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Fishing power of conventionally harvested wetland baitworms compared to black soldier fly larvae as alternative baits in tropical artisanal hook fishery

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Abstract
Extensive and intensive, harvesting of earthworms and polychaetes from wetland substrate, for artisanal hook fishery, affect structural and functional integrity of these critical habitats. Cultured Black Soldier Fly larvae (BSF, *Hermitia illucens*), are suggested as sustainable alternatives. This study compares bait and landed fish properties of wild earthworm (*Eisinia* sp) and polychaete (*Marphysa mossambica*), with cultured BSF larvae as bait, in hook fishery. Participating fishers, were supplied with known quantity of bait, and the duration and quantity of fish obtained, monitored. Hook casting, attractiveness and killing power, as well as fish quality and quantity, were computed and compared among sites and bait. Results reveal significant ($P<0.05$) differences in bait and landed fish properties. Lower bait casting (8.8%), but higher attractiveness (0.96) and killing power (55%), were obtained using polychaete in marine habitats, than either earthworms or BSF. Similarly, higher fish landings (0.59 $kg.hr^{-1}$), were obtained using polychaete, than comparable BSF or earthworm (<0.1 $kg.hr^{-1}$). We surmise that wild baitworms, are easier to handle, attract and land more fish, leading to higher variety and abundant landed fish, than cultured BSF larvae. Lower performance of BSF is attributed to; poor response of target fish to imprinted physical and chemical attributes of the bait. This may imply that fishers, have limited justification for substituting cultured BSF, with conventional wild baitworm in artisanal fishery. Further elucidation of drivers to bait choice and performance coupled with improvement in cultured bait quality might, provide sustainable solutions.

Keywords: Polychaete, earthworm, Black Soldier Fly; Bait efficiency, landed fish property

1. Introduction

Tropical artisanal hook fishers, deploy a diverse array of bait organisms, especially invertebrates (e.g. wetland polychaete and oligochaete in marine and freshwater, respectively), to enhance fish catchability and fishing power [1-5]. Although the fish stocks targeted by these fishers, are better studied, and shown to be overexploited) [6], bait use, remains largely conjectural. Widespread excavation and harvesting, of freshwater oligochaete (e.g. *Eisinia* sp) and marine polychaete baitworms, are however, reported from temperate [7, 8], subtropical [9] and tropical [4, 5] intertidal habitats. Bait harvesting, is known to affect habitat quality, which ultimately impedes floral and faunal survival [10, 11]. This precipitates unintended cascades on target and non-target biota, and ecosystems [1, 11, 12], and hence require sustainable interventions.

In temperate intertidal habitats, polychaete excavation, is regulated by restricting access and offtake, coupled with culture of a variety of invertebrates, as alternatives [13-15]. Black soldier fly larvae (BSF- *Hermitia illucens*), are polysaprophagous, ubiquitous, immature feeding dipterans, commonly associated with decaying matter in tropical regions. They are touted as ideal alternative animal protein source, due to the ease of culture, using organic side-streams, such as discards, offal, manure etc., and superior nutritional profile [16]. However, despite being frequently mentioned as bait [17], their performance as alternative to wild baitworm, has rarely been explored.

Bait performance, which is intimately linked to gear fishing power, encompasses handling properties, together with attractiveness and subsequent landing of target fish [18, 19]. Bait fishing power in marine longline and freshwater recreational fishery, has attracted attention, due to implications on by-catch and landings [20-22], but tropical artisanal bait performance, is rarely documented. Bait properties, such as shape, size, texture, scent, color, liveliness, among others, influence fishing power [17, 23, 24], with firm textured bait, such as squid, recording lower bait loss in marine longline fishery [23]. Similarly, despite limited details, Smith[17] (2002) imply higher landings, using unnamed maggots, than chironomid larvae, among recreational fishers.

Hook handling properties (i.e. ease of bait attachment and fish removal from hook), is influenced by hook, bait and fish morphology and texture, and also fisher experience [19, 22]. For instance, tiny or very large slippery hooks, bait and fish, would require more handling. Bait attractiveness to fish (i.e. bites, soaking duration), is influenced by among other factors, target fish behavior, habitat characteristics, but ultimately, physical, chemical and mechanical properties of the bait [18, 19]. Furthermore, fish catchability (i.e. killing power; proportion of fish encountered landed) of the bait, is critical to fisher bait choice and preference. Bait with low handling, but high fish attractiveness and catchability (killing power), are therefore ideal.

Fish quality and quantity, are important fishing power attributes of interest to the artisanal fishers. Ideally large, plump (e.g. higher condition factor) or higher trophic level fish, associated with superior nutritional profile [5, 25], are preferred. Similarly, quantity of fish landed, sustain personal nutritional needs, but also provide surplus, for livelihood support [26]. Thus, an alternative cultured bait, must demonstrate superior or comparable fishing power, as conventionally wild baitworms, in order to promote adoption by fishers, and hence this study.

This study compares bait and fish landing properties, between cultured (BSF larvae), and wild freshwater (earthworm) and marine (polychaete) artisanal bait. We hypothesize that there are no significant differences in the bait fishing power between cultured, and commonly exploited wild hook fishery baitworms.

2. Materials and Methods

2.1 Study area

2.1.1 Freshwater bait fishery

Freshwater fishery, was conducted at sites in Njoro (0° 22′11.0″S; 35°55′58.0″E), that is approximately 25 km south of Nakuru town, within Nakuru County, Kenya. The region, lies approximately 2700 m asl, within the Mau river catchment. Dense natural montane forest, dominated by *Juniperus-Podocarpus* complex, occur in the upper reaches, which is replaced by agricultural and peri-urban developments, towards Nakuru town. The area experiences high rainfall (650-1200mm) and low temperature (<20 ºC), especially during the long rain season (April to July).

Three manmade dams, located at; store Mbili (~300 m^2, 30 m deep), Kihingo (~150m^2 wide, 12m deep), and Kigesha (~200 m^2 wide 16m deep), created during quarrying in preceding eras (Mr. Maina, area chief, *Pers Comm*), were used. These impoundments are filled by rainwater and drained by gravity, and are important for livestock watering, during the dry season. Fish (~2400 fingerling), were stocked, during the 2007 Economic Stimulus Program targeting aquaculture development in Kenya. The fish are exploited by adjacent residents, using handheld hook and lines. Fishers, attach a single small hook (no 16 - 22) to makeshift wooden rods, and stand on the bank during casting. Fishing, is mostly performed at dawn and dusk, and fish harvested are for own consumption, but surplus may be periodically sold.

Wild freshwater oligochaete baitworm; earthworm (*Eisinia* sp), were obtained by shoreline mud excavation, using simple sticks, and baitworms harvested, carried in small containers. During bait attachment, pieces of worm are cut and attached to the whole hook, and baited hooks, cast into the water. Participating consenting fishers, were provided with known quantity (~50g) of earthworm, during each fishing occasion. The term ‘earthworm’ will be used in subsequent sections to denote *Eisinia* sp, in this paper.

2.1.2 Marine fishery

Marine fishery, was conducted at Mtwapa creek (3°57’16.2” S 39°45’29.1” E), in Kilifi County, that lies, approximately 10km north of Mombasa town, Kenya. The 13.5 km long creek, is fed by three seasonal rivers, with peak discharge of 0.3 $m^3.s^{-1}$. Climate at Mtwapa, is characterized by high rainfall (900-1100 mm) and temperature (25-30 ºC), especially, during the North Eastern monsoon driven rainy season (April-March).

A *Rhizophora* dominated mangrove forest, borders the creek [10]. Adjacent to the forest and upstream, arable subsistence farming predominate, but residential and tourism facilities, prevail at the creek mouth. 95 fish species occur in the creek, dominated by gerrid, haemulid and teraponid, with declining diversity upstream in a comparable creek, adjacent to Mtwapa Creek [27]. Mtwapa Creek fishers, undertake hook fishing during daytime low tide throughout the year. 2 to 3 hooks (size >14), are commonly attached to handheld nylon line. Hand and engine propelled canoes, are used to access nearshore fishing sites within the creek.

Five fishing sites; Pirates, Beach, Navy, Coral & Severin, within the creek, under the jurisdiction of the Mtwapa Beach Management Unit, were used during this study. Participating consenting fishers, were purposively identified and recruited with the help of local community and/or BMU at the respective freshwater and marine fishing stations. Consenting fishers, with at least five years of bait fishing experience, were used in the fishing trials, at respective fishing stations and sites.

Wild marine polychaete (*Marphysa mossambica*) baitworms, were obtained by excavation using a wooden stake (*chulo*), from mudflats at the edge of mangrove forest, commonly utilized by local fishers. The bait obtained, were weighed and enumerated and known quantity (~100g) provided to each fisher during a fishing occasion. The term ‘marine polychaete’ will be used in subsequent sections to denote Marine polychaete in this paper.

2.1.3 Cultured Black Soldier Fly bait

Fresh black soldier fly (*Hermitia illucens*) 5th instar larvae (BSF), were purchased from the Mtopanga Haller Farm Training Centre (at Mombasa, Kenya). The larvae were reared on a mixture of fruits and offal, over a duration of 14 days. The larvae were transported to the study station (freshwater/marine) and respective fishing sites in sealed containers. The initials ‘BSF’ will be used in subsequent sections of this paper to denote *Hermitia illucens* larvae.

BSF bait individuals, provided to fishers, were observed for viability before supply to participating fishers. Each fisher at each fishing station (Freshwater, marine) and respective fishing site, was allocated a known quantity of BSF (~75g), during each fishing occasion.

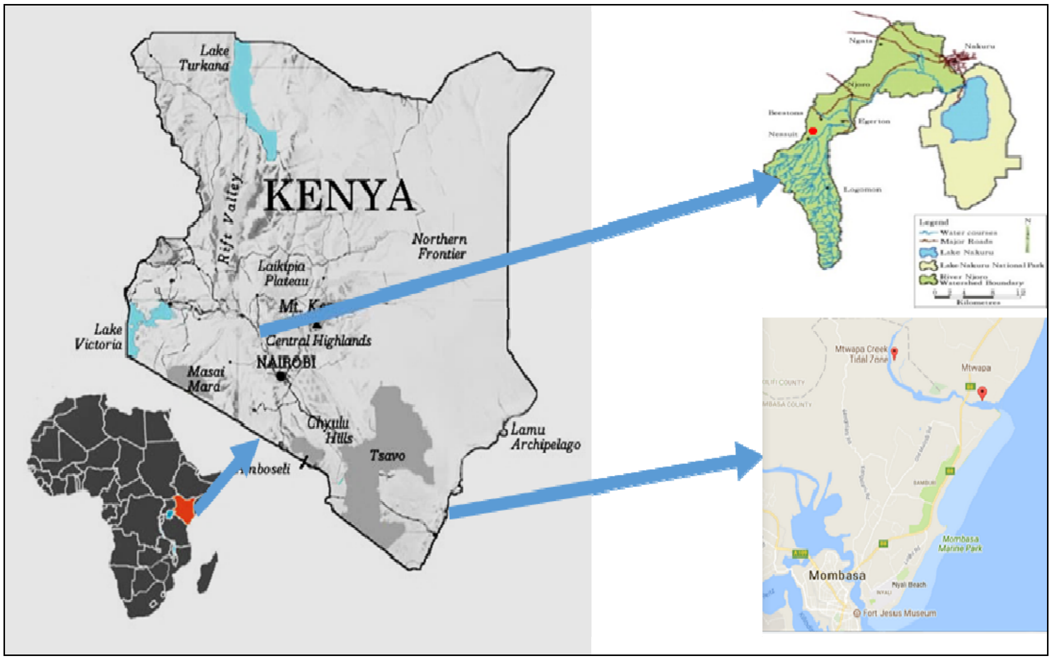

Fig 1: Map of Africa, Kenya with detailed sketch map of sampling locations at inland freshwater (Mau catchment) and coastal marine (Mtwapa Creek) sampling stations, Kenya

2.2 Determination of bait properties

Bait handling properties were evaluated by monitoring the duration for each hook preparation, prior to casting for each individual participating fisher. This comprised duration of; hook preparation (i.e. cleaning to detaching fish-HP_i), Casting (i.e. Attaching bait to casting hook- AC_i) prepared line, and Soaking (i.e. period from casting to catching or retrieving hook-St_i), for each fisher. Summation of hook preparation (HP_i) and Casting (AC_i) derived, Hooking Time (Ht_i), which was summed with Soaking Time (St_i) to derive hook Casting Time (Ct_i) for each bait. The values obtained, were used in computing Bait Casting Efficiency (BCE_i), using the following formula;

$$BCE_i = \left(\frac{\sum Ht_i}{Ct_i}\right) \times 100$$

Computed Casting time (Ct) and Catch Efficiency (BCE) for each bait type (i), were then compared. It is assumed that low Ct, but high BCE, correspond to superior bait.

Bait attractiveness (BA_i) was determined by monitoring and summation of the frequency of bites (bites or nibbles with no bait loss-B_i), losses (bait or fish lost-L_i), and catches (bite with fish on-C_i), obtained during each casting (n_i), and compared among the bait types. The values obtained were used to compute bait Attractiveness Efficiency (AE_i), using the following formula:

$$AE_i = \frac{BA_i}{n_i} \times 100$$

Attractiveness (BA) and efficiency (AE) values computed, were then compared among the bait types. It is assumed that bait with higher BA and corresponding AE, are more attractive to fish.

The soaking time (St_i) and also to fish landing time (Ft_i), for each casting and fisher, were also recorded. The values were used to calculate Soaking Yield (SY_i), using the following formula;

$$SY_i = \left(\frac{\sum St_i}{Ft_i}\right) \times 100$$

The soaking time (St) and soaking yield (SY) computed, were compared among the bait types and sites, assuming bait with low St, but high SY, have superior efficiency.

Data on bait attraction (BA_i) and fish landed (FC_i), was also used to compute bait killing power (i.e. proportion of fish encountered landed; catchability-k_i) using the following;

$$k_i = \frac{FC_i}{BA_i}$$

Killing power (k_i) values obtained, were compared among the treatments, assuming higher values correspond to superior bait.

2.3 Determination of fish landing properties of the bait

Quality of fish landed, was determined by monitoring and comparing morphometrics; weight (w_i), length (l_i) and width (h_i) of each fish landed, using respective bait, at each casting occasion. The data were used to compute fish condition factor (B_i) using;

$$B_i = \frac{\sum w_i}{\sum h_i . l_i^2}$$

The B values obtained, were then compared among the bait types, with the assumption that higher condition factor landings are of higher quality.

Additionally, fish obtained were identified using Richmond (2011) [28], among others, and the trophic level (TL_i)

determined from Fishbase [29] (Fishbase, 2011). Landed bait Fish Trophic level (FTL_i), was then determined for each casting, computed using;

$$FTL_i = \sum TL_i / n_i$$

The FTL values obtained, were then compared among the bait types, with the assumption that higher values correspond to superior landings.

Quantity of fish landed (Catch-FL_i) and duration of each casting expedition (effort-Ct_i), for each participating fisher, were determined, and compared among the bait types and station. The data was also used to compute Bait Catch per Unit Effort ($CPUE_i$) using;

$$CPUE_i = \frac{FL_i}{Ct_i}$$

Values obtained, for each bait type and station, were then compared. Higher Bait CPUE values are assumed to correspond to superior bait.

3. Results

A total of 360 castings, over a total of 9 fishing occasions, in freshwater (120 castings) and marine (240 casting) stations, were evaluated. Results suggest; fishers spent 13.06±0.19 sec preparing hooks, 599.18±19.84 sec soaking, giving an average casting time of 612.24±19.82 sec.

On average, fishers in marine habitats, spent significantly less time handling (ANOVA; F=180.60, $P<0.001$), soaking (F=34.01; $P<0.001$) and casting hooks (F=34.22, $P<0.001$), than corresponding fishers, at freshwater habitats (Table 1). BSF recorded significantly higher hook preparation (8.57, 17.55 sec in freshwater and marine stations, respectively) and soaking duration (458.44, 1064.81 sec in freshwater and marine stations, respectively), than corresponding wild bait at either station (i.e. Marine and Freshwater). Detaching duration for BSF (0.89, 0.13 sec in freshwater and marine stations, respectively), was however significantly lower, than respective wild bait in both habitats (Table 1). Hook handling, was lowest in BSF (9.43 sec) in marine habitats, but highest (17.68 sec) in freshwater habitats. However, casting time (216.09 sec) for Marine polychaete in marine habitats, was more than fivefold lower than the highest observed on BSF (1082.55 sec) in freshwater habitats.

Table 1: Hook handling properties of baited wild worms and BSF larvae in freshwater (FW) and marine (M) hook fishery in Kenya

Bait/Habitat	Hook prep (sec)	Soaking time (sec)	Detach time (sec)	Handling time (sec)	Casting Time (sec)
BSF (M)	8.57±0.14	458.44±32.40	0.89±0.28	9.43±0.31	467.88±32.37
Marine polychaete	7.09±0.14	205.01±32.40	3.99±0.28	11.03±0.31	216.09±32.37
BSF (FW)	17.55±0.19	1064.81±45.82	0.13±0.39	17.68±0.44	1082.55±45.78
Earthworm (FW)	12.78±0.19	668.40±45.82	1.25±0.39	14.03±0.44	682.43±45.78
Total	11.50±0.08	599.18±19.84	1.56±0.17	13.06±0.19	612.24±19.82

The average casting efficiency of bait examined, was 4.54±0.33%, however, there were significant differences among bait types (F=17.55, $P<0.001$) and stations (F=6.69, $P<0.001$). Marine polychaete casting efficiency (8.83±0.46%) in marine habitats, was significantly higher than either earthworm or BSF (Figure 2). Additionally, casting efficiency in freshwater habitats (2.47±0.54%) was lower than in marine habitats (6.61±0.38%).

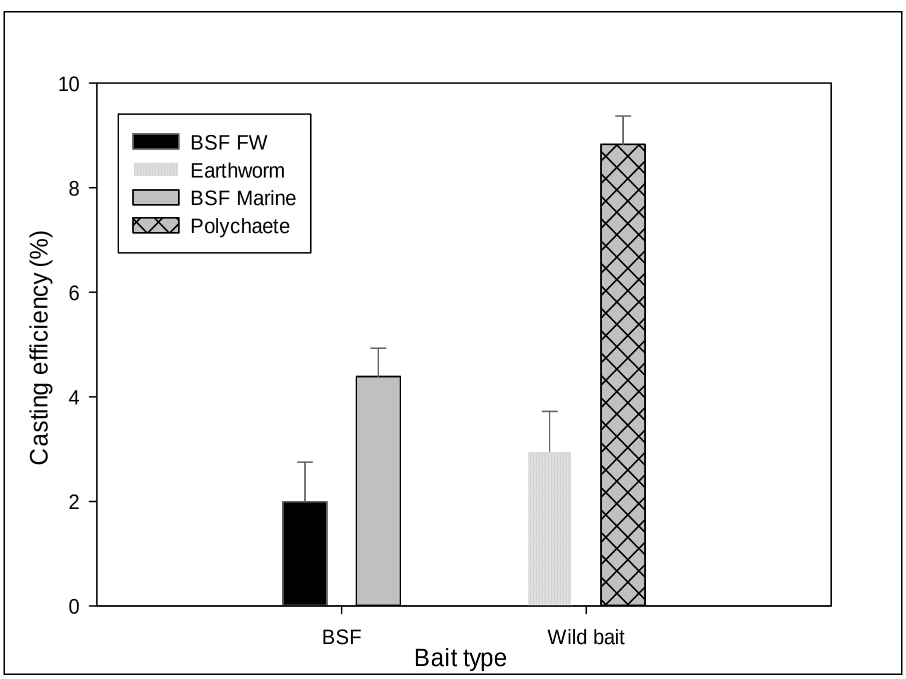

Fig 2: Casting effectiveness of wild bait and cultured BSF larvae in artisanal hook freshwater and marine fishery

In freshwater, the most common fate of bait was no interest (NI-60%) and loss (34%), while catch (6%) was least frequent. There were no significant differences (*P*>0.05) in the fate of bait among the bait in freshwater (Figure 3). In contrast, in marine habitats, the most common fate of bait was catch (33%), loss (33%) and no interest (26%), while nibbles were less frequent (9%) (Figure 3). This pattern however, differed among bait types, with BSF (47±5%), having significantly higher no interest (Mann-Whitney; U=48.0, *P*<0.001), while Marine polychaete (53±7%) recorded significantly (U=481, *P*<0.001) higher catch (Figure 3). Nibbles (>10%) and loss (33%), were however comparable (*P*>0.7), among the bait types.

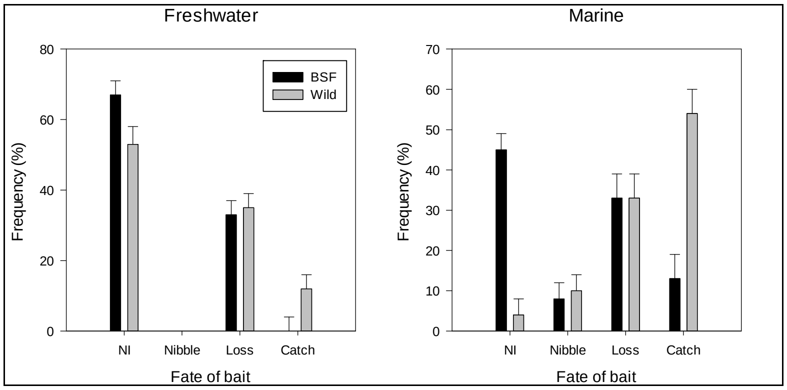

Fig 3: Fate of wild baitworms and BSF bait offered at freshwater and marine habitats in Kenya

In freshwater, on average 0.40±0.03 bait.cast^{-1} offered, were attractive to fish, corresponding to killing power of 9±4%. In freshwater, despite bait attractiveness and killing power of earthworms, being slightly higher than corresponding BSF, the difference were not significant (*P*>0.05).

In Marine habitats, 0.74±0.04 bait.cast^{-1} offered in marine habitats were attractive to fish, corresponding to fish killing power of 38±5%. Attractiveness (Mann-Whitney; U=532, *P*<0.001) and killing power (U=417.5, *P*<0.001), differed among the bait types (Table 2). Significantly higher attractiveness (0.96 bait.cast^{-1}) and killing power (55%), was recorded using Marine polychaete than corresponding BSF (Table 2).

Table 2: Attractiveness and killing power of wild worm and BSF bait in marine (M) and freshwater (FW) hook fishery in Kenya

Bait	N	Attractiveness (bait.cast^{-1})	Killing power (%)
BSF (M)	30	0.53±0.05	20.0±8.0
Marine polychaete	30	0.96±0.05	55.0±7.0
BSF (FW)	12	0.33±0.05	0±6.0
Earthworm	12	0.47±0.05	18±6.0

A total of 87 fish, from 9 taxa, were landed from both habitats. More taxa, were landed using Marine polychaete (8), than either BSF (3) or earthworm in freshwater. In the freshwater dams, only one taxa, *Oreochromis nilotica* was landed using earthworm, while corresponding BSF offered, landed no fish. In contrast, in marine habitats, the most common fish taxa landed, were *Lethrinus harak,* which comprised over 70% of landings for both Marine polychaete and BSF (Figure 4). The other important taxa, were *Lutjanus monostigma* (9, 19%, for Marine polychaete and BSF, respectively) and *Terapon jarbua* (3, 6%. for Marine polychaete and BSF, respectively) (Figure 4).

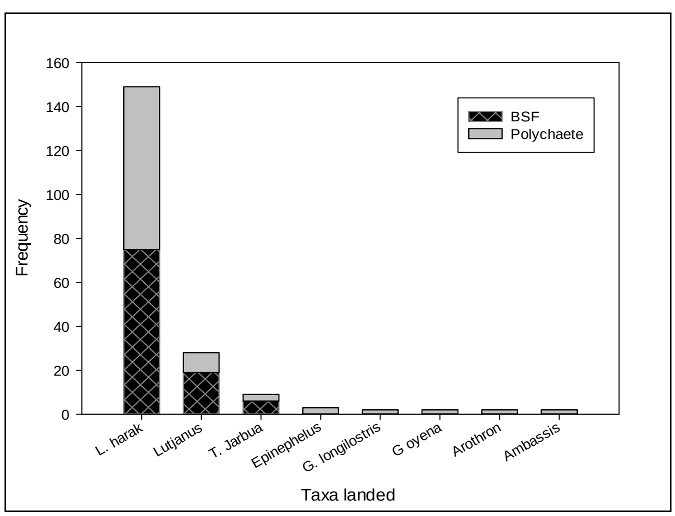

Fig 4: Composition of fish landed using polychaete baitworm and BSF bait in marine artisanal fishery at the Mtwapa creek, Kenya.

A total of 83 fish landed during the trials, were examined in marine (79) and freshwater (14) habitats. The average dimensions of fish landed, were 11.75 cm and 55.65g, corresponding to mean trophic level of 3.14 and condition factor of 0.10.

Although BSF landed slightly larger fish (12.59 cm), there were no significant differences in the fish morphological characteristics (Kruskall-Wallis; $P>0.5$), but trophic level ($\chi^2=30.06$, $P<0.001$), and condition factor ($\chi^2=9.87$, $P<0.01$), differed among the stations and bait types (Table 3). The highest trophic level (3.67) was encountered on BSF in marine habitats, while the highest condition factor (0.13), was recorded using earthworm in freshwater habitat (Table 3).

Table 3: Quality characteristics of individual fish landed using wild baitworm and BSF bait in marine and freshwater hook fishery in Kenya.

Bait/Habitat	N	Length (cm)	Weight (g)	Trophic Level	Condition factor
BSF (M)	16	12.59±0.81	58.23±12.31	3.75±0.07	0.07±0.04
Marine polychaete	63	11.97±0.41	46.30±6.21	3.67±0.03	0.09±0.02
BSF (FW)	0	-	-	-	-
Earthworm	7	10.97±1.22	62.43±18.62	2.00±0.10	0.13±0.06
Total	89	11.75±0.51	55.65±7.72	3.14±0.04	0.10±0.03

A total of 72 fishing occasions, were monitored in marine (48) and freshwater (24) habitats. During these fishing trials, an average of 0.85±0.04 hr were spent, landing 0.05±0.01 kg of fish, corresponding to catch per unit effort (CPUE) of 0.18+0.06 $kg.hr^{-1}$. Comparison of landings among habitats, reveal significant difference in fishing effort ($F=53.79$, $P<0.001$), but similar quantity fish ($F=1.71$, $P>0.05$) and corresponding CPUE ($F=0.32$, $P>0.05$). However, comparison of landings among bait types, show significant difference in effort ($F=15.32$, $P<0.001$), catch ($F=6.37$, $P<0.001$) and CPUE ($F=7.75$, $P<0.001$).

Among the habitats, the highest effort (1.23±0.07 hr) was recorded in freshwater habitats compared to 0.48±0.05 hr in marine sites. Although marine catch (0.08±+0.01 kg), was higher than freshwater (0.02+0.02 kg), the difference was not significant. Among bait types, the highest effort was encountered using BSF in freshwater (1.50 hr) and marine (0.30 hr), compared to corresponding wild baitworms (Table 4). On the other hand, the highest catch (0.12 kg) was recorded using Marine polychaete, which was threefold higher, than either corresponding BSF (0.04 kg), but also earthworms in freshwater (Table 4).

Table 4: Quantity metrics of fish landing obtained using wild worm and BSF bait in marine and freshwater hook fishery in Kenya.

Bait/Habitat	N	Effort (hr)	Catch (kg)
BSF (M)	24	0.65±0.07	0.04±0.02
Marine polychaete	24	0.30±0.07	0.12±0.02
BSF (FW)	12	1.50±0.07	0
Earthworm	12	0.95±0.07	0.04±0.01

Comparison of catch per unit effort (CPUE) among sites, reveal that in marine habitats, although catch (0.34±0.08 $kg.hr^{-1}$), was tenfold higher, than that from freshwater habitats (0.03±0.02 $kg.hr^{-1}$), this difference was not significant ($F=0.32$, $P=0.6$). However, comparison of CPUE among bait types, show significant differences ($F=7.75$, $P<0.001$). The highest CPUE was recorded using Marine polychaete in marine habitats (0.59 $kg.hr^{-1}$), which was six fold higher than BSF (0.09 $kg.hr^{-1}$), and tenfold higher than earthworm (0.06 $kg.hr^{-1}$), in freshwater habitats (Figure 5).

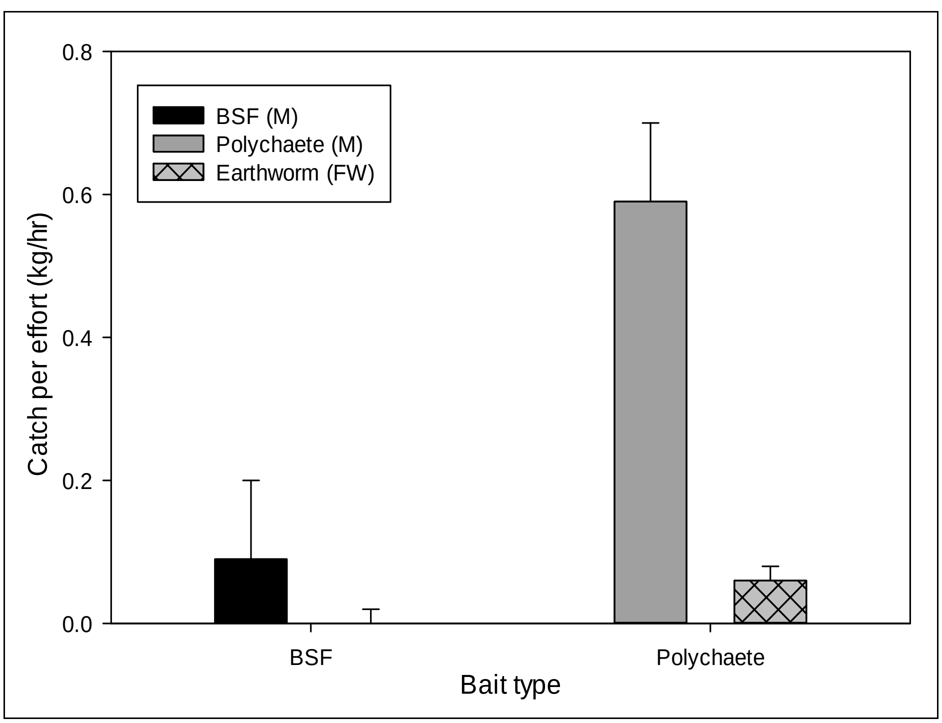

Fig 5: Quantity of fish landed using wild and BSF bait in marine (M) and freshwater (FW) fishery trials at sites in Kenya

4. Discussion

Hook gear casting consists of; hook handling (bait attachment and fish removal from hook) and soaking. Most fisher casting time, was expended during soaking (<90%), while over 60% of hook handling time, was spent in hook preparation. *Marphysa mossambica* (Marine polychaete-*choo*) is the least handled and soaked bait, while BSF, especially in freshwater, the most handled. Additionally, there is nearly a twofold higher soaking when using BSF, than conventionally exploited wild marine and freshwater baitworms.

Higher handling of BSF is related to the physical attributes of each individual, but higher soaking is attributed to lower attractiveness of the bait to fish, contributing to higher total casting time for cultured BSF. BSF larvae are commonly less than 5mm, while both earthworm and polychaete are over 10 cm long and 2-5 mm wide(eg [30]) (e.g. Kihia *et al*., 2017). BSF on the other hand, have lower detaching time, linked to lower fish catch, than corresponding conventional baitworm. Subsequently, conventional Marine polychaete and earthworms, have higher casting efficiency, than corresponding cultured BSF bait.

Additionally, there is higher handling, soaking and consequently higher casting time, but lower casting efficiency in freshwater, compared to marine habitats. This may be related to differences in habitat attributes, as well as target fish density, in the two habitat. We suspect there is lower fish density in the cold highland dams, than that at the warmer marine coastal creek.

Bait proffered to target fish on hooks, encounters three possible attractiveness responses of concern to fishers; nibbles, loss or catch. Bait, which, elicit neither of these responses i.e. No interest (NI), may imply limited attraction to target fish. Among the attractiveness responses; nibbles and loss, imply presence of fish or other organisms interested in the proffered bait, and hence, encourage further casting by fishers. However, it might also be precipitated by bites from unsuitable fish (e.g. fry, unpalatable fish) or other non-target organisms (e.g. frogs, aquatic snakes, among others). Both nibbles and loss, thus contribute to wastage of a finite resource (bait in hand, fishing time), affecting fishing efficiency and power, and may be critical, when bait supply is limited.

Over 60% of bait proffered in freshwater habitats, elicit limited response, culminating in lower attractiveness and killing power (>10%), compared to marine habitats, implying greater attractiveness in the latter. This may be attributed to higher fish density and variety in marine than freshwater habitats. In contrast, 70% of bait proffered in marine habitats, elicit attractiveness response, and culminating in higher killing power (38%). Nibbles (or bite) on bait proffered, are synonymous with gustatory investigative tasting response of the target fish, while loss and catch, is related to olfactory response (eg [31]) (e.g. Marui & Caprio, 1982). Similarly, killing power in this study, is synonymous with fish catchability(eg 19) (e.g. Ward & Myer, 2007).

This study has reported higher fish olfactory (Loss & Catch) and gustatory (Nibbles) response, and subsequent fish catchability (killing power), using marine polychaete, than either BSF or Earthworm. Differences observed, are attributed to physical and chemical profile of proffered bait. Physical and mechanical bait attributes, such as; vibrant colors, active movement and recognizable shapes, imprinted on predator memory, affect fish predatory response [32-34] (Lundmark, 2010; Chiao *et al*., 2011; Abbas & Meyer, 2014). Polychaete possess regenerative ability, and hence may retain some locomotor twitching, longer than either earthworm or BSF, when attached to hooks. Additionally, the stage of BSF larvae used (prepupating 5th instar), may also affect liveliness, and earlier stages need to be investigated. Furthermore, both wild earthworm and polychaete, are reddish-brown colored, while BSF are yellowish and become darker with pupation. Preference of red to bluish colored prey and avoidance of dark and yellowish prey, among carps (cyprinid) and salmonids has been described [35]. This tends to support the lower gustatory response to the novel bait (BSF larvae), compared to conventional baitworms, as reported in the current study.

Aquatic habitats, are visually limited but chemical stimuli rich, environments, which precipitated elaboration of sensitive chemosensory systems, among biota [36] (Barnard, 2006). Fish possess complex gustatory and olfactory organs, capable of not only collecting, screening and detecting, but interpreting chemical signals [37] (Enders, 1980). Gustatory and olfactory response of fish, are not merely important for feeding, but also govern reproduction, antipredator and migration activity[38] (Kasumyan, 2004). Fish have been shown to elicit gustatory and olfaction response, when exposed to amino acids, bile, nucleotide, steroids, prostaglandins and aliphatic polycations [35] (Rolen, 2000). These responses, are however dependent on the fish, but also prey type and behavior. Benthic and nocturnal foraging fish, are more sensitive to chemo stimuli, than pelagic visual predators [38] (Kasumyan, 2004). This may explain the higher attractiveness and catchability, in marine creek fishery, compared to freshwater.

Furthermore, live and dead prey, excrete and exude, a variety of chemical signals, which include organonitrates, semiochemicals, and aliphatic acids, known to elicit gustatory and olfaction response in fish [38]. These signals, are useful in prey detection, but also convey vital information on prey quality, that guide foraging strategy [36] (Barnard, 2006). Variation in concentrations of stimulants, attractants and deterrents in prey, may therefore impact predator response. Amino acids, such as alanine and lysine, in worms and insect larvae, respectively, elicit response in a variety of fish [36] (Barnard, 2006). Similarly, aliphatic acid exudates, such as putrescine, cadeverine and spermine, initiate four to tenfold stronger response, than conventional amino acid stimulants [35] (Rolen, 2000).

Earthworms and polychaete are rich in essential proteins (40-60% CP), such as lysine, alanine and leucine [39, 40] (e.g. Paolletti *et al*., 2002; Lourdumary *et al*., 2012). However, cultured BSF larvae also harbor substantial protein (38-46% CP) and essential amino acids e.g. methionine and lysine [16] (Schiavone *et al*., 2017). It is apparent that, although protein content, may be important in eliciting gustatory response, subsequent olfactory and killing response, may be influenced by the type and quality of chemical stimuli delivered. There is need to elucidate the biochemical profile of bait exudates, and consequent impacts on fish behavior.

This study has reported higher multispecies fish landing, dominated by Gerrids and Lethrinids in marine fishery, compared to monospecies in freshwater high altitude dams (Njoro, Kenya). The marine fish landed, are reportedly creek dependent benthopelagic fish [41, 42] (Mavuti *et al*., 2004; Wainaina *et al*., 2013), and hence their predominance at Mtwapa creek, Kenya. Nonetheless, evaluation of the fish quality attributes of landings, reveal predominance of small (>15 cm, 70g), low condition (>0.5), secondary carnivores (<3.0 TL). The size range and trophic levels reported here, concur with those of 4,5 Kihia *et al*. (2015 a, b) [4, 5], but condition factors are lower, in the current study. Differences may arise due to seasonality in catches, with lower catch in the NEM season, compared to the main fishing season (SEM)(eg [43]) (e.g. Frame survey, 2012). Apparently, bait type, may not influence landed fish quality, especially in marine habitats. It was expected that higher handling, lower attractiveness and catchability reported for BSF, would coincide with lower fish quality. The landing of several large (<200g), and probably more aggressive, high trophic level fish (>3.5), such as *Terapon jarbua* and *Lethrinus harak* by BSF bait, may have contributed to observed discrepancy. More data, especially during the main fishing season, is therefore needed in order to clarify drivers to landed fish quality.

In contrast, examination of quantity of fish landed per unit effort, reveal higher effort, but lower catch, corresponding to lower catch per unit effort using BSF and in freshwater, compared to Marine polychaete in marine fishery. CPUE is an important metric to fishery managers, but is a critical livelihood tool to resource limited artisanal fishers. Artisanal marine fishers commonly land between 1 and 4 $kg.d^{-1}$, from the semi-diurnal (~6hr) artisanal fishery [6, 43, 44] (McClanahan & Mangi, 2004; Frame Survey, 2012; Kihia *et al*., 2016). Only the marine polychaete (~3.5 $kg.d^{-1}$), has the potential of delivering comparable landings, which is sevenfold higher, than estimated landings using BSF.

5. Conclusions and Recomendations

Wild tropical polychaete and earthworm, have superior bait and fish landing properties, than corresponding cultured BSF larvae, in either freshwater or marine fishery. Higher performance of wild baitworm in fishery, is attributed to response of target fish to imprinted physical and chemical attributes of the bait. There is therefore limited justification for the uptake of BSF, as an alternative to baitworms by tropical artisanal fishers. Improvement in quality of BSF as bait, as well as testing of other suitable cultured bait such as; earthworm (vermiculture) and polychaete, may provide meaningful insights.

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