Tuungane Project Baseline Ecological Study: An Assessment of the Near-shore Biodiversity of Lake Tanganyika in Mahale Mountains National Park and Surrounding Villages

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Tuungane Project Baseline Ecological Study: An Assessment of the Near-shore Biodiversity of Lake Tanganyika in Mahale Mountains National Park and Surrounding Villages

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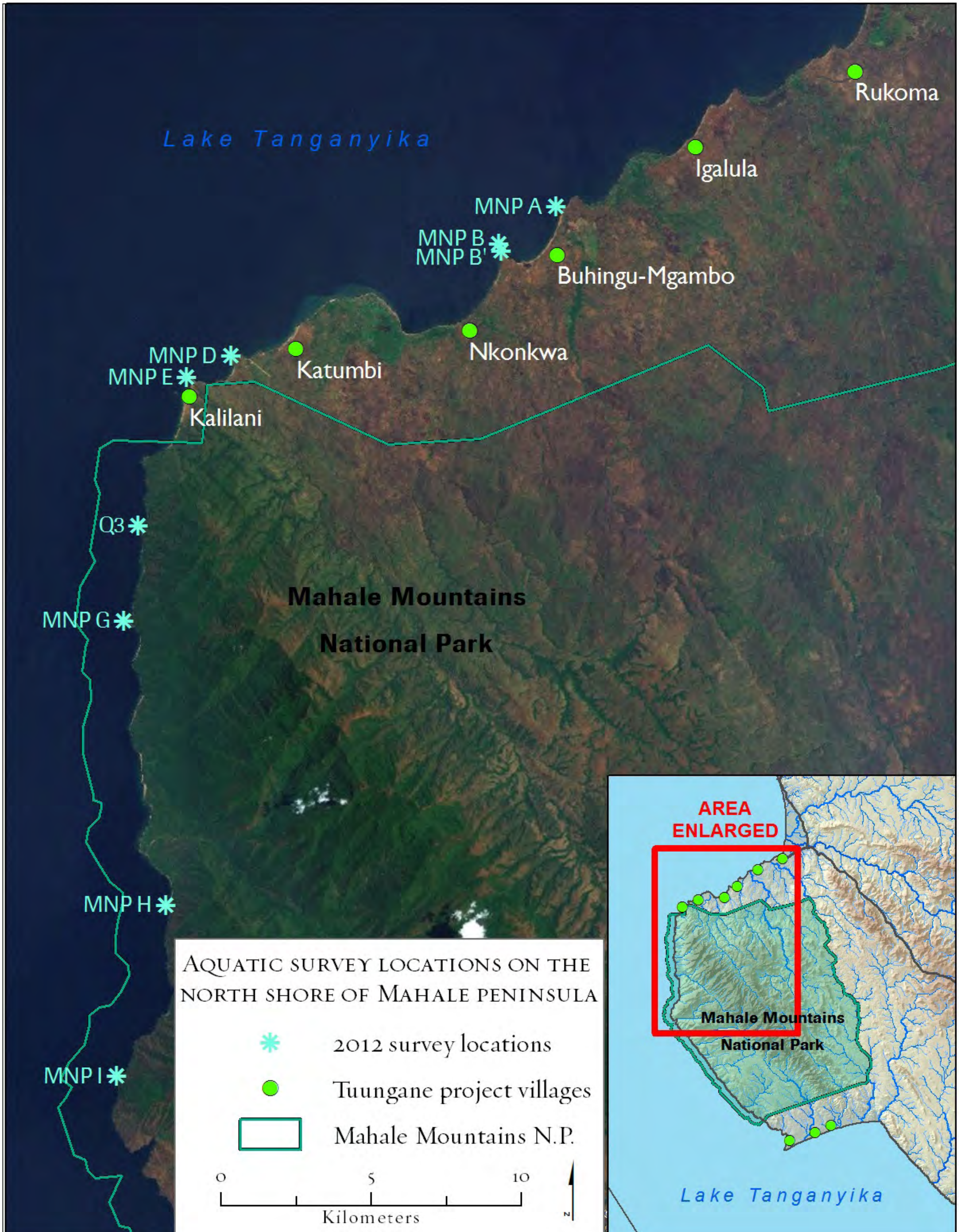
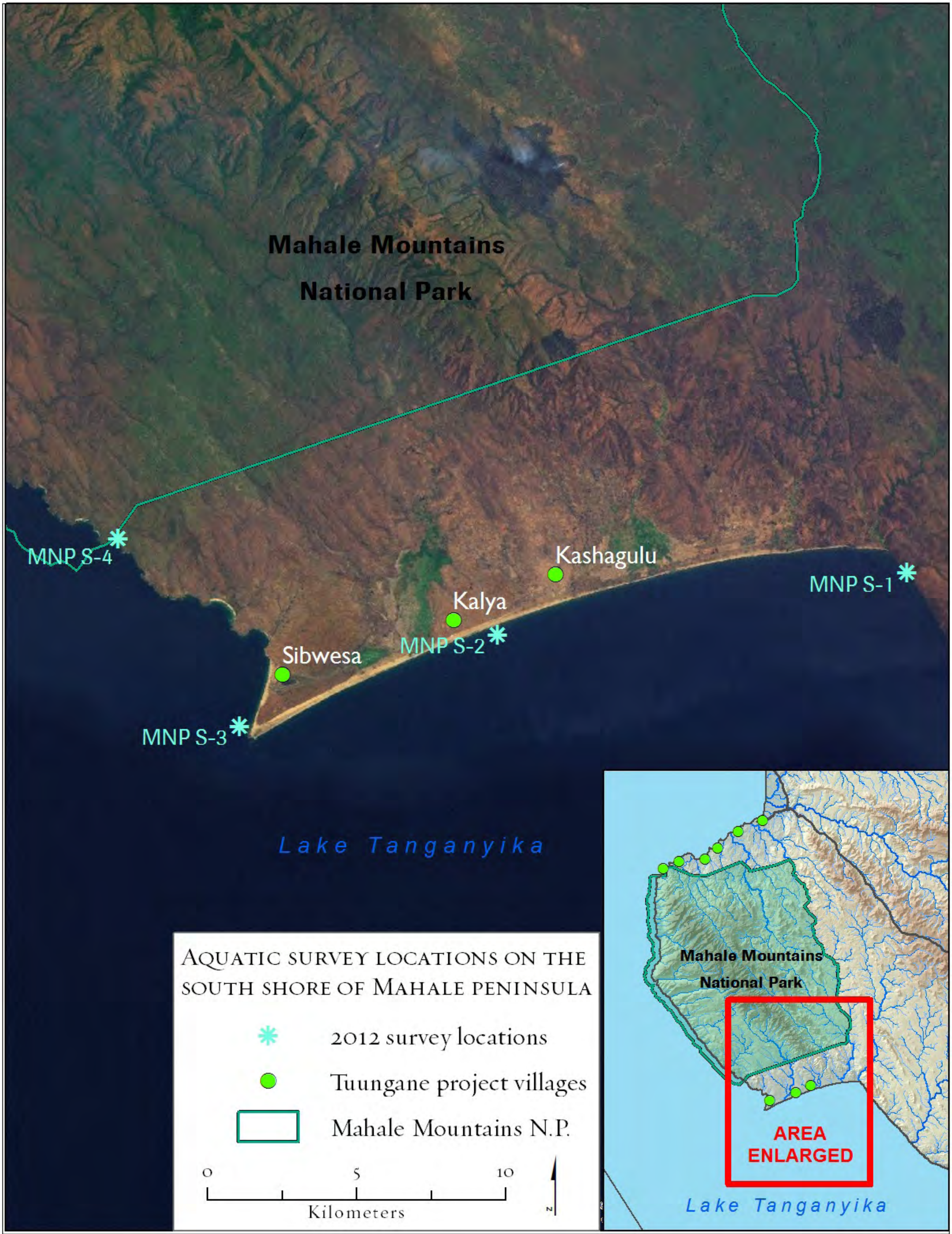


Aquatic survey locations on the north shore of Mahale peninsula


Mahale Mountains
National Park
MNP S-4
Kashagulu
MNP S-1
Kalya
MNP S-2
Sibwesa
MNP S-3
Lake Tanganyika
Aquatic survey locations on the south shore of Mahale peninsula
2012 survey locations
Tuungane project villages
Mahale Mountains N.P.
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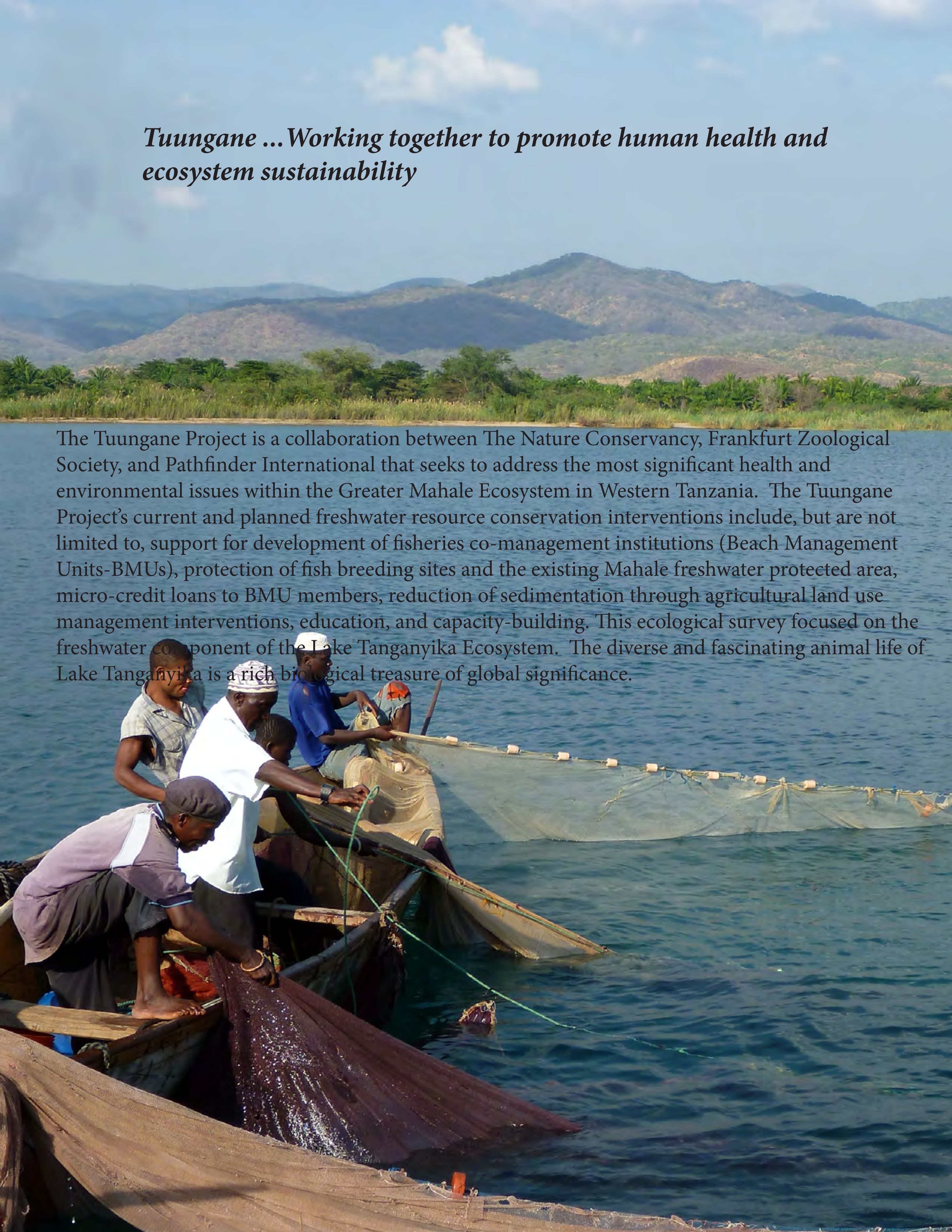
Lake Tanganyika

Lake Tanganyika – an integral part of the African economy and a global hotspot of freshwater biodiversity

Lake Tanganyika is one of the oldest (12 million years old) and deepest (1470 m) lakes on Earth and is a global hotspot of freshwater biodiversity. The offshore and near shore fisheries of Lake Tanganyika provide a critical regional protein source, and the negative effects of climate change on the offshore fisheries are already evident. Whereas the vast open waters of the lake support relatively few species of fish and zooplankton, the near shore waters of Lake Tanganyika support over 280 species of fish, predominantly of the Cichlid family, and more than 400 species of invertebrates. The majority of these species are found nowhere else on earth, and over 85% of species live in the narrow band of shallow water (< 60 m) at the edge of the lake, the littoral zone. Although the littoral zone is a tiny fraction of the lake surface area, it is important to both the Lake Tanganyika Ecosystem and the local human economy. The littoral zone provides critical spawning habitat for offshore fish, and littoral fish provide an important sustenance fishery for people around the lake. Furthermore, littoral fish are valued aquarium pets in other parts of the world and people living around Lake Tanganyika participate in a poorly regulated aquarium trade. Mahale Mountains National Park, on the eastern side of the lake, features the largest freshwater protected area on the lake (and one of the largest in the world). Fishing is prohibited along the entire 60km shoreline of Mahale Mountains National Park (MMNP) and to 1.6 km offshore. This freshwater protected area is managed and enforced by Tanzanian National Parks (TANAPA).

The Lake Tanganyika watershed. This survey was conducted in the waters adjacent to the Mahale peninsula, circled in red. Image courtesy of the Lake Tanganyika Authority

Tuungane …Working together to promote human health and ecosystem sustainability



The Tuungane Project is a collaboration between The Nature Conservancy, Frankfurt Zoological Society, and Pathfinder International that seeks to address the most significant health and environmental issues within the Greater Mahale Ecosystem in Western Tanzania. The Tuungane Project's current and planned freshwater resource conservation interventions include, but are not limited to, support for development of fisheries co-management institutions (Beach Management Units-BMUs), protection of fish breeding sites and the existing Mahale freshwater protected area, micro-credit loans to BMU members, reduction of sedimentation through agricultural land use management interventions, education, and capacity-building. This ecological survey focused on the freshwater component of the Lake Tanganyika Ecosystem. The diverse and fascinating animal life of Lake Tanganyika is a rich biological treasure of global significance.

Summary

This survey focused on the rocky habitats of Lake Tanganyika because they are biodiversity hotspots within the Lake Tanganyika ecosystem. The algae growing on the rocks are critical to health of the near shore ecosystem because the algae provide food for many fish species. Key threats to freshwater ecosystem are overfishing, sediment runoff from the deforested hillsides that negatively impacts algae, snails and fish, and excess nutrients from sewage or agriculture that can cause algae in the water to bloom, shading out algae on the rocks.

Many ecosystem health characteristics were measured at each site to establish a baseline description of the underwater habitat. This survey helps the Tuungane project to understand better the threat of sedimentation, overfishing, and eutrophication.

Major Findings from this survey included:

- No evidence that nitrogen from human waste is affecting the ecosystem to the north or south of Mahale Mountains National Park (MMNP).
- Rocks at the village sites had about 5 times the amount of sediment on them as rocks at sites within MMNP.
- There was no difference in algal growth rate between the sites inside and outside the park.
- Strong differences existed between the biodiversity at rocky habitats near the villages and those sites within MMNP.
- Both fish species richness and fish densities were much higher within MMNP than outside the park.
- The maximum body size of almost every fish species in MMNP appeared considerably larger than the same species near the villages outside the park or the northern end of the lake near Kigoma.
- The biodiversity of the snails in and around the northern end of MMNP is very high, while snails collected from heavily impacted sites were very small.

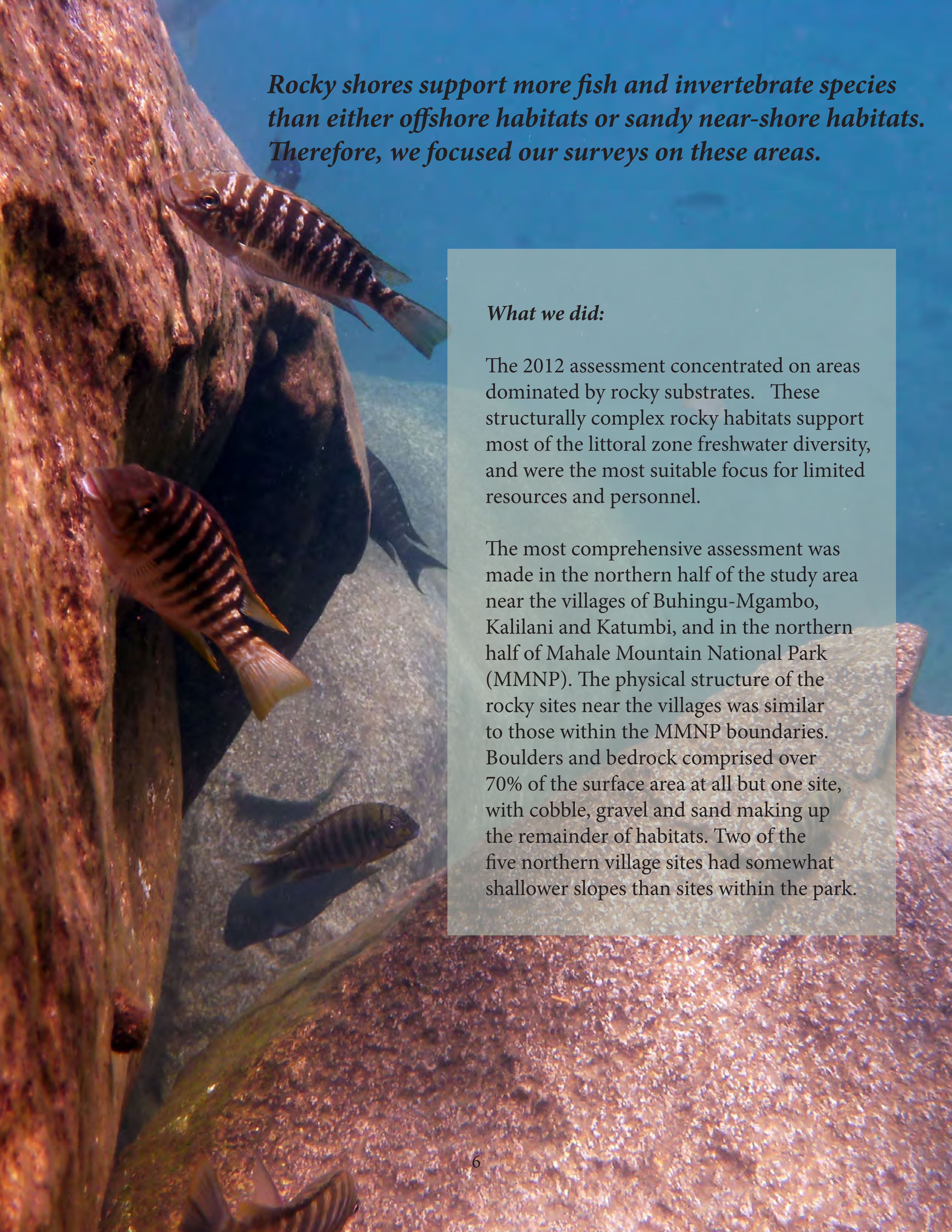
There are four major conservation implications of this survey:

1) Two key threats to the spectacular near shore biodiversity of Lake Tanganyika—sedimentation and over-fishing—are both affecting aquatic habitats outside the boundaries of MMNP, but are virtually absent within the Park. However, there was no evidence that water pollution from human sewage is negatively impacting these same areas.

2) An important conservation priority should be to encourage land uses that reduce sediment loading into the near-shore zone. Increased native vegetation on the hill slopes can yield benefits to the aquatic ecosystem, and likely the fishery.

3) Enforcing the fishing ban within MMNP's coastal waters and discouraging overharvest near villages are essential for sustaining near shore fisheries, and are a high priority for conservation efforts.

4) Terrestrial conservation efforts within MMNP are effective in sustaining water quality and terrestrial conservation goals, and should continue to be supported. The survey team saw more species of birds, mammals, and trees along the shoreline in two weeks of work in MMNP than has been observed in over a decade of research near Kigoma.



Rocky shores support more fish and invertebrate species than either offshore habitats or sandy near-shore habitats. Therefore, we focused our surveys on these areas.

What we did:

The 2012 assessment concentrated on areas dominated by rocky substrates. These structurally complex rocky habitats support most of the littoral zone freshwater diversity, and were the most suitable focus for limited resources and personnel.

The most comprehensive assessment was made in the northern half of the study area near the villages of Buhingu-Mgambo, Kalilani and Katumbi, and in the northern half of Mahale Mountain National Park (MMNP). The physical structure of the rocky sites near the villages was similar to those within the MMNP boundaries. Boulders and bedrock comprised over 70% of the surface area at all but one site, with cobble, gravel and sand making up the remainder of habitats. Two of the five northern village sites had somewhat shallower slopes than sites within the park.

What we found:

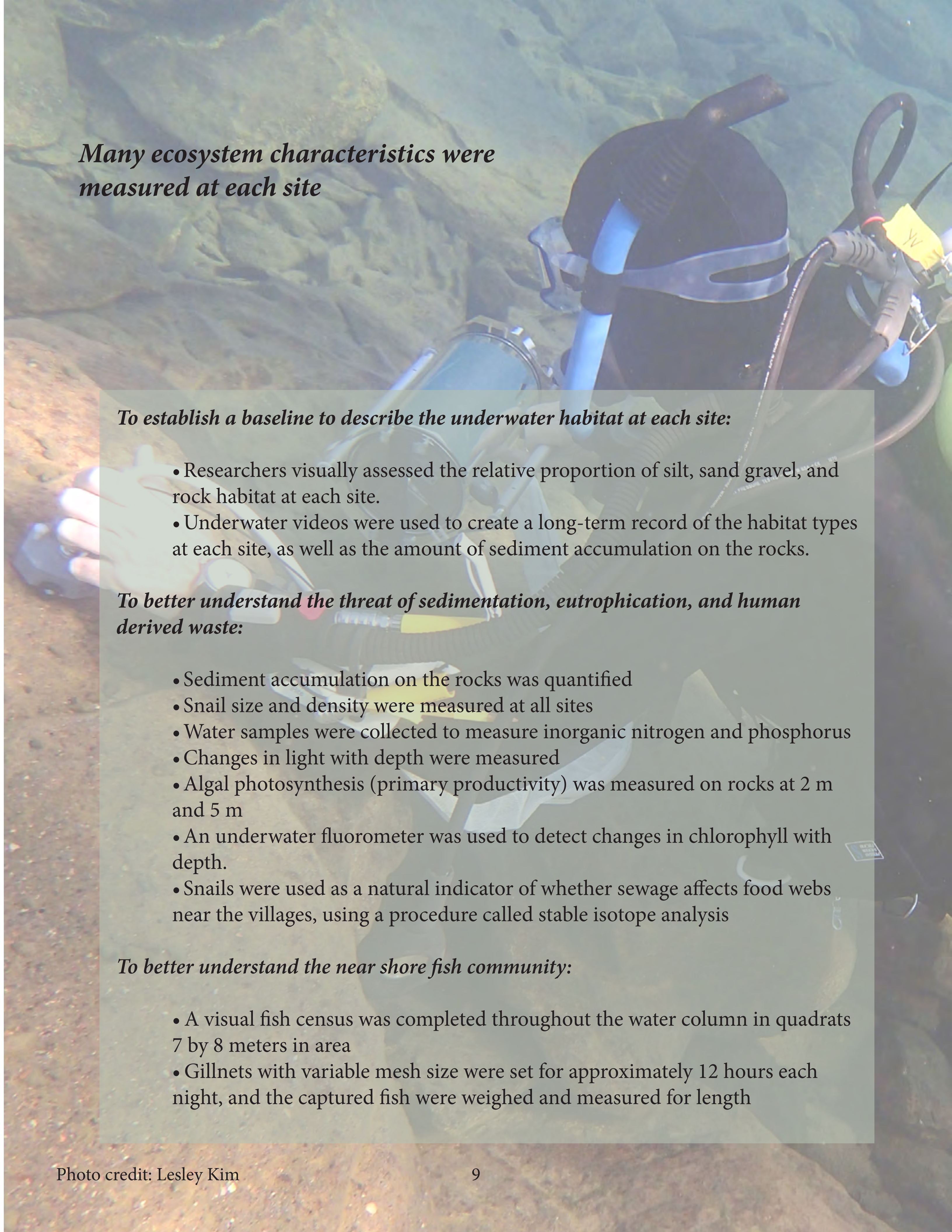
The underlying structural composition of habitats was similar at all sites. However, there were important differences among sites due to altered ecological processes. For example, silt and sand blanketed the rocks at the village sites, while rocks within MMNP had very little silt on them. Although it is impossible to be certain based on existing data, it is likely that the biological community in village sites resembled MMNP sites before ecological degradation from human land use and fishing activities took place.

The littoral zone of Lake Tanganyika supports a diversity of fish and invertebrates found nowhere else on Earth. The long-term health of this unique aquatic community requires that the ecosystem supplies the food, shelter and other resources that the animals depend upon. Most of the fish and invertebrates in the rocky habitats directly or indirectly rely on microscopic algae for energy. Lake Tanganyika has a unique community of grazing fish that eat the algae coating the rocks. Careful analysis of the food web has demonstrated that many of the predatory fish eat organisms that eat these attached algae. Thus, the algae growing on the rocks are critical to ecosystem health.

Threats to freshwater ecosystem health

Algae on the rocks can stop growing if light availability is reduced because water becomes cloudy from sediment runoff from the land. Sediment from hillsides can cover the rocky habitats of the near shore, negatively impacting algal growth and the digestion of grazing fish. Additionally, nutrients from sewage or agriculture can cause algae growing in the water to bloom, shading out algae on the rocks. These nutrients can stimulate the growth nuisance algae relative to the nutritious algae favored by many fish. Nitrogen and phosphorus are two elements that, in excess, stimulate nuisance algal growth. This process is called eutrophication and it dramatically changed the ecosystem of Lake Victoria just north of Lake Tanganyika. This is one good reason to be concerned about the threat of eutrophication to Lake Tanganyika.

Photo credit: Dr. Saskia Marijnissen



Many ecosystem characteristics were measured at each site

To establish a baseline to describe the underwater habitat at each site:

- Researchers visually assessed the relative proportion of silt, sand gravel, and rock habitat at each site.
- Underwater videos were used to create a long-term record of the habitat types at each site, as well as the amount of sediment accumulation on the rocks.

To better understand the threat of sedimentation, eutrophication, and human derived waste:

- Sediment accumulation on the rocks was quantified
- Snail size and density were measured at all sites
- Water samples were collected to measure inorganic nitrogen and phosphorus
- Changes in light with depth were measured
- Algal photosynthesis (primary productivity) was measured on rocks at 2 m and 5 m
- An underwater fluorometer was used to detect changes in chlorophyll with depth.
- Snails were used as a natural indicator of whether sewage affects food webs near the villages, using a procedure called stable isotope analysis

To better understand the near shore fish community:

- A visual fish census was completed throughout the water column in quadrats 7 by 8 meters in area
- Gillnets with variable mesh size were set for approximately 12 hours each night, and the captured fish were weighed and measured for length

Photo credit: Lesley Kim

We found no evidence that nitrogen from human waste is entering the ecosystem to the north or south of Mahale Mountains National Park.

The value of this information to conservation:

Nitrogen and phosphorous are critical nutrients for algal growth. At high concentrations they can cause nuisance algal blooms and lead to ecosystem degradation. We expected nutrients to be higher around the villages because both human sewage and runoff from cultivated land can increase nutrients. The concentrations of both nitrogen and phosphorus inside and outside of MMNP were uniformly low, typical of lakes that are not influenced by human sewage. ***The high water quality throughout the area is excellent news.***

The analysis of algal productivity and growth largely corroborated the nutrient results. There was no difference in algal productivity between park and village sites. The analysis of stable isotopes of nitrogen in snails was used to detect long-term influence of human sewage on the near shore ecosystem. Algal growth is generally enhanced by nutrient pollution, and previous stable isotope surveys of near-shore waters in the Kigoma region have shown that villages often create areas of local nutrient pollution along their shores. The stable isotope analysis detected no evidence that nitrogen from human waste is entering the food web.

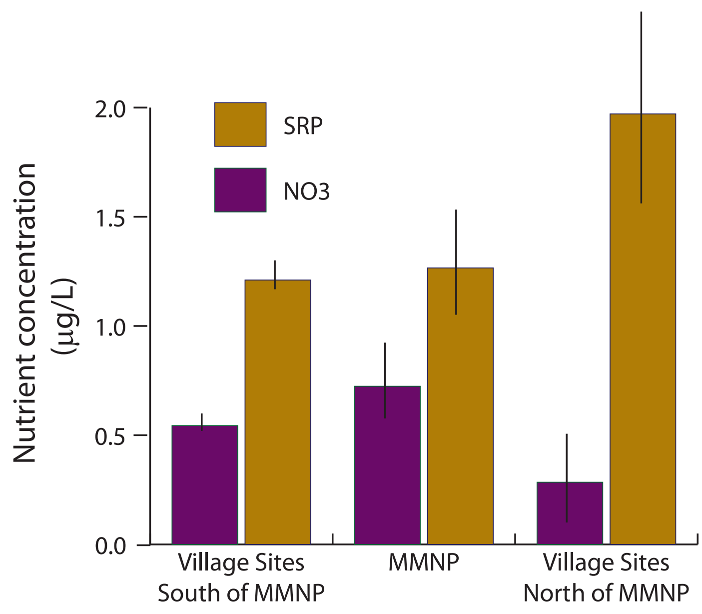


Figure 1. Nitrogen as nitrate (NO_3) and phosphorus as soluble reactive phosphorus (SRP) in and around Mahale Mountains National Park

We infer that the northward currents along the MMNP shoreline are sufficient to flush pollution away from the shore and dilute it into deep water. These currents may also reduce risks of *E. coli, cholera,* and *schistosomiasis* infections due to contaminated lake water at villages in the MMNP region.

Rocks at the village sites had about 5 times the amount of sediment on them as rocks at sites within Mahale Mountain National Park.

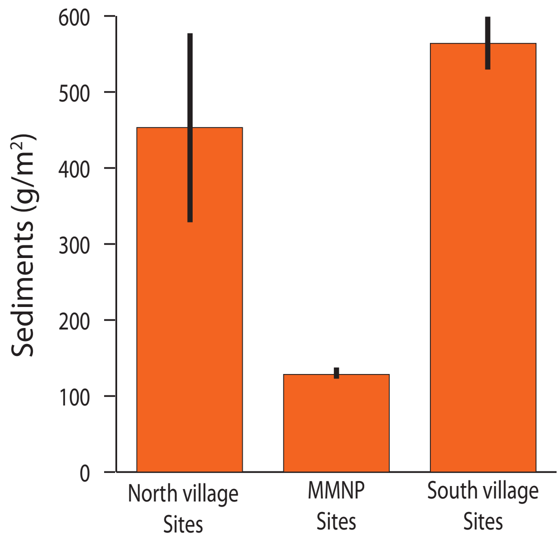


Figure 2. The concentration of sediment on rocks inside and outside Mahale Mountains National Park. Sand and silt that is transported to the lake during rain events can accumulate on the lake bottom, as indicated by these sediment concentrations.

The value of this information to conservation:

Sediment concentrations on rocks outside MMNP were much higher than within the park boundary. This is an indication of habitat degradation around the villages. It was very apparent that the forested shoreline within MMNP minimized the amount of sediment washed into the lake during the rainy season. Sediment covered the rocks at the village sites and there was circumstantial evidence of a negative impact of this sediment on algae, snails and grazing fish. The steep valleys of Mahale Mountain National Park are thickly forested, while the hillsides bordering the lake to the north and south of the park are sparsely vegetated. During the rainy season, sediment is delivered to the lake by rivers and overland flow. Deforestation outside the park likely contributes to heavy sediment load to the lake. The majority of this loading probably occurs during the rainy season and was not directly observed by the field team.

There was no difference in algal growth rates between the sites inside and outside the park

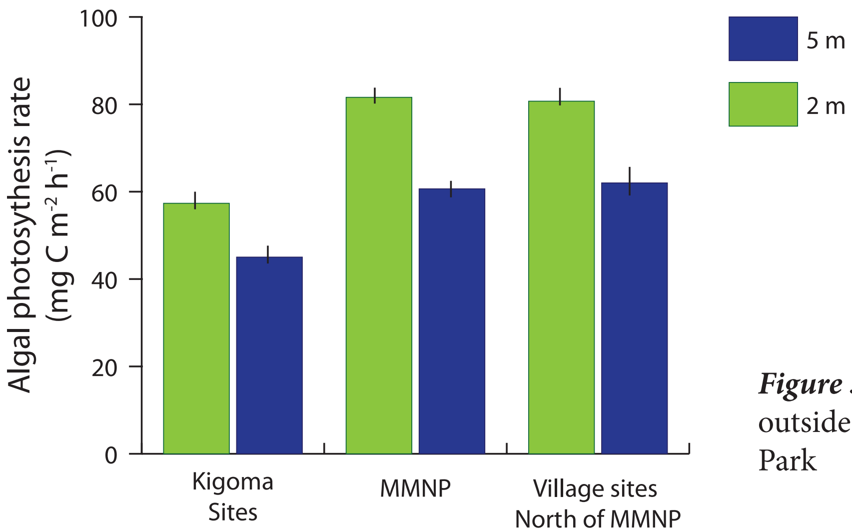


Figure 3. Algal growth rates inside and outside of Mahale Mountains National Park

The value of this information to conservation:

Algae growing on rocks is a critical resource for the entire near-shore food web. There was no difference in algal growth rate between the sites inside and outside the park (Figure 3). Photosynthetic rates overall were higher than in the Kigoma region, which is consistent with historical data. This suggests that the potential negative effects of ***sediment*** on algae at village sites (seen in Figure 2) may be offset by a reduction in grazing by fish. There were fewer grazing fish at village sites compared to sites within MMNP (Figure 4).

Strong differences in biodivesity exist between rocky habitats at village sites and sites within Mahale Mountains National Park

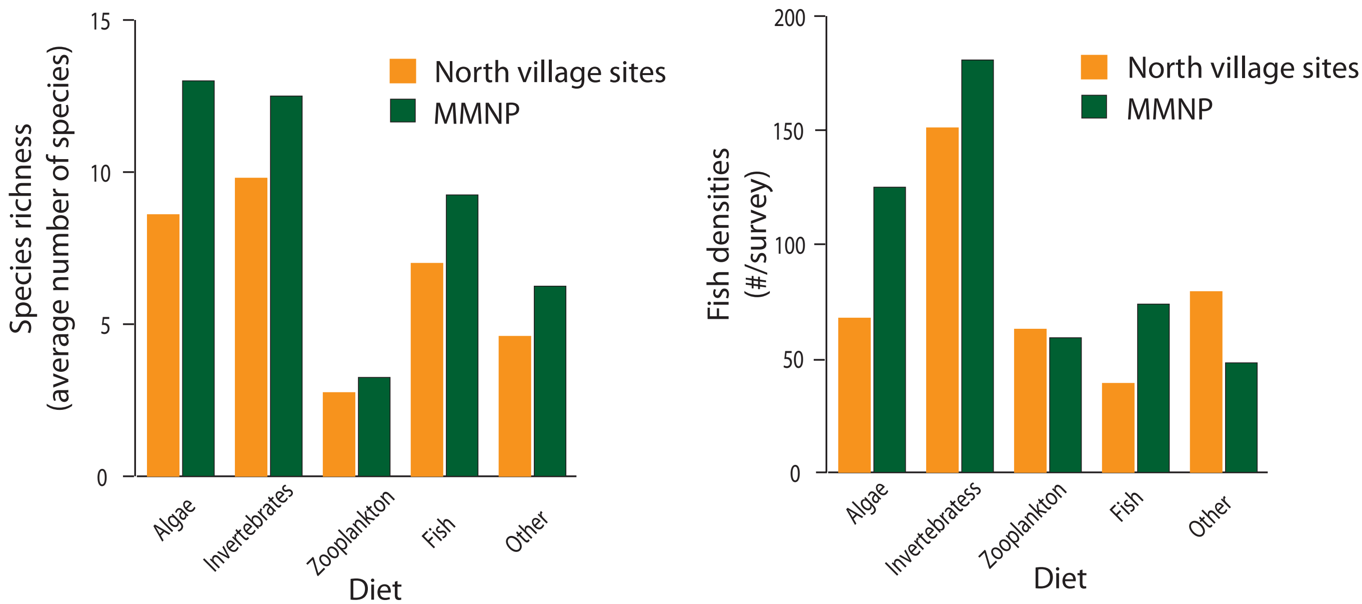


Figure 4. a) Average number of fish species observed at sites inside and outside of Mahale Mountains National Park (MMNP). b)Average number of individual fish observed. Data are from the visual census and species are categorized by feeding group

The value of this information to conservation:

Species richness of fish within MMNP (~45 species per site) was much higher than at the village sites near Kalilani and Buhingu-Mgambo (~32 species per site). All of Lake Tanganyika's major evolutionary lineages of fish are represented within the MMNP boundaries, and there is a similarly high diversity of feeding strategies. Fish species that specialized on attached algae, bottom-dwelling invertebrates, tiny crustaceans in the water column (zooplankton), whole fish, or fish scales were abundant at all MMNP sites.

At the village sites, there were many fewer species of algae eaters, and their densities were much lower that within the park boundaries. The fish community at village sites was dominated by small carnivores (fish- and invertebrate-eaters), and spiny eels were noticeably common.

Both fish diversity and fish densities were much higher within Mahale Mountain National Park than outside the park.

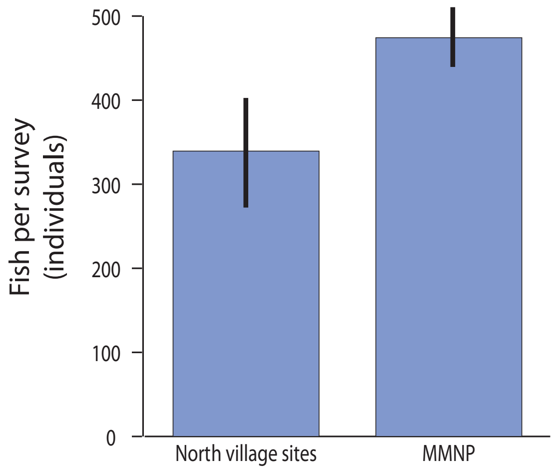


Figure 5. Number of individual fish seen per survey site inside and outside Mahale Mountains National Park (MMNP).

Nearly one and a half times more fish were found at each site within the park versus outside the park. Within MMNP an average of 475 fish were counted at each site, compared with 340 fish at each of the sites beyond the northern border of the park. This difference in abundance is a clear indication that the dramatically reduced fishing pressure inside the park can result in greater fisheries productivity. This is supported by, among other things, our anecdotal observations that fish inside the park boundaries were much less skittish.

All of this information suggests that strategies to employ small-scale freshwater protected areas and better regulate fishing pressure are warranted. Effective use of BMUs could significantly benefit the conservation of freshwater species diversity and help to increase fisheries productivity outside the current national park boundaries.

The maximum body size of almost every fish species in Mahale Mountains National Park appeared considerably larger than the same species near the villages outside the park or near Kigoma

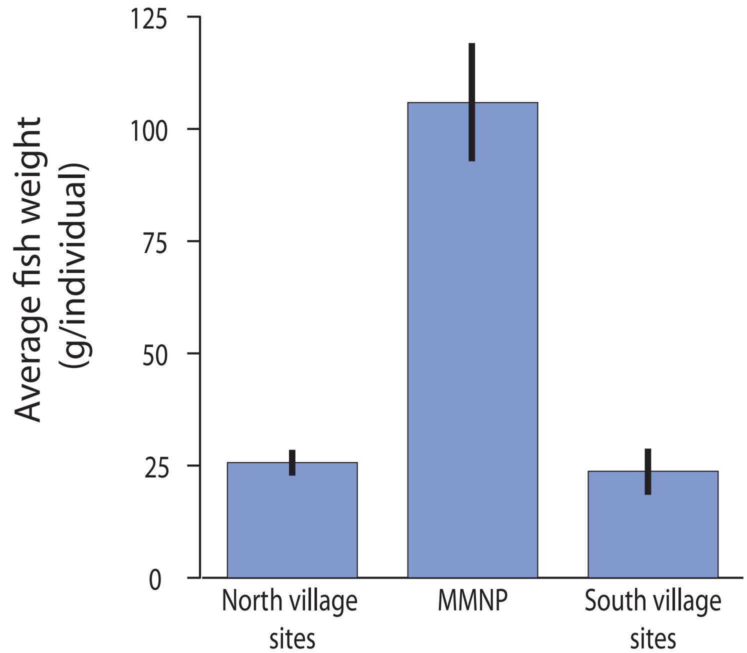


Figure 6. The average fish weight of individual fish caught in gillnet surveys inside Mahale Mountains National Park (MMNP) and near surrounding villages to the north and south of the park.

The value of this information to conservation:

Gillnet surveys inside and outside the MMNP boundary detected a clear impact of the no fishing zone. The average size of individuals caught in the overnight net sets within the park was much greater than at the village sites. In addition, large fish species that swim higher in the water and are targets of fisherman were more abundant within the park boundaries.

More specifically, individual *Lates microlepis* within the park were 1.4 times the weight of the largest individuals captured outside the park. Notably, large fish species that swim widely and are easily targeted by fisherman were common in the near shore habitat within MMNP: large *Auchenoglanis* catfish, mackerel cichlids (*Bathybates*), large African tetras (*Brycinus*), and many species of barbs (*Barbus* and relatives). Moreover, the abundance of barbs (which breed exclusively in tributary rivers) as well as tetras, crocodiles, and hippos suggests that MMNP provides an important reserve for lake-river-wetland connections. These connections have been lost along much of the Tanganyika shoreline due to habitat degradation and overfishing.

The fish within the park boundaries were also much larger than similar species near Kigoma, in northern Lake Tanganyika. The large size, high densities and high diversity of fish within the managed area of Mahale Mountains National Park compared with other areas of the lake is strong evidence of the ecological benefits of the fishing ban. These data suggest that small-scale or year round protected areas similar to MMNP are likely to be effective conservation tools. In contrast, the prevalence of smaller fish and lower fish abundances outside the park indicate a probable long-term decline in lake-derived protein for people in the region consuming the fish caught legally outside the park. Management strategies that reduce the harvest of fish outside of conservation areas may help ensure the long-term sustainability of the Lake Tanganyika near-shore fishery.

The biodiversity of the snails in and around the northern end of Mahale Mountains National Park is very high.

The value of this information to conservation:

Snails are an excellent monitoring tool because they are common and easily collected grazer on the attached algae that is a critical food resource in the Lake Tanganyika ecosystem. Lake Tanganyika has extremely high snail biodiversity compared to other freshwater lakes and the majority of snail species are found nowhere else in the world. Snails can be used as an indicator of the impacts of sediment on grazers in the ecosystem, and their body chemistry can be used to determine whether nutrients from human sewage are entering the food web.

Experts on Lake Tanganyika snails found many undescribed species in the 2012 collection. It may be many years before the diversity of the collection from northern MMNP is completely inventoried and this may well lead to a reevaluation of the taxonomic diversity of Lake Tanganyika snails. This is just further evidence that the freshwater diversity in Lake Tanganyika is globally significant, as there are likely to be many species previously unknown to the scientific community. Snails are simply one of many under-inventoried groups in the lake.

Photo credit: Dr. Saskia Marijnissen

However, snails at sites near northern villages were very small compared with those living in the park.

There were striking differences between the size of snails at village sites compared with sites within the park boundaries (Figure 7). Snails were much smaller and tended to have higher densities at the village sites compared with the sites within MMNP, perhaps because silt on the rocks outside the park interferes with snail foraging and digestion leading to lower growth. There appear to be different, and fewer, snail species on rocks outside the park, though the taxonomic challenges make this impossible to determine at this time. Strikingly similar patterns were documented in earlier research on sedimentation effects on snails near Kigoma, suggesting a broad syndrome of aquatic habitat degradation leading to loss of invertebrate biodiversity. This places greater importance on conservation strategies that reduce sedimentation to the lake.

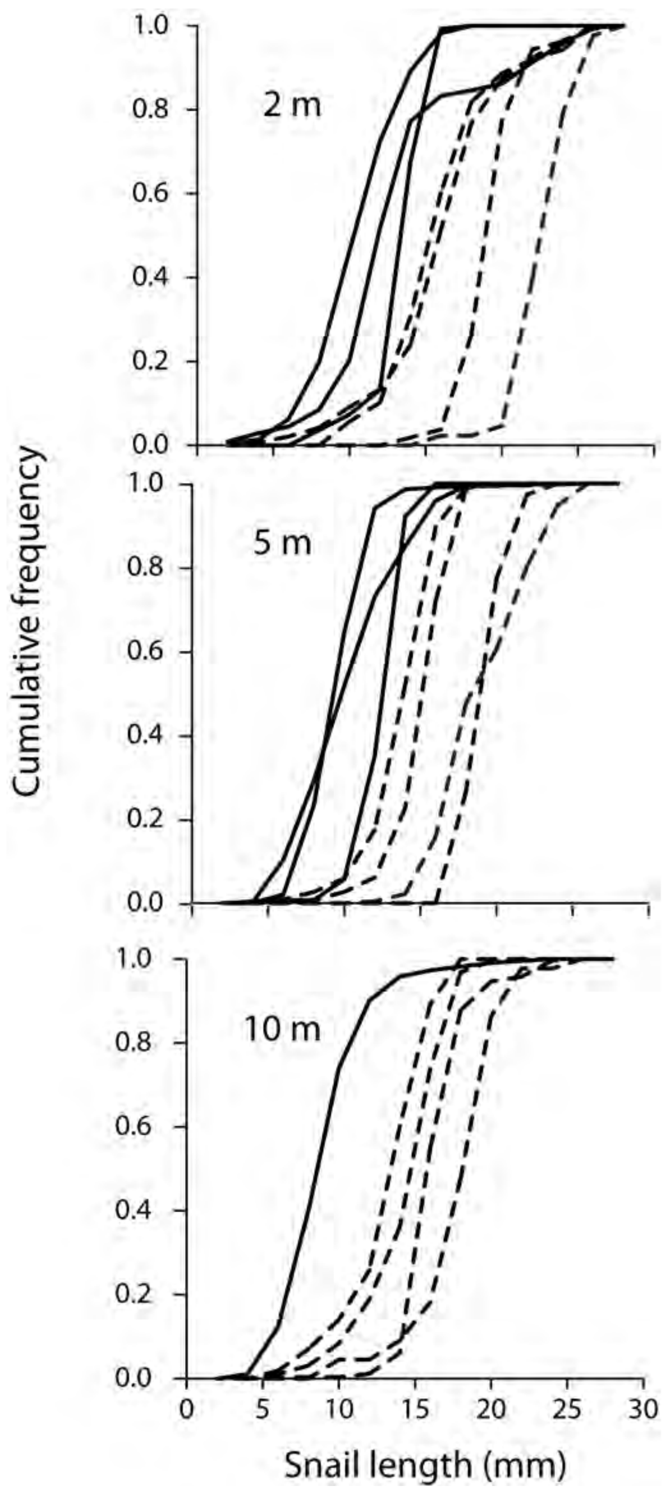


Figure 7. The cumulative frequency of snails collected from Lake Tanganyika. Snails from sites within MMNP (dotted lines) were bigger than those collected near the village sites (solid lines) outside the park. The y-axis shows the cummulative proportion of the population that is less than a given size. Snails were sampled at three different depths (2, 5, and 10 meters) and are illustrated by the three graphs.

Both of the key threats to the spectacular near shore biodiversity of Lake Tanganyika—sedimentation and over-fishing—are obvious in the villages just outside the boundaries of MMNP, but virtually absent within the Park. However, there was no evidence that pollution from human sewage is negatively impacting the ecosystem in these same villages.

Aquatic biodiversity within MMNP is extraordinary; our experienced team has never seen such rich fish assemblages and abundant large snails. Past work near Kigoma suggests that snail sizes are sensitive indicators of sedimentation while fish sizes reflect the intensity of artisanal fishing. Both fish and snail sizes within the park suggest effective protection from these threats. As we surveyed village sites to the north of the park boundary, both taxa shifted dramatically in size, and the team felt that conditions were some of the worst seen outside of Burundi. Interestingly, our analysis of local nutrient pollution near villages suggests that natural hydrological flushing of the near shore zone in the MMNP region buffers the near shore zone against chemical pollution from current human sources.

As there is now further local evidence to show these two threats are real and negatively impacting the freshwater resource around the park, conservation strategies to conserve freshwater biodiversity and fisheries productivity should focus on reducing the threats of sediment loading to the lake and over-fishing.

Photo credit: Yvonne Vadeboncoeur

Implementing land uses that reduce sediment loading into the near shore zone can yield benefits to the aquatic ecosystem and likely the fishery

Sedimentation arises from removal of the coastal vegetation for farming or grazing, allowing heavy rainfall to erode fine soil particles from the steep hillsides into the water. Dry-season burning is rampant along the Tanzanian shoreline, and surely contributes to erosion by removing grasses and shrubs that anchor the soil as well as detritus that shields the soil surface from rain. There will always be pressure from local populations to use the shoreline for agriculture and grazing, but advocating for methods that increase soil retention and mitigate potential damage to fisheries could lead to better practices that would be self-perpetuating. If sediment inputs cease, most of the silt currently covering near shore substrates will be displaced into deeper water within a few years, though the potential for complete reversal of sedimentation is uncertain.

Enforcing the fishing ban within MMNP's coastal waters and discouraging overharvest near villages are essential strategies for sustaining near shore fisheries.

The fishing ban within park waters has prevented the removal of large, predatory fishes that have been lost from most of the lakeshore, and allowed natural dispersal and recruitment processes to support a diverse suite of cichlids and other fishes. Immediately outside the park, intensive artisanal fisheries have dramatically reduced the diversity, density, and size of fish available for harvest. Use of fine-mesh beach seines and bag nets allows capture of even young fish, ensuring that stocks near villages cannot recover. Net size and style are the most easily regulated factors. The key constraints that currently prevent more extensive overfishing are high gear loss rates in rocky areas, lack of snorkeling masks to enable targeting individual fish, and the expense of motors/fuel for traveling far from villages. If any of these limits is eased, the intensity and spatial scale of fishing pressure could increase further.

Photo credit: Lesley Kim

Terrestrial conservation efforts within MMNP are effective in sustaining water quality and terrestrial conservation goals. Conservation efforts should continue to be supported. The survey team saw more species of birds, mammals, and trees along the shoreline in a few weeks of work in MMNP than we have observed in over a decade of research near Kigoma.

The survey team was struck by the richness of biodiversity along the park shoreline. Divers never encountered water cobras at the village sites, but they were common and thrilling diving companions in the park along with the occasional hippo or crocodile. The park is protecting all types of lake-dependent vertebrates, some of which may have the capability of re-colonizing village waters if given the opportunity. In particular, the lack of gill nets inside the park likely enables water cobras and crocodiles to persist; both are subject to by-catch mortality in gill nets. We found one hippo bone underwater near a northern village, and our observations of crocodiles and birds suggests that all large, semi-aquatic animals are currently restricted to the park itself. The common occurrence of large water cobras within the park suggest that the fishing ban has had the unintended and welcome consequence of protecting this endemic reptile.

Photo credit: Lesley Kim