Testing and Promoting Fishing Gear Innovation to Reduce Ghost Fishing of Lost Gillnets Project

Contract Number: TF.NFIOD.6D350020146

<u>Final Project Report</u>

May 2023

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1.0 INTRODUCTION

This report highlights the activities carried out during the implementation of the project. It has been prepared in fulfillment of the contractual obligations detailed in contract number TF.NFIOD.6D350020146 between the Food and Agriculture Organization of the United Nations (FAO) and Kenya Marine and Fisheries Research Institute (KMFRI) for testing and promoting fishing gear innovation to reduce ghost fishing project implemented by KMFRI in collaboration with the other key stakeholders.

2.0 BACKGROUND

Kenya is currently promoting the development of Blue Economy to support both county and national economy. The key priority sectors are fishing, aquaculture, maritime transport, tourism and offshore mining. Even though these sectors have greatly diversified with regard to trading patterns and the entrance of new stakeholders, fishing sector remains one of the large-scale activities supporting a large proportion of the coastal communities. Fishing is carried out using different types of gears that are often lost or discarded, thus contributing to marine litter pollution. Generally, resource management in the fishery sector is poor with less than 10% of fishers actively participating in marine conservation and community beach management issues. As a result, reduction and management of abandoned, lost or otherwise discarded fishing gear (ALDFG) is challenging, thus requiring interventions at an input level.

Kenya with the support of Glo Litter Project recently developed the first Kenya National Action Plan on Marine Plastic Litter from Sea-based Sources (2023-2032) that details a number of actions aimed at improving the management effectiveness of Kenyan marine and coastal environments through the prevention and reduction of marine plastic litter from sea-based sources. The plan recognizes upstream interventions as more cost effective and practical in controlling and reducing sea based litter and proposes the identification and promotion of innovations that aims at reducing ALDFG as one of the upstream measures. Testing and Promoting Fishing Gear Innovation to Reduce Ghost Fishing of Lost Gillnets Project is one of FAO funded upstream projects in response to this action.

The project objectives were

1. Test the efficacy of various natural fibre twine types (cotton, sisal and jute) to be used in modifying gill nets
2. Test the performance of the modified gear in reducing marine litter and in catching fish in comparison to the ‘normal’ gill nets
3. Raise awareness on the performance of the modified gear for buy-in and possible replication and up calling

The choice of gillnets is based on the fact that it is the most commonly used net by the small-scale artisanal fishery sector in Kenya and has a higher possibility of getting lost and contributing to ghost fishing. The project replaced the polyamide (nylon) twine hanging lines attaching the gillnets to the float lines with biodegradable twines to enable it to collapse once the biodegradable twines decompose thus reducing the nets catchability coefficients and the associated ghost fishing once the modified net is lost. Gear modification is thus intended to increase the probability of recovering the lost gear, reducing ghost fishing and ALDFG.

The research activities implemented in the project included i) an inception meeting with Tudor Creek Beach Management Units (BMUs) fishers, ii) selection of twines and net tensile strength testing, testing iii) design and modification of gillnets iv) testing the performance of modified gillnets in reducing ghost fishing and marine plastic litter, iv) testing the performance of modified nets in catching fish and v) holding dissemination meetings to raise awareness on the project activities and key findings.

ACTIVITY 2.1 - INCEPTION MEETING WITH TUDOR CREEK FISHER'S

Two inception meetings were carried out on 7th and 8th February 2022 at KMFRI, Mombasa Kenya to inform the stakeholders of the project activities, provide the opportunity to gain their input on gillnet gear design and modification and to come up with a clear understanding of the project activities and responsibilities. The inception meetings were two-tier involving a technical committee meeting attended by the project experts, and a general stakeholder engagement meeting that brought together the experts and the fishers from Tudor and Old Town Beach Management Units (BMUs).

2.1.1 Inception Meeting 1 (Technical committee meeting)

A technical committee meeting was held on the 7th of February 2022 and attended by the technical personnel from KMFRI and a representative from the Ministry of Agriculture, Livestock and Fisheries Development. Broadly, the meeting sought to gain a common understanding of the ghost fishing problem and the interventions being proposed by the project, plan and set agenda for the stakeholders meeting, identify any information gaps to be clarified by the stakeholders and define responsibilities and timelines at the technical level.

Two presentations were made by the core project team (KMFRI). Presentation 1 summarized what marine litter is, the sources, pathways, impacts. It made special emphasis on the contribution of the fishing industry to marine litter. Presentation 2 highlighted the specific role of abandoned, lost, discarded fishing gear in plastics pollution. It further highlighted the role that hotspot mapping, legislation, gear retrieval and recycling were playing to reduce the impacts of ghost fishing. It identified product innovation as the missing link in addressing ghost fishing. It reported that the fishing effort was on increase and associated with an increase in the number of fishing gears that are getting lost increasing ghost fishing. The presentation further provided a detailed insight into the project. Component 1 will deal with the selection of the natural twines to be used for gear modification through target strength experiments; component 2 will deal with gear modification by replacing the hanging synthetic lines with biodegradable twines identified under component 1; component 3 will involve experimental fishing using normal gillnets and modified gillnets to determine if the modification had any significant impact on the gear catchability while component 4 involves awareness creation in which the process and the results will be disseminated to Wasini and Ungwana Bay BMUs.

The following were agreed on based on the technical committee meeting awaiting endorsement by the stakeholder inception meeting

1. Natural twine sizes and procurement issues
2. Depths for exposure of the natural twine for degradation experiment
3. Length of the gill nets and the number to be deployed for catchability experiment
4. Mode of modification (both hanging lines and float lines)
5. Modalities of awareness creation
6. Timelines for the various project activities.
7. Roles and responsibility

2.1.2 Inception Meeting 2 (Stakeholder engagement meeting)

The stakeholder engagement meeting 2 brought together representatives and fishermen of Tudor and Old Town BMUs, technical personnel from KMFRI, and a representative of the Ministry of Agriculture, Livestock and Fisheries Development. This meeting was predicated on the need to gain the initial buy-in of the project and ensure the safety of the gill nets during the experiment stage. The meeting utilized presentations, hands-on demonstrations and plenary discussions to enable the stakeholders to gain a general view of marine litter, its sources, composition status, trends and impacts and appreciate the problem of ALDFG, their sources, extent, risks and impacts. The demonstrations were conducted by gear technologists who gave a brief demonstration on areas of interest in the gear modification undertaking including i) parts of the gill net- headline, hanging twine, etc., ii) gear hanging coefficient and iii) mesh size preference and twine size.

Delivery of the project objectives shall be met through a four-component approach entailing laboratory degradability experiment, gear modification, gear catchability experiment, and awareness components. The specific elements of the fishing gear modification project were extensively disseminated and discussed with the stakeholders as outlined below.

Component 1: Laboratory degradability experiment

Laboratory net tensile experiment shall involve the exposure of natural twines to similar conditions to those in fishing grounds (i.e., salinity, temperature, depth). During the experiment, an initial 14 test twine fibre shall be exposed & 1 piece retrieved every successive 2 weeks for a period of 4 months to test for tensile strength. The ideal twine fibres for gear modification shall be more durable when mimicking real fishing conditions but degrades quickly when submerged or lost and shall be of the following specifications. The twines that will be exposed include; cotton twine - twisted (1.5, 2 & 3 mm) & braided (1, 2 & 3 mm); jute twine (1.5, 2 & 3 mm); sisal twine- 2 mm & 3 mm and a control multifilament polyester (24, 36 and 48 ply). Top 3 natural fibre twine materials with the highest biodegradable rate when fully submerged but more durable when mimicking fishing conditions will be recommended for gear modification.

Component 2: Gear modification

Suitable degradable natural fibre selected from component 1 will be used to modify gillnets. The modification will be made to the headline /float line by using the degradable natural twine to attach it to the gill net. Upon loss and continuous exposure to the ambient conditions of the fishing ground environment, the natural twines of the modified gillnet are expected to degrade within six months and detach the float line/ headline from the rest of the net causing it to collapse to the seafloor. Similarly, the buoy is also expected to break off. The float line shall remain afloat, without the detached buoy for easy identification and retrieval.

Component 3: Gear catchability experiment

Fish catchability experiments will be carried out on both the modified and the unmodified gillnets to gauge their fishing efficacy. This is key in the project to dispel any doubts on the possibility of modified gears catching less fish. This component will be spearheaded collaboratively by KMFRI and the local fishermen under the auspices of the engaged BMUs.

Component 4: Awareness creation

Tudor and old town BMUs will be leveraged for knowledge sharing to create awareness on gear modification. The awareness campaigns shall include but are not limited to impacts of ALDFG, the significance of gear modification and retrieval, best practices, materials and best available local technologies for gear modification, conventional and modified gear catchability. This component will be spearheaded by BMUs based on the training of trainers' concept.

Plenary discussions and clarifications

Deliberations during the plenary session with the stakeholders agreed on the following:

1. Project shall only consider modifying legal fishing gear
2. Gear modifications shall strive to as much as possible should be beneficial to the local fishermen by not reducing the amount of catches
3. Refraining from modification of the footrope to increase the chances of retrieval of the lost gears.
4. Making the modified gears affordability and increasing their acceptability particularly focusing on the cost of the natural twines for ease of adoption
5. Need for modifying gears with natural materials twine size that are the same as what the fishermen are currently using.
6. Use of modified buoys to avoid vandalism
7. Consideration of the length of net and the corresponding depth where the net will be set for experiments

The other key resolutions from the meeting are summarized below

Issue/comment	Response
Size of the fishing net- mesh and twine	A 30 m by 3 m net to be used. Twine and mesh size will depend on where the net will cast/ set
Depth of the fishing stations in Tudor Creek	Nets are usually set during low tide Depth in Tudor creek ranges between 4 m and 15 m Net placed at depths greater than 15 m - catches more fish, but the net is at a higher risk of getting lost
Type of fishing net	Tudor BMU fishers use gillnets of mesh size 2.5, 3 and 3.5 inches in the creeks which are targeted by the project.
Legality of mesh size	The project will work with only nets with mesh size that are legal in the Kenya (from 2.5 inches) and must be multifilament NOT MONOFILAMENT
Wear and tear of the fishing nets	Fishers reported that due to wear and tear, replacement of biodegradable twines be done in each season, (approximately after 4 months)

Time Plan

The project will be implemented within a period of 14 months, with components 1,2,3 and 4 delivered in months 1-4, 5, 6-12 and 13 respectively.

Project way forward

The stakeholders agreed that KMFRI should proceed with twine procurement and tensile strength experiments and update the stakeholders after the experiment. Thereafter, the BMUs will join the project activities on gear modification, trial fishing and awareness creation.

ACTIVITY 1.1 - NET TENSILE STRENGTH TESTING

1.1.1 Twines selection

The twines selected for gillnet modification were synthetic (normally used by fishers) and biodegradable twines. Biodegradable twines selected were those that were locally available in the market as suggested by the fishers during the inception meeting. Different sizes of four natural and one synthetic (multifilament nylon used as control) twines were subjected to degradation exposure under normal fishing conditions in the field (Table 1).

Table 1: Twines subjected to degradation exposure experiment

Twine type	Twine	Size (diameter)
Biodegradable	Jute	1.0 mm
		1.5 mm
		3.0 mm
	Sisal	2-ply
		3-ply
	Twisted cotton	1.5mm
		2.0 mm
		3.0 mm
	Braided cotton	1.0 mm
		2.0 mm
		3.0 mm
Non-biodegradable	Multifilament nylon	24-ply
		36-ply
		48-ply

1.1.2 Twine degradation experiment

1.1.2.1 The approach

The twines listed in Table 1 were cut into 3 pieces of 2.3m each and submerged at 1m, 5m and 9m depths to simulate fishing depths in Tudor creeks. The cut pieces were hung on two ropes with anchors and firmed in-situ (in the field/ ocean) at KMFRI aquaculture cages site to keep the twines straight during the experiment as shown in Figure 1.

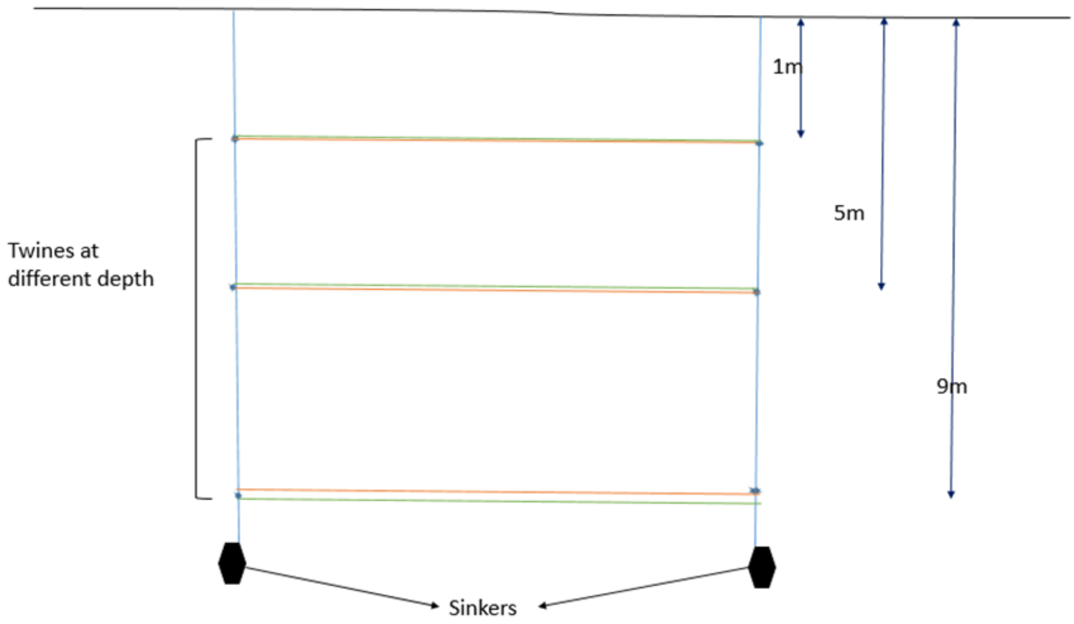


Figure 1: Twine set-up at depths of 1, 5 and 9 meters.

The first set of twines were exposed on 13th of April 2022 and the subsequent set after every two weeks, following the same approach. In total, 333 twines were deployed for degradation experiment. The schedule for exposure and retrieval and conditions for exposure is shown in Table 2. Environmental parameters (temperature, salinity and conductivity) were measured prior to the deployment of the twines using a YSI professional plus multi-parameter meter (Table 2).

Table 2: Exposure duration and exposure environmental conditions

Experiment	Deployment date	In situ water Parameters			Retrieval date	Duration of exposure
		Temperature (°C)	**Salinity (PSU)**	**Conductivity (µS/cm)**		
1.	13/04/2022	28.7	32.4	55635	)3/08/2022	16 weeks
2.	27/04/2022	29.6	32.3	55637	)3/08/2022	14 weeks
3.	11/05/2022	29.3	32.2	55663	)3/08/2022	12 weeks
4.	25/05/2022	30.1	32.3	55644	)3/08/2022	10 weeks
5.	08/06/2022	29.6	32	54965	)3/08/2022	8 weeks
6.	22/06/2022	27.8	31.6	55766	)3/08/2022	6 weeks
7.	06/07/2022	29.6	3	55707	)3/08/2022	4 weeks
8.	20/07/2022	30	32	55701	)3/08/2022	2 weeks

1.1.2.2 Retrieval of exposed twines

Twines used in the exposure experiment were retrieved on 3rd August 2020 giving varied exposure duration (from 2 to 16 weeks) as shown in Table 2. Only 266 out of 333 twines were retrieved representing a 20% loss. The loss of twines can be attributed to degradation and fall off. It is worth noting that, the twines recovered were at different integrity (degradation) stages, some being very brittle to undergo tensile strength testing. Annex 1 provides the summary of twine recovery success.

A total of 174 twines were retrieved in good status while 92 twines were brittle as shown in Table 3. The 53 % total loss of the exposed twines were lost at sea.

Table 3. Summary of status of twines retrieved after exposure periods 2, 4, 6, 8, 10, 12, 14 and 16 weeks

Exposure duration (weeks)	**Condition of the twines**		**Twines lost at sea**	
	Non-brittle	**Brittle**	**No.**	**%**
2	42	0	0	0
4	42	0	0	0
6	38	3	1	2.4
8	24	16	0	0
10	6	7	29	69
12	11	16	15	35.7
14	10	24	8	19
16	9	18	15	35.7

1.1.3 Selection of twines for determination of tensile strength

The integrity of the twines differed after the twine degradation exposure experiment. Only twines that were complete (size not reduced during the experiment) and non-brittle were considered for the tensile strength testing. In addition, unexposed twines were selected for testing to provide baseline tensile strength of the twine used in the exposure experiment. Only week 16 nylon twines were selected for tensile strength testing due to their low degradation rate.

Prior to testing, all the twines were washed to remove any organic material and any other foreign item attached to them. The twines were thereafter dried under a shade to untangle. Sisal twine (all sizes) were the most degraded during the exposure experiment. Braided cotton and jute (all sizes) were also fully degraded by the sixth week while the normal nylon twine did not degrade throughout the exposure period (Annex 2). Table 4 summarizes the twines retrieved and submitted for tensile strength testing.

Table 4: Summary of twines submitted for tensile strength analysis

TWINE	**SIZE**	**NUMBER**
Twisted cotton	1.5mm	9
	2mm	20
	3mm	11
Nylon	24ply	3
	36ply	3
	48ply	3
Unexposed Nylon twine for baseline	24ply	1
	36ply	1
	48ply	1
Unexposed Twisted cotton for baseline	1.5mm	1
	2mm	1
	3mm	1

1.1.4 Tensile strength testing

1.1.4.1 Methodology

Twines tensile strength testing was subcontracted to Kenya Bureau of Standards (KEBS). The testing was carried out following the procedure outlined in ISO 2307 (Fibre ropes: determination of certain physical and mechanical properties). Briefly, the measurement was carried out by increasing the maximum tension achieved in the measurement of elongation of a rope to the breaking point.

A total of 55 twines were tested for their tensile strength consisting of 49 from the experiment, 3 from unused biodegradable twine and 3 from unused multifilament nylon twines. The unused twines were subjected to testing to provide the baseline strength before degradation.

1.1.4.2 Results

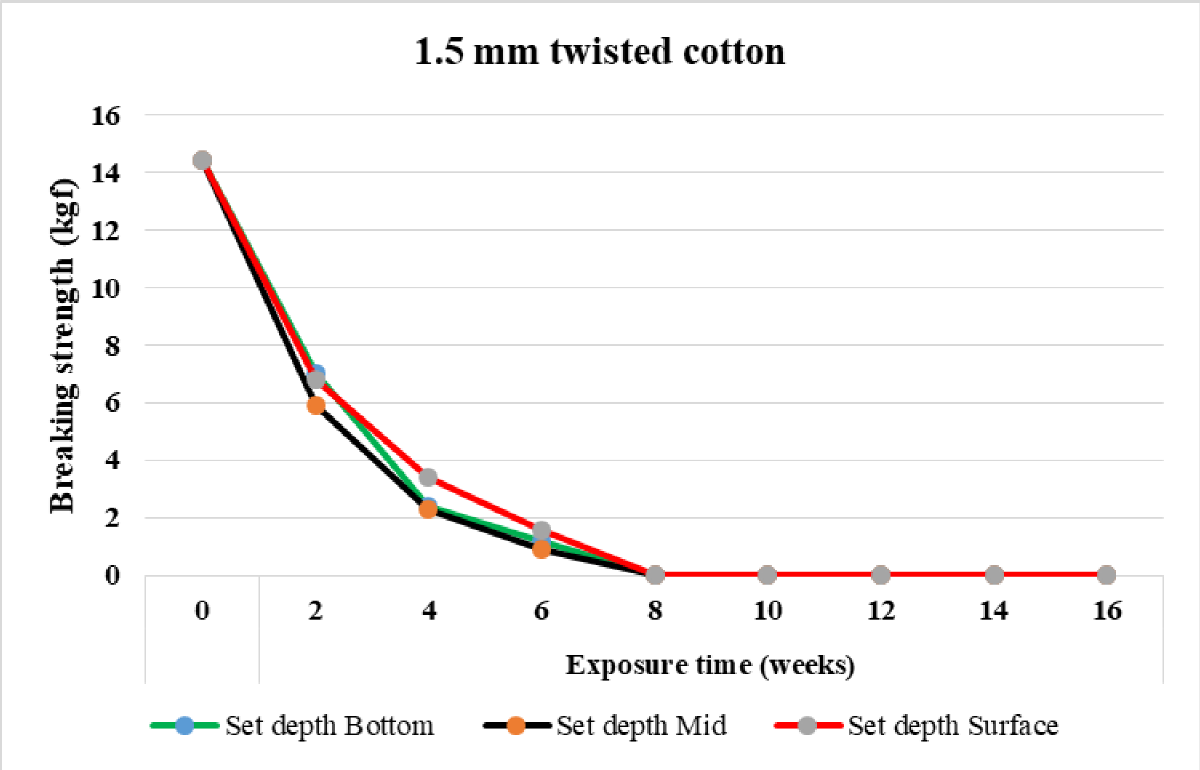


Figure 2: The degradation pattern of 1.5 mm twisted cotton

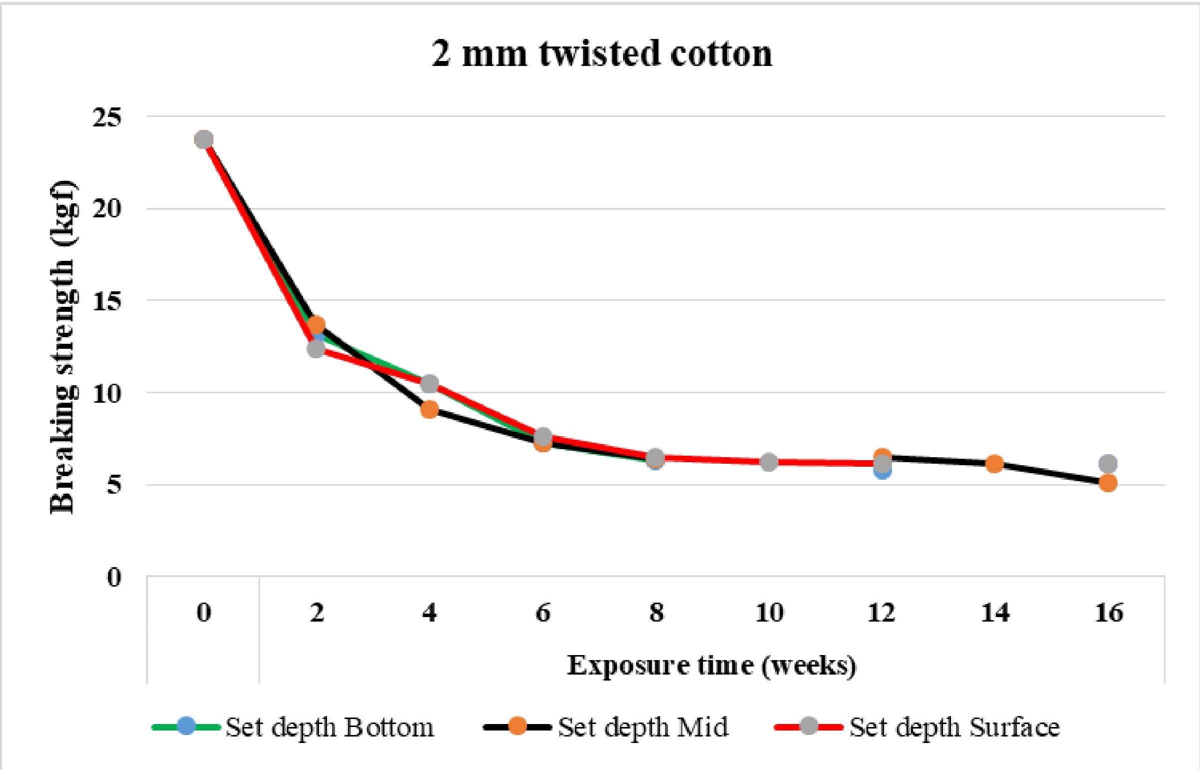


Figure 3: The degradation pattern of 2.0mm twisted cotton

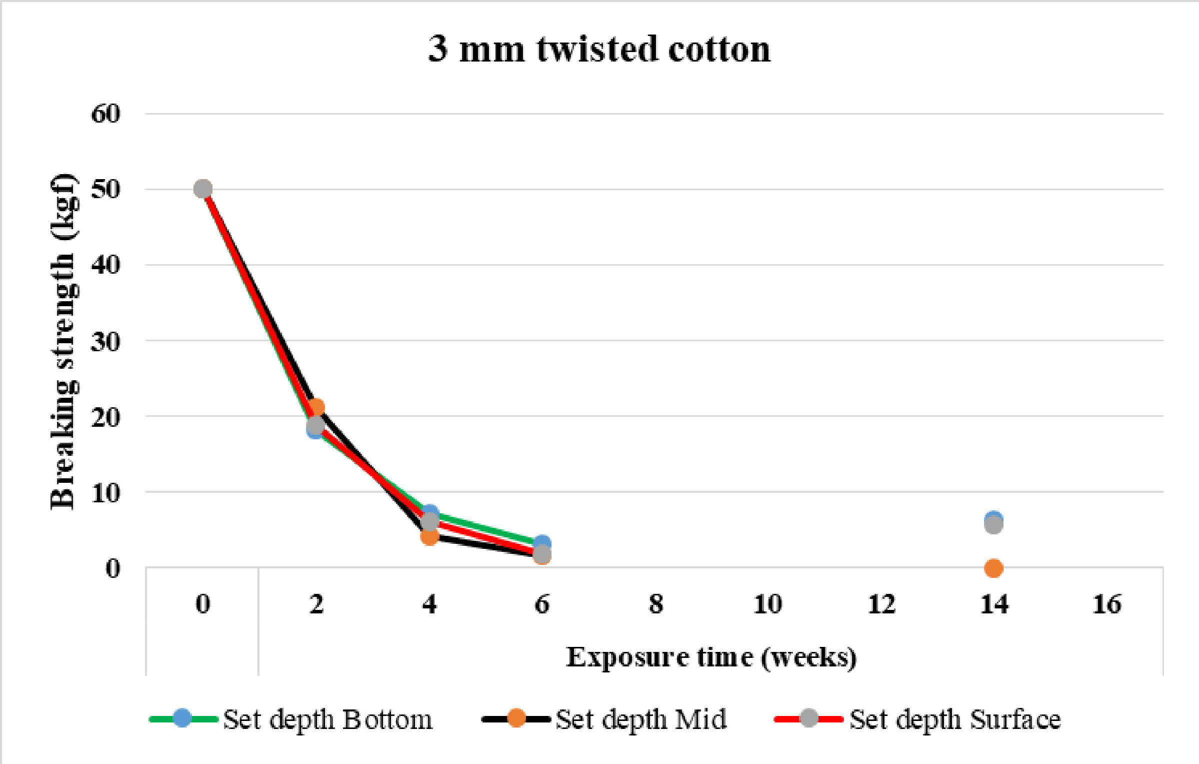


Figure 4: The degradation pattern of .30mm twisted cotton

The time series reduction in the tensile strength measurements are provided for 1.5 mm twisted cotton (Figure 2), 2.0 mm twisted cotton (Figure 3) and 3.0 mm twisted cotton (Figure 4). Tensile strength results for nylon twines are shown in Table 5.

Table 5: Nylon twine tensile strength results before exposure and after 8 weeks' exposure and the percentage reduction in strength

Size	**Depth**	**Tensile strength after exposure (kgf)**	**Tensile strength before exposure (kgf)**	**% reduction in tensile strength**
48ply	Bottom	32.9	36.6	10.1
36ply	Bottom	27.3	28	2.5
24ply	Bottom	26.8	29	7.6
48ply	Middle	33.6	36.6	8.2
36ply	Middle	23.9	28	14.6
24ply	Middle	25.9	29	10.7
24ply	Surface	26	29	10.3
36ply	Surface	26.5	28	5.4
48ply	Surface	32.2	36.6	12.0

The results indicated that:

1. 1.5mm twisted cotton lost 100% of its original tensile strength after 8 weeks of continuous exposure
2. 2.0mm twisted cotton lost between 74.5% and 78.6% of its original tensile strength after 16 weeks of continuous exposure
3. 3.00mm twisted cotton lost 100% of its original tensile strength after 6 weeks of continuous exposure
4. Nylon synthetic rope only lost between 5.4 and 14.6% of its original tensile strength after 16 weeks of exposure.

1.1.4 Conclusion

We recommend modification of gillnets with the 2.0 mm twisted cotton to reduce the frequency and cost of net repairs. However, the 1.5 and 3.0mm twines will also be used during the gear modification and testing with a disclaimer to the fishermen that a higher frequent of repairs is expected if they are used to modify net.

ACTIVITY 1.2: GILLNET MODIFICATION

Gillnet was chosen for this activity based on the fact that it is the most commonly used net in the artisanal fishery and has a higher chance of being lost while the choice of 3 inches' net mesh size is based on the most preferred legal size used by the fishers. The 1.5, 2.0 and 3.0 mm twisted cotton used for gillnet modification is based on the results of the tensile strength testing (see report for activity 1.1). 24-ply nylon twine (chosen based on what is normally used by the fishermen) was used to modify a control net.

1.2.1 Design of the modified gear

The gillnet modification entailed the replacement of the regular nylon twines used to attach the gillnet to the head rope with biodegradable twines sizes of 1.5, 2.0 or 3.0mm twisted cotton following the design (Figure 5). A control net was modified using the same design but using nylon twine (Figure 6). The nets are designed such that in the event of loss, the attaching biodegradable twine degrades and the net collapses to the bottom of the sea while the buoy, headline and connecting rope remain attached to the collapsed net (Figure 7) to facilitate retrieval.

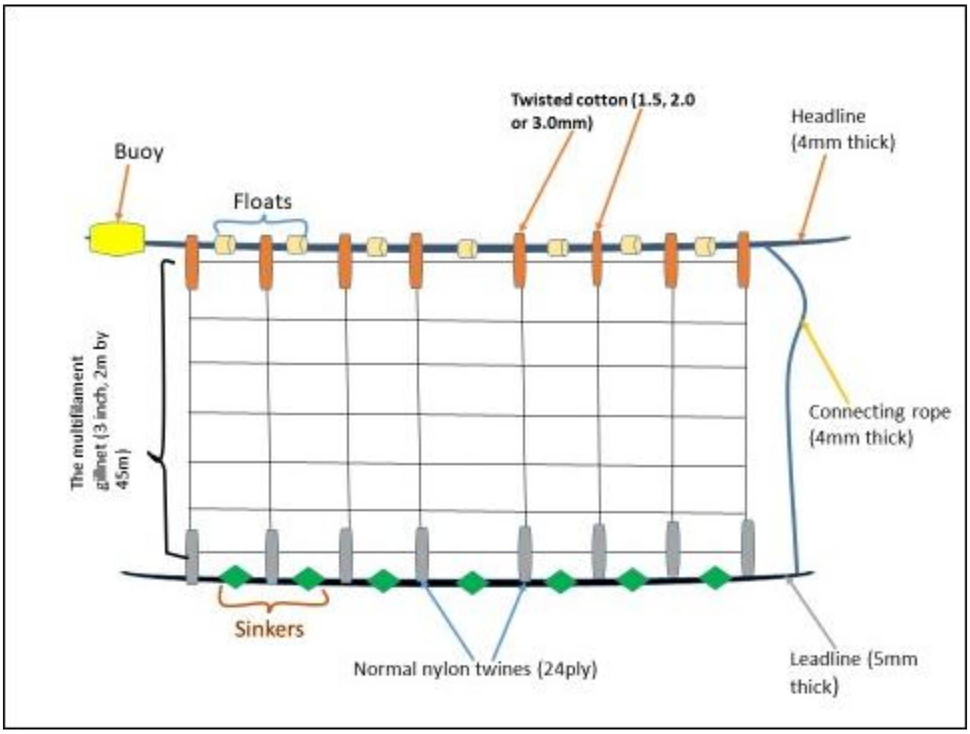


Figure 5: An illustration of the unmodified multifilament gillnet

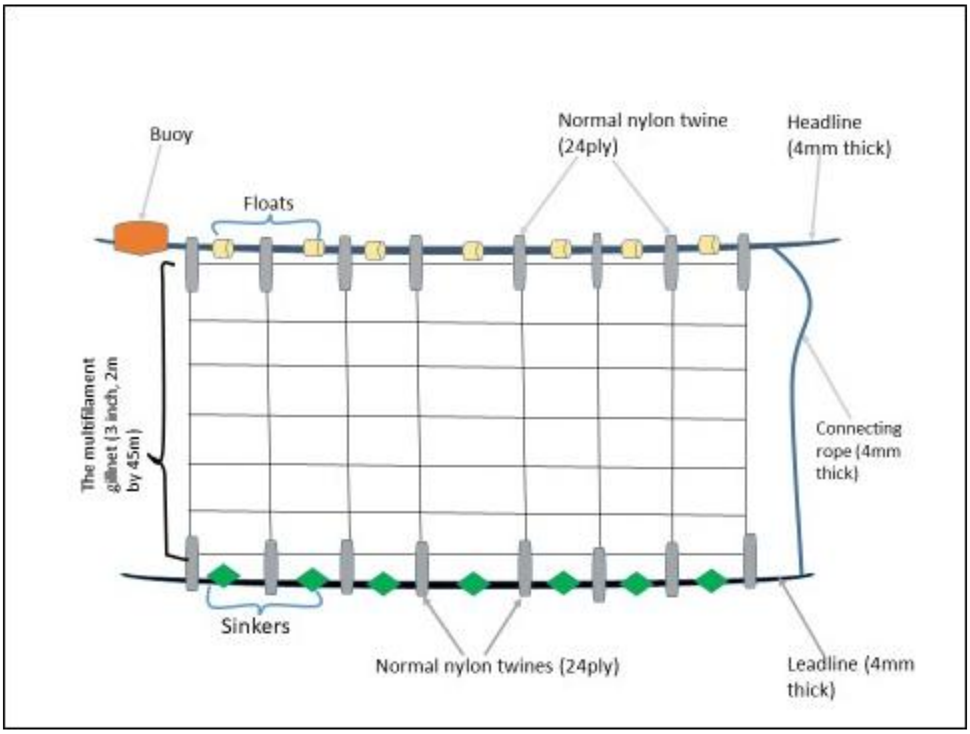


Figure 6: An illustration of the modified multifilament gillnet

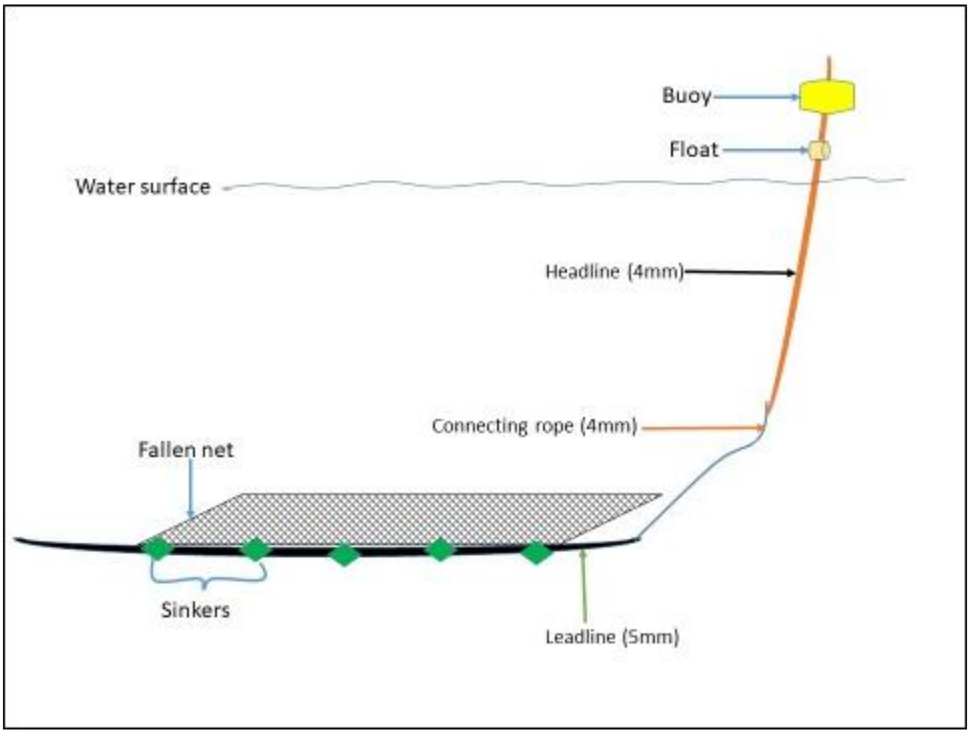


Figure 7: An Illustration of a collapsed modified net in the event of loss

1.2.2 Training of fishers on gear modification

Eight stakeholders were trained including six fishers from (two from Mikindani and four from Old Town) Beach Management Units (BMUs) who were engaged during the project inception meeting on gear modification were invited to KMFRI offices for a one-day training on gillnets modification. In attendance was one diver and one bosun who were to familiarize themselves with the project as they will be useful in implementing activities 1.3 and 1.4 respectively. The training was facilitated by trained gear technologists.

1.2.3 Gillnets modification

The trained fishers were engaged to carry out the 5 days' gear modification exercise under the guidance of KMFRI gear technologists. Multifilament gillnet (90m by 2m, mesh size 3 inches) was used for the modification. The net is of a legal mesh size permitted by the government. Three multifilament gill nets (90m by 2m) each were modified using 1.5, 2.0 and 3.0 twisted cotton twines and additional three nets modified using 1.5 mm nylon twine totaling to 12 nets that are intended for fish catchability experiment (Activity 1.3). In addition, one multifilament gill nets (45m by 2m) each was modified using 1.5, 2.0 and 3.0 mm twisted cotton twines and additional net modified using 1.5 mm normal nylon net totaling to 4 nets that are intended for gear degradability experiment (Activity 1.3).

1.2.4 Conclusion

1. The training on gear modification was concluded successfully and the knowledge passed to the local fishers who will be engaged in future for capacity building on Training of Trainers (ToT) basis.
2. Gillnet modification was concluded successfully with the products of 12 multifilament gillnets to be used for fish catchability experiment and 4 nets to be used for gear biodegradation experiment.

ACTIVITY 1.3 TESTING THE PERFORMANCE IN REDUCING GHOST FISHING AND MARINE PLASTIC LITTER

The nets modified under activity 1.2 was subjected to degradation experiment in situ as outlined below

1.3.1 Briefing meeting

Prior to the deployment of the modified and normal nets, KMFRI team held a meeting on 12th November 2022 with the Wasini BMU and community divers to familiarize them with the project. Further, an in-depth explanation on the project and the expected deliverables from the project was presented to the BMU

1.3.2 Deployment of the nets

The nets deployment was done in 12-14th November 2022. Three modified nets of size 30m by 2m of mesh size 3.5 inches (modified nets were twisted cotton twines of sizes 1.5mm, 2.0mm and 3mm) were used in the degradability test. One non modified net used as a control was also deployed.

The experiment was conducted adjacent to Wasini Locally Managed Area (LMMA) in Shimoni, Kwale County by KMFRI and Wasini BMU divers. The buoys were labelled according to the twine size used in each modified net to facilitate identification during retrieval. The progress of the experiment was monitored weekly until all nets were retrieved.

1.3.3 Results of the experiment

The net modified using 3.0mm twisted cotton twine was retrieved on 5th April 2023, after the float line was sighted whereas modified using 1.5mm and 2.00mm twisted cotton twines took additional 1 month for the float line to be release and were retrieved on 9th May, 2023.

1.3.4 Conclusion from the experiment

The experiment was completed successfully and the float line released to the surface of the ocean while the net collapsed to the bottom of the ocean.

ACTIVITY 1.4 -TESTING THE PERFORMANCE OF THE MODIFIED GILL NETS IN CATCHING FISH

This activity was aimed at clearing any doubts on under performance of modified nets compared to normal nets with regards to sizes, types and weight of fish caught. The activity was carried out as follows.

1.4.1 Nets deployment approach

The gillnets modified using 1.5, 2.0 and 3.0 mm twisted cotton (based on the results of the tensile strength testing, see report for activity 1.1) were used for the fish catchability experiment. 24-ply nylon multifilament nets were used in a control net. The catchability experiment was carried out along Tudor creek by two experienced local fishermen from Tudor BMU who were involved in gear modification exercises, one fisheries biologist and a trained fisheries observer from KMFRI. The nets were cast at various fishing grounds (to cover a wide range of fishing grounds), including Silos cement, Forodhani, Mama Ngina, Jiwe la Umbu, English point, and Tiwi.

The activity was conducted as a typical fishing activity while keeping observance of equal net exposure durations and randomized net deployment. All the three modified nets and one control net were cast in the morning and retrieved after 24 hours for a period of seven days. Upon retrieval, the fisheries observer recorded various details about the fishing grounds, such as their GPS locations, the date and time the nets were set and retrieved, and the species of fish caught in each net. They also measured the total length and width of the fish caught. The modified net with the 3 mm twines was lost on the first day of the experiments (probably stolen) and therefore the deployment of 3 mm modified net was discontinued. The key questions that the experiment was seeking to answer were 1) can the modified nets catch fish like the unmodified ones? 2) are the modified nets selective of specific species caught? 3) are the modified nets selective of the fish sizes caught? and 4) are the modified nets selective of the specific weight of fish caught?

1.4.2 The experiment's key findings

Can the modified nets catch fish like the unmodified ones?

A total of 95 fish were caught in the experiment, with 28 fish caught using a normal net, 33 fish caught using a 1.5 mm modified net, and 35 fish caught using a 2 mm modified net. The results indicate that the modified nets catch fish just like the unmodified nets.

Table 6. Performance of modified and normal gillnet in fishing

Net	Fish Length		Fish Weight		Species number	
	Range (cm)	Mean±SD (cm)	Range (kg)	Mean±SD (kg)	Range	Mean±SD
Original Net	6-46.5	26.54±10.19	0.071-0.718	0.324±0.038	2-6	3.16±1.60
1.5 twine cotton modified	5.8-51.6	24.62±8.48	0.025-0.91	0.227±0.158	2-7	2.33±2.16
2.0 Twine cotton modified	6.6-55	25.04±7.30	0.1-1.257	0.257±0.189	2-8	2.83±1.60

Are the modified nets selective of specific species caught?

The number of species caught ranged from 2-6 for the original net, 2-7 for the 1.5 mm and 2-8 for the 2.0 mm modified net with the mean of 3.16±1.60, 2.33±2.16 and 2.83±1.60 respectively (Table 6). The differences in the number of species caught were not statistically significant ($F = 0.323$; $p > 0.05$) indicating there was no selection of species by the three nets.

Are modified nets selective of the fish sizes caught?

The length of species caught ranged from 6.0-55.0 cm. The length ranges for the original net were 6-46.5 while for the 1.5 mm and 2.0 mm were 5.8-51.6, 6.6-55 respectively. The mean length of fish caught by the original, 1.5 and 2.0 were 26.54±10.19, 24.62±8.48 and 25.04±7.30 cm respectively (Table 6). The differences in the sizes of species caught by the three nets were not statistically significant ($F = 0.407$; $p > 0.05$) indicating there was no selection of specific sizes of fish by any of the three nets.

Are the modified nets selective of the specific weight of fish caught?

The weight of species caught ranged from 0.025-0.91. The weight ranges for the original net were 0.071-0.718 while for the 1.5 mm and 2.0 mm were 0.025-0.91, 0.1-1.257 respectively. The mean sizes of fish caught by the original, 1.5 and 2.0 were 0.324±0.038, 0.227±0.158 and 0.257±0.189 respectively as shown in Table 6. The differences in the sizes of species caught by the three nets were not statistically significant ($F = 2.192$; $p > 0.05$) indicating there was a selection of specific sizes of fish by any of the three nets.

1.4.3 Cost benefit analysis

Cost benefit analysis was calculated as Net Present Value using the below formula

Net Present Value (NPV) = Σ (Benefits - Costs) / (1 + r) ^t

where:

Σ = the sum of all the benefits and costs over the life of the project

r = the discount rate, which reflects the time value of money and the risk associated with the project (For this project considered to be 10% p.a)

t = the time period over which the benefits and costs will be realized (for this project considered to be 1 year).

For modified nets the annual benefits considered included, fish catch, reduced cost of replacement of nets, reduced ghost fishing whereas the annual costs included cost of procurement and modification of net, cost of fishing, and costs to the environment (ghost fishing).

For normal nets the annual benefits considered included, fish catch whereas annual costs included cost of procurement and modification of net, cost of fishing, and costs to the environment (ghost fishing).

The following assumptions were applied during calculation of CBA

1. Probability of losing a net is once a year
2. Net recovery costs is negligible
3. Modified nets will only ghost fish for 3 months until the twines degrade whereas the normal net will continue to ghost fish the entire year under consideration
4. Only ghost fishing was considered as an environmental cost.

The results of CBA

Modified net had a positive NPV of KES 53,602 indicating that the benefits of using modified nets outweighs direct and environmental costs. Normal Nets had a negative NPV of KES 118,590 indicating that direct and environmental costs of using normal nets outweighs the benefits.

1.4.4 Conclusion and recommendation

It is clear from the results of the catchability experiment that there were no statistically significant differences in species, sizes and weights of the fish caught by the 3 nets. The study concludes that modifying gillnets with the 1.5 and 2.0 mm biodegradable twine does not affect the types, sizes and weight of fish caught and recommends the adoption of the nets modified using 1.5 and 2.0 mm biodegradable twines to reduce ALDFG and their impacts. The cost benefit analysis confirms that the benefit of using a modified gillnet outweighs the direct and environmental cost.

ACTIVITY 2.2. FISHER'S ENGAGEMENT ON THE PERFORMANCE OF THE MODIFIED GILLNETS

Two dissemination meetings were conducted on 10th and 18th May 2023 in the Vanga and Shella BMUs, which serve fishers from Vanga and Ungwana Bay communities, respectively. The objective of these meetings was to raise awareness on the issue of marine litter, its impacts, as well as the impacts of Abandoned, Lost, or otherwise Discarded Fishing Gear (ALDFG). Additionally, the meetings aimed at educating the communities on measures that can be taken to reduce the loss of fishing gear and sharing experiences, lessons learned on the modification and performance of modified gillnets. Printed posters were shared with the stakeholders who attended the engagement.

2.2.1 Awareness in Vanga BMU

The awareness meeting was held on 10th May 2023 in Vanga Social Hall and attended by 39 fishers from the Vanga BMU, 2 local gear technologists, 3 fisheries officers from the Kenya Fisheries Service, 2 fisheries officers from the Kwale County fisheries department, KMFRI project implementation team and 2 fishers from Mombasa Tudor BMU who were involved from the inception of the project, gear modification and catchability experiments (as Trainers of Trainers). The meeting was officially opened by the BMU chair lady, Manatumu Kadau. The welcoming address was delivered by Mr. Charles Odindo, the Assistant Director of Kenya Fisheries Service, Coast region.

KMFRI made a presentation that provided a comprehensive overview of marine litter pollution, including its sources, pathways, and impacts. The presentation specifically underscored the contribution of the fishing industry to marine litter and highlighted the significant role of ALDFG in plastic pollution. The presentation further elaborated on the critical role that hotspot mapping, gear retrieval, and recycling were playing in mitigating the effects of ghost fishing. It identified product innovation as the missing link in addressing ghost fishing as the fishing effort continues to increase, resulting in an increase in lost fishing gear and ghost fishing.

The presentation provided a detailed insight into the project methods and results, focusing on specific activities. These activities included Activity 1.1, which involved selecting natural twines through target strength experiments for gear modification; Activity 1.2, which replaced synthetic lines with biodegradable twines as detailed in Activity 1; Activity 1.3, which tested the performance of modified gears in reducing ghost fishing and marine plastic litter; and Activity 1.4, which compared the performance of modified gillnets with normal ones in catching fish.

To demonstrate the technical aspect of the project, two fishers from Tudor BMU, Mombasa led the discussion on how to modify gillnets using biodegradable twines. The presentation highlighted the need for continued efforts to address the issue of marine litter and ghost fishing, with a focus on product innovation and sustainable fishing practices.

The following concerns and suggestions were raised during the discussion:

1. The fishers expressed their appreciation for the innovation and requested the development of a similar technology for ring nets.
2. The Vanga BMU currently use a single rope on the float line while making the gillnets, which differs from the modified gillnets. However, following a demonstration on how to modify gill nets, the fishers agreed to adopt the use of two ropes on the headline.
3. All the fishers, regardless of the fishing gear used, acknowledged ghost fishing as a problem and supported the initiative to modify and use biodegradable twines

2.2.2 Awareness in Shella BMU (Ungwana Bay Fishers)

The meeting was held on 18th May 2023. In attendance were i) 45 fishers from the Shella BMU ii) 5 fisheries officers from the Kilifi County fisheries department iii) KMFRI project implementation team and iv) 2 fishers from Mombasa Tudor BMU who were involved from the inception of the project, gear modification and catchability experiments (as Trainers of Trainers). The meeting was opened by the Shella BMU chairman, Mr Yunus Aboud and welcoming remarks made by the fisheries officer, Ms Irene Furaha from Kilifi County Fisheries Department.

KMFRI made a presentation giving a summary of marine litter, the sources, pathways, and impacts. Emphasis was made on the contribution of the fishing industry to marine litter, and the role of ALDFG in plastics pollution. It further elaborated on the role that hotspot mapping, gear retrieval and recycling were playing to reduce the impacts of ghost fishing. It identified product innovation as the missing link in addressing ghost fishing. It reported that the fishing effort was on the increase and associated with an increase in the number of fishing gear that are getting lost increasing ghost fishing. The presentation further provided a detailed insight into the gillnet modification method and results at the stages of the project including biodegradable twine selection, exposure experiments, tensile strength testing, gear modification exercise, modified gillnet performance test, and fish catchability experiment.

To demonstrate the technical aspect of the project, two fishers from Tudor BMU, Mombasa led the discussion on how to modify gillnets using biodegradable twines. The presentation highlighted the need for continued efforts to address the issue of marine litter and ghost fishing, with a focus on product innovation and sustainable fishing practices.

The following concerns and suggestions were raised during the discussion:

1. The fishers expressed their appreciation for the innovation
2. The possibility of extending modification research to encompass other common gear used in the area, including drifting gill nets that are used in deeper offshore waters.
3. Need to develop a technology for modifying drift nets.

OVERAL CONCLUSIONS AND RECOMMENDATIONS

The Testing and Promoting Fishing Gear Innovation to Reduce Ghost Fishing of Lost Gillnets Project aimed to identify fishing gear at high risk of getting lost at sea; modify fishing gear to reduce catchability coefficient once lost at sea; and test the effectiveness of modified fishing gear in reducing the risk of ghost fishing. The project successfully achieved its objectives and concludes that

1. Twisted cotton twine (2mm) was the most suitable biodegradable twine for gillnet modification having shown satisfactory results in degradation experiments and tensile strength testing experiments.
2. Gillnets modified by 2mm cotton twine demonstrated viability of concept in providing a good balance in releasing and cost of nets maintenance.
3. Both the modified and normal nets caught same amount (weight and size) and type of fish.
4. The cost benefit analysis confirms that the benefit of using a modified gillnet outweighs the direct and environmental cost while the direct and environmental costs of using normal nets outweighs the benefits.

The project recommends

1. Modification of gillnets using 2.0 mm twisted cotton as the most preferred. However, 1.5 and 3.0 mm twisted cotton can also be utilized with the rider that the frequency of gear maintenance will be higher than when using 2.0 mm twisted cotton.
2. Future research should consider modification of deep water gillnets and ring nets.

ANNEXES

Annex 1. Exposure experiment (Net tensile strength). Twines retrieved (Y) and lost (N) after the exposure experiment for twines set at the surface (green colour), middle (yellow colour) and bottom (blue colour) depths.

TWINE	SIZE	WEEK							
		2	4	6	8	10	12	14	16
Sisal	2ply	Y	Y	Y	Y	N	N	N	Y
		Y	Y	Y	Y	N	N	Y	Y
		Y	Y	Y	Y	N	Y	N	N
	3ply	Y	Y	Y	Y	N	N	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	N	N	Y	N
Braided cotton	1mm	Y	Y	Y	Y	N	N	Y	N
		Y	Y	Y	N	Y	N	Y	N
		Y	Y	Y	Y	N	N	N	N
	2mm	Y	Y	Y	Y	N	N	N	Y
		Y	Y	Y	Y	Y	Y	N	N
		Y	Y	Y	Y	N	Y	N	N
	3mm	Y	Y	Y	Y	N	N	N	Y
		Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	N	N	Y	N
Jute	1.5mm	Y	Y	Y	Y	N	N	Y	N
		Y	N	Y	N	Y	Y	Y	N
		Y	Y	Y	Y	N	N	Y	N
	2mm	Y	Y	Y	Y	N	N	Y	Y
		Y	Y	Y	Y	N	Y	Y	Y
		Y	Y	Y	Y	N	Y	Y	N
	3mm	Y	Y	Y	Y	N	N	Y	N
		Y	Y	Y	Y	N	Y	Y	Y
		Y	Y	Y	Y	N	Y	N	N
Twisted cotton	1.5mm	Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	N	Y	Y	Y
		Y	Y	Y	Y	N	Y	N	Y
	2mm	Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	N	Y	Y	Y

		Y	Y	Y	Y	N	Y	Y	Y
	3mm	Y	Y	Y	Y	N	Y	Y	Y
		Y	Y	Y	Y	N	Y	Y	Y
		Y	Y	Y	Y	N	Y	Y	N
Nylon	24ply	Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y
	36ply	Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y
	48ply	Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y
		Y	Y	Y	Y	Y	Y	Y	Y

Annex 2. Exposure experiment (Net tensile strength)

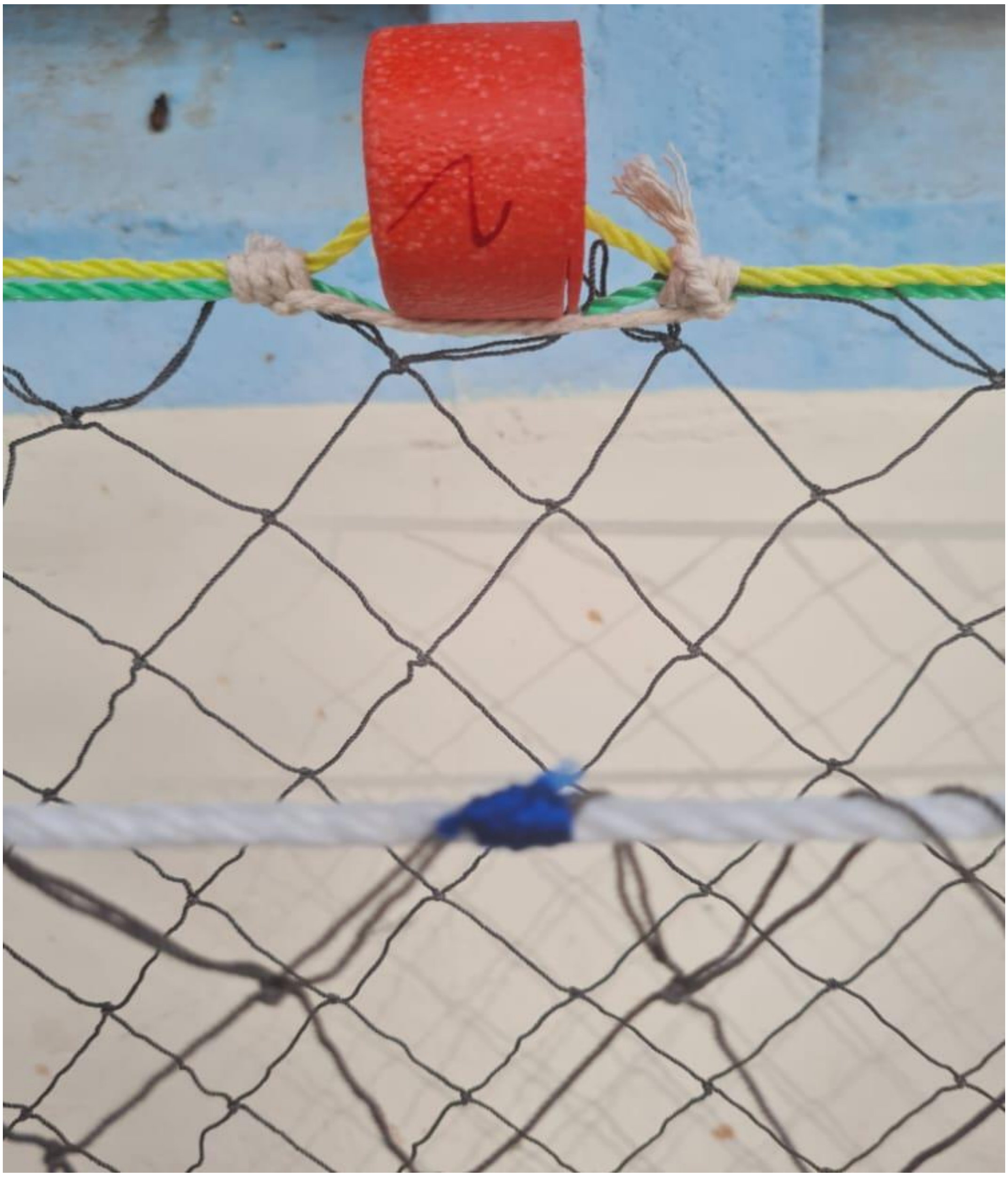
Twines retrieved (Y) and lost (N) after the exposure experiment for twines set at the surface (green colour), Middle (brown colour) and Bottom (Blue colour) depths that were selected for tensile strength testing

Twine	**Size**	**Exposure duration (weeks)**							
		2	**4**	**6**	**8**	**10**	**12**	**14**	**16**
Sisal	2ply	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
	3ply	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
Braided cotton	1mm	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
	2mm	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
	3mm	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N

		N	N	N	N	N	N	N	N
Jute	1.5mm	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
	2mm	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
	3mm	N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
		N	N	N	N	N	N	N	N
Twisted cotton	1.5mm	Y	Y	Y	N	N	N	N	N
		Y	Y	Y	N	N	N	N	N
		Y	Y	Y	N	N	N	N	N
	2mm	Y	Y	Y	Y	Y	Y	N	Y
		Y	Y	Y	Y	N	Y	Y	Y
		Y	Y	Y	Y	N	Y	N	Y
	3mm	Y	Y	Y	N	N	Y	N	N
		Y	Y	Y	N	N	Y	N	N
		Y	Y	Y	N	N	N	Y	N
Nylon	24ply	N	N	N	N	N	N	N	Y
		N	N	N	N	N	N	N	Y
		N	N	N	N	N	N	N	Y
	36ply	N	N	N	N	N	N	N	Y
		N	N	N	N	N	N	N	Y
		N	N	N	N	N	N	N	Y
	48ply	N	N	N	N	N	N	N	Y
		N	N	N	N	N	N	N	Y
		N	N	N	N	N	N	N	Y

PICTORIALS

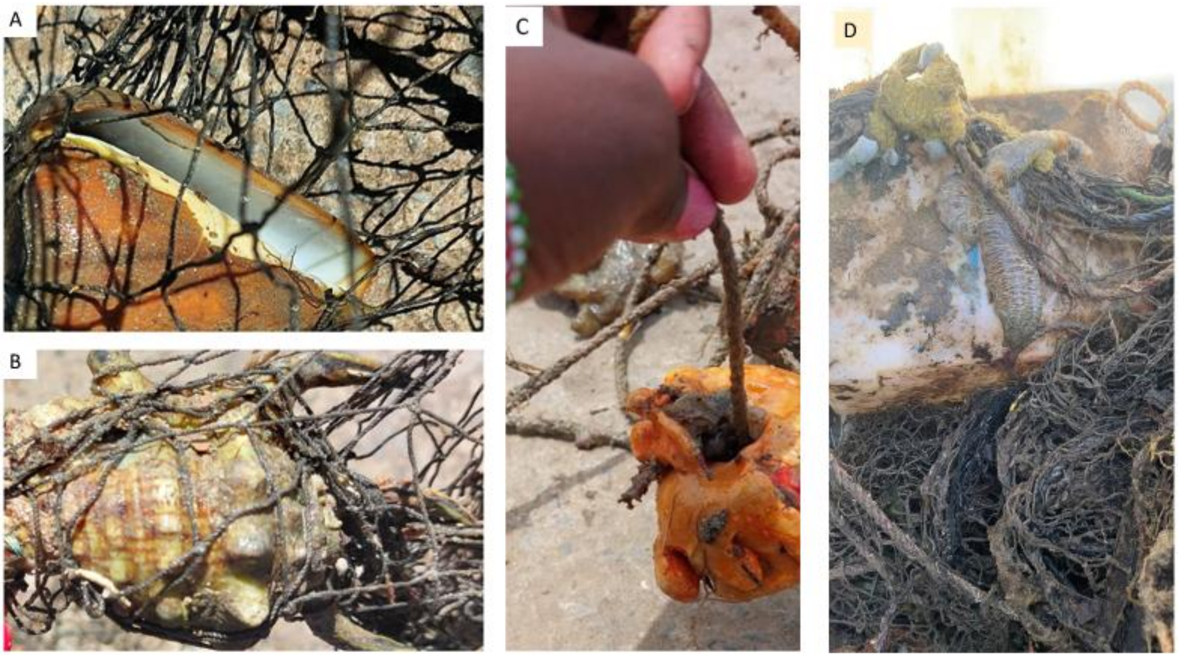
Picture 1: Retrieved twines before drying, washing or detangling



Picture 2: **Net modified with 2mm twisted cotton twine showing float and lead lines**

Picture 3: **Modified gillnets**

Picture 4: 30m by 2m size modified nets for the degradation testing experiment



Picture 5: A prince cones (A) spider conch snail(B), and sponge (C), Sea Cucumber (D)- some of the marine organisms found on the nets after retrieval