairs can be had most of the time.

[7] Jim Robinson (1999) A Controlled Experiment Concerning Skewed Sex Ratios in *Simpsonichthys*. Available at http://www.cynolebias.org/SAA/public/care/Experiment_SexRatioSimp.htm

This is not new information, many moons ago Rosario La Corte reported on how raising killifish fry in lots of two fry per container produced matched pairs. This piece of information lay forgotten for years until the mid 90s when it was rediscovered. That Rosario learnt this from a Russian hobbyist (name long lost to history) long before is also rarely remembered. This “duet” method of raising fry does not work for every species.

In the author’s experience, raising *Nothos* singly will yield females 70% of the time. Data obtained by Martinez et al by experiment [8] similarly suggest that 70% of the time a *Notho* will mature as a female and that the likelihood of obtaining a matched pair from two fry is about 45.5% (at least for *N.* sp. Nyando River KE 01-3).

Varying the temperature when raising the fry can also help. By raising *Fp. spoorenbergi* at warm temperatures the badly skewed sex ratios can be avoided. At low temperatures the fish tend to produce mainly females. In the case of *Austrolebias bellottii* the reverse is reported. Low temperatures produce mainly males while higher temperatures are needed to get females.

Hardness and pH are also implicated in the manipulation of sex ratios[9]. For *Epiplatys dageti*, *Fundulopanchax gardneri* and *Pseudoepilplatys annulatus* it has been observed that harder water will produce more females. For *Aphyosemion zygaima*, *Aph. ogoense* and *Rivulus xiphidius* soft acidic water has produced balanced sex ratios. For fish from habitats with a near constant temperature such as *Aphyosemion* pH seems more important for sex ratio determination than temperature.

For *Rivulus* it has been observed that by raising fry in the parent’s water balanced sex ratios can be achieved. This has also been observed for *Leptolebias* species. In the specific case of *Rivulus xiphidius*, temperatures below 24°C in soft water will yield mostly females. In contrast, *R.* sp. Mahdia will only produce female fry at temperatures above 26°C in soft water. There is no one solution applicable to all killifish.

The age of the fish and time of spawning also seems to affect the gender of the fry. It has been observed that for *Aphyosemion*, eggs that are spawned early in the morning tend to produce more females than spawns late in the day. For *Aphyosemion*, older fish produce batches of fry of more even sex ratio.

Another interesting observation made by Gene Lucas from experiments using *Betta splendens*[10], suggest that the composition of the spawning pair

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[8] MARTINEZ, R; NGUYEN, M & STOERY, J (2006) Two killifish fry in a tank = 1 sexed pair—does it really work? *JAKA* 39:6–11.

[9] For more information see http://www.cincikillies.org/.

[10] Lucas, G. Bettas. . . and more. *FAMA*, February 1979.

influence gender determination. Gene observed that even sized pairs produced fry of near even sex ratios. Large males with small females produced female heavy spawns; and small males with large females produced male heavy spawns. It has been observed that old killifish pairs produce spawns of more even sex ratio. It is interesting to note, that older pairs tend to be more balanced in size than younger pairs where males rocket in growth and females often lag behind. (In the case of ravenous *Nothos* this normally means the slow growing females are eaten long before they mature giving rise to the impression skewed sex ratios favoring males.)

It goes without saying that the factors affecting sex ratio are rather mysterious. As a side note, *Gnatholebias* species, *Garmanella pulchra*, *Megupsilon aporosus*, *Nothobranchius furzeri*, *Nothobranchius guentheri*, *Orestias laucaensis* and *Oryzias latipes* are the only killifish currently known to have sex chromosomes, and hence will theoretically produce batches of fry of even sex ratio.

Part II

Killifish Review

What follows is a review of the more commonly available or beautiful killifish species and groups. This is to serve as a rough guide to the tremendous variety of killifish and their habits. Some general hints at breeding will be given where information is available.

It is advised that any serious killiphile consult Jiri Vitek and Jaroslav Kadlec's Compendium on Killifishes (http://www.akvarium.cz/halancici/killi3E.html) and Jean Huber's Killidata (http://www.killi-data.org) for a more comprehensive review of each species.

Chapter 6

Non-annuals and Semi-annuals

This chapter is an introduction to all killifish not considered to require a drying period for the eggs for proper development. Because of the sheer volume of species, it is not possible to cover each species in detail. Of all the species groups, *Aphyosemion*, is covered in the most detail, if but only because of its predominance in the hobby.

Collectively there are many more species of *Epiplatys* and *Rivulus* potentially available to the budding killinut, but it has been the brightly colored and relatively easy (mostly) to care for *Aphyosemion* that have gained prominence in the hobby.

Most of the fish can be bred using very much the same techniques, which have been covered in Chapter 5. Maintenance issues have been discussed in Chapter 3, and here additional information pertaining to each group are mentioned.

6.1 *Aphyosemion* and allies

This group ranges from Guinea to Northern Angola (Cabinda) and comprises two evolutionary distinct entities: the *Aphyosemion* lineage and the *Archaphyosemion* lineage.

6.1.1 *Aphyosemion*

The genus *Aphyosemion* is comprised of several subgenera: *Chromaphyosemion* containing the *bivittatum*/*bitaeniatum* killifish; *Diapteron*; *Kathetys* (the *exiguum*-group); *Mesoaphyosemion* (the *cameronense*-group) and *Raddaella* (the *batesii*-group) that does not seem to fit in anywhere taxonomically. Some people (such as the author) regard these four subgenera as genera. The fish of the genus *Episemion* is very closely related to *Diapteron* but are much more like *Epiplatys* in behavior and ecology.

The generic name *Aphyosemion* strictly applies to the fish of the *elegans*-group. In addition there are the *calliurum*-, *coeleste*-, *ogoense*- and *striatum*-groups, that were previously dumped into *Mesoaphyosemion* (which has now been restricted to the *cameronense*-group[1]). Remaining, are a small band of taxonomic oddities that do not seem to fit in anywhere.

The taxonomy of this group will probably not be settled for a long time to come. The *Aphyosemion* range from Togo to Northern Angola (Cabinda), and may stretch deep into the Congo river system. They inhabit sparsely forested savannah to tropical forest.

The *Chromaphyosemions* range from Togo (*Chr. bitaeniatum* to Northen Gabon (*Chr. alpha*) and include the island of Bioko in their range. It comprises the *bivittatum*-group of Scheel. Ichthyologists have pried the complex apart revealing no less than eleven distinct species. Collections in Cameroon, Gabon and Equitorial Guinea regularly turn up new species, most of which still need to be described. This subgenus is the most speciose in Cameroon, where seven species occur in addition to at least four undescribed species. All the fish are colorful with large sail-like dorsal fins. Colors range from dark reds to bright blue. These fish tolerate a wide range of temperatures from 18 to 27°C. Many will only breed at temperatures of 24°Cand above, while a few, such as *Chrom. loennbergii* prefer cooler waters. They can be found under the forest canopy in shallow streams as well as open savannah. All prefer small foods. They are perfect for permanent setups. Eggs take about 12 days to incubate, but some can take as long as 21 days. Fry are large enough to take bbs on hatching.

The species are: *alpha*, *bitaeniatum*, *bivittatum*, *kouamense*, *loennbergii*, *lugens*, *melanogaster*, *poliaki*, *punctulatum*, *riggenbachi* and *splendopleure*.

The old aquarium strain of *Aphyosemion multicolor* is a synonym for *bitaeniatum*, but in the hobby corresponds to a phenotype of *splendopleure*. *Chrom. splendopleure* is composed of several phenotypes which are strongly

[1] Sonnenberg, R. & Blum, T. (2004) *Aphyosemion (Mesoaphyosemion) etsamense* (Cyprinodontiformes: Aplocheiloidei: Nothobranchiidae), a new species from the Monts de Cristal, Northwestern Gabon. *Bonner Zool. Beiträge* **53**:211–220.

suspected to represent distinct species.

Of the above species, *bitaeniatum* is the most frequently encountered species; *poliaki* is perhaps the easiest to breed; and *riggenbachi* grows the largest: 9 cm. Most species reach about 5 cm total length. *Chrom. bivittatum* grows slightly larger.

Diapteron occur in the highlands of Gabon and Congo and require cool conditions to thrive. There are five described species but the fifth, *D. seegersi*, is in dispute, being considered as a junior synonym to *D. abacinum*, and will probably be synonymized with the latter, based on DNA and distribution data. These fish need small foods and are best bred in a permanent setup. Some species begin to breed from six months while others only start breeding from one year of age. Sex ratios are often skewed badly towards males. *Diapteron* are not beginners fish. They do best, maintained between 18 and 22°C, and fed a rich and varied diet of small arthropods such as *Daphnia* and *Cyclops*.

D. abacinum is the most popular, but in the author's opinion *D. cyanostictum* is the most beautiful, being crimson red with sky blue spots. *D. georgiae* and *fulgens* are also extremely gorgeous and always sought after by killiphiles. Males can be very aggressive towards each other. In spite of this, it is suggested that they be bred in small groups.

Kathetys are the beautifully colored *exiguum*-group. It is represented by *K. elberti*[2], *exiguum*, *dargei* and *kekemense*. All the fish are blue with red striping. Some populations have splendid yellow in the unpaired fins. These fish span the forest/savanah cross-over in Cameroon and Central African Republic. They can tolerate warmer temperatures (24–26°C) but need cooler temperatures (19–23°C) to breed. The fry can take bbs from hatching. These fish are not too difficult to maintain. The *K. elberti* Diang strain is perhaps the easiest strain to maintain as it tolerates and breeds at warm temperatures. The eggs are best incubated with some methylene blue.

The definitive source of information for this group is the JAKA *Kathetys* issue[3] compiled by *Kathetys* master breeder, Monty Lehmann.

Mesoaphyosemion was the taxonomic dumping ground for *Aphyosemion*. Strictly, this subgenus is reserved for the *cameronense*-group. This group has some of the most splendid fish conceivable. The group is composed of: *amoenum*, *cameronense*, *etsamense*, *haasi*, *halleri*, *maculatum*, *mimbon* and *obscurum*.

[2] *K. elberti* used to be known as *A. bualanum* but this taxon is now reserved for a different fish, not currently in the hobby. Some people argue that they are one and the same fish. Some people then argue that *elberti* is the correct name and *bualanum* the junior synonym. . .

[3] JAKA, **34** #s 5 & 6, 2001.

All require cool (18–24°C) water to thrive. They hail from the highlands of Cameroon, Gabon and the Congo. Some species do well in permanent setups while others need more attention. *Mes. amoenum* occurs on the Cameroon lowlands and may be more temperature tolerant (there is no concensus). Lowering the aquarium water level and increasing the frequency of water changes will encourage some strains to breed. Best foods are small aquatic arthropods such as *Daphnia*, but some strains can be coaxed to accept flake foods. My *A.* sp. aff. *cameronense* Makokou[4] subsisted for months on a commercial micro-granulate food.

Mes. cameronense is represented in the hobby by many strains, and at least eight distinct phenotypes, easily recognizable by color. These phenotypes are suspected to be distinct species but due to the innate variability of colour among living organisms, colour and slight variation in body form are not good indicators of distinctiveness between species.

The *coeleste*-group is composed of the following species: *aureum*, *citrineipinnis*, *coeleste*, *ocellatum* and *passaroi*.

These are reported to do best in cool water, between 18 and 24°C, with spawning occurring at the lower end of the range. The author and his friends' attempts to keep these fish have always failed (unless fed very heavily on small arthropods such as *Cyclops*) on account of intense summer heat, where upon the fish simply waste away.

These fish come from the Ogooue drainage of Gabon and are remarkably beautiful. In the same habitat are the fish of the *ogoense*-group, composed of: *ferranti*, *labarrei*, *caudofasciatum*, *joergenscheeli*, *louessense*, *ogoense*, *ottogartneri*, *pyrophore*, *tirbaki* and *zygaima*.

Aphyosemion joergenscheeli is a diminutive stunning green/blue cool water terror in great demand by killiphiles. They are best raised like *Bettas splendens*, or else in very large tanks. Males are alleged to fight to the death! In the wild the *joergenscheeli* males will stake out large territories while the females will shoal with the sympatric *Aphyosemion occelatum* in hope of avoiding the aggressive males. The other species, except *labarrei*, are not nearly as temperamental. While *joergenscheeli* does best in a large permanent setup with some dither fish, most can cohabit in smaller tanks without too much trouble. Many, as a single pair, will rapidly fill a tank with fry. Concerted mop spawning is also productive.

The *striatum*-group is composed of: *boehmi*, *escherichi*, *exigoideum*, *gabunense*, *marginatum*, *primigenium*, *raddai* and *striatum*.

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[4] In taxonomy and the above sense, sp. means "undefined species", aff. means "having an affinity or similarity to". So, the above name implies this fish from Makokou looks very much like a *cameronense* but we suspect it is something distinct but can't prove it yet.

For a long time, *boehmi* and *marginatum* were considered subspecies of *gabunense*; and are now considered to represent a species group of their own, but are more likely a recently evolved species complex.

A. punctatum and *wildekampi* used be part of this group, and are believed to be the closest phenoptye resembling the ancestors of the *ogoense*- and *striatum*-groups.

Of the species, most need cool water (22–24°C) and frequent water changes for breeding. While *striatum* and *gabunense* will spawn at warmer temperatures, the best results are had at temperatures near 24°C. All are adept jumpers. *Aphyosemion raddai* is very similar to *striatum* with its blue body and horizontal red stripes, but is reported to be a far more active fish.

For spawning, *A. punctatum* requires frequent water changes. In the author's experience, it can thrive at temperatures above 24°C.

Raddaella are represented by two species in Cameroon and Gabon. The type species is the splendid *Raddaella batesii*. These fish are difficult to maintain. They need temperatures between 20 and 24°C for breeding. Some authorities state the eggs need a dry period in peat for incubation, while others have great success with a permanent setup. Sex ratios are badly skewed—even in nature where one female can be caught for every nine males according to the breeder/collector Mr. Rudolf Koubek of Randvaal, South Africa. The second species is *Raddaella splendidium*. A third species, *Raddaella kunzi* is now regarded to be synonymous to *batesii*. These fish grow large; and while growing fast, they mature only late in life.

Fishes of the *elegans*-group are very striking. *Aphyosemion christyi* is the type species for *Aphyosemion*. In this group the following species can be found: *chauchei*, *christyi*, *cognatum*, *congicum*, *decorsei*, *elegans*, *lamberti*, *lefiniense*, *lujae*, *polli*, *rectogoense* and *schioetzi*.

Most have a basic blue body with red vermiculation. All have lyre tails, with some having extravagant extensions. The highland species prefer cool temperatures with most hovering on the threshold between cool and warm. These fish are not exceedingly difficult to maintain, but are often not as productive as some other *Aphyosemion* species. Mops or permanent spawning setups have proven fruitful.

The *calliurum*-group is composed of the old favorites: *ahli*, *australe*, *calliurum*, *celiae*, *edeanum* and *heinemanni*.

All but *australe* hail from Cameroon, coming from Gabon instead. The type species, *A. calliurum*, is found in Nigeria and Cameroon. They occur along the coast and are adaptable as far as temperature is concerned. Most are productive and easy to maintain. *Aphyosemion australe* is the most commonly available *Aphyosemion*. These fish will spawn in mops, over peat or gravel and do well in a permanent setup. Some report that *A. australe* needs acidic water to spawn well, and that adding tea or peat extract stimulates spawning and increases fertility. Temperatures between 20 and 26°C are seemingly fine for this group.

Aphyosemion hera is a beautiful green/blue fish with red stripes that is far more friendly than the *joegenscheeli*. It is a relatively new fish in the hobby and has rapidly become one of the more popular *Aphyosemion*. It is suspected to be related *A. pascheni* and the goby like *A. franzwerneri*.

There are many more stunning *Aphyosemions* but there just is not enough room to even briefly discuss them all. Other fish worthy of mention for their spectacular color are *Aphyosemion herzogi*, *hofmanni* and *wachtersi*.

Most of these fish will spawn on the substrate if denied floating or sunken mops. Given a choice between mops and plants, such as Java fern, they will normally choose the mops as a spawning substrate. A trick used to spawn some more demanding fish, is to separate and condition the sexes and then bring them together as a single pair over a shallow peat substrate for spawning. The fish are not fed, and only kept together for 24 to 48 hours. The peat is then stored semi-dry or kept under water with some frequent stirring to ensure the peat substrate does not turn anaerobic. It is important to do frequent water changes with cool water to retain water quality, and stimulate developed eggs to hatch.

Bill Shenefelt (AKA), supplies valuable breeding data on his website (http://shene.killi.net). Some of this data, concerning *Aphyosemion*, is reproduced in a table on page 60.

6.1.2 *Fundulopanchax*

The *Fundulopanchax* are semi-annual killies ranging from Ghana to Equitorial Guinea. Some of the fish grow large but most remain a manageable size. All are very attractive. Most will prosper at 24°C.

The*gardneri*-group is composed of several species and subspecies that are still taxonomically confusing. The two most commonly kept species are *Fp. garnderi* and *Fp. nigerianus*, which are near impossible to tell apart. These fish are all steel blue with red spotting. Some strains have yellow unpaired fins. All are easy to keep in the aquarium. They eat most foods (even dry foods) and do not normally molest their fry. The older fry will predate the younger fry so the older siblings are best removed. *Fp. mirabile* is represented by three diverse subspecies (a fourth was recently described as a full species). All are stunningly beautiful and undemanding. All are from Cameroon. The fish can be successfully spawned using mops, gravel or peat substrate, or in a permanent setup. *Fp. gardneri lacustris* is reported to be fully annual in reproductive nature, but the literature is not 100% clear on this issue.

As research on this taxonomically confusing group continues, no doubt more species will be defined. This entire group is placed in the subgenus *Paraphyosemion*, that may be promoted to full generic level with further research.

Fp. scheeli looks very similar to *gardneri* but is not included in the group as it has a different chromosome number. It too is undemanding in the aquarium. *Fp. marmoratus* and *oeseri*[5] share the same taxonomic grouping with *scheeli*. A fish very similar to *Fp. oeseri* has been collected in Cameroon. Because it is also very similar to *Fp. marmoratus*, this fish has not been assigned to any species as of yet, and may be an intermediate between the two meaning that *marmoratus* may be synonymized with *oeseri* in the future.

Fp. ndianum forms the type species of the *ndianum*-group. In this group is the stunningly beautiful *Fp. amieti*. This fish's beauty was recently surpassed by the smaller *Fp. avichang* collected in Equatorial Guinea. These fish are semi-annual. Their eggs take about four to six weeks to develop in water and about two to three months in peat. They grow rapidly and are not picky eaters. Getting them to spawn can be challenging. Permanent setups seem to work best. They prefer cool to warm temperatures. *Fp. puerzli* is a much easier fish to care for. It is productive and hardy. The spectacular *Fp.* sp. Korup National Park has recently made its debut on the killifish scene and is a fish to behold. *Fp. spoorenbergi* is a larger member of this group. It is accused of producing very skew sex ratios (one male to as many as 50 females!). This can be overcome by spawning and raising the fry at warmer temperatures (26°C according to David Ramsey, AKA). *Fp. cinnamomeus* is a very different fish to the rest. It has a purple/grey body with yellow edged fins. It is the most demanding member of this group, but still not a difficult fish.

These fish are often best spawned over a substrate of peat or peat moss, that is removed and incubated semi-dry for about six weeks and then rewet to yield many fry. Alternatively the peat can be kept submersed as described for *Aphyosemion* on page 57.

Fp. walkeri is another attractive easily maintained fish. Some strains have lovely orange in the unpaired fins. The Kutunse GH2 strain has brilliant vertical red striations along its neon blue flanks. This strain also represents

[5] *Fp. oerseri* is regarded as being extinct in the wild. All the fish are descendant from the Fernado Po strain. The location at Fernado Po has since been destroyed and no other locations have been found. The American Killifish Association has a conservation program setup to ensure the survival of this species.

one of the major triumphs of the killifish hobby. Shortly after collection, the collection location was destroyed, and the wild population of this phenotype lost. Only through concerted conservation efforts of the American Killifish Association has this strain survived to today. All the fish of the Kutunse strain in the hobby are suspected to have passed through the fishroom of one Mr. Wright Huntley of California.

Fp. filamentosus and *arnoldi* are two annual species that are very attractive. Both have lyre tails and are a brilliant blue-lavender with orange fin coloration. *Fp. rubrolabiale* is slowly making a come back via commercial fish exports from Cameroon but is not nearly as colorful as the previous two species. These fish require a two to three month incubation period in moist peat. These three species are assigned to the subgenus *Paludopanchax*.

Fp. sjoestedti is the king of killies. It reaches 15 cm in length, eats anything and lays eggs by the hundreds when you can get it to lay eggs at all. The eggs take about three to six weeks to develop in water, and about six weeks to three months to develop in peat. The fry grow at a furious pace. It breeds best around 24°C but can do well at warmer temperatures but most breeders suggest temperatures below 24°C. (Confused? So am I.)

The related *Fp. gulare* and *kribianus*[6] also grow large and are productive and very colorful. This group can be spawned over peat with containers like *Nothos* and South American annuals (see section 5.2). Unless large tanks are used the sexes are best kept apart till spawning.

Adding tea to the water has proven successful for the author in improving egg viability of *sjoestedti*, which can be terrible at times. Eyed-up eggs do not last long in peat and are best wet as soon as they eye-up. Incubating the eggs on top of peat is recommended.

The killifish breeder, Bill Shenefeldt (AKA), reports that most *Fundulopanchax* prefer to spawn in bottom mops or in fine gravel. *Fp. gardneri* types need about three weeks water incubation, while the larger species (e.g. *gularis* types) require six to 10 weeks incubation in damp peat.

6.1.3 The fish that were *Roloffia*

Callopanchax, *Scriptoaphyosemion* and *Archiaphyosemion* were previously known as "*Roloffia*"—a name still used by die-hard German killifish fans. Of the three, *Archiaphyosemion* is the most ancient group. Its species are rarely encountered as they hail from politically inhospitable places like Sierra Leone and Liberia. *Archiaphyosemion guineense* and *petersi* is perhaps the most frequently available species of this genus.

[6] This fish is considered to be synonymous with *Fp. fallax* by some authors.

Breeding data in respect to temperature, tds and breeding method. Data taken from http://shene.killi.net/Articles/shenebreedingfish.htm by Bill Shenefelt (AKA). pH, unless otherwise stated, can be assumed to be be between 6.4 and 6.8. There parameters work the best for the Bill, but may not be the best for you.

Species & Strain	°C	TDS	Notes
A. australe BSWG 97-24	26	50–100	single pair ignores fry
A. australe Aquarium Strain	26	50–100	
A. congicum Z 82-17	25	50–100	pH $<$ 6.5, mature, acidic water; single pair ignores fry
A. lamberti BSWG 97-9	25	60–150	
A. ocellatum N'Zele	21	50–100	single pair ignores fry
A. ogoense Kimono Yellow	22	60–150	single pair ignores fry
A. ogoense GHP 80-24	20	60–150	single pair ignores fry
A. ogoense Poubara	22	60–150	single pair ignores fry
A. o. pyrophore RPC 18	21	60–150	single pair ignores fry
A. raddai Medouneu	25	60–150	single pair ignores fry
A. rectogoense PEG 95-16	25	60–150	group spawn then move mop
A. schioetzi CHG 85-1	24	60–150	
A. sp. aff. *primigenium* GBN 88-10	25	60–150	single pair ignores fry
A. striatum LEC 93-24	22	50–100	single pair ignores fry
A. zygaima CMBB 89-1	22	50–80	pH $<$ 6.5, single pair ignores fry; rear fry $\leq$21°C to get females
Chrom. bivittatum CI 2000	26	50–80	group spawn, then move mop
D. cyanostictum	20	30–50	
D. georgiae 90-18	20	30–50	
D. fulgens	20	30–50	
D. abacinum	20	30–50	
*Fp. kribianus**			spawned over peat
Fp. gardneri	24	60–150	single pair/group ignores fry
Fp. greseni Takwai		60–150	multiple pairs seem to ignore fry
Fp. puerzli		60–150	single pair ignores fry
Fp. scheeli	24	60–150	single pair ignores fry
Fp. sjoestedti		60–150	spawned over peat
Scr. roloffi cauvetti	24	60–150	single pair ignores fry

* Huber synonymizes *fallax* with the senior taxon, *kribianus*.

Callopanchax is composed of three (perhaps four) species. These are *monroviae*, *occidentalis* and *toddi*. *C. huwaldi* is the putative fourth species, but is regarded by some authorities to be synonymous with *occidentalis*. All are true annual fish. They are very colorful and grow to a reasonable size very quickly. Their breeding is complicated. They are often difficult to spawn, and the eggs take up to eight months to develop. Most sources report the incubation time to be six weeks to four months. They are also very aggressive towards each other and will take every opportunity to jump out of the tank. Their growth is rapid and the fry are not picky about what they eat.

Scriptaphyosemion contains several species that are commonly available in the hobby. These are *cauveti*, *chaytori* and *geryi*. These fish are easy to spawn and are very attractive little fish. These fish spawn well in permanent setups, in mops, or over gravel.

The *Callopanchax* inhabit the coastal plains and tolerate warm water temperatures. The other species prefer cooler conditions, but generally prove adaptable. Both *Archiaphyosemion* and *Scriptoaphyosemion* can be handled much like any other *Aphyosemion* while *Callopanchax* is best handled as an annual.

6.2 *Aplocheilus* and allies

Aplocheilus, *Epiplatys* and *Pachypanchax* form an ancient group of killifish. *Aplocheilus* occur in Asia; *Pachypanchax* occur on Madagascar and the Seychelles; and *Epiplatys* occur in Africa. All are surface cruising fish. Relatively few are spectacularly colored, but those that are are magnificent. Most are easy to keep and breed in captivity.

The easiest species are those of the genus *Aplocheilus*. These fish grow large, eat anything and can often be seen in pet stores. These are tropical fish in the true sense. 30°C is normal for these fish, but they can stand cooler temperatures down to about 18°C. All are colorful and reproduce easily. *A. lineatus* is available in two color forms: red and gold. They also jump…Egg incubation is ten to 14 days, and the hardy fry are large enough to take bbs on hatching. Growth is rapid.

Pachypanchax are in peril. Of the three accepted species the two on Madagascar could soon become casualties of the environmental catastrophe that is Madagascar. Habitat destruction is rife and the species do not have a wide distribtuion. Several undefined species have recently been discovered. These fish reproduce easily and feed well, taking most foods offered. The Seychelles *P. playfairi* has been translocated to the Island of Zanzibar where it supposedly flourishes. Alas these fish are not as common in the hobby as they used to or should be. Both the American and the British Killifish Associations have programs in operation to try and boost the numbers of these fish in captivity. They all spawn readily and the large, hardy fry are not difficult to raise. All are very beautiful. They can get a bit belligerent as they age. A peculiarity of these fish is that the scales of the male fish stand up when in breeding condition as if the fish had dropsy.

The genus *Epiplatys* is widespread and diverse. The most popular species are the Rocket killi *Pseudoepiplatys annulatus*, and *Epiplatys dageti*. The former is best maintained in a permanent setup. Its fry are very small, needing infusoria on hatching. Scheel found *Paramecium* to be too large a first food for these fish. Fed rotifers (that they find among surface plants) they survive well. The fish is not long lived and much care and attention is needed to maintain it. It does best around 23°Caccording to some authors, but killifish friends of the author in Singapore have no trouble breeding this fish in the hundreds. Adding tea to the water has been reported to be beneficial in encouraging spawning and boosting viability of the spawn. A dense covering of floating plants seems to aid in fry survival. *Riccia* is supposedly a good plant to use.

E. dageti is a robust fish that is very productive and easy to maintain. Its fry are large enough to take bbs from hatching. This fish can be so productive that it can fill every tank you have with fry without you noticing. The eggs are laid in plants (and mops), and the indiscriminate exchange of plants between tanks can spread the fish around like the common cold. The subspecies *monroviae*, has an orange to red throat and brighter colors.

These fish do not like being kept together in crowded conditions. They are very susceptible to disease under such conditions. Such dense conditions can spark an epidemic (hypothesized to be bacterial or protzoan–perhaps *Costia*—but no one has bothered to find out exactly what it is) where the fins clamp up and the skin takes on a slimy appearance. The disease can be treated with acriflavine. Such maladies are common place in crowded tanks, and all fish are susceptible, but not equally so. In the wild, the fish of this genus are reported to shoal. In captivity, males can be belligerent.

Other commonly encountered species are the stunning *E. ansorgi*; the easy to breed and maintain *E. chaperi*; and *E. sexfasciatus*. *E. fasciolatus* is also becoming common.

There are many more species of *Epiplatys*. Most are lovely and easy to keep fish. Some are difficult to breed due to special temperature needs (cool water), or the susceptibility of the eggs to bacterial infection or handling. Some grow large while others remain tiny. Some are dull and uninteresting, others (such as *E. lamottei*) glow in the dark. The former only becomes sexually mature at nine to 12 months, while *dageti* can spawn at as young an age as three or four months.

6.3 *Rivulus*

The genus *Rivulus* is diverse and current taxonomic research threatens to break it up into several smaller genera. There are at least 90 supposed species ranging from Southern Florida to Argentina.

Color patterns are diverse. Some have green/blue bodies with red or orange striations, while others are leafy brown with blue/green sides, still others are covered with small spots from snout to tail. All have the "rivulus" spot in their tails. Some are far more extravagant as regards color. *R. xiphidius* is one such fish. It is adorned from head to tail with a broad neon blue stripe, that is strikingly contrasted by a dark band. Its body color ranges from bright orange to deep red, depending on collection locality. It requires cool conditions to do its best. It tends to throw very skew sex ratios depending on the water parameters. Cooler and softer water is reported to skew the sex ratio in favor of females. 24°C is the all round best temperature for egg productivity and sex ratio.

R. rectocaudatus is very colorful. So colorful, that it is often hard to tell the males from the females! *R. agilae* is another colorful fish. It reaches a decent size but like most *Rivulus* it is not very exciting as it lurks about the tank—but the same can be said for some of the more popular and extravagant *Aphyosemion*.

In spite of their lack of activity, their habits can be endearing. They will often approach the front of the tank to meet their keeper, before disappearing back into the plants after eating. There antics of sun bathing above the water line make them quite curious pets. Their eyes are positioned pointing forward, making their faces appear to almost look directly at you, the keeper. The reason for this, is perhaps an adaptation to spending so much time out of water along stream banks hunting down small insects and worms out of the water!

R. cylindraceus is another colorful species regarded as a good beginners fish.

All the *Rivulus* lay large eggs that take about 21 days to develop. The fry are large, being able to eat bbs on hatching. The adults will spawn in bottom mops. These fish are not very productive however. Their eggs are large and normally a high percentage are fertile. Spawning is stimulated by shallow water and/or water changes.

One (of many) interesting *Rivulus* is *Kryptolebias marmoratus* that is a hermaphrodite. Each fish is both male and female. It produces sperm and ova that are fertilized internally. All fish are born with the female phenotype: dull brown. However, under environmental stress such as temperature, males can be produced that are humbly colored with yellow, blue and red. This fish was recently moved to the genus *Kryptolebias* and will most likely be broken up into several different species distributed from the southern USA to Brazil.

Rivulus are avid jumpers, and will not be able to resist the slightest temptation to show off their acrobatic skills. Their aquarium must have a hood on at all times. They prefer live foods. Most fish do well at cool to warm temperatures. Some prefer cooler conditions while other prefer warmer temperatures. It is suggested that one research the needs of each individual species; but most likely you will be the first researcher.

It is impossible to generalize about this group due to its size, but it would be safe to say they can be dealt with like *Aphyosemion* whose niche they fill in South/Central America.

6.4 North American native killifish

Due to the dominance of the African killifish in the hobby, the charming killifish of North America are largely neglected. This section will focus on three groups of fish: the *Fundulus*, springfish (*Crenichthys*) and pupfish .

The 48 species of *Fundulus* are encountered from Florida to New York State. Many can be described as stunningly unattractive, homely little stripy fish. Some can be gorgeous such as *F. rubrifrons* and *F. catenatus*. The rather dull *Fundulus zebra* is spectacular.

All are adaptable little fish. Many species occur in marshes, others in streams. All make good aquarium subjects and many reproduce freely. The mummichog *F. heteroclitus*, is famous for its ability to survive in the most degraded habitats. This little fish is often encountered in bait shops, which is sad as the breeding males have spectacular yellow bellies and bright blue barring.

Fundulus cingulatus is a pretty yellow killi from Florida with brown/red spots running down its flanks. It can be spawned with mops like most other *Fundulus*.

The Bluefin killi *Lucania goodei* from Florida will spawn freely in mops. This fish is commonly found for sale in pet stores in the USA. It often hitches a ride into stores as eggs on aquatic plants grown in Florida. This is an easy, undemanding species. The three-tenors fish *Lucania parva* is so adaptable that it has established ferrel populations in California after hitching a ride in the ballast water of ships. They can tolerate full strength sea-water but need freshwater for breeding.

The springfish of the genus *Crenichthys* are charming little fish deserving of attention. They make delightful aquarium fish, as attractive as many rainbowfish according to some sources. There are two species: *baileyi* and *nervadae*. Several subspecies exist of *bayleyi*. Both species are restricted to two valleys in the South East USA and are endangered by introduced fish species. These fish are closely related to the Goodeidae. The springs that these fish inhabit are clear alkaline to neutral waters with sandy bottoms. The fish ingest primarily plants and algae in the wild, suggesting a diet of spirulina flake in captivity would suffice.

Crenichthys baileyi grandis is able to tolerate temperatures from 5 to 35°-C, other species have been recorded living at temperatures of 38°C. The fish will spawn among plants or roots near the bottom of the spring suggesting mops would work in captivity. Eggs take eight to ten days to develop at 25°C. The fish, in captivity, are reportedly intolerant of large water changes.

A frequently overlooked feature of both the spring and pupfishes is the ability to flash chromatophores like rainbowfish in order to attract mates. Springfish are yellow to gold, while most pupfish are neon blue.

Pupfish (*Cyprinodon*) inhabit some of the most inhospitable water-holes in the world. None so infamous as Devil's Hole and its Devil's Hole Pupfish, *C. diabolis*. This little fish is unique—not because it sole habitat is an algae covered ledge in a deep hole—but because it stopped the inexorable march of "progress". Because of the delicate nature of this fish's habitat, Las Vegas had to find another source of water. The exhaustive pumping of under ground water in Nevada by Las Vegas was draining the sink hole the fish found themselves in. A judge ruled the fish too special to loose, and the water pumping was stopped.

One subspecies of *C. salinus* tolerates water four times more saline than sea water, while the geographically nearby *C. nevadensis* lives in soft water springs. *C. radiosus* is capable of surviving in frozen-over puddles in winter, to summer temperatures exceeding 30°C.

Little is known about their captive requirements as many are threatened species, and so illegal to maintain. The exceptions are *C. dearborni*, *C. macularius* and *C. variegatus*, for which much is known. These fish turn neon blue in the breeding season—well the males at any rate. They do best at about 27°C. Their main diet is algae, and should be fed a high quality *Spirulina* flake in captivity. They will spawn on mops or pieces of filter floss, but will not molest fry, so a permanent setup will suffice for breeding. The eggs take four to 16 days to hatch depending on species and temperature. On hatching, the fry still have large yolk sacks and will not swim initially. They are free swimming several days after hatching and are easily raised on bbs and microworms. They benefit from some salt being added to the water.

C. dearborni is suggested as a good beginners fish that is hardy with the addition of one teaspoon of sea salt per gallon of water.

The most commonly available member of the pupfish group is *Jordanella floridae*, the American Flagfish. This fish grows to 6 cm and is adorned with red and sparkling blue/green stripes with one to many black spots midway along the flanks. These fish do well in captivity, where it will eat most foods offered. Its favorite food is hair algae, which makes it a tremendous asset in planted tanks. The only drawback is that males can be territorial. The fish exhibits two spawning strategies. With the first strategy the males will stake out a territory and create a “nest” where females will be lured in to spawn. The fierce protection of this site has lead to reports that this fish will protect its brood like cichlids. With the second strategy, the male does not select any particular site for spawning, but will spawn wherever in its territory, even in spawning mops.

Jordanella floridae and *Garmanella puchra* are both salt tolerant and have spread all along the Mexican Gulf coast. The latter is able to breed in sea water. *Adinia xenica* is another attractive sea water tolerant killifish. These fish are temperature tolerant, capable of surviving both cold and tropical temperatures.

Most fish in this grouping, benefit from a cooling period, simulating the natural summer/winter cycle.

6.5 *Aphanius* and related species

The *Aphanius* species of Africa, Europe and the Middle East fill the same niche as the pupfish of North America. There are two genera in this group: *Aphanius*(the name *Lebias* for this group has been rejected by the ICZN) and *Valencia*.

These fish inhabit small pools, springs and streams that are often subject to extreme temperatures and temperature changes. Many fish are endemic to a single location. Many are under threat of extinction due to introduced *Gambusia*.

These fish are not overly popular in the hobby. The most popular species is *Aphanius mento*. This is a jet black fish with a multitude of blue spots on its flanks. It spawns readily and is hardy but needs hard saline water of at least one teaspoon of salt per gallon of water to do well. They tolerate a wide temperature range from below 14°C to well over 30°C. All require vegetables in their diet. Spawning begins at low temperatures. Egg incubation is 14 days at 18°C.

The two species, *Aphanius sophiae* and *Aphanius vladykova* are doing the rounds in Britain currently. These fish do well in hard alkaline water, and tanks of at least 40×30×30 cm with a simple sponge filter and Java fern. The eggs are 2 mm in diameter and robust. The fry hatch from the eggs 14 to 15 days after spawning and are able to take bbs. The growth rate is steady with the fish sexing out at three months. The fish are not picky about what they eat. The males of this genus have a reputation for being a bit aggressive.

There are two species of *Valencia*. *V. hispanica* is the best known of the two species. It was originally distributed along the eastern coast of France and Spain but the French populations are long since extinct. The Valencia strain of *V. hispanica* is a lovely gold fish with faint vertical dark barring along the flanks. The fish reaches a maximum size of 8 cm. It favors freshwater with little salt content, and a neutral to alkaline pH. It tolerates temperatures between 8 and 26°C. It does best in well planted tanks where it will spawn among the plants (or spawning mops). The eggs take two weeks to develop and the fry are large enough to take bbs on hatching.

These fish benefit from a cooling period, simulating winter.

6.6 Lamp-eyes

Lamp-eyes are an interesting group, largely neglected by the majority of the killifish hobby. They are evolutionary ancient: the *Poeciliidae*. In Africa they radiated into many different egg-laying species, while in the Americas only one egg laying genus remains (*Fluvipanchax*), while all the other species are live-bearing. Only the egg-laying species will be discussed here.

The members of this family are small to medium size fish. Few have spectacular colors. Some more common species are *Lacustricola katangae* and *bukobonus*; *Poropanchax normani* and *Poropanchax stennatus* (formally *Aplocheilichthys scheeli*). *Aplocheilichthys spilauchen* is becoming available in pet stores, but remains rare in the hobby.

Lacus. katangae occurs from Kinshasa, Congo to Kosi Bay, South Africa. This fish reaches about 6 cm in length. It is covered in turquoise scales with a dark horizontal stripe running along its flank from mouth to tail. Its fins may be clear or yellow. It spawns freely laying large eggs that are almost always fertile. Adult females can lay five to six eggs per day. The fry are the size of baby guppies and grow rapidly. *Lacus. bukobonus*, from Uganda and Kenya, is a smaller species but is both very productive and attractive. The fish is an iridescent blue/green. The fins have clear yellow to orange striping. This species does well in a permanent setup. The most commonly available species in the hobby as of late are *Lacus. kassenjiensis* and *pumilus*.

Porop. stennatus comes from Cameroon. It is not a spectacular fish, but like *Porop. normani*, it is attractive as a large shoal. Both are productive, hardy little fish that eat most foods offered. Both are routinely available in the pet trade. *Porop. luxophthalmus* is also seen occasionally in the trade.

Aplocheilichthys spilauchen will spawn in mops, laying large eggs. They do well with some salt added to the water, but seem to spawn best without it. There are various strains with varying amounts of yellow in the fins. In some strains the yellow is replaced by red. It is suggested that this color is diet related and not genetic. They enjoy a warm aquarium.

The Tanganyika Pearl Killifish *Lamprichthys tanganicanus* is always very popular with killiphiles, but has a bad reputation. It is said to require hard alkaline water for survival—never mind spawning. It is also said to ship poorly. On the other hand, there are people who cite no difficulty in maintaining and spawning the fish.

The fish of the genus *Procatopus* are richly adorned with red, blue and orange in the fins. The body is iridescent blue. Like the lamp-eyes mentioned earlier they are very productive but prefer a more rigid spawning structure than a loose mop. Often the gender ratio is badly skewed. Wolfgang Sommer[7] corrected for this by incubating the eggs in peat.

P. nototaenis is perhaps the most attractive member of the genus.

Procatopus are the most commonly kept lamp-eyes in the hobby—perhaps only because they are commonly exported from West Africa—and do excellently in planted tanks with high water quality. *P. similis* is the species most commonly encountered on the market.

Other attractive genera to look out for are *Hypsopanchax*, *Plataplochilus* and *Rhexipanchax*. *Pantodon* (which may be reclassified to a totally different order) is also a very attractive lamp-eye, but only survives in brackish water.

These fish require high water quality: clean and well oxygenated. They appreciate currents to swim against, and may be caught spawning against powerhead filters. They should also be fed a varied diet. Fry care is straightforward.

[7] **W. Sommer** (1996) Lampeyes: Neglected Beauties. *TFH* 45(4):86–92

Chapter 7

Annual Killifish

Annual killifish are no more difficult to breed and maintain than the afore discussed non-annuals. Annual fish do require more patience from the keeper, and the often long wait between spawning and hatching leaves room for a lot of error. With a little experience, this long wait becomes a blessing more than a curse.

The African annuals are well known in the hobby, and their generally uniform care recipe has made them very popular and easy to maintain. The South American annuls species are far more diverse in habitat and breeding, making them more challenging—and so also more rewarding to the annual killifish aficiado. For many species, the secrets to successful breeding are still not widely known. To the author this group remains a challenge, with such treasures as *Simpsonichthys flammeus* and *igneus* remaining the stuff of dreams.

7.1 African Annuals

African annual fish are some of the most splendid fish in the world. Some have the most brilliant blue bodies, with striking red tails. Many have bodies vermiculated with blues, oranges and violets, while others are more subtle, but no less beautiful. Some are easy to maintain and breed, while other are more challenging.

7.1.1 *Fundulosoma*

The genera *Fundulosoma* and *Pronothobranchius* each contain only one species: *F. thierryi* and *Pron. kiyawense*. *F. thierryi* has a remarkable distribution stretching from the Niger delta, up along the Niger river into Mali and then into Sengal and Gambia along the Gambia river. *P. kiyawense*, has an equally large distribution along the Niger river, as well as up to Lake Tchad, and even into the Central African Republic.

These are annual fish, which while being splendidly colored, do not reach an appreciable size. The eggs are not that small, relative to body size; and the resulting fry are well able to take bbs from hatching. The fry are sensitive to velvet. The eggs can be erratic in development time (especially for *kiyawense*). *F. thierryi* eggs can eye-up at only three weeks, but an incubation time of three months is more typical. The eggs of *P. kiyawense* eggs are reputed to survive up to 30 years in peat! There normal incubation period is about six weeks to six months. It is suggested, that the prospective breeder routinely sift egg containing peat, and wet those eggs that are ready to hatch.

7.1.2 *Nothobranchius*

Nothobranchius come from East and South Central Africa. They occur as far North as Sudan and as far south as the peat marshes of Kwa-Zulu Natal, South Africa. The western extreme of their distribution is currently Lake Tchad, but there are unconfirmed reports of *Nothos* in eastern Nigeria.

Aphyobranchius is a subgenus of *Nothobranchius* and contains some of the most difficult to rear *Nothos*. The fry are tiny, requiring infusoria for extended periods of time. The fry seem only to take *Paramecium* and small worms (but refuse vinegar eels). The adults are picky eaters and often refuse to spawn in a tub, requiring that the whole substrate be covered in peat.

They are all lovely and active fish that are long lived in captivity. They are constantly swimming about in the upper water column displaying to one another. In large tanks they will shoal.

The critical “trick” to breeding these fish is to only rear small numbers of fry. You want about ten fry per 2 L tub. Stuff the tub with Java moss and feed powdered food and add some snails. The snails and infusoria consume the powdered food and produce more infusoria for the fry to feed on. After two weeks the fry are ready for bbs. Barry Cooper (AKA) reports success with feeding Azoo artificial rotifer powder. Observations by the author and Ian Sainthouse suggest the fry only prey on *Paramecium* and small worms.

The eggs develop in a staggered fashion, with the first eggs eyeing-up in weeks rather than months, but viable undeveloped eggs can still be encountered six months after spawning.

A diet of bbs is inadequate for the adults. The diet needs to be supplemented with a variety of live and frozen foods. These fish can be tempted to take dry foods such as *Spirulina* flake, but they do not relish this diet. Beef heart is also taken but should not be fed exclusively, and water quality should be carefully monitored.

This group consists of three species: *geminus*, *janpapi* and *luekei*. *N. willerti* is often included in this group. *N. annectens* shares some similarities with these fish suggesting this is an purely artificial grouping.

The rest of *Nothobranchius* is composed of two other subgenera: *Zononothobranchius* and *Paranothobranchius* Some authors include a third subgenus: *Adiniops*. The taxonomy of this group is still under study, with DNA evidence for the intra-relationships awaited shortly.

Nothobranchius are some of the most easily maintained killifish. They tolerate a wide range of temperatures, have large fry and are very productive. Their only drawback is that the eggs need to be dried for an extended period of time and few species live longer than about 18 months.

Nothos can be divided into short, medium and long duration incubation species. The short incubation species take one to three months for the eggs to eye-up. The medium incubation species take three to five months, and the long incubation species may need five to nine months if not more. Some species, such as *N. furzeri* exhibit an erratic incubation period spanning weeks to years.

Of the short incubation species *N. foerschi* (the authors favorite), *korthausae* and *palmqvisti* are the easiest fish to maintain. All are colorful fish that are uncomplicated in maintenance. The golden rule with all *Nothos* is the addition of half to one teaspoon of salt per four liters of water, to stave off velvet in the case of soft water. The addition of some calcium carbonate to buffer the pH is recommended instead of table salt. The *Notho* breeder, Ian Sainthouse (BKA), does not use salt at all in spite of his soft water. He instead puts extra effort into maintaining clean water in his tanks, that discourages velvet out-breaks. The author has done likewise in the past with good results.

The fry grow rapidly, being sexually active at one to two months. The fish are very productive, with well conditioned females of certain species laying as many as 50 to 75 eggs per week. They can live up to 18 months. Other, more short lived species (e.g. *N. furzeri*), can lay much more than 50 eggs per day!

N. guentheri has an incubation period of three to four months. The fry are robust and not difficult to rear; and the adults are long-lived. This is an excellent beginners fish. *N. eggersi* is another medium length incubation species. It occurs as two forms: red and blue. Here too, the males are hard on the females. They are short lived. *N. jubbi* is another medium incubation species that is attractive and easy to maintain. Some difficulty is had in obtaining balanced sex ratios but this problem can be corrected (supposedly) by raising the fish in lots of two fry from two or three days after hatching.

Of the longish incubation species, it is the fish of the *kafuensis*-group that are the most attractive. These fish are stunningly colorful. *N. kafuensis* occurs in several color forms, from sky blue (the Caprivi phenotype), to purple-blue to flaming orange. The related specie, *symoensi* is a magenta color; while *N. rosenstocki* is more like a dulled down *N. rachovii*. The major stumbling block with these species is wetting the eggs too soon. This can result in many belly-sliders. The next stumbling block is growing out the fry. The males grow quickly but in bursts. Remove the larger fry else they will consume all the females before you know what you have. Females take a while to fatten up. Males can drive females very hard, so it is best to keep track of the state of the females and separate them when needed. Most fish live between nine and 12 months in captivity.

The most impressive and popular species is *N. rachovii*. Both the red Beira and the black strains are impressive fish. The fry are small, and according to some authors, may need infusoria at first (this has not been the author's experience with any of the strains). The fish grow very fast. They can be spawning in six weeks or less! While *N. furzeri* is short lived (three to four months), *N. rachovii* is long lived (as much as two years). The other long incubation species: *N. orthonotus* can live about a year depending on strain. It occurs in two color forms: red and green. The red strain is reported to be more aggressive than the green. In the author's experience the green is rather nasty itself. Mixed red/green strains exist, which are more docile than the pure strains.

Many *Notho* eggs respond well to a period of cooling down to 14 to 16°C. After the cooling, and the gradual increase in temperature, the eggs will develop rapidly but care must be taken not to wet the eggs too soon. Eggs incubated at temperatures above 26°C will develop much faster than normal. At an average temperature of 29°C the eggs of *N. eggersi* will be ready to hatch in four weeks and the eggs of *N. rachovii* in six. This rapid development at high temperature has the disadvantage that the window for successful hatching is greatly shortened. Being one week too late in wetting the eggs could see a reduction in yield of up to 70%. The best incubation temperatures are between 23 and 25°C.

You never want to sit with 200 fry (which is not too difficult). Ideal broods should be about 40 fry. These can be comfortably reared to adulthood on a diet of bbs and chopped bloodworm. A more diverse diet supplemented with other live, frozen and dried foods is best for the fish and the wallet. Fish fed only on bbs can develop a nervous disorder where they dart about the tank in a panic injuring themselves. This may be due to a HUFA shortage. The author begins to feed fry on chopped bloodworm from as young an age as they can take it. It is very important to feed the fish generously to attain proper growth, else the females may never grow large enough to spawn productively. With heavy feeding, large frequent water changes are essential as these fish do not tolerate heavy filtration. By introducing the fry to dried food early on, feeding problems associated with these fish can be avoided.

Observations made in the author's former lab suggested that longer lived *Nothos* take longer to learn how to use the spawning tubs than shorter lived species. Once adult, *N. furzeri* took to a spawning tub in minutes while *N. kilomberoensis* took two months to learn the function of the tub.

7.2 South American Annuals

South American annuals are a diverse group composed of several evolutionary lineages, that conveniently help subdivide the "general care" demands of these fish.

In the South, and along the Eastern sea board, one gets the *Cynolebiatinae*. All the members of this group used to be known by the genus name *Cynolebias*. This large genus has been split up and the name *Cynolebias* is now restricted to a handful of "monsters". The popular species are assigned to the genera *Austrolebias* and *Simpsonichthys*.

Austrolebias nigripinnis is the star of the show. This small fish is a dark chocolate to jet black with shimmering white or blue spots. It is an undemanding little fish from Argentina, Paraguay and Uruguay. In the wild it is found in habitats that freeze over, but is able to stand high temperatures without problems. It spawns willingly and can be very productive. The only snag is that the fish will often produce many belly-sliders on hatching. This is corrected for by wetting the peat with cold 10°C fresh water with some peat extract added. According to some hobbyists, the problem can be totally avoided by incubating the eggs at a low temperature (about 20°C). The fry are able to take bbs from hatching. Other popular species from this genus are *A. alexandrii* and *A. bellottii*. Most are easy to care for. Best growth is had at temperatures around 18°C.

Other striking members of this genus are *Austrol. affinis*, *Austrol. adloffi*, the highly variable and popular *Austrol. luteoflammulatus* (beautiful yellow tinged fins), *Austrol. uruguayensis* (now more correctly called *Austrol. arachan*), *Austrol. viarius*.

These are all cool water fish. The rainy season is during the winter. During summer the pools dry out and the fish perish either by dehydration or heat exhaustion. The eggs require a cool incubation on account of evaporative cooling of the ponds. While there is just as much rain during summer as winter in Argentina, Paraguay and Uruguay, due to the increased heat the pan dry out, but not by direct evaporation but by the plants pumping the water out of the soil into the atmospher by transpiration. Incubation is between three and four months for most species.

Simpsonichthys occurs from Paraguay, north up to just below the Amazon River. The Southern species can tolerate cool water conditions while the Northern species must have tropical conditions.

The most popular member of this genus is *S. whitei*. This fish was first collected by General White in the 1940s. It has been maintained in aquaria since the late 1940s. This fish is chocolate brown with gold/blue iridescent spots along the flanks and in the unpaired fins. It will take flake food and grow to about 10 cm without problems if raised at cool temperatures. It can live for almost two years. Females are very productive. The eggs can be water incubated. Peat incubation takes eight to 12 weeks. Some strains are fairly placid while others can be aggressive, with the males fighting incessantly. A temperature of 24°C is suggested for breeding. This fish is so easy to care for even the author has little difficulty with it!

Other attractive *Simpsonichthys* are *Simp. fulminantis*, *Simp. magnificus*, *Simp. picturatus* and *Simp. zonatus*. There are many more species, but these are the most commonly available in the hobby. While *S. whitei* and *constanciea* can tolerate temperatures down to about 16°C, most of the others require warmer water, around 24°C minimum. Friends in Singapore are having no problems keeping and rearing these fish (particularly the more challenging *Simp. magnificus*), suggesting tropical conditions to be key in long term maintenance of *Simpsonichthys* species.

Incubation for the coastal *Simp. whitei* and other species is a mere six weeks, but can take as much as four months. The inland species of the Rio Sao Fransisco, requiring more tropical conditions, require an incubation period of three to four months at 24°C and above.

Fry of *Austrolebias* and *Simpsonichthys* are in general large and easy to rear (with the notable exception of the gorgeous *Simp. costai*). They will thrive on bbs and most will switch to dried foods without problems. Maximal growth is achieved by raising the species in cool water (not exceeding 24°C).

Many can develop long filamentous fin extensions, but for these to develop properly the fish require a lot of space, clean water, good feeding and very little intra-species aggression. Fully developed males of *Simp. flammeus* or *hellneri* are a breathtaking sight.

Based on DNA evidence, the *Neofundulini* grouping consists of the genera *Aphyolebias*, *Moema* and *Trigonectens*. The *Rachoviini* grouping contains two lineages: the *Plesiolebiatina* and the *Rachoviniina*.

Aphyolebias peruensis is the most common member of the first group. It is a splendid fish with a lovely large decorated caudal fin. It is easy to maintain and breed, but the incubation time can vary between three months and (in the author's case) forever, but in general nine months is about the maximum.

Moema and *Trigonectens* are more difficult to care for. Their eggs can be water incubated—in fact for some breeders, this is the only way to obtain good fry as the eggs seem to disintegrate in the peat.

The *Plesiolebiatina* contains a collection of small fish which are harder than *Aphyolebias* to maintain. *Maratecoara lacortei* is shy fish with splendid blue body and orange markings. It is relatively productive but has the tendency to produce badly skewed sex ratios. It is also difficult to feed, requiring live foods. It is often difficult getting eggs to hatch... It is still very popular among South American annual fans for reasons that are obvious when one sees the fish in person.

Also in this grouping is *Pterolebias*. The species maintained are *bockermanni* and *longipinnis*. There is much confusion as to what specie or species are in the hobby. These fish spawn freely, are productive and fry rearing is uncomplicated.

In the *Rachoviina* all come from Venezuela. There are three genera that are regularly encountered in the hobby and are not too difficult to maintain.

The *Gnatholebias* are special among killifish in that they have sex chromosomes. They grow large, about 15 cm, and are very attractive fish. They lay large eggs in peat. There eggs require some special attention. The eggs must be incubated at 27°C for about 14 weeks, whereupon they must be wet by running cool water through the peat and then storing it for a further 4 weeks and then submerged. Any fry should be removed from the hatching tub and the peat redried and rewet a month later. There seems to be not definite limit as to how many times the peat can be rewet. The third wetting normally yields the most fry. Given the size and productivity of these fish, if you have incubated the eggs correctly, the first wetting will yield more than enough fry.

Rachovia is a genus composed of several small to medium size species.

These fish hail from coastal Columbia and Venezuela. Salt can be added to the water to prevent disease. *Rachovia brevis* is the most common and is not difficult to maintain. *R. pyropunctata* is very attractive. They lay biggish sized eggs and are productive fish. Eggs take about three to four months to incubate at 24 °C and the fry can take bbs on hatching.

Terranatos dolichopterus is from Venezuela. It has large flowing fins and lovely colors of red, orange and blue. It does not grow very large and needs tropical temperatures to do well. It also prefers live food to frozen, and will not eat dried food. In spite of the difficulty in maintaining this fish it is very popular and not uncommon. It can however, be difficult to attain. In a recent census held among South American Annual Study Group killifish keepers, it took 16th place out of 83 species for most commonly kept species. In a previous census it was in the top ten. Eggs take about 14 weeks to incubate at 27 °C. Cooler temperatures are not suggested. The fry are small and require infusoria. Adults can be very productive.

The key to success with South American annuals is rewetting the peat. In most instances the eggs will not all hatch first time round. In the case of *Gnatholebais* species, no eggs may hatch first time round. The second wetting often yields more fry than the first. In many instances, the third and fourth wetting may yield more fry than the first and second wettings.

The eggs are also easy to water incubate (see section 5.3). Hatching is triggered by the addition of fresh peat to the eggs. Putting the eggs and peat in a jar and sinking it in a deep tank will trigger hatching and reduce belly-sliding among the fry. The addition of peat extract and oxygen tablets is also said to promote hatching and reduce the incidence of belly-sliders.

The book *A hobbyist guide to South American Annual Killifish* by Dr. Roger Brousseau is an excellent and inexpensive guide to this large and diverse group of fish.

Part III

2704 WHERE TO FIND KILLIFISH

Chapter 8

Collecting

When it comes to collecting killifish, the safest place to go collecting is your pet store. But as with most things: the less risk, the less the rewards. If you like adventure maybe you should stop by a bait-and-tackle shop and purchase a net and waders—if you live in the eastern USA you may even find killies at your bait-and-tackle shop! If you want to bankrupt your bank account, attend a killifish convention. If you like the idea of traveling, you may even want to explore the option of a trip to Gabon or Guiana.

8.1 Pet stores

Pets stores are a notoriously bad place to find killifish. If something special comes in, it is normally expensive and in poor health; but every now and then one can find a surprise or two.

Aplocheilus lineatus, *dayi* and *panchax* are regularly imported from the east. They are hardy, robust fish that adapt well to captivity and do not suffer much in shipping. In the USA *Lucania goodei* is often encountered in pet stores. It too is a good find. For more interesting items you will need to get resourceful.

The odds are that someone in your general area keeps killifish. These people stick out like sore thumbs (behaving like a missionary with their killi-conversion zeal) and chances are that the person running the pet store may know of this person. Alas with the rampant commercialism of pets, the Mom-and-Pop pet store is getting scarce, and likewise the resource of the knowledgeable pet store owner, who knows more about his customers than his fancy new filters.

To find killifish, you have to find the small, special pet stores run by people who keep fish and who talk fish. These people can sometimes be coerced to import killifish if you are keen to pay. More often than not a killifish or two will be on the catalogues fish farms or importers send out to pet stores. There are people actively breeding killifish in Czechoslovakia, Malaysia and Thailand. Killifish are not imported because of the erroneous belief that they do not live long enough to sell, only eat live food or are too delicate. With a sure buyer, pet stores will be more willing to import the fish.

8.2 Local Clubs

Local aquarium clubs are also a good place to ask about for killifish. Your local pet store owner should know if there is a club in the area and where they meet or who the contact people are.

We fish keepers like to get together and talk fish. Once you are in the communication channels, you are certain to find someone who keeps killies or knows someone who knows someone who keeps killifish.

8.3 Collecting your own fish

This is the most exciting way to acquire killifish! Many a killifish keeper lies awake at night dreaming about the streams of Gabon, with all the beautiful killifish teaming in the cool inviting water.

If you live in the USA you have a great killifish resource in your backyard. Killifish are found over much of the USA, as far North as New York State. In Europe *Aphanius* can be collected at interspersed localities along the coast of Southern Europe. Those people in Africa and South America could not be more lucky were it not for one stumbling block: paranoid nature conservation departments and under-development.

Wherever you collect, you have to consider the *Law*. Always make sure you have the proper permits before embarking on a trip. Also, always get permission before you collect on other people's property.

You will need other items when collecting as well as the correct documentation.

Transport is very important. While transport for a local trip may not be so exorbitant in an overseas location it can be very expensive. If you are going off the beaten track you will need a four wheel drive vehicle. Along with the vehicle you will need supplies (food and water), spare fuel and the all important first aid kit. It would be a good idea to research possible health hazards (such a malaria) and take precautions (such as a mosquito net). Packing in a tent, if you are going to more remote locations, is also a great idea. People in the rural African country side tend to be very hospitable, provided you are always polite and not simply camp on their front lawn. In most of Africa the bush is some tribal chief's front lawn. In more poverty stricken areas, it is a good idea to keep a keen eye on one's belongings. Generally, if you have the Chief's blessing, you can sleep a bit easier. It is a good idea to pay the Chief a small tribute for his kindness. Most of Africa is littered with missionaries who are always glad to talk with someone from western civilization. Such missionaries can prove very helpful as regards obtaining information, a possible guide to the area and other resources and assistance.

Information is critical. The more information you can gather as to the place where you want to go the easier the trip will go. It is inevitable that something will go wrong, and how much information you have will determine just whether you experience a hick-up or a total disaster. The best source of information is obtained from people who have gone previously. Most of my information was gleamed from conversations with the intrepid killifish collectors: Brian Watters and Wolfgang Eberl.

Collecting gear is critical. Seine nets are very helpful in ponds and other open water bodies, but not in water with a lot of reeds or grass, or in very shallow water typical of *Aphyosemion* habitat. Here dip nets will be of greater use. Large dips nets are good for wide open shallow waters but small nets are more useful in narrow creeks with lots of nooks and crannies.

Holding containers are essential. Cooler boxes and buckets are the best option for holding fish. When on long collection trips in Africa, collectors usually use plastic bags that can hold one fish. Other collectors advocate small plastic containers that can be sealed. Packing fish singly helps keep your fish safe from one another. Water has to be changed every day and there is no feeding. Fish are able to live several weeks without food. Water changes should be done as often as possible.

For the trip home, Kordon breathing bags are all the rage. These small bags allow gaseous exchange through the plastic. This enables fish to be packed in small volumes of water and the bags packed snugly together with only enough space between each bag for air circulation. Normal polyethelene fish bags work just fine too.

Safety concerns are important. If you are in Florida you best look out for alligators. In Africa you get big crocodiles, cobras and bilharzia. Because of the latter it is important to always wear waders. Waders and strong boots are a good idea in any circumstance.

Collecting your own killies is fun but expensive. Pet store finds are lucky but rare. You will almost certainly have to get fish and eggs from other killifish keepers.

Chapter 9

Killifish by post

This is the way the killifish hobby works. In the past it was possible to send killifish eggs around the world by post. Today it is possible to send fish around the world by post! Note that the latter option is illegal, breeching customs laws for shipping between different countries and states. But everyone does it.

The best source of fish and eggs are local or national societies. The internet has revolutionized the killifish trade. Today it is possible to log onto the internet and search across the world for that killi you so desperately want. Using the Killietrader *e*mail list (http://groups.yahoo.com/group/killietrader/) one is able to request and sell fish by *e*mail. Aquabid (http://www.aquabid.com) also offers a wide range of killifish and other aquarium related products.

The most rewarding way to find killifish is to join a killifish society (see next chapter) and trade using what facilities it has. Most offer a Code of Ethics that insures that trades are carried out in good faith.

When requesting eggs always insist on fresh eggs. Mature eggs do not travel well. It is not impossible to be sent a packet containing 100s of eggs and end up with only a few fry because the eggs were ready to hatch when sent.

Eggs should be packed in peat in an insulated container if need be. The peat should be "fluffy" and the plastic bag it is in should not be tight. It should be loose so that the packet can breathe and equalize pressures in transit. Larger volumes of peat are better than small volumes.

Non-annual eggs can be sent in various ways. The best is in wet peat. The eggs are picked and put onto the wet peat. The peat is then put inside a small styrofoam box. The master breeder, Kenjiro Tanaka of Japan, makes his own little styrofoam boxes. The box is 7.5×5×3 cm in dimensions with a small hollowed out center. The box is taped together with the peat inside and then posted in a padded envelop. Once more, fresh eggs ship best.

Another easy way to ship non-annual eggs is to spawn the fish and send the damp mop. Squeeze out the excess water and pop the mop into a plastic bag, and then post that with some insulation. The more the eggs are handled the greater the risk of loss.

Annual eggs can also be sent on damp mops. Damp mops have the advantage of being less likely of being confiscated by customs officials as most countries are very paranoid about soil or plant material samples, in fear of the organisms that often hitch a ride with them.

As shipping takes about two weeks to most destinations, it is best to collect as many eggs as possible in as short a space of time to ensure that few eggs go bad or hatch in transit, else all the eggs may be ruined.

Within a country it is a simple task shipping live fish. Many countries have a priority postal service that will courier post overnight to its location. This is a great asset in a hobby where the members are spread over vast distances.

Fish should be shipped singly. Once again the breathing bag manufactured by Kordon is a great advantage that works wonders for this hobby. If normal plastic bags are used then the bag must be filled with air at a ratio of one part water to four parts air per volume, but not to the point where the bag is taut. The corners taped up so fish cannot get stuck in them. The water to air ratio should be at least one to four. To limit ammonia build up in the bag, some ammonia/nitrite adsorbant should be used. Boxes with fish in should be well insulated against sudden changes of temperature. While fresh eggs can tolerate temperature fluctuations to some extent live fish are far more fragile in respect to sudden temperature swings. Most killies, can however, tolerate declines in temperature. Well conditioned, prepared and packed fish can be sent by post to other countries. Some species can stand as much as 21 days in the post without loss.

Chapter 10

List of Killifish Societies

American Killifish Association
www.aka.org

British Killifish Association
www.bka.freeuk.com

Deutsche Killifish Gemeinschaft
dkg.killi.org

French Killifish Association
www.kcfweb.com/

Killi Fish Nederland
kfn.killi.net

South East Asian Killifish community: killies.com/forum
www.killies.com/forum

There are many other killifish societies, and most maintain a website. Active links can normally be found on the above sites. A good place to start your search for killifish is www.google.com.

Part IV

APPENDICES

Appendix A

Conversion factors

A.1 Temperature

The table below lists the temperature in degrees Celsius in increments of two degrees. In the righthand side column the equivalent temperatures are given in degrees Fahrenheit.

16°C	60.8°F
18°C	64.4°F
20°C	68.0°F
22°C	71.6°F
24°C	75.2°F
26°C	78.8°F
28°C	82.4°F

Temperatures can be easily converted between Celsius and Fahrenheit using the equation below:

$$^\circ\text{C} = (^\circ\text{F} - 32) \times \frac{5}{9} \text{ or } ^\circ\text{F} = (^\circ\text{C} \times \frac{9}{5}) + 32$$

A.2 Mass and volume

The beauty of the metric system is that it is designed around the properties of one liter of water. 1 L of water will have a mass of 1 kg. 1 L also equates to 1’000 cubic centimeters (cc or cm^3, also known as mL) in volume. This means that if you have a cube of dimensions $10 \times 10 \times 10$ cm its volume will be 1 L. So, if you have a tank with dimensions $91.5 \times 32.5 \times$ 38.1 cm you will have 113'299.9 cm^3. Recall that 1000 cm^3 is the same as 1 L, so the tanks volume is 113.3 L. This equates to 29.8 US gallons (3.8 L/gallon) or 24.9 UK gallons (4.5 L/gallon). (Note the different definitions of gallon for different countries. A Liter in the USA is the same as a Liter anywhere else.)

The dimensions of the above tanks could of just as easily been expressed as $39 \times 13 \times 15$ inches because in 1 inch there are 2.54 cm. Converting the volume (7605in^3) into gallons or liters would of required the extra step of multiplying the volume in inches by the arbitrary value of 0.0039 because there are 0.0039 US gallons per cubic inch. For the UK gallon the factor is 0.0033.

To convert cubic inches into pounds requires a conversion factor of 2.205 because in 1 Kg there are 2.205 pounds. In the metric system, mass and volume of water could both be determined by the same calculation.

For the reason of these extra steps, that are difficult to remember, the metric system is better than the alternative for calculating volumes based on dimensions due to its simple to recall logical reasoning and design. People using the alternative, should join the rest of the world in the simpler metric age.[1]

[1] An interesting factoid: the metric system was devised by Anton Lavoiser just before the French Revolution of 1776. In devising and developing the system, Lavoiser consulted with none other than Benjamin Franklin, who was then the US ambassador to France. So it is interesting that the USA has not embraced the genius of this, one of its founding fathers.

Appendix B

How to build your own tanks

Keeping killifish means you will need a large array of tubs and small tanks. To make the most use of the space you have, you will eventually need to obtain tanks of odd sizes—that is tanks not of standard dimensions.

The author likes tanks of the dimensions 40×30×30 cm. This is close on 10 gallons in volume. It offers a good ratio of surface area to volume (1:3), which means better gaseous exchange and more room for the fish to establish some personal space (territory). The next best size down in 30×22×22 cm which gives a ratio of 1:2. Going one size up a tank of 60 ×30×30 is a good size with a surface area to volume ratio of again 1:3. Deeper tanks have more water volume and hence requires less water changes, but the shallower tanks with better gaseous exchange can hold more fish comfortably. With adequate lighting the plant growth alone will be all the filtration one would need. As male killifish tend to be aggressively territorial, you cannot keep many fish in a tank to begin with.

To build your own tanks, you will need to obtain the correct glass. For the 30×22×22 cm tanks 3 mm glass is adequate. For the 40 and 60 cm tanks 4 mm glass is fine but it is important you fit a brace along the top and bottom of the tank. You will want to do this in any case to support the cover glass that will be needed to keep the fish in the tank.

Lets begin the building of our 40×30×30 cm hypothetical tank. You will need to order the following glass panes:

Qty	dimensions	description
1×	40×30 cm	for the base; using thicker glass for the base is always a good idea
2×	40×30 cm	for the front and rear panes

2×	30×29.2 cm	for the sides. Note the reduction in length to allow for the front and rear panes
4×	39×1.5 cm	for the braces and cover glass supports
2×	39×15 cm	for the cover glass; remember to cut the corners from one piece for the air tubes etc…

To build the tank you will need a firm surface on which to work. You will need silicon suited for aquarium construction. These brands lack antifungals and do not get brittle as fast as ordinary silicon. The silicon used to construct fish tanks is good for an average of ten years. After ten years it may/will need to be replaced. Glass also grows brittle with age, there is no reduction in strength but such glass cannot be safely cut and will shatter more readily. Large thin panes nearing 25 years of age should be regarded as suspect. A silicon gun is better than tubes of silicon.

You will need some glass sandpaper to sand down the sharp edges[1]. You will also need some methylated spirits and old newspaper to clean the glass[2]. After sanding and cleaning the glass, you can commence construction. Having some tape handy that has already been cut into strips. The adhesive quality of the silicon is all you need for small tanks, to hold the panes in place while the silicon cures.

The first step is laying a bead of silicon all along the edge of the base. Taking the silicon gun in your right/left hand, guide the nozzle and bead of silicon with your left/right forefinger, but letting your forefinger glide along the outside edge of the glass and the nozzle along the top edge.

Second, you take one of the front/rear panes and lay a bead of silicon along the two side edges like above. Keep one of the side panes close at hand. Lift the front/rear pane and place it down on top of the bead of silicon on the base. Now take one of the side panes and place it in position with one side in contact with the silicon on the base and the adjacent side in contact with the silicon on the front/rear pane. Position the panes so they are perfectly in position (not sticking out over the base or further in than supposed to). Insert the other side pane as explained for the first.

Third, as explained for the front/rear pane above do the same for the other. When all four panes are in place make sure all the panes are positioned over the base perfectly, and in contact with each other, with no gaps in the

[1] The author has scars as testament to why this is important.

[2] Newspaper will not leave dust or thread fragments on the glass like paper towels and clothe.

silicon between the panes.

Fourth, smooth out the seems. You should not of applied so much silicon that the seems are oozing with silicon. You should have to apply another bead of silicon along the inside seems. Smooth the seems out. A finger, ice-sucker stick or old credit card is fine for the job, but new handy-man products do a far superior job. While the silicon is still a gel you must insert the braces/struts.

Fifth, to insert the struts you need to lay a bead of silicon along the front edge and both sides. Before this you must of cut yourself six or more strips of tape. Press the strut against the inside of the tank about 5 mm from the top. Use the tape to hold the struts in position. Three pieces of tape per strut should be adequate.

After waiting a day the silicon should of set. With a sharp knife or blade remove any excess silicon and clean the glass till it is perfect. A piece of glass works just as well if not better than a blade for this task. After the second day you can fill the tank and test it for leaks. Do not worry about scratching the glass. Glass is harder than steel or iron so a blade or knife will not scratch the glass. Considerable effort is needed to scratch glass with glass using a flat level surface on a flat level surface as they are of equal strength. Sand or gravel scratch glass very easily.

The whole operation is such that one person can do it. It is a good idea to always have someone close at hand as glass can be dangerous.

If you are feeling adventurous you can build a filter into the tank. Have a piece of glass cut of the dimensions 4×28.5 cm and a second piece of 12×6 cm. The first piece is the uplift and is to be siliconed into one corner with a 1 cm gap between it and the base. The second piece is siliconed in front of the first and becomes the filter compartment. The filter can be filled with gravel or sponge etc…An airstone is sunk behind the uplift to draw water through the filter.

As a finishing touch black insulation tape can be used to wrap around the top 2 cm of the tank to create a more aesthetically pleasing tank. Broader adhesive vinyl tape can be used instead.

Appendix C

Suggested Reading

Brousseau, R. (1994) *A hobbyist guide to South American Annual Killifish* www.geocities.com/dr_rog

Hellner, S. (1990) *Killifish: a complete pet owner's manual.* Barrons, USA.

Huber, J. *Killi-data.* www.killi-data.org.

Markis, A.C. and Langton, R.W. (1990) *The American Killifish Association's Beginner's Guide.* American Killifish Association, Inc USA. www.aka.org.[1]

Scheel, J. (1975) *Rivulins of the old world.* TFH, New Jersey USA.[2]

Seegers, L. (1997) *Aqualog: Killifish of the world: old world killies I.* Verlag A.C.S. GmbH, Germany.

Seegers, L. (1997) *Aqualog: Killifish of the world: old world killies II.* Verlag A.C.S. GmbH, Germany.

Seegers, L. (2000) *Aqualog: Killifish of the world: new world killies.* Hollywood Import & Export Inc., USA.

Vitek, J. and Kadlec, J. (2003) *Hobby Compendium: KILLIFISHES CD-ROM.* Jiri Vitek publishing house, Brno, Czechoslovakia.

[1] A new edition is currently available that is supposedly superior to the one mentioned here.

[2] The book *Atlas of killifish of the old world* by the same author and publisher has far more glossy photos but is virtually impossible to come by.

www.akvarium.cz/halancici/ivinfo.html

Warner, E. (1977) *Success with killifish.* Palmetto Publishing Company, Florida.

Wildekamp R. (2000) *A world of Killies: Atlas of the oviparous Cyprinodontiform fishes of the world. Volumes I–IV.* American Killifish Association, Inc., USA. www.aka.org

Index

About the author

The author, born in Cape Town South Africa, has been keeping fish since the age of six, finally taking the leap to keep killifish in 1997. He has attained an Masters of Science degree in the biochemistry of steroid hormone metabolism. He has run courses in animal and plant physiology, genetics, ecology and evolutionary biology in addition to biochemistry.

The author has done research work on the biology of aging of the annual fish *Nothobranchius furzeri* and related species at the Institute of Neurobiology at the CNR, Pisa Italy. He currently teaches science at Camps Bay High School, Camps Bay South Africa