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Solar-LED alternatives to fuel-based Lighting for night fishing

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ABSTRACT

Many of the 12 to 33 million artisanal ("small scale") fishers in the developing world work at night using energy-intensive kerosene lanterns to attract fish to their nets. In Tanzania—where 100,000 such fishers operate, spending US$70 million per year on lighting—we identified current practices and conducted user-centered field tests of LED-based system usability, performance and energy savings potential, and estimated the market size for today's fuel-based lighting. Fishers in the areas we studied spend 35% to 50% of their take-home pay on lighting equipment and fuel. Due to the combination of higher intensity pressurized lanterns, and longer operating hours, Tanzanian fishers use as much lighting fuel as would about 1 million ordinary household lanterns. We found that similar catches could be obtained with battery-powered LED lighting systems, with a simple payback time for the LED system investment of three to four months. The fishers we interviewed were almost universally pleased with the concept behind the lights used in the field tests, and eager to purchase them provided the right price and performance. However none of the LED systems we tested were adequate for this use. Essential product modifications include improved durability and performance in harsh fishing environments. Independent testing and certification would encourage product quality and support consumer confidence as they adopt these highly beneficial new technologies. Our results provide a roadmap for product manufacturers and others interested in deployment, with an overnight-conversion market size of US$17 to US$21 million in Tanzania alone, plus US$6 to US$7 million per year in ongoing replacement expenditures. This potential could well justify retooling and marketing investment on the part of lighting manufacturers.

Introduction

Fuel-based lighting is pervasive in the developing world (Mills, 2005), and alternatives have been noted since the early 1990s (Dutt and Mills, 1994). Most efforts to understand the current conditions and potential for these alternatives focus on household uses. Yet, non-household uses tend to be more energy intensive because they often use higher-power lanterns and have longer operating hours. Also of importance, by virtue of occurring in a business context, there is often more structure and available capital to invest in alternatives. One such application is night fishing, the subject of this study.

Around the world, night fishers use lights to catch small pelagic fish, such as sardines and herring. These fish, which live near the water surface and usually move in schools, feed on zooplankton. When zooplankton are attracted to light, the fish follow, schooling—in a sense unknowingly—around the light source, and can then be harvested.

In small artisanal fisheries in developing countries, pressurized kerosene lanterns are widely used to attract fish. Typically consuming between 1 and 2 l of fuel per night of fishing (and in rare cases up to 3 l per night), these lanterns are expensive to operate and thus pose an obstacle to economic development. At the same time their use is associated with the emissions of a considerable amount of carbon dioxide (CO_2) to the atmosphere and a variety of health risks (Mills, 2012).

The aim of the research described in this article is to investigate the technical and economic value of replacing kerosene lanterns with off-grid LED technology. We employed a user-centered process, assessing both technological and socioeconomic dimensions of existing and alternative methods of illumination. This enabled us to identify possibilities for the fledgling off-grid lighting industry to manufacture and deploy a viable commercialized product to this sizeable and previously untargeted market segment.

Our field work, conducted over a five-week period in Tanzania, focused both on freshwater fishing – Lake Victoria (Mwanza and the surrounding area) and Lake Tanganyika (Kigoma region) – and ocean fishing — Stone Town, Zanzibar and Pangani, mainland coast. In addition to testing specific technologies, we characterized the market in each location in order to obtain a deeper understanding of the socio-economic structures of the fishing communities and how lighting equipment is obtained and financed.

Interviews were conducted with the fishers to assess needs and obtain a very specific user assessment of various LED alternatives during repeated periods of night fishing. The prototypes we tested were

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improved or otherwise varied and retested. To gain insight into the broader socioeconomic and market factors potentially impacting the uptake of alternatives, the team conducted extensive interviews with boat owners, fish traders, local experts and institutions.

With LED and solar technology at its current stage of development, a commercialized replacement product is doubtlessly feasible and demand among fishers for a cheaper and better solution is high.

Light and fish

In water, the relation between light intensity and range of attraction for fish is not proportional. Ben-Yami (1976) cites an example from the Caspian Sea. Here, an increase in light (lumens) by a factor of 80 increased the radius of attraction only by a factor of 1.6, and the volume of water in which fish were attracted by a factor of 4.1 (Ben-Yami, 1976; 36). This implies that there are decreasing marginal returns to more powerful light sources, both in physical as well as in economic terms (capital and operating costs, whether electric or fuel). It may be more sensible, then, to use an array of smaller lights rather than a single larger one so as to illuminate a greater area less intensely.

Fish will gather in schools around the source of light, allowing the fishers to seine (net) around them. There are different interpretations of and explanations for this behavior (Ben-Yami, 1976). The most common one is feeding. One relevant process is that zooplankton move toward light, followed by the fish.

Within East Africa, where our project took place, the main species sought by local fishers belong to the *sardinella* and *sardina* genera. These two genera muster similar behavior patterns (Ben-Yami, 1976). During the day, they move in schools relatively deep below the surface. During the night, they disperse and ascend closer to the surface. Confronted with artificial light, they again-gather into schools and move toward the light source. It seems that the fish need light to school but avoid strong light. They remain at a certain distance from the light source, which is why some fishers dim their lanterns in the final phase of fish attraction so as to draw the fish close. When faced with a light intensity beyond their level of comfort, the fish are disoriented and react with erratic movement. The fish feed inside the illuminated zone. Other factors, such as age and gender of the fish, season, water temperature, and phase of the moon also have an effect on the attraction to light. Experiments suggest that these *sardinella*-type species react more advantageously in fishing terms to short wavelengths of light, that is, blue, green, and violet.

The global market & environmental context

Night fishing using light to attract fish is practiced virtually all around the world, both in developing and in developed countries (Ben-Yami, 1976). The technique is practiced on large and small scales. The sources of light range from crude flame torches to kerosene lanterns to high-intensity electrical lights in commercial fisheries. The use of kerosene lanterns for fish attraction, prevalent in small-scale[1] artisanal fishing in developing countries—the focus of this article—is less effective than modern practices, but requires a lower initial investment. Yet it has high operation and maintenance cost in developing countries due to the low quality and energy inefficiency of the lanterns.

Hence, artisanal night fishers would benefit most from a more energy- and cost-efficient lighting solution. Kerosene is not only an obstacle from a profit-maximizing point of view; it can consume a substantial portion of already very limited earnings, and thus contribute to poverty (Fig. 1).

From a sustainability perspective, artisanal fisheries are often a point of focus. In comparison with commercial fisheries they can have lower ecological impact, lower energy consumption, and higher labor intensity. They provide employment opportunities, are integrated into local communities, and have lower technology and investment cost (Johnson, 2005). One estimate identifies more than 12 million artisanal fishers worldwide, producing about 30 million tons of fish, and providing nutrition upon which approximately 150 million people depend (Pauly and Jacquet, 2008). Another estimate places the number at about 18 million fishers, of which 95% live in developing countries (Decoster and Garces, 2007), and a third places the number of fishers (those employed as fishers 30% of their time or more) at 33 million in the developing world alone (Mills et al., 2011). It is not known what fraction of the total is represented by artisanal *night* fishers who use fuel-based lighting to attract fish.

Other authors have identified kerosene-based light attraction techniques throughout the developing world, including elsewhere in Africa [Ghana (Bannerman and Quartey, 2004), Nigeria], Asia [India (Achari et al., 1998; Apte et al., 2007), Philippines, Sri Lanka (GNF, no date)], Indonesia (Van Oostenbrugge et al., 2001), Oceania [Polynesia, Micronesia, and Kiribati (Dalzell, 1992); and Papua New Guinea (Sullivan et al., 2004)], and South America [Brazil (Martins and Perez, 2006)].

A recent visit by the author team to Senegal found very different practices, with primary reliance on electric flashlights, with the primary purpose of ensuring safety (rather than attraction) from the larger and more dangerous fish netted there (e.g., barracuda, tuna, and sting rays). Low-quality LED products and batteries are used, which are unreliable and costly to operate.

Practices clearly vary by locality. There has been no global meta-analysis on the problem of fuel-based lighting for night fishing in the developing world. A small number of lighting manufacturers have promoted systems based on electrical light for replacing kerosene in fishing applications, and a handful of pilot studies have been conducted, few of which published much hard data (Gengnagal et al., 2013).

Market structures: the case of Tanzania

Within East Africa, night fishing has widespread application. In addition to the freshwater fishing sites the team visited in Tanzania–Lake Victoria and Lake Tanganyika, which share borders with Kenya and Uganda on the one hand and the DRC, Zambia, and Burundi on the other hand–kerosene-based fish attraction is practiced at Lake Malawi (Tanzania and Malawi), Lake Albert (Uganda and the DRC), Lake Kivu (Rwanda and the DRC), Lake Kariba (Zimbabwe and Zambia) Lake Cahora Bassa (Mozambique), and Lake Mweru-Luapula (Zambia and the DRC) (Legros and Luomba, 2011). The light-attracted fish of interest is called *Dagaa* in Tanzania, encompassing various species of *sardinella*, *sardines* and *carp*.

The technique is also practiced at the Indian Ocean fishing sites along the coastlines of Tanzania, Kenya, and Mozambique, and perhaps other coastal states in East and South-East Africa.

The Tanzanian fishing sector has great importance for the country's economy and employment. In 2005, it contributed 2.9% to the Tanzanian GDP—with around 150,000 artisanal fishers—and the sector is a source of income for about two million people. Fish is the third most important export commodity after mining and tourism, with a value of about $145 million per year. Additionally, fish provide 27% of the animal protein consumed in the country (FAO, 2007). The annual catch volume amounts to around 400,000 metric tons per year. Inland freshwater fishing clearly dominates in terms of catch volume. The most important species in inland fisheries are Nile Perch, Tilapia, Lates, and *Dagaa* (INFOSA, undated). *Dagaa*, and in some cases Lates, are caught by light attraction.

[1] The FAO seems to equate small-scale with artisanal fisheries, a convention we follow for this article. However, this is not always the case. Some publications define as one distinct feature of artisanal fisheries that they are collectively owned and operated. In Tanzania, however, most of the fishermen we worked with were organized such that all equipment was owned by one fisherman, who employed a crew. Yet, these fishermen should qualify as artisanal. Market data reported in the literature may be contingent on the demarcation conventions.