Mud, mud, and mud.

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If any information can be gained from their common name, mudskippers (about 35 species included in the genera *Boleophthalmus*, *Periophthalmus*, *Periophthalmodon*, *Scartelaos*, and *Zappa*) are fishes that 'skip on mud'[1].

The average aquarist will be probably unable to offer a mudskipper artificial conditions approximating those found "in nature". Mudskippers are highly territorial animals and their daily cycle and behavioural patterns are typically set by tides. The defended areas, both around the burrows and where food is exposed by the ebb tide, are relatively large[2], and tides[3] drastically change their behaviour, movements and average distances between individuals.

However, mud will greatly improve the quality of an artificial mudskipper setup, if the goal is providing the best "seminatural" conditions. Since all mudskipper species are burrowers, mud will also offer the opportunity to observe a larger variety of behaviours, including digging, clearly increasing the attractiveness of having a mudskipper tank. It should be

[1] *Periophthalmus* mudskippers can also be found on rocky, pebble and sandy shores, but it is unclear whether these individuals are stranded fishes (e.g. after a storm), or young individuals wandering about in the search of a territory ("errants"), or individuals developed from larvae that settled in the wrong place during larval recruitment. It is also unclear whether these are "sink populations", i.e. individuals that cannot reproduce. The little we know of mudskipper reproduction, learned from few species of the first four genera mentioned above, suggests that mudskippers cannot reproduce in/on a non-cohesive sediment, such as sand or gravel, or on solid rock. They probably need a soft and plastic (cohesive) substrate, because eggs are laid inside a burrow, in a dome-shaped chamber containing a bubble of air. Burrows made in sand easily collapse (especially in the intertidal area), and reproductive burrows must be stable at least during the whole incubation (about one week). However, even the species that are sometimes found on sand, are usually found on mud, suggesting that they indeed prefer mud to dig their burrows.

[2] I measured maximum densities of about 3.5 individuals per square metre in *Periophthalmus gracilis* and *P. chrysospilos* (in 4 m x 4 m sampling plots in mangrove forests of Peninsular Malaysia); however, most *Periophthalmus* species (including the smallest species among the five mudskipper genera) would typically have a density >10 times smaller than this.

[3] see a description of a tidal simulation system in the Files section

noted that even if mud is provided, a mud layer enabling a mudskipper to dig a burrow of "natural" proportions can be deeper than an average tank would allow. Burrows' size and shape are extremely variable even within species, but the smallest burrows (e.g. in *Periophthalmus gracilis*, reaching a maximum total length of about 5 cm) are 20–30 cm deep. Larger species would dig much deeper burrows, and one of the largest species, *Periophthalmodon schlosseri* (reaching more than 25 cm in total length) can dig burrows more than 2 m deep. For these reasons, if one of the goals is observing a mudskipper digging a "normal burrow", a good setup (for fishes less than 10 cm in total length) is a mud slope that is at least 30–40 cm deep in its deepest portion.

I will here describe a method to treat the mud found in the field, making it safe for mudskippers. Another option is to use mud from mixtures of sediments (clay, silt) bought in a pottery shop[4].

Mud is a sediment with plastic, cohesive properties. This means that with the right amount of water, it is a malleable, sticky material that maintains its shape if worked in a shape. Non-cohesive sediments crumble and cannot maintain a definite shape, especially if wetted. When mud contains an excess of water, and is thoroughly mixed, it becomes semiliquid. Mudskippers typically do not live in semiliquid mud, but live in plastic mud containing 30–60% of water in weight[5].

If you don't live in a mudskipper country (Indo-West Pacific region and West Africa) thus being unable to collect the mud right where the mudskippers are, you have to source your mud from local rivers or lagoons[6]. The banks of large meandering rivers, especially when

[4] Double-check the mineral content of the clays and silts you buy: some may contain toxic substances, like arsenic minerals and heavy metals.

[5] That is, 1 Kg of mud would contain 300–600 g of water, and 700–400 g of sediment. Mud water content can be obtained by weighing a certain amount of mud (e.g. 1 litre), drying it out in an oven at 65°C to constant weight (that is, taking out all the water by evaporation), and then weighing it again.

[6] In the past, I used mud from the bank of the highly polluted river Tiber in Rome, and Venice Lagoon in Venice (both in Italy).

access points are available thanks to bridges, are particularly good as a mud source. However, if you collect mud in the field, there is an obvious risk of introducing parasites and toxic substances in the tank. Mudskippers are extremely resistant to bacterial and fungal infections, and have virtually no external parasites (from protozoans to worms), even on the gills[7]. They also are extremely tolerant of organic and inorganic pollutants (including ammonia and sulphides). However, mudskippers can be sensitive to internal parasites, and internal worms (e.g. digenean trematodes) can be particularly dangerous for their health. They can obviously also be damaged by artificial pollutants (e.g. herbicides, pesticides). Therefore, treating mud collected in the field for a mudskipper setup essentially boils down to eliminating parasitic worms (including their resistant stages, and their intermediate hosts, like aquatic snails) and artificial pollutants.

1. As a first treatment, the mud should be washed. Add an excess of water on top and thoroughly mix the mud, breaking up all the clasts and hardened pieces with your hands (wear thick gloves), putting all the sediment into suspension. Then wait a few days for the mud to settle, and throw away the water on top. Repeat two or three times. This will dilute any pollutant that may be present in the mud.
2. The second treatment is to eliminate potential parasites and harmful organisms. I recently had a trematode infestation[8], and I strongly recommend to go through this passage, since these parasites can be lethal, if not treated in time. Some trematodes can be particularly hard to eliminate, since they live in intermediate hosts like snails that can resist to several treatments in the mud, and can also develop very resistant cysts in the sediment or inside other organisms. The safest option is heating up the mud in a regular oven: 2–3 hours at 150–200°C would kill any worm and snail, and

[7]They can be attacked by leeches (Hyrudinea) and parasitic crustaceans, like argulids and gnathiid isopods.

[8]See file HelminthiasisSHARED in the Files section. A preventive deworming treatment (e.g. PraziPro) is highly recommended for any mudskippers in a new setup.

other potential parasites. Importantly, the mud must be uniformly heated to the goal temperature, and heating up a larger amount of mud takes more time. The safest option is to throw away all the water on top, let the mud dry in the air for a few hours, and then cook it in layers 4-5 cm deep. If the mud solidifies it can be easily rehydrated by submerging it in water for a day or two, and then thoroughly mixed up with water, until reaching the desired consistency.

3. The third treatment acts chemically on artificial pollutants potentially present in the mud, using hydrogen peroxide (depending on countries, 3.0–6.5% H_2O_2: usually available in pharmacies and supermarkets). This chemical is perfectly safe to handle, reacts completely in the mud and water decomposing into water and oxygen, and leaves no residues. I use two litres of 3% hydrogen peroxide in 20 litres of mud, covered by 2-3 cm of water and thoroughly mixed to a creamy consistency directly in the tank. After a couple of days, the mud will settle on the bottom of the container and the excess water can be eliminated, to let it dry to the right consistency.
4. The fourth treatment (it can be conducted during the previous step, but I use that step to wash the mud one more time) is to soak the mud with water at the desired salinity. Mudskippers are highly euryhaline, meaning they are able to live in waters with highly variable salinity. A salinity of about 10 ppt (specific gravity: 1.0050–1.0070 g/l at 25–30°C) is probably a good option for most species. Just prepare the brackish water using salts in commerce for marine fishes (e.g. “Instant Ocean”), cover the mud with 2 cm of water, mix it up thoroughly, wait for the mud to settle, then throw away the water on top and let it dry to the desired consistency. Just replace evaporated water with freshwater to control the salinity.