

INTRODUCTION

In freshwater ecosystems, predicted effects of climate change include more extreme temperature fluctuations, hypoxic events, and degradation of water quality. Small-scale fish farmers will be affected by these changes as they pose a threat to their income and overall wellbeing by eventually creating environmental conditions too harsh to continue with current practices. The AquaFish Innovation Lab has been investigating the contribution of air-breathing fish (ABF) to local economies and the potential for increased cultivation to improve climate resilience. This diverse group of fishes has developed the ability to utilize atmospheric oxygen for respiration, allowing them to survive in aquatic environments with low to no oxygen, low water levels, and poor water quality, presenting unique advantages for aquaculture. Exploring some of the challenges to ABF aquaculture, such as high protein diets required by some species, this research includes techniques such as alternative feeding and polyculture practices. As many ABF species have not been well studied, this exploratory work is providing insight into the existing role of ABF in local communities and opportunities for diversifying and optimizing practices to improve the climate resilience of small-scale fish farmers.

FOCUS SPECIES

The research highlighted in this poster focuses on current AquaFish investigations on three air-breathing fish species indigenous to regions in Africa and Asia.



Protopterus aethiopicus
(Image from pbase.com)

Heteropneustes fossilis
(Image from fishbase.com)

Channa striata
(Photo by Hap Navy)

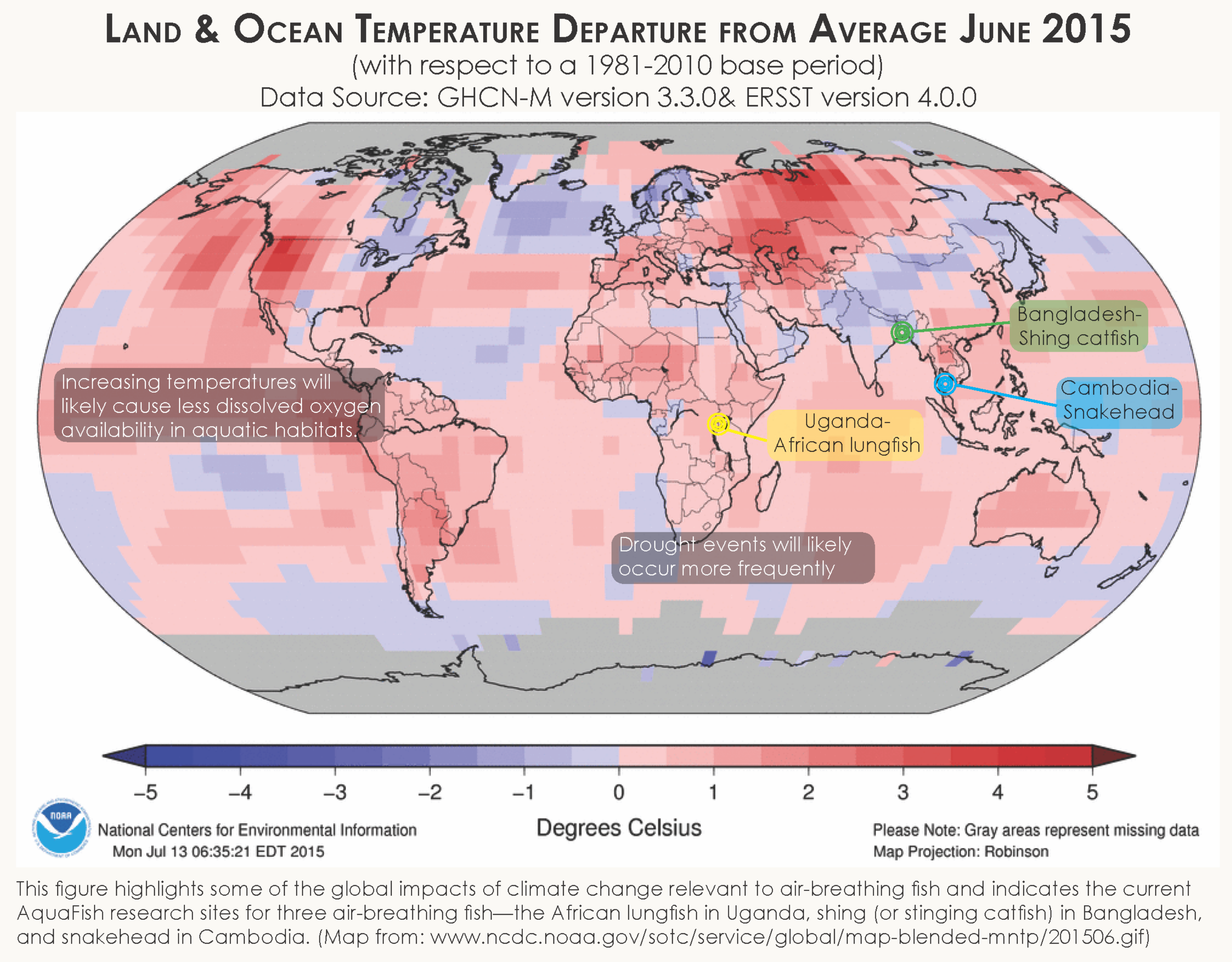
AFRICAN LUNGFISH (*PROTOPTERUS AETHIOPICUS* AND *P. AMPHIBIOUS*)

"Development of Low-Cost Captive Breeding and Hatching Technologies and Management Practices for Two African Lungfish Species to Improve Livelihoods, Nutrition, and Income for Vulnerable Communities in Uganda"

- Many small- and medium-scale fish farmers struggle with poor water quality and seasonal water deficits—the air-breathing **lungfish has been identified as a potential alternative for income generation.**
- The marbled lungfish (*P. aethiopicus*) and African lungfish (*P. amphibious*) are endemic to Uganda, where populations are declining primarily due to overexploitation, environmental degradation, and large-scale conversion of wetlands to agricultural land.
- AquaFish researchers have collected fish samples from sources throughout Uganda to assess genetic diversity. This will serve as a **baseline for future breeding programs.**
- Breeding trials are ongoing towards the development of a low-cost breeding and hatching technology.



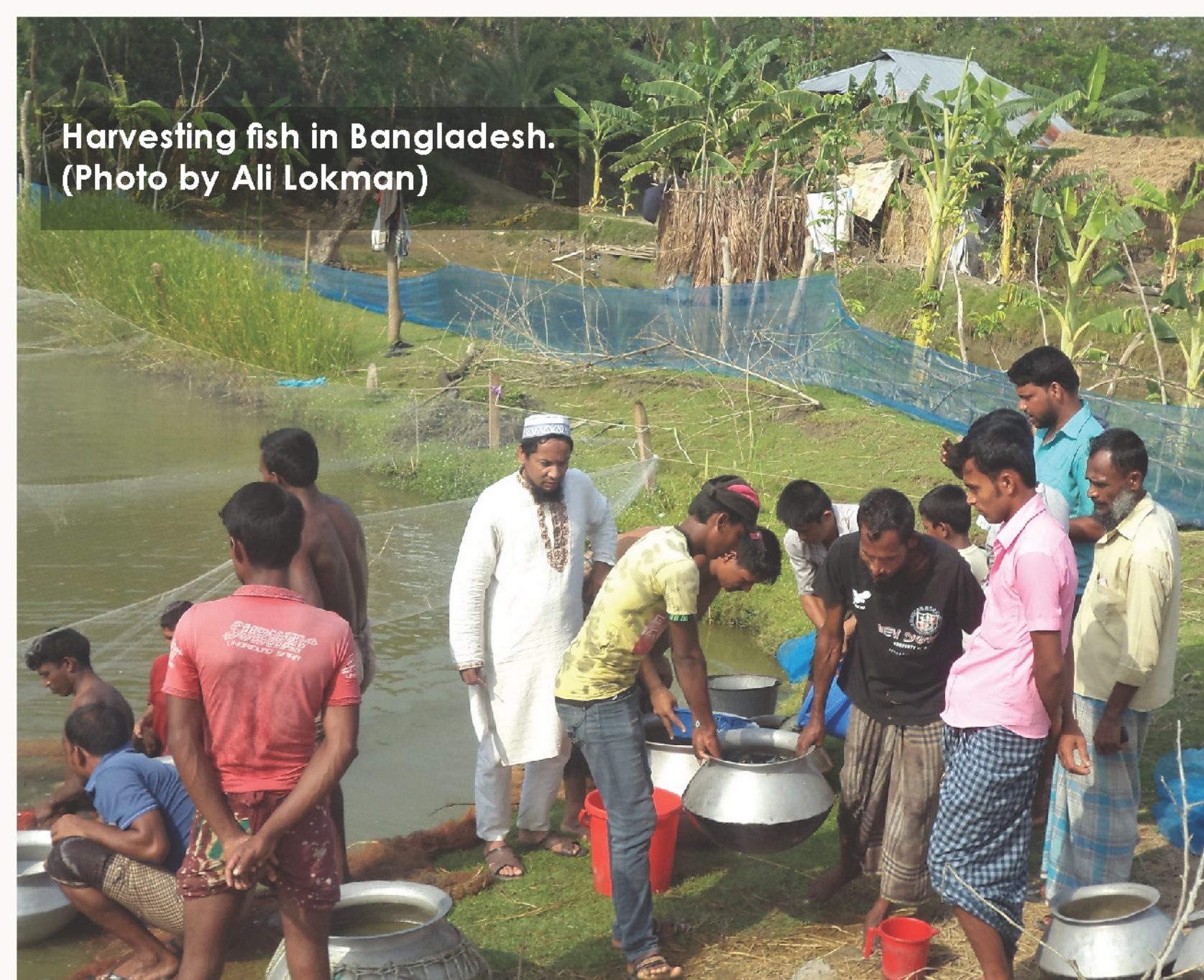
Fish ponds in Uganda. (Photo by Hillary Egna)



SHING OR STINGING CATFISH (*HETEROPNEUSTES FOSSILIS*)

"Novel Approach for the Semi-intensive Polyculture of Indigenous Air-Breathing fish with Carps for Increasing Income and Dietary Nutrition While Reducing Negative Environmental Impacts"

- An air-breather indigenous to Bangladesh, *H. fossilis* has been successfully cultivated in monoculture systems and commands a **high market price** for its taste and nutritional value (high in iron and calcium).
- Reductions in feed and overhead costs, combined with mixed-trophic level nutrient utilization, may make **semi-intensive culture of Shing catfish feasible for greater adoption** among farmers while also mitigating environmental impacts associated with nutrient loading.
- Initial results indicate that *H. fossilis* can be **co-cultured with carps** with little impact on production, providing significant additional income.
- Additionally, preliminary results suggest that **reductions in daily feeding** by half with pond fertilization may provide additional benefit.



Harvesting fish in Bangladesh.
(Photo by Ali Lokman)



Snakehead retailer in a Cambodian marketplace.
(Photo by Hap Navy)

AIR BREATHING FISH

Air-breathing presents several advantages due to the stability of oxygen concentrations in the atmosphere, but presents some interesting tradeoffs for fish.

- Air-breathing fish have been found to employ a range of air-breathing organs, which allow them to **persist in low oxygen conditions or prolonged exposure to air**
- The more primitive groups of air-breathing fish have a primitive lung or respiratory gas bladder, whereas more advanced teleosts have recruited new respiratory structures such as pharyngeal and bronchial pouches in the head region or respiratory organs along the digestive tube.
- Air-breathing fish can be further classified into two primary groups:
 - Obligate** air-breathers are dependent on atmospheric oxygen.
 - Facultative** air-breathers supplement their oxygen requirements by breathing air.
- As **bimodal breathers**, air-breathing fish are known to maintain a functional gill structure for a variety of purposes such as ion regulation, ammonia excretion, and CO₂ gas exchange.
- The ability to breathe atmospheric oxygen has evolved in fish species several times, with more than **450 air-breathing freshwater and saltwater fish species** known to date.
- With climate change affecting water temperatures and water availability (among countless other things), the characteristics of air-breathing fish provide a unique insight into the fish cardiorespiratory response to increased water temperatures, degrading water quality, and more frequent droughts.

CHALLENGES

Understanding the environmental impacts of aquaculture is critical for the development and use of responsible practices. Two issues associated with air-breathing fish culture (though they are not necessarily unique to air-breathing fish) are listed below.

- Many air-breathing fish species are piscivorous**, making their feeds expensive for farmers and environmentally taxing.
- The introduction of non-native fish** for aquaculture can be detrimental to existing flora and fauna.

SNAKEHEAD (*CHANNA STRIATA*)

"Sustainable Snakehead Aquaculture Development in the Lower Mekong River Basin of Cambodia"

- Native to parts of Asia, including Cambodia, the striped snakehead (*C. striata*) is a high value food fish throughout the region, fetching **more than 10 times higher profits** than other fish species.
- Generally cultured in small cages and ponds, snakehead aquaculture relies on a high protein diet that consists largely of locally caught fish (pictured below). Feed represents more than 70% of the operational costs of snakehead aquaculture.
- AquaFish researchers have developed a formulated feed with soybean meal replacing 50% of the fish protein. Researchers were able to get ***C. striata* to accept the formulated feed 30 days after hatch.**
- As a way to **alleviate the wasteful practice of snakehead seed collection from the wild**, AquaFish researchers have also developed a domesticated broodstock.
- Current research is focused on optimization of domestication breeding and of alternative feeds.



More than 35 species of small-sized fish often used for snakehead feed. AquaFish researchers have developed an alternative feed to help make snakehead farming more sustainable. (Photo by So Nam)