Exploitation Currency among Artisanal Bait Fishers; Are Intertidal Bait Harvesters Optimal Foragers? Some Consideration for Holistic Management

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Abstract

Optimal foragers target prey with superior energetic returns, and such metrics underlie most management interventions. However, tropical artisanal bait harvested by intertidal excavation and collection, enhance fish landings, and hence determinants to choice remain conjectural. Fisher interview were used to infer bait preference, and monitoring bait and fish landings, to compute energetic and fishery profitability. Harvesting of hermit crabs, mangrove whelk and polychaetes from mangrove and mudflat, and subsequent fish landings, were quantified at Mida creek, Kenya. Deshelled hermit crab weight was estimated by regression, and documented energy content and fishing fixed costs, were used to compute energetic and fishery profitability. Results show that despite whelks being least targeted (<5%), they had significantly (P<0.0001), higher harvesting (0.87 kg.hr^{-1}) and energetic returns (9750 kcal), compared to more popular, polychaete and hermit crabs. Mudflat polychaetes (preference>25%), recorded the lowest harvest return (0.13 kg.hr^{-1}) and harvest energetic conversion (0.87). Nonetheless, polychaete and hermit harvesters, had higher fish landings (>2 kg.d^{-1}), corresponding to higher income (>3$.d^{-1}) and profitability (>2.0), compared to whelk fishers. Therefore, fishery returns, rather than conventional harvesting metrics (e.g. energy), are important determinants to bait choice and harvesters may pursue preferred bait, due to perceived fishery gains, irrespective of harvesting constrains, with consequences on biota and ecosystem integrity. Bait management interventions that not only ignore the interrelatedness of the foraging and fishing grounds, but also the realities of fishery profitability, will inevitably impact lifestyle.

Keywords: Bait fishery; Fishery profitability; Harvest and energetic returns; Hermit crab, Mangrove whelk and polychaete.

INTRODUCTION

Artisanal fishers harvest a multispecies assemblage of bait, for insertion into hooks and traps, subsequently deployed in fishing (Kihia *et al.,* 2015a, b; Samoilys *et al.,* 2011). At the Kenyan coastline, hook fishers forage for polychaete from mudflats and hermit crabs from mangrove forest, while trap fishers gather whelks from mangrove forests (Njuguna *et al.,* in press; Nthiga *et al.,* in press). Despite several aspects of artisanal fishery being well known, patterns of bait utilization including drivers to preference, remain conjectural.

Optimal foraging strategies are Darwinian evolved heterotrophic predatory behaviors and activities that culminate in the capture and consumption of prey, while maximizing energetic returns (Charnov & Orians, 1973). This is achieved by minimizing prey search and handling constrains, by a judicial mix of habitat (patch choice) and prey selectivity (diet breadth), accounting for both hunt specific intrinsic (e.g. prey quality, weather) and extrinsic (e.g. habitat, biota knowledge) attributes (Aswani, 1998). Ethnographic literature is replete with descriptions of human hunting and gathering for edible prey, however, use of bait to enhance landings is scarcely pursued, despite ramifications on sustainability and cultural evolution.

The basic tenets of human hunter-gatherer strategy are gleaned from descriptions of indigenous hunter-gatherer (e.g. Marlow, 2002;Jones *et al.,* 1994; Hawkes & O'Connell, 1981) and fisher societies (e.g. Begossi *et al.,* 2005), employing handmade gears to pursue game mainly for; meat, medicine and ornaments, but also tools and clothing (Ripple *et al.,* 2016). They undertake both passive (sit and wait) and active (tracking and chase) hunts (e.g. Alves *et al.,* 2009), primarily motivated by economic (commercial) or subsistence needs (Ripple *et al.,* 2016; Garcia *et al.,*2012; Holmern *et al.,* 2004). Superior hunting strategy is commonly associated with higher hunter reproductive success, than contemporaries (Smith, 2004). Consequently, classical foraging models predict hunters optimize energetic returns by either targeting energy dense prey or easier to exploit patches (Charnov & Orians, 1973). Whether similar decisions apply to the adoption of fishery bait foraging strategy, remains unresolved.
Despite foraging strategies that maximize energetic returns being intuitive and commonly reported among a variety of predators, departures occur (e.g. Rutten *et al.,* 2006). Among human hunters (e.g. Ikung, Hadza; Hawkes &

O'Connell, 1981; Jones *et al.*, 1994; Marlow, 2002), and artisanal fishers (Begossi *et al.*, 2005), easier prey closer home, are frequently ignored, for less vulnerable, but superior quality prey or patches. Hence, apart from energetic and hunt success, other prey attributes (currency), such as prey quality, are also critical (Hooper *et al.*, 2015). In the context of bait fishery using a non-commercial and inedible bait, the quantity and quality of fish landed, may therefore be crucial to observed strategy.

Quantity and quality of fish landed by the bait fishers is closely linked to effectiveness of the respective bait, synonymous with gear killing power. Bait effectiveness is manifested in higher bait attractiveness, consumption and eventually landing of target prey (Kihia *et al.*, 2018). Hence bait foragers, may also target bait, due to their superior fishlanding power.

Furthermore, monetary consideration can rarely be ignored as a powerful driver to human hunting, and has been blamed for extirpation of a swathe of wild fauna (e.g. Cowlishaw *et al.*, 2005). Landing large quantities of fish, is not only critical to the subsistence needs of the fisher, but also supplies surplus for sale or barter. Monetary value of prey, is a unique humanistic value that is especially relevant when hunters have limited alternative sources of income (Wright & Priston, 2009). Among artisanal fishers, a nutrient poor subsistent diets, coupled with high poverty levels, are frequently blamed for making fishing, a critical tropical livelihood (e.g. Cinner *et al.*, 2010). Among fishers, higher value large top predators, as well as above average landings, may therefore ensure sufficient nutritional and monetary returns for the fisher and his dependents. Additionally, since man is a cultural being, other prey attributes such as size, ferocity, are also associated with demonstration of bravery, prestige and other socially acceptable 'costly signaling' norms (Agam & Barkai, 2018). Human hunt for large, rare, evasive or dangerous prey is linked to prestige, social status and phenotypic superiority (Rutten, *et al.*,2006; Smith, 2004). Whether bait foraging strategy adopted, optimizes fishlandings, requires elucidation.

This study examines observed fisher bait preference at two foraging patches to discern the most plausible explanation. We test the overlying hypothesis that bait harvesters are optimal foragers (i.e. maximize energy returns), compared to alternative hypothesis; optimize bait harvest returns, fish killing power, or monetary gain. Understanding drivers to observed preference, will subsequently provide important clues to guide initiation of appropriate inclusive, holistic ecosystem management strategies alive to the realities of extractive resource use along tropical shorelines (e.g. Aswani & Vaccaro. 2008).

MATERIALS AND METHODS

Study Area

Mida creek ($3^0$20´S, $40^0$00”E), located in Kilifi county, lies 88km North of Mombasa and approximately 25 km South of Malindi town (Figure 1). The creek covers an area of 31.6 km^2, consisting of mangrove forests, seagrass beds, sand flats, rocky outcrops and sub tidal habitats critical for juvenile fish. In recognition of the rich biodiversity in the area, the Watamu Marine National Reserve was protected in 1968, and subsequently gazetted as a marine national reserve in 1976, one of the three protected areas with mangroves in Kenya. Subsequently, in 1979, the Mida creek and adjoining coast were designated as UNESCO Biosphere Reserve.

Unlike other creeks and bays at the Kenyan coast, Mida Creek, lacks overland riverine input, but is sustained by belowground flow. Five sampling sites at the Mida creek; Dabaso, Kirepwe, Mayonda, Uyombo and Dongokundu (Figure 1), were chosen for sampling and fisher interviews, on the basis of prevailing artisanal fishing activity.

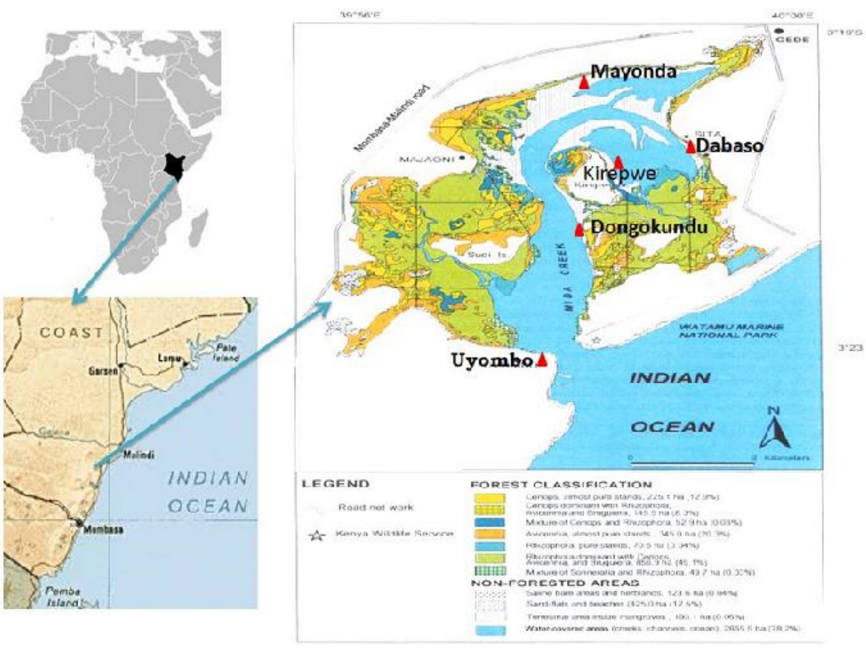

Figure 1: Map of Africa and Kenya showing location of the study area and the sampling sites at the Mida creek

Dabaso: (S 15°03 20.53”: E 039°59.23”) has a wide band (150-200m) of mature closed canopy mangrove trees, dominated by large mature *Rhizophora mucronata*. The intertidal mudflat extends for nearly 50m at low tide and is sandy-muddy in texture, especially adjacent to channels in the extensive mangrove forest. Coral outcrops predominate at the seaward margin of the mudflat. Harvesting of gastropods (*Terebralia palustris*) and hermit crabs (*Clibanarius* spp) from within the mangrove forest, and excavation for polychaete (*Marphysa mossambica*) at the mudflats, by fishers, were common.

Kirepwe: The Kirepwe Island (S03°27.28”: E039°58.490”), lies to the West of Dabaso village. The beach is characterized by a narrow band (20-40m) of mangrove forest, dominated by *Ceriops tagal* saplings. The intertidal habitat is narrow (>30m) and mainly sandy-muddy. Harvesting of polychaete and hermit crabs is carried out by hand line fishers, but gastropod collection by basket trap fishers, was rare.

Mayonda (S03°19.274”: E039°59.098”): lies approximately 4km due Northwest of Dabaso village. The landing beach has a moderate band (50-70m) of mature open canopy mangrove forest, dominated by large, mature, widely spaced *Avicennia marina*. The intertidal mudflat at low tide, is wide (<100m) and gently sloping. The mudflat is mostly sandy with muddy sections restricted to a narrow band at the mangrove forest margin. The presence of fish traders and boats at this site is evidence of intense fishing activity. Extensive excavation for polychaete was evidenced by predominance of old excavation along the beach. No gastropod or hermit crab harvesters were encountered at Mayonda.

Uyombo (S03^{o}230”; E 039^{o}570”); occurs approximately 10km to the south west of Dabaso village. The Uyombo landing beach is accessed by either crossing the creek using a boat from Dongo Kundu or after 1-1.5 hr. drive from Malindi town, a distance of approximately 30-40 km, diverting at Matsangoni, through a rough road stretch for 20-30 min. At the beach, the Uyombo beach management offices lie close to the beach. Scattered mangrove stands (mainly (*Sonneratiaalba*) are visible from the landing beach. The beach is sandy with limited rocky terrain. A number of fishing boats and fish trader stalls are clear evidence of intense fishing activity at the site. Several migrant basket trap fishers from Pemba were encountered at the site.

Dongo Kundu (S03^{o}210"; E 39^{o}059"); lies approximately 4 km southwest of Dabaso village. The landing beach is accessed by a 20-30 minute drive along the Malindi-Watamu road. The road traverses a number of tourist class hotels and exclusive residential homes. A narrow mangrove band (*Ceriops-Rhizophora*) growing on a rocky terrain characterizes the landing beach. A number of fishing and tourist tour boats were sighted anchored at the beach. The beach is rocky with patches of sandy areas.

Determination of Bait Utilization Patterns

Data on bait and patch choice were collected using structured interview at the villages described above. The questionnaire tool was pretested among 10 randomly selected respondents at an adjacent fishing village (Marereni Village ~50 km from Mida creek) and suitable adjustments incorporated into the tool. Minimum sample size of 13 respondents was computed with formulae used in Cochran (1977) with fixed variables; fisher number (~500 pers), proportion of bait fishers (~50%) and a precision (0.05).

Questionnaires were administered in 2nd October to 7thNovember 2013 to fishers at the five fishing villages in Mida creek; Dabaso (27 pers), Mayonda (22 pers), Kirepwe (16 pers), Uyombo (10 pers), and Dongokundu (8 pers). All fishers encountered at the landing beaches at each site were included in the sample. Interviews commenced at dawn, (when night fishers were landing) and continued till dusk. All participating interviewees were informed of the goals of the study and verbal consent obtained prior to administration of the questionnaire. Question were transcribed or translated into coastal Kiswahili dialect by experts at University of Nairobi and native speakers among the research team. Interviewers were trained on concise explanation and translation of each specific question in the questionnaire.

Information obtained from each interviewee include: fisher demographics, bait use, harvesting and processing, Fish catch, among other data. The data was used to calculate bait and patch preference.

Recruitment of Bait Harvester/Fishers

Consenting fishers with a minimum of 2 year of continuous participation in artisanal bait harvesting and fishery as a livelihood at the Mida creek, were purposively recruited for subsequent sampling. Bait harvesting sites identified were intertidal non-vegetated, with sandy-muddy substrate adjacent to the mangrove forest (polychaete), and within the mangrove forest (hermit & whelk). Additionally, these sites identified showed evidence of harvesting by prevalence of old excavations (mudflat), shell crashing sites (forest), as well as occasional encounters with harvesters. Sampling at the sites were conducted over two sampling occasions, in November 2013 and February 2014. Four key informant (4) harvesters per site were engaged and used during determination of bait harvesting. These participants were recruited at their respective harvesting site, during their normal harvesting activity. Informed consent were obtained from all participating harvesters prior to inclusion in the study.

Quantifying Bait Harvest Returns

Recruited harvesters identified were followed during their normal bait harvesting activity at each sampling location. Harvest duration (BHD_i) was determined by recording duration of travel (BD_{travel}), extraction ($BD_{harvest}$) and processing ($BD_{processing}$) of respective bait. The number and weight of each bait individual (BW_s) and total bait harvested (B_q) was determined. A subsample of harvested shelled bait was taken for determination of deshelled bait weight. Deshelled weight for the hermit crabs were obtained by cracking the shell and determining the weight of the individual therein (BW_d). Hermit crab bait weight were corrected for processing because, as opposed to whelk, the whole shell was cracked and discarded, prior to the fishing operation. The data was used in regression between deshelled bait (BW_d) and shelled weight (BW_s) using the following formulae;

$$BW_d = m(BW_s) + c$$

Where; m & c are regression constants; m- slope of the line, c-y intercept.

This model was subsequently used in deriving the corrected bait weight for shelled bait (BW_c).

Data on bait harvesting duration (B_{HD}) and corrected bait weight (BW_c) were used to compute bait catch per unit effort (B_{CPUE}) and compared.

$$BHD_i = BD_{travel} + BD_{harvest} + BD_{processing}$$

$$BCPUE_i = \frac{Bwc_i}{BHD_i}$$

Quantifying Bait Harvesting Energetics

Energy expended during each bait harvesting activity was estimated by multiplying data obtained on harvest activity duration (HD) with documented energy expenditure(EE_a) for related communities; 50-80 kg male, aged 30-60 yr., under digging (excavation ~605 kcal.hr-1), stalking (collection~619 kcal.hr-1), walking (~394 kcal.hr-1) and moderate strenuous activity (processing~422 kcal.hr-1) (FAO, 2001; O’Keefe *et al.*, 2010).

$$HE_{Ei} = bHD_i \times EE_a$$

The energy value of each bait harvested (BE_i) was estimated by multiplying documented estimates for polychaete (5.0 $kcal.kg^{-1}$; Muli et al., unpublished data), hermit crab (3.0 $kcal.kg^{-1}$) and whelk (3.5 $kcal.kg^{-1}$; Evans *et al.*, 1996), with the recorded harvested bait weight (B_{wc}). It was assumed that only 60% of the bait organism is fully used.

$$BE_i = Bwc_i \times E_i$$

Bait conversion energetics (BCE_i) for each bait type were subsequently computed and compared.

$$BCE_i = \frac{BE_i}{HE_i}$$

Where BCE_i- bait conversion efficiency, BE_i- bait energy content, HE_i- harvesting energetic cost (Jone *et al.*, 1994)

Quantifying Bait Fishing Efficiency

Fishers identified as outlined above, were followed during their normal fishing activity and the fishing duration (FD) and quantity of fish landed (FW) was monitored and recorded during each bait fishing occasion. Fishing efficiency was computed as fish catch per unit effort (F_{CPUE}) using the following formulae as used in Begossi *et al.*, (2005);

$$F_{CPUEi} = \frac{FW_i}{FD_i}$$

Bait fishing efficiency (BFE_i) of each bait was computed using;

$$BFE_i = \frac{FW_i}{Bwc_i}$$

Data obtained on F_{CPUE} and BFE_i were compared among the bait types and patches.

Determination of Bait Fishing Economics

Fish labor cost was obtained by multiplying summation of bait harvest duration (bHD) and fishing duration (FD) obtained above with 0.31 $\$.hr^{-1}$ (documented wage cost in Kenya; Thornton, 2013). Variable cost of fishing was obtained by summation of landing fees, payable to local BMU (BMU-Beach Management Unit; ~0.01 $ksh.kg^{-1}$) (USAID, 2008), and overheads (any food, water, emergency, gear maintenance), estimated at about 0.5$ d^{-1}. Depreciated gear cost (GC) were estimated by calculating fishing gear cost of hook and line (~2.5 $), *malema* (~5$) and canoe (~50$), a useful life of 5 years (Versleijen & Hoorweg, 2008), giving a value of 10.50$$.yr^{-1}$ (~0.03

$.d^{-1}). Total fishing coast (TFC) was subsequently computed for each bait as summation of labor (FL), variable costs (VC) and gear cost (GC).

$$FL_i = (bHD_i + FD_i) \times 0.31$$
$$VC_i = BMU\ fee_i + Overhead_i$$
$$TFC_i = FL_i + VC_i + GC_i$$

Fish value (FV_i) was calculated by multiplying landed fish weight (FW_i) obtained in preceding section with 1.80 $.kg^{-1}, (cost of fish at landing beach; Malleret-King *et al.*, 2003). Net income (NI_i) from fishery was then derived from difference between fish value (FV) and total fishery cost (TFC) (as in Hooper *et al.*, 2015);

$$FV_i = FW_i \times 1.80$$
$$NI_i = FV_i - TFC_i$$

Fishing profitability(FP_i) was then computed using;

$$FP_i = {}^{NI_i}/_{TFC_i}$$

Total fishing cost (TFC), fish value (FV), net income (NI), and profitability (FP), computed were compared among the bait types.

RESULTS

At total of 83questionnaires were deployed among fishers at Mida creek, with a response rate of 97.6%. Among these respondents, 62.6% used bait exclusively (either hook or traps), 2.4% used both baited gears, while 26.5% used combination of baited and non-baited gears (nets). Trap fishers, mainly deployed whelk collected from the mangrove forest, while hook fishers, preferred polychaete and hermit crab. The hermit and whelk were collected from mangrove forest and required processing by crashing the shell to expose the bait, but, polychaete harvested from the mudflat by excavation, required less processing. Polychaete (24.1%) and hermit crabs (22.6%) were the most preferred intertidal inedible baits, followed by mangrove whelk (Table 1). Intertidal habitats supplied over 52.8% of bait, from forest (3 types; 27.7%) and mudflat (2 types; 25.1%), compared to subtidal habitats (Table 1). Generally, 80% (4/5) of the intertidal bait, were solely used for fishing bait, compared with 16.7% (1/6) of subtidal bait (Table 1).

Table 1: Bait and foraging patch choice among respondents at the Mida creek, Kenya (values in parenthesis are frequencies from multiple entries; Use categories B-bait, F-food)

Habitat	Bait type	Taxa	Preference %	Use
Forest	*Dophe* (hermit crab)	*Clibanarius spp*	22.6 (44)	B
	Tondo (whelk)	*Terebralia palustris*	4.1 (8)	B
	Kaa (crab)	*Sycylla (?)*	1.0 (2)	F/B
Mudflats	*Choo* (polychaete)	*Marphysa mosambica*	24.1 (47)	B
	Sigara (Bivalve)	*Solen sp*	1.0 (2)	B
Subtidal	*Mwata* (sipunculid)	unknown	6.7 (13)	B
	Kamba (prawn)	*Peneus sp*	11.3 (22)	F/B
	Ngisi (squid)	*Sepioteuthis sp*	16.4 (32)	F/B
	Pwesa (octopus)	*Octopus sp*	4.6 (9)	F/B
	Simsim (sardines)	*Sardinella sp*	3.6 (7)	F/B
	Jumburu (gobid)	*Periopthalamus (?)*	2.6 (5)	F/B
	Others		2.1 (4)	

The harvested intertidal bait monitored, were identified as hermit crabs; a mixture of 7 species dominated by *Clibanarius longitarsus* (~57%), the polychaete; *Marphysa mossambica* and mangrove whelk; *Terebralia palustris*. There was a significant correlation between hermit crab deshelled and shelled weight (r^2=0.51, F=50.38, P<0.0001). An equation of the form;

$$BW_d = 0.07(BW_s) + 0.25$$

The model was subsequently used in deriving the corrected hermit crab bait weight; where BW_d- Deshelled weight, BW_s- shelled weight.

There were significant difference in the quantity of bait harvested (F=43.75, df=2, P<0.001), corresponding to significant difference in Bait returns(F=15.75, df=2, P<0.001). Mangrove whelk recorded the highest bait catch (1.14±0.08 kg) and bait return (B_{cpue}; 0.87±0.08 kg.hr^{-1}), while polychaete (0.16±0.03 kg, 0.13±0.03 kg.hr^{-1}) had the least harvest returns (Table 2). Harvest duration (BHD),were however comparable among the bait types, and ranged from 1.27±0.12to 1.49±0.04 hr., for hermit and polychaete, respectively (F=0.05, df=2, P>0.05) (Table 2).

Table 2: Variation in bait harvesting returns among artisanal bait fishers at the Mida creek

Bait type	N	Bait catch (kg)	Harvest duration (hr)	Bait return (kg.hr^{-1})
Polychaete	147	$0.16 \pm 0.03_c$	$1.49 \pm 0.04_a$	$0.13 \pm 0.03_c$
Hermit crab	19	$0.40 \pm 0.08_b$	$1.27 \pm 0.12_a$	$0.44 \pm 0.08_b$
Whelk	19	$1.14 \pm 0.08_a$	$1.39 \pm 0.12_a$	$0.87 \pm 0.08_a$

Means in columns followed by same letter a, b or c are similar (P<0.05)

The average harvested bait energy content was 4074.29±141.46 kcal, obtained after expending 701.85±30.76 kcal, during each harvest occasion, this corresponds to conversion efficiency (BCE) of 5.47±0.10. Nonetheless, the bait energy content (F=356.50, P<0.001) and conversion efficiencies, differed among the bait types (F=1314.68, P<0.0001). Energy expenditure(BE) were however, similar amongst the bait types and ranged from 658.16 kcal to 726.79 kcal (in hermit and polychaete, respectively) (Table 3). Polychaete recorded the lowest bait energy content (487.78 kcal) and conversion efficiency (0.79) (Table 3). On the other hand, whelk had the highest content (9750.41 kcal) and correspondingly higher conversion efficiency, while hermits, which had intermediate levels, were 4 times lower than whelk values,but 3 times higher than polychaete energetic returns (Table 3).

Table 3: Bait harvesting energetics among artisanal bait fishers at the Mida creek

Bait type	N	Bait Energy content (kcal)	Energy used (kcal)	Conversion efficiency
Polychaete	147	$487.78 \pm 104.56_c$	$726.79 + 22.73_a$	$0.78 \pm 0.08_c$
Hermit crab	19	$1984.68 \pm 290.83_b$	$658.16 + 63.33_a$	$2.32 \pm 0.21_b$
Whelk	19	$9750.41 \pm 290.83_a$	$720.60 + 63.33_a$	$13.31 \pm 0.21_a$

Mean (±SE) in column followed by the same letter a, b or c are similar (P<0.05)

The average fish catch using bait was 1.81±0.16 $kg.bait^{-1}$, corresponding to bait efficiency (BFE) of 15.27±+3.69 $fish.bait^{-1}$ and fish catch per unit effort of 0.24±0.03 $kg.hr^{-1}$. However, there were significant differences in fish landings (F=8.52, P<0.01), Fish catch per unit effort (F=5.67, P<0.05), and fishing duration (F=584.16, P<0.000)), but bait efficiency were similar (F=2.51, P>0.05) among the bait types. Polychaete and hermits landed the most fish (2.54±0.17, 2.11±0.34 kg, respectively),more rapidly (6.33, 8.15 hr), and consequently had the highest fish CPUE (0.43±0.04, 0.25±0.07 $kg.hr^{-1}$, respectively), compared to whelk landings (Table 4). Nevertheless, despite whelks having lower bait efficiency (0.11 $fish.bait^{-1}$), compared to either polychaete (29.22 $fish.bait^{-1}$) or hermit (16.48 $fish.bait^{-1}$), this difference was not significant (Table 4).

Table 4: Variation in bait fishing efficiency among bait used by artisanal fishers at the Mida creek

Bait type	N	Fish landed (kg)	Fishing time (hr)	Fish CPUE (kg fish.hr^{-1})	Bait efficiency (fish.bait^{-1})
Polychaete	55	2.54±0.17$_a$	6.33+0.25	0.43±0.04$_a$	29.22 ±3.99$_a$
Hermit crab	15	2.11±0.34$_a$	8.15+0.48	0.25±0.07$_{ab}$	16.48 ±7.63$_a$
Whelk	18	0.77±0.06$_b$	24.00+0.44	0.03±7.00$_b$	0.11±6.97$_a$

Mean (±SE) in column followed by same letter a or b are similar (P<0.05)

On average, the total cost of bait fishing (TFC) was 1.07±0.03 $, during which, fish valued (FV) at 3.23±0.29$were landed, corresponding to a net income (NI) of 2.17±0.29$ and a profitability (FP) of 1.98±0.24. Nonetheless, significant differences in Fish value (F=8.52, P<0.01), net income (F=8.84, P<0.01) and profitability (F=17.41, P<0.001), were detected among the bait types. Polychaetes and hermit bait types landings had significantly higher fish value (4.58, 3.79 $, respectively), net income (3.01, 2.96$, respectively) and profitability (2.56, 3.35, respectively) than whelks (Table 5), and concur with observed intertidal bait preference. However, total bait fishing cost (F=0.003, P>0.05), were similar among the bait and ranged from 0.83$ (for hermit and whelk) to 1.56$ (for polychaetes) (Table 5).

Table 5: Variation in fishing economic returns among bait type used by artisanal fishers at the Mida creek, Kenya

Bait type	N	Total cost ($)	Fish value ($)	Net income ($)	Profitability
Polychaete	55	1.29±0.02$_a$	4.58±0.32$_a$	3.29±0.31$_a$	2.56±0.27$_a$
Hermit	15	0.83±0.04$_a$	3.79±0.61$_a$	2.96±0.60$_a$	3.35±0.52$_a$
Whelk	18	0.83±0.04$_a$	1.38±0.55$_b$	0.56±0.54$_b$	0.57±0.47$_b$

Mean (±SE) in column followed by same letter a or b are similar (P<0.05)

DISCUSSION

This study reveals that although bait fishers know a large repertoire of bait types (>10 taxa), they show marked preference for intertidal polychaetes and hermit crabs. The mudflat and mangrove forest are more frequently exploited foraging site, than the adjacent subtidal habitat. Since these adjacent intertidal habitats are exploited by fishers for different baits, this has implications for management. Restricting access to either intertidal mangroves and mudflat, and subtidal; sea grass or coral reefs, implemented to reduce harvesting or protect foraging and breeding grounds, may have dire consequences on artisanal bait fisher livelihoods. Conversely, it is clear that fisher livelihoods is closely intertwined with the health of these intertidal habitat complex, and hence their value should be accorded more prominence.

The target bait consist of *dophe*-hermit crabs (7 species, dominated by *Clibanarius longitarsus*), *choo* (*Marphysa mossambica*) and *tondo* -whelk (*Terebralia palustris*). Whelks are large gastropods (>20cm) occurring in aggregation at density of over 30 ind.m^{-2},at the forest floor(e.g. Shrijvers *et al.,* 1997). Hermit crabs are relatively smaller individuals (shell volume <50cm^{3}) occurring as inconspicuous solitary individuals among whelk aggregations, especially at the mid and seaward edge of the forest (Kihia *et al.,* 2015b). Polychaetes are long slender (>30cm) burrowing eunicids, occurring in mudflat at relatively high density (Kihia *et al.,* 2017). Whether the Polychaete bait as reported in this study also consist of the related *M. mackintoshi* mentioned in literature (Richmond, 2010), requires further detailed taxonomic examination.

Whelks are harvested at (1.14 kg.fisher^{-1}) rates nearly ten fold higher than either polychaetesor hermit crabs. This may be related to the gear used in subsequent fishing and their deployment. Small pieces of both the polychaete and hermit, are attached to 2-3 moderate sized hooks, and deployed during subsequent canoe fishing expedition, immediately after harvest. On the other hand, whelks are inserted in relatively larger numbers (10-20 ind) into large or small basket traps (*malema*), for overnight soaking in mangrove creeks. The higher quantities used also act as additional ballast, securing the trap at deployment. Furthermore, each trap fisher commonly owns and sets several traps (3-5 traps), during each fishing occasion (Gomes, 2012). This has implication on management, since alteration in patterns of gear use e.g. increase in trap fishers (e.g. Uyombo, Dongokundu), may impact patterns of bait utilization, with consequences on ecosystem integrity. For instance, despite the reported decline in adoption of traps among Kenyan youthful fishers (Mirera *et al.,* 2013), traps are the gear of choice among seasonal migrant fishers from Pemba, Tanzania (Gomes, 2012). These migrant fishers deploy larger traps in deeper water, achieving higher landings than locals, precipitating simmering conflict. There is need to further evaluate bait use among the migrant fishers and their impacts, in order to ameliorate these conflicts but also reduce pressure on inshore resources.

This study reveals that although whelks are the easiest intertidal bait to harvest in substantial quantities (20.88 kg.d^{-1}), they are not the preferred fishing bait in Kenya. Conversely, polychaete (3.12 kg.d^{-1}) and hermit crabs (10.56 kg.d^{-1}), with over 50 -80% lower yields, are preferred. These findings seem to concur with reported prey choice among indigenous hunter and fishers targeting rare, evasive and dangerous prey. Additionally, persistent indigenous hunters, have relatively lower hunt success and return rates (<7 kg.d^{-1}) than whelk harvester, however, their returns are in the same order of magnitude as polychaetes (corrected for success; 5.6 kg.d^{-1}) and also hermit crab (when corrected for shell weight) (Liebenberg, 20006). Among artisanal fishers, lower whelk returns, may be linked to either inadequate knowledge of trap fishery among local fishers (see above), low prestige associated with their use or inadequate indigenous knowledge of bait quality among locals. Nylon line and metal hooks, are relatively recent introduced gears, and additionally, many local artisanal fishers are recently converted subsistence farmers (e.g.Versleijen & Hoorweg, 2008). Among amazon hunters, the adoption and emergence of guns, led to specialization on primate prey that were more evasive (Alves *et al.,* 2009). Consequently, the emergence and adoption of modern fishing techniques and gears may therefore allow less experienced fishers to land favorable quantities of fish. However, the deployment of baited trap gears by migrant fishers at deeper offshore fishing grounds, requires further elaboration.

Additionally, local fishers may lack the requisite knowledge to fabricate and repair traps and/or the patience and constitution to deploy them within mangrove creeks or elsewhere. Trap deployment involves diving in murky waters, skills that many locals may find unattractive. However, recent emergence and proliferation of spear gun (banned in Kenya), among youthful fishers, tend to militate against lack of diving skills, but this is deployed in less turbid, reef habitats (e.g. Samoilys *et al.,* 2011). Furthermore, fishers suggest the pilferage of catch and traps, during extended soaking periods, may have led to preference and adoption of hook and other active gears. Apparently, polychaete and hermit crabs may be targeted by harvesters irrespective of their occurrence and availability of alternatives bait at accessible intertidal habitats, with consequence on sustainability.

In energetic terms, results showed that bait harvesting is generally an energy gaining activity where expending 701.85 kcal of energy,gains4074.29 kcal, a 5.4 fold increment in energy. The level of energy expenditure reported is comparable to carrying meat (706 kcal) among hunter-gatherer communities (O'Keefe, 2010). The amount of energy gained during bait harvest is comparable to returns obtained by ikung hunters in dunes of Botswana (Jones *et al.,* 1994). In contrast, the bait harvester energy activity levels (~70kg, BMR 1691kcal.d^{-1}, PAL 2.41) fall within the range of heavy work and are comparable to agriculturalist (2.4) and Ache foragers (2.17), but are higher than more sedentary lifestyles (Leonard, 2004).

Although energy expenditure during harvest were similar among the bait types, energy gained and conversion efficiency differed. The most efficient energy conversion strategy is whelk harvesting (13.31), where massive quantity of energy (9750.41 kcal) are gained from minimal expenditure (720.60 kcal). In contrast, polychaete harvest gains the least amount of energy (487.78 kcal) from expenditure of (726.79 kcal) corresponding to a net energetic loss (0.78). Apparently, bait choice flies in the face of optimal foraging model prediction, since the least energy efficient bait types (polychaete & hermit crabs), are preferred over more energetically efficient alternatives (whelk).

Among hunter gatherer communities, rigid task segmentation, ensure that women and children harvest fruit, nuts and seeds, which are relatively more nutrient dense than lean wildlife meat (Marlow, 2002). Furthermore, some authors (e.g. Jiddawi, 2012) claim mangrove whelks, are also consumed during starvation period. It is possible rigid that role segmentation accompanied by lack of expertise and low prestige in whelk use, discourage participation of status conscious male fishers. Apart from honey, male hunters expend considerable energy hunting energy poor, but relatively nutrient dense prey, for instance in persistent hunts (e.g. Liebenberg, 2006). On the other hand, women and children participate in fishing by gleaning (sessile, slow moving fauna), along shallows combined with cultivation of energy dense crops (e.g. cassava, maize) (e.g. Pontzer *et al.*, 2013). The lower energy conversion efficiency of males is counteracted by gains in essential proteins, fats, vitamins, and minerals contained in the landed lean meat. We surmise therefore that similar to male hunters, bait energy value, is not an important driver to bait choice.

Evaluation of fish landings obtained using foraged bait reveals that on average the fish catch per unit effort (0.24 $kg.hr^{-1}$) reported in the current study are comparable to levels elsewhere (e.g. McClanahan & Mangi, 2004). Significantly higher catch efficiency, were however, obtained using polychaete and hermit crabs compared to whelks. This difference was attributed to lower fishing duration (<8.15 hr) among both polychaete and hermit crab fishers, compared to whelk fishers (~24 hr). Whelk deployed in *malema* traps are soaked overnight, while both polychaete and hermit crabs, are deployed in hooks soon after harvest and soaked for shorter duration. Kihia *et al.*, (2018) report soaking duration for polychaete of 205 sec (3.42 min) during deployment in artisanal marine fishery casting. Furthermore, most hook fishers undertake fishing during low tide, which is approximately 6 hours under the semidiurnal tidal regime along the Kenyan coastline. Evaluation of bait efficiency however, revealed that although efficiency in whelks (0.11), was more than hundred fold lower than either polychaete (29.22) or hermit crabs (16.48), these differences were not significant. Trap fishers in Mpunguti (Gomes, 2012) and migrant fishers at Uyombo (unpublished data), report far higher landings from deeper offshore fishing grounds. It is possible that deployment of traps in near shore grounds are less effective than other habitats. This reveals that although fish landings and bait efficiency are more plausible explanation for bait choice, especially among hook fishers, further evaluation of traps in richer fishing grounds, are needed. In general, bait fishery is a highly profitable activity, involving minimal expenditure on fixed fishing cost (~1$), resulting in net incomes of over 2$ per occasion. These earnings are comparable to reported wage among unskilled laborers in Kenya, but lower than skilled workers (Thornton, 2013). The rates are however, higher than the reported 40-50$ per month among rural farmers in Kenya (Dose, 2007). Hence bait fishery provides the most profitable livelihood option available to resource poor coastal communities, and unless more profitable livelihoods are identified, bait fishery will continue being attractive.

Nonetheless, polychaete and hermit crab fishers, register comparable and significantly superior economic returns (net income, profitability) than whelk fishers, despite comparable investment. This coincides perfectly with observed bait preference pattern (i.e. polychaete and hermit preferred). This therefore implies that among drivers to foraging strategy evaluated here, economic returns, are apparently the most plausible explanation. This however, presumes that bait fishers have an inherent knowledge of resource economic valuation. Some evidence of such cognizance may be gleaned from the persistence of terrestrial wildlife poaching in the region despite inherent dangers (injury, rarity, imprisonment), expenses (fines, transport cost etc.) and availability of less risky alternative livelihoods (e.g. Ripple et al., 2016; Wright & Preston, 2010). Consequently, bait harvesting interventions that ignore economic returns of available alternative livelihoods, will be plagued by persistent contraventions, and without massive investment in policing, are bound to fail.

CONCLUSIONS AND RECOMENDATIONS

Despite familiarity with a wider repertoire of bait types, fishers at Mida creek prefer polychaetes, excavated from mudflats, and hermit crabs, collected from mangrove forest floor. Bait harvesting returns and energetics, are higher among the least preferred bait type (whelk), while, fishing efficiency and economic returns are higher for both polychaete and hermit crabs. Similarly, net income and profitability are highest for polychaete and hermit crab fishers, and hence are the most plausible explanation for observed bait preference and foraging patterns. Implementation of holistic bait harvesting management, should therefore incorporate resource economic evaluation of suggested alternative livelihood, to ensure broad acceptance and success. Nonetheless, further elucidation of factors influencing bait effectiveness such as attractiveness to superior quality fish, not only in near shore habitats but also adjacent offshore habitats, are needed.

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