International Journal of Fisheries and Aquaculture

Volume 7 Number 2 February 2015
ISSN 2006-9839

Academic Journals

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International Journal of Fisheries and Aquaculture

Table of Contents: Volume 7 Number 2 February 2015

ARTICLES

Research Articles

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Vol. 7(2), pp. 9-14, February 2015
DOI: 10.5897/IJFA15.0469
Article Number: E49D5FB50581
ISSN 2006-9839

http://www.academicjournals.org/IJFA

International Journal of Fisheries and Aquaculture

Full Length Research Paper

Some aspects of reproductive biology on effect of heavy metal pollution on the histopathological structure of gonads in *Labeo rohita* (Hamilton-Buchanan) from Harike wetland, India

Onkar Singh Brraich and Sulochana Jangu*

Department of Zoology and Environmental Sciences, Punjabi University Patiala, India.

Received 1 January 2015; Accepted 27 January 2015

Water pollution caused by heavy metals affects breeding and development in fishes of Harike wetland. The effects of heavy metals on fishes are related to their uptake and accumulation by the organism, resulting in metal induced disturbances in the structures and functions of various tissues and organs. Early life stage of fish development, such as oocytes maturation is very sensitive to intoxication. Samples of the fish *Labeo rohita* were collected from the two sites to assess the effects of the water quality and concentrations of heavy metals on the fish ovary. The histopathological changes in gonads have been studied due to exposure of different pollutants. It was concluded that incidences of gonadal abnormalities in the form of deformed oocytes, reduction in their numbers and lack of active oogenesis have been observed. From the results it is inferred that wetland is passing through an alarming situation because deformities in early stages of oocytes have been observed. It is posing a serious threat to the biodiversity existing there. It is recommended that waste water discharge from various sources should be treated to protect the fish and the public health from the menace of pollution.

Key words: Wetland, Industrial pollution, toxicity, *Labeo rohita*, oocytes.

INTRODUCTION

Heavy metals are the major source of water pollution, as it eradicates the economically important species either indirectly through breaking the biological chains or directly produces toxic stress by means of chemical changes in water. As a result, large scale mortality of fishes has been observed due to discharge of heavy metal pollution into natural water resources (Srivastava and Srivastava, 1994). Fishes are very sensitive to a wide variety of toxicants in water, various species of fish uptake and accumulate many toxicants such as heavy metals (Herger et al., 1995). The accumulation of heavy metals in tissues thus causes many physiological, histological and biochemical changes in the fishes and other freshwater fauna by influencing the activities of several enzymes and metabolites (Nagarathnamma and Ramamurthi, 1982).

*Corresponding author. E-mail: sulochanajangu@gmail.com

Figure 1. Collection sites at River Beas and Harike wetland.

The pervious histopathological studies of fish exposed to pollutants also revealed that fish organs uptake toxicants and are efficient indicators of water quality (Cardoso et al., 1996; Cengiz et al., 2001; Benejam et al., 2010). The effects of different toxicants on the aquatic fauna, particularly on fish have received attention of many investigators (Das and Baruah, 2002; Athikesavan et al., 2006; Gupta and Srivastava, 2006; Tilak et al., 2007).

The main objective in aquaculture is to enhance fish production by producing high numbers of viable oocytes in controlled conditions and subsequently to ensure the development of normal embryo (Lubzens et al., 2010; Bobe and Labbe, 2010). Nevertheless in natural aquatic ecosystems, environmental toxicants discharged from various sources causes detrimental effects on important features such as metabolism, growth, reproduction and ultimately the survival of the fish becomes very difficult (Adams et al., 1992; Benejam et al., 2008). For further propagation of the fish, the quality of oocytes plays a key role in the proper development of an embryo. The competence of oocytes depends on numerous processes taking place during the whole oogenesis, but its final steps such as oocyte maturation, seems to be of key importance (Jezierska et al., 2001; Burger and Gochfeld, 2005; Marteil et al., 2009; Ebrahimi and Taherianfard, 2011). The toxicological effects on reproduction in the wild fish have been barely investigated with regard to alterations in the gonads (Adams and Greely, 2000; Jobling et al., 2002; Toft et al., 2004). Hence, the present investigation was undertaken with a view to study in detail about histopathological changes in the ovary of *Labeo rohita*, under the influence of heavy metal toxicity and to assess the extent of damage in this wetland.

MATERIALS AND METHODS

The present study was conducted from March 2013 to February 2014 during different seasons. Two sites (Figure 1) were chosen to carry out present study; the first one was located in River Beas at Marrar village, latitude 31°09'55.08"N and longitude 74°57'38.40"E (used as the reference point) and the second was selected in Harike wetland, latitude 31°08'42.08"N and longitude 74°59'31.47"E.

Fish sample collection and histopathological examination

Five samples of Indian Major Carp *L. rohita* were collected from each site during breeding season. The fishes were dissected on the spot for histological studies. After dissecting the fish, ovaries were removed and fixed in Bouin's solution for 24 h. The tissues were routinely dehydrated in an ascending series of alcohol, cleared in xylene and embedded in paraffin wax. Sections of 4 to 6 µm thick were cut, processed and stained with heamatoxylin and eosin (H&E). They were examined and photographed under light microscope unit.

RESULTS

Histopathological findings

The histological examination of the ovaries of *L. rohita* from river Beas (Figures 2 to 6) showed that in early stage of oocyte maturation the ovary is mainly composed

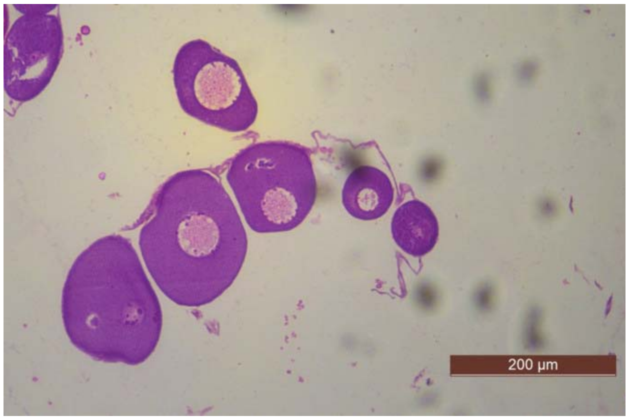

Figure 2. Micrograph showing different stages of oocytes in ovary of *Labeo rohita* from River Beas or control group.

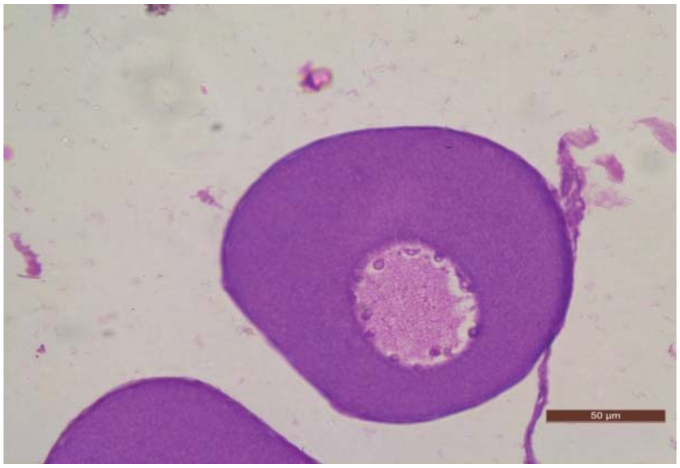

Figure 3. Periucleoar stage of oocyte.

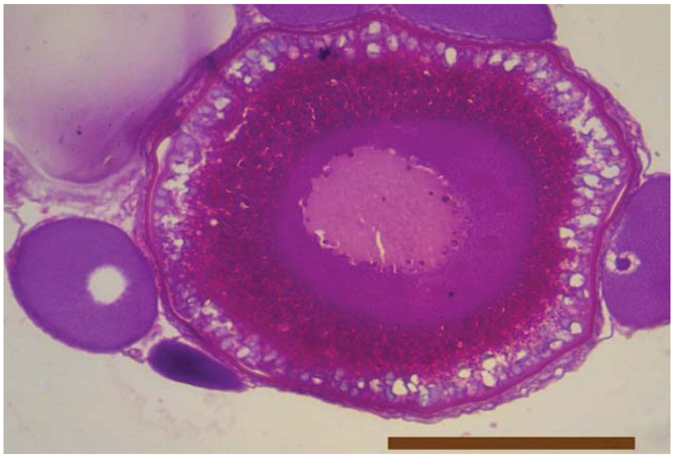

Figure 4. Cortical alveolus stage of control group with demarcation of zona radiata and germinal vesicle migration stage of oocyte.

of small oogonia (Figure 2) and this stage is called chromatin nucleolus stage of oocyte maturation.

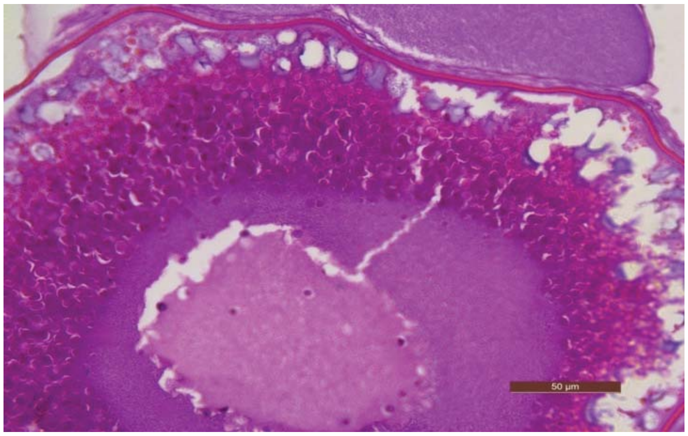

Figure 5. Micrograph showing cortical alveolus stage of oocytes.

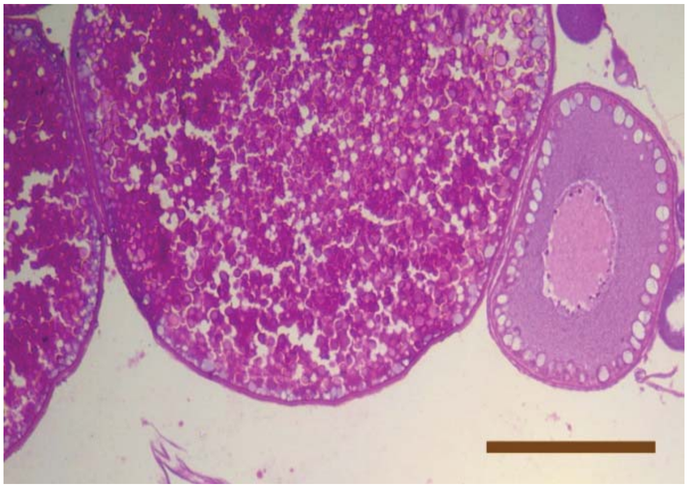

Figure 6. Vitellogenic stage of oocyte and privitellogenic stage of oocyte in control group.

The perinucleolar oocytes are enlarged in size with undifferentiated membrane, the nucleoli increased in number and become close to the nuclear membrane (Figure 3). On further maturation, the oocytes entering yolk vesicle stage in which deposition of yolk and fat globules starts which increase the size of maturing egg. The oocyte membrane at this stage became well developed (Figure 4). The cytoplasm loses its basophilic nature and became fully occupied with yolk granules. At vitellogenic stage the vacuoles become connected to each other and nucleus began to liberate its substances into cytoplasm and the nucleus starts to migrate to the animal pole (Figure 5). In mature egg, nucleus also loses its membrane and merged entirely into the cytoplasmic inclusion and moves towards the animal pole, liquefied yolk material is distributed throughout the cytosome (Figure 6).

On the other hand fishes collected from Harike wetland (Figures 7 to 13) showed different histological forms. Atretic oocytes with broken membrane which invade the

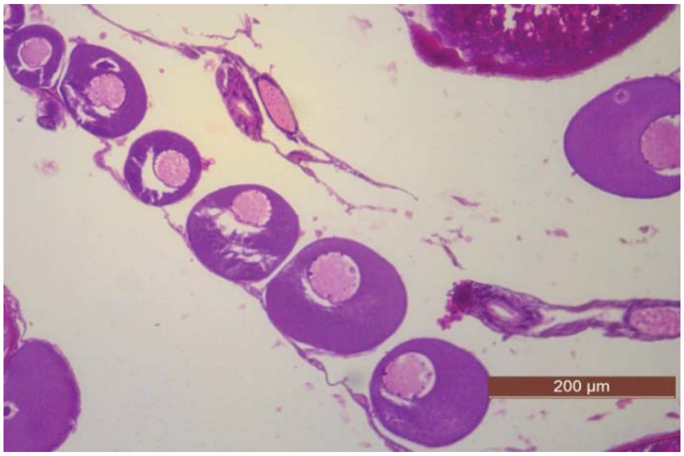

Figure 7. Atretic oocytes, decreased nucleoli in perinucleolar stage.

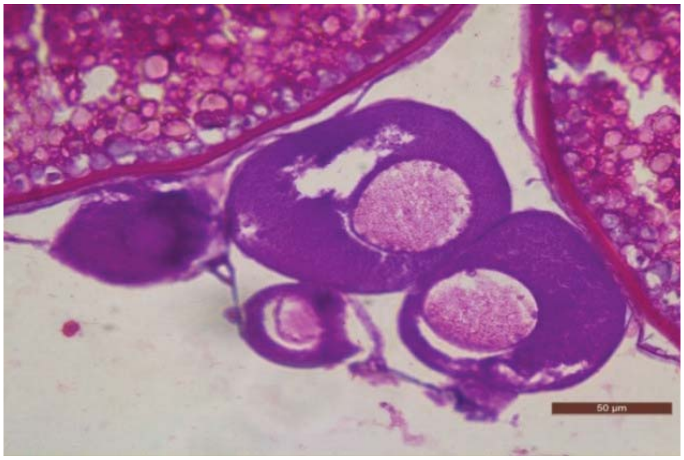

Figure 8. Atretic oocytes and altered chromatin nucleolar stage of oocyte development.

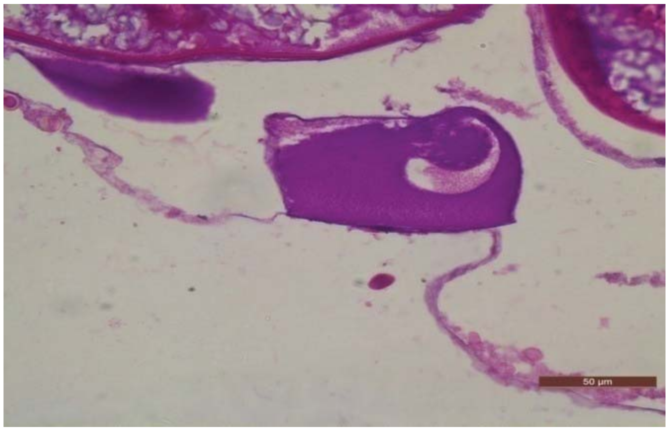

Figure 9. Atretic oocytes in ovary of fish.

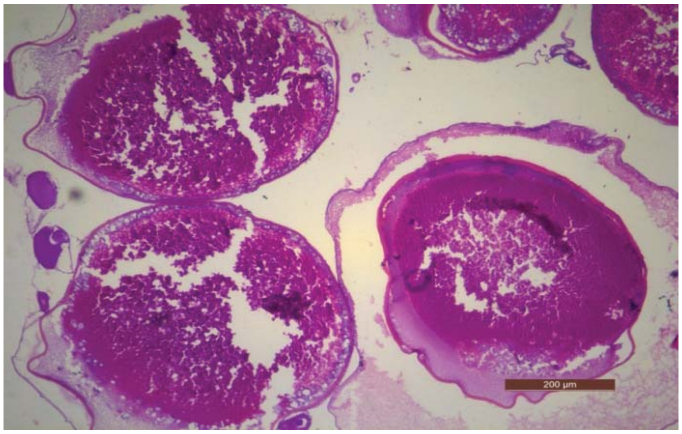

Figure 10. Development of interafollicular space in oocytes and dissolution of oocyte wall.

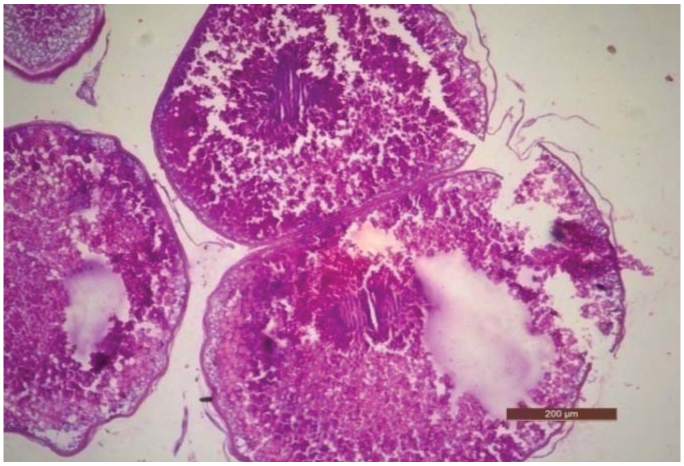

Figure 11. Vacuolation and broken wall in vitellogenic oocytes of fish.

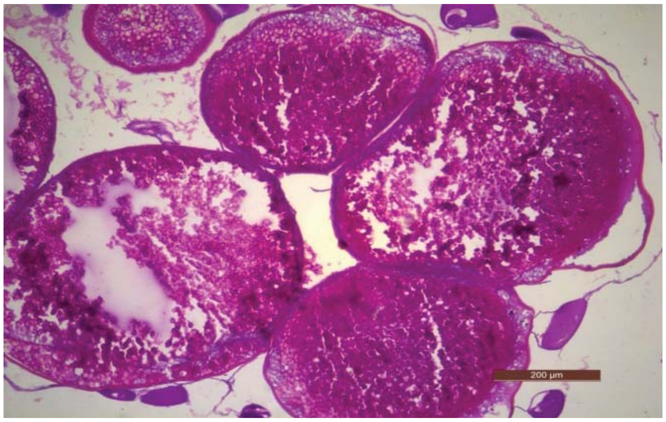

Figure 12. Dissolution of yolk globles and vacuolation in vitellogenic oocytes.

dead ova and vacant space in the ovary (Figure 7). Atresia was seen in the maturing follicles, ovarian follicle separated due to loss of inter-follicular connective tissue, inter follicular spaces were larger and vacuolation in developing oocytes were also observed (Figures 8 and 9).

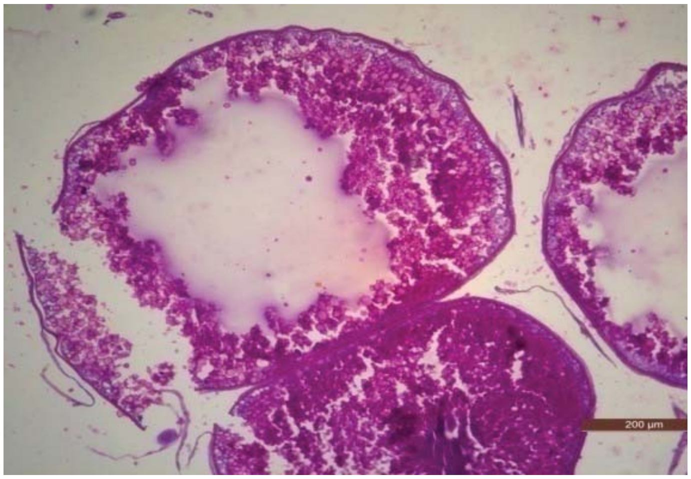

Figure 13. Damage to yolk vesicle and clumping of cytoplasm in mature oocytes.

Development of interafollicular space in oocytes and dissolution of oocyte wall was also observed (Figure 10). Vacuolization in the cytoplasm of the vitellogenic oocytes was observed (Figure 11). Dissolution of yolk globules and vacuolation in vitellogenic oocytes of fish is shown in Figure 12. Damage to yolk vesicle clumping of cytoplasm of maturing oocytes was observed too (Figure 13).

DISCUSSION

Histological abnormalities in ovaries may be caused by several factors, viz., parasitic infection, mechanical injuries, ionizing radiations, by a variety of toxic effluents and aquatic pollutants resulted in liquification of perinucleolar cytoplasm and condensation of nucleus, disappearance of nuclear membrane, cytoplasmic clumping and atretic oocytes (Kling, 1985; Sukumar and Karpagaganpathy, 1992; Sakthival and Gaikwad, 2001; Abou-Seedo et al., 2003; Deshmukh and Kulkarni, 2005; Olfat and El-Greisy, 2007). Similar abnormalities were observed during present investigations.

The different pollutants such as industrial and agricultural wastes, pesticides and heavy metals have histopathological effects on the reproductive tissues of fish gonads (Johnson et al., 1991; Lye et al., 1998; Pedlar et al., 2002; Hanna et al., 2005), these effects may disturb the development of germ cells and may reduce the ability of the fish to reproduce (Inbamani and Seenivasan, 1998; Kumar and Pant, 1984; Mehanna, 2005). In the present study, higher incidence of oocyte atresia was found in the area of Harike wetland than River Beas. Jobling et al. (2002) stated that, atresia was recorded in roach living in rivers that receive treated sewage effluents. Johnson et al. (1997) reported that atresia is thought to be an uncommon event in healthy females and it has been linked to poor nutrition and environmental stress. During the present course of work, it is observed that numbers of mature oocytes have been reduced with large follicular spaces, these observations coincides with those recorded by Unal et al. (2007), Abou Shabana et al. (2008), Mazrouch and Mahmoud (2009), Shobikhuliatul et al. (2013) and Masarat et al. (2014). From this study, it could be concluded that deformed and infected gonads of *L. rohita* collected from Harike wetland area were found in a higher percentage than those of River Beas. These results confirm the presence of different types of pollutants and heavy metals in the water of this wetland.

Conclusion

The changes induced by heavy metal pollutants in fish oocyte maturation may be related to intoxication of eggs, accumulation of metals in eggs or a direct effect of metal on the oogenesis process. The oocyte maturation is the most sensitive to metal intoxication. Therefore, various disturbances induced by heavy metal pollutants during development of oocyte results in a reduced quantity and quality of eggs. Hence, toxicity of wetlands can pose a big threat to the unique biodiversity existing there.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENT

Authors express their special thanks to the Head, Department of Zoology and Environmental Sciences, Punjabi University Patiala for providing necessary laboratory facilities funded by University Grant Commission-Basic Scientific Research scheme to carry out this work.

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Vol. 6(2), pp. 15-24, February 2015
DOI: 10.5897/IJFA14.0451
Article Number: 72990C650585
ISSN 2006-9839
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http://www.academicjournals.org/IJFA

International Journal of Fisheries and Aquaculture

Full Length Research Paper

Morphometric and developmental characteristics of fish landed by artisanal bait fishers at the Mida Creek, Kenya

Kihia Charles Maina[1]*, Hendrick Yvone[2], Muthumbi Agnes[3], Okondo Julius[4], Nthiga Aniel[3] and Njuguna Vincent[3]

[1]Department of Biological Sciences, Egerton University P. O. Box 536, Egerton, Kenya.
[2]Rift Valley Water and Service Board, P. O. Box 561-20117, Naivasha, Kenya.
[3]Department of Biological Sciences, University of Nairobi, P. O. Box 30197-00100, Nairobi, Kenya.
[4]Kenya Marine and Fisheries Research Institute, P. O. Box 81651, Mombasa, Kenya.

Received 8 October, 2014; Accepted 27 January, 2015

Although artisanal commercial and net fishers landings has received attention, the morphometrics of bait fisher landings is poorly documented. This is in spite of the importance of such data to infer fished stock growth and developmental status in order to reduce excessive removal of immature and highly fecund fish. This study compares fish species, size and weight, and derived fish condition, Gonadosomatic and Fishing Indices, between hook and line gear baited with polychaetes and hermit crabs, and traps baited with gastropods. Results indicate fishers land over 20 fish types with similar condition and GSI below unity and fishing index of below 20%. Variation in growth indicators was largely attributed to species specific differences, with high value apex predators, such as carangidae, having lower morphometrics than smaller bodied permanent creek and mangrove residents. Participatory effort controls through closure, alternative livelihoods, and voluntary release of immature, coupled with limiting the use of small mesh traps and hooks, may reduce harvesting of immature and lead to improvement of future landings and sustainability of the fishery.

Key words: Bait, condition factor, gear, Gonadosomatic index, fishing index, immature.

INTRODUCTION

Tropical artisanal fishers contribute to significant amount of global fisher landings (Cheunpagdee et al, 2006). Along the Kenyan coastline, artisanal fishers land 90% of marine fisheries landings (8 Mt), with hook and line and basket trap fishers forming 40 to 60% of fishers (Fondo, 2004; Frame Survey, 2012). Tropical artisanal fishers use a variety of gears to target multispecies assemblage of fish using unmotorised crafts (Van der Elst et al., 2005). Among gears used, a variety of nets (e.g. seines, cast nets etc), hooks (e.g. handline, long-line) and traps (e.g. basket traps, weirs, fence traps), have been mentioned in literature. While the morphometrics of fish landed using nets by artisanal fishers along the Kenyan coast (Kaunda-Arara et al., 2003; Agembe et al., 2010; Mbaru

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*Corresponding author. E-mail: charles.kihia@gmail.com.

et al., 2010; Gajdzik et al., 2014) and elsewhere, have been described, those landed by bait fishers (hook and trap fishers), have received less attention and hence the current study.

In temperate regions, angler fisher landings using baited hooks (Arlinghaus et al., 2008) and traps (e.g. Garrison et al., 2004; Fisher and Fisher, 2006; Alos et al., 2009), are available, similar information is scanty for tropical bait fishers. For instance, description of tropical artisanal bait fishery is limited to the mention of unidentified baits, such as worms, squid, octopus and small fish, for hook fishers, and seaweeds, urchin, mollusks and octopus for trap fishers with limited data on the fish they target (Samoilys et al., 2011; Elders of Atafu Atoll, 2012). Tropical baited trap fish landings in general is described for instance in Wambiji et al. (2008), Harnish et al. (2004) and also Garrison et al. (2004), however from these studies, bait use is inadequately described.

Tropical bait fishers use a variety of bait, attached to hooks or inserted into traps to target nearshore fish, prevalent in coral or mangrove fringed shores and lagoons (Glaesel, 1997; Samoilys et al., 2011). Currently, net mesh size restrictions are enforced along the East African coastline, primarily to reduce off-take of juvenile immature fish (Samoilys et al., 2011), but the catch and selectivity of bait and baited gears are less known and consequently unregulated.

Fish size and weight, are commonly used morphometrics used to derive information on fisher induced mortality, and hence the status of a fishery. Condition factor (k) is a derived morphometric indicator that infers the health of a fishery, with high k associated with a fishery specializing in large, healthy, and plump fish stocks (Froese, 2006; Richter et al., 2000). Gonadosomatic index (GSI) on the other hand, is an indicator that reflects the fertility, spawning and fecundity of the fish (Nandikeswan and Anandan, 2013). Fish condition and GSI have been shown to vary with season, diet and fish shape (Nash et al., 2006). Condition factor of 0.2 to 1.2 have been recorded with values close to or above unity, representing fish with superior condition (Agembe et al., 2010; Al-Zibdah and Kan'an, 2009; Mbaru et al., 2010). Depending on fish species and sex, GSI cutoff of between 1 to 10% have been suggested to indicate mature adults (Al-Zibdad and Kan'an, 2009; Kreiner et al., 2001; Zeyl et al., 2013). Seasonal variation in nutrition and breeding patterns affect both condition factor and gonadal maturity (Calderone et al., 2012; Daliri et al., 2012). Mangrove fringed creeks are closely associated with breeding fish and hence the need for their protection (Krumme and Saint-Paul, 2010).

An ideal fishery should therefore have a high condition factor and relatively low GSI. In fisheries with poor morphometric indicators, it is essential to demonstrate the potential harm to the resource and ecosystem to both managers and users prior to implementing changes. For that matter, size at first maturity of targeted fish is also an important parameter that informs resource managers whether the fishery target sub-adults or mature fish. A suitable index (here referred to as Fishing Index) can be derived by comparing morphometrics of landings with standard adult dimension documented elsewhere (Fishbase, 2011) and measuring departures.

This study evaluates morphometrics of bait fisher landings by comparing size, species and derived indices such as condition factor, gonadosomatic and fishing index of fish landed using basket traps baited with *tondo* (*Terebralia palustris*- mangrove whelk), and hooks baited with *choo* (*Marphysa* sp) and *dophe* (*Clibenarius sp*-hermit crab). The underlying question addressed is whether the fishers are employing the different baits, land fish with similar characteristics. Information derived from this study may thus be useful to resource managers to identify and design targeted intervention for unsustainable bait fishery. The study site adopted here, Mida creek, occurs within a Marine Biosphere reserve, where commercial fishery exploitation is restricted (Tuda and Omar, 2012) and hence is suitable for evaluating artisanal fisheries patterns and impacts.

MATERIALS AND METHODS

Study area

Mida creek (03° 21'S; 39° 59'E) is a Marine National Park and World Biosphere Reserve situated 88 km North of Mombasa town, that has been in existence since 1968 (Figure 1). The creek covers an area of 31.6 km^2, consisting of mangrove forests, seagrass beds, sandflats, rocky outcrops and subtidal habitats.

The communities living around the creek (a population of 10,000), are actively involved in fishing, subsistence farming, small scale businesses and tourism (Mwaipopo et al., 2011). A 2012 fisheries survey estimates between 250 and 500 registered fishers, dependent on the Mida creek ecosystem (Frame Survey, 2012). The Mijikenda and Bajuni tribal groups dominate the fisher community (Hoorweg et al., 2006). Additionally, migrant seasonal fishers from Pemba (Tanzania) also participate in fisheries at Mida during the Northeast monsoon period (October to January).

Trap fishing at Mida

The hexagonal basket traps (*malema*) used (2×3 m at widest part × 0.5 m height), are woven using local fibers, and have funnel mouth opening of 6 to 8 cm and mesh openings of 3 to 5 cm on the sides. The traps are baited using crushed *tondo* (*T. palustris*- Gastropoda; mangrove whelk), collected from the adjacent mangrove forest floor. Although other species are used elsewhere by trap fishers, at Mida, *tondo* are preferred. Fishers gather 200 to 300 *tondo* from within the mangrove forest. Trap fishers insert 50 to 100 gastropods within the traps. Each trap fisher owns and operates between three and five traps. The traps are weighted with coral rock and retrieved after overnight soaking, within creeks in the mangrove forest.

Hook fishing at Mida

Bait used by hook fishers is either *choo* (*Marphysa* sp- polychaeta) or *dophe* (*Clibanarius* sp-crustacea; hermit crab) gathered and prepared prior to the fishing. Although other bait types may be used

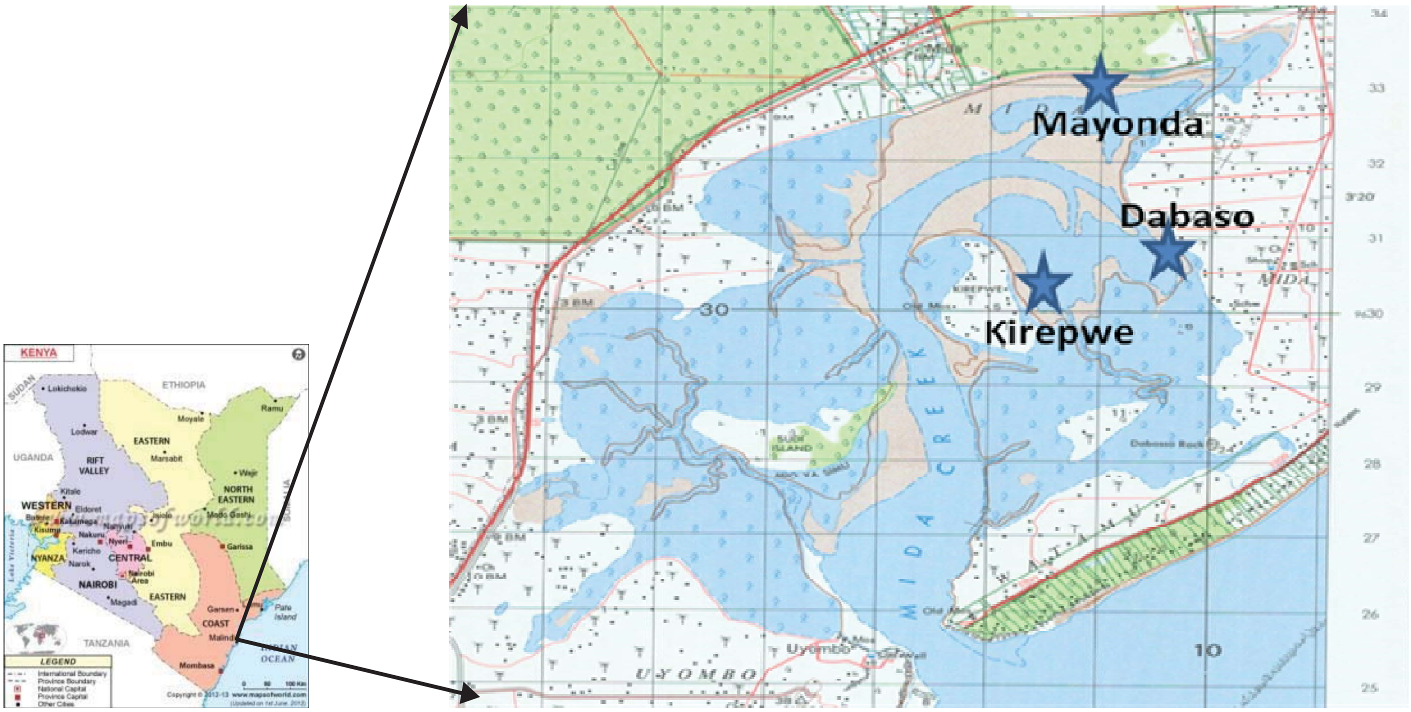

Figure 1. Map of Kenya showing location of Mida creek and a detailed sketch of the creek indicating the sampling sites at Mayonda, Dabaso and Kirepwe.

at Mida, and elsewhere, hook fishers at Mida prefer *choo* and *dophe*. The local names of the bait, that is, *choo- Marphysa* and *dophe- Clibanarius*, will be used interchangeably in subsequent discussions. The *choo* are extracted at the seaward edge of the mangrove forest by digging and extraction from the sandy-muddy substrate and placed in suitable containers for subsequent fishing. On the other hand, the *dophe* are gathered by searching within the mangrove forest floor and collected for processing. The hermit crab shells are crashed and the crab within removed. The abdomen of the crab is cut off and subsequently used as the bait for fishing.

Hook fishers attach appropriate bait to one or more hooks of size 8 to 18', and to a line, sinker and Styrofoam float. Hook fishing occurs from a dugout canoe and the line is reeled in by hand, and catch placed at the bottom of the canoe.

Fish sample collection

Fish specimen were collected from fishermen during two sampling occasions in November 2013 and February 2014. The North Eastern Monsoon period that runs from November to February represents the main marine fishing season in Kenya (Tuda et al., 2008). Participating fishers were identified at fishing villages at Mida: Kirepwe, Mayonda and Dabaso, and monitored daily over a period of 10 days during each sampling occasion. Approximately 140 fishers were monitored (~10 per day × 7 days). The types of bait used, as well as the fish landed, were evaluated. In situation where fisher landing was less than 1 kg the whole haul was taken, however, when landing was larger subsampling was done by sorting the fish into species and size categories and 10% of the fish samples taken. The fish specimen obtained were appropriately labeled and immediately preserved in ice for transportation and subsequent refrigeration. In the laboratory, preserved specimen were thawed, identified according to Fishbase (2011) and Richmond (2011) and used in morphometric analysis. Fish species occurring more than three (n=3) times were included in subsequent morphometric analysis.

Determination of morphometric parameters

Condition factor

The standard length of fish was determined using a measuring board, as distance from snout to the tip of caudal fin, while height was taken as distance at widest part of the fish specimen. Excess moisture was removed prior to weight determination, with a sensitive balance. Precision for the size and weight determined were 0.1 cm and 0.01 g respectively. Data obtained was used to calculate condition factor (B) using the modified Foulton's condition factor, as used by Richter et al. (2000):

$$B = \frac{W_f}{L_f^2 H_f}$$

Where B- condition factor, W_f- weight of fish, and L_f- standard length of fish and H_f- height of fish. It was assumed that fish had isometric growth due to correction by inclusion of height in the original Foulton condition factor equation as described by Richter et al. (2000). Condition factor data obtained were compared between gear and bait.

Gonadosomatic index

The gonad of each fish was dissected out and the weight determined. Data obtained was used to calculate the Gonado

Table 1. Variation in morphometric parameter of fish landed using baited gears at Mida creek (Values are means ±SE).

Gear used	N	Body weight (g)	Gonad weight (g)	CF	GSI	FI
Hook	197	88.31±7.35^b	0.35±0.05	0.82±0.04	0.50±0.07	22.57±0.6
Trap	28	141.91±19.25^a	0.34±0.13	0.99±0.08	0.53±0.17	19.05±1.0

Table 2. Influence of bait type on morphometric characteristics of fish landed by fishers at Mida creek (Values are means ±SE).

Bait used	N	Body weight (g)	Gonad weight (g)	CF	GSI	FI
Marphysa	68	101.02±12.52	0.25±0.01	0.95±0.06	0.45±0.10	21.68±0.83
Clibanarius	131	81.49±8.96	0.40±0.06	0.78±0.05	0.54±0.08	19.28±0.67
Terebralia	26	147.44±19.88^a	0.37±0.13	1.00 ±0.07	0.54±0.13	19.12±1.02

Somatic Index (GSI) using the following equation:

$$GSI = \frac{W_g}{W_f} \times 100$$

Where GSI- Gonadosomatic Index, W_g- Weight of gonad, W_f – Weight of the fish.

Data obtained was compared between different gear and bait used by the fishers.

Fishing index

Fishing impact was assessed using a fishing index (FI):

$$FI = \frac{100L_f}{L_s}$$

Where FI- fishing index, L_f- size of landed fish, L_s- size of adult.

Adult sizes of landed fish were obtained from Fishbase (2011). Sizes at first maturity were adopted, whenever possible, and where absent, common size was used. Where multiple records of size at first maturity for a species were indicated in Fishbase (2011), the lower value was adopted. Data on fishing index obtained were compared between gear and bait.

RESULTS

Fishers at Mida landed fish with an average body weight of 115.11±10.30 g and an average gonad weight of 0.35±0.07 g corresponding to a Gonadosomatic Index (GSI) of 0.51. The mean condition factor (CF) for fish landed at Mida was 0.87±0.04, while the average fishing index (FI) for landed the fish was 21.4±0.5.

Variation in fish landings with gear employed

Although trap fishers landed higher weight of fish (ANOVA F=6.77, df=1, $P<0.05$) than hook fishers, condition factor (χ^2=184, df-179, P=0.4), GSI (χ^2=80.4, df=85, P= 0.6), and fishing index (χ^2=91.9, df-84, P=0.3), were similar (Table 1). Trap fishers landed fish with a condition and GSI slightly higher than hook fishers, but lower Fishing index than hook fishers (Table 1).

Variation in fish landings with bait types

Three types of bait; *Marphysa*, *Clibanarius* and *Terebralia* used by Mida fishers were tested. Significant differences in weight of fish landed were detected among the bait used with *Terebralia* landing the heaviest fish (147.44±19.88 g), while *Clibanarius* the lightest fish (81.49±8.96 g) (Table 2). However, condition factor (χ^2=363, df-358, P=0.4), GSI (χ^2=165.4, df-170, P=0.6) and fishing index (χ^2=177.7, df-168, P=0.3), were not significantly different among the bait types (Table 2). The lowest condition factor was from *Clibanarius* fishers (0.78), while the highest for *Terebralia* fishers (1.00). On the other hand, *Clibanarius* (0.54) and *Terebralia* (0.54) fishers had higher GSI. In contrast, *Marphysa* fishers had the highest FI of 21.7.

Variation in condition factor among the fish species and bait types

Comparison of condition factor among the species revealed no statistical difference (χ^2=4995, df-4945, P=0.3). The highest condition factor was reported for *Platax* (2.4), *Silago* (1.39), *Epinephelus* (1.14) and *Gobius* (1.0), while *Drepane* (0.26) had the lowest (Figure 2).

Apart from *Epinephelus*, *Lethrinus harak, Lethrinus lentjan* and *Plectorhinchus*, most species landed using *Terebralia* had condition factors of above 1.0, with the highest being *Siganus sutor*. *Marphysa* fishers had only 3 fish types; *Platax* (2.42), *Gobius* (1.0) and *L. lentjan* (1.17) with condition factors above unity, however, other species condition factor rarely fell below 0.6. Among *Clibanarius* fishers, only two species *Epinephelus* (1.89) and *Lethrinus nebulosus* (1.07) had condition factor above unity, while the lowest was *Drepane* (0.26).

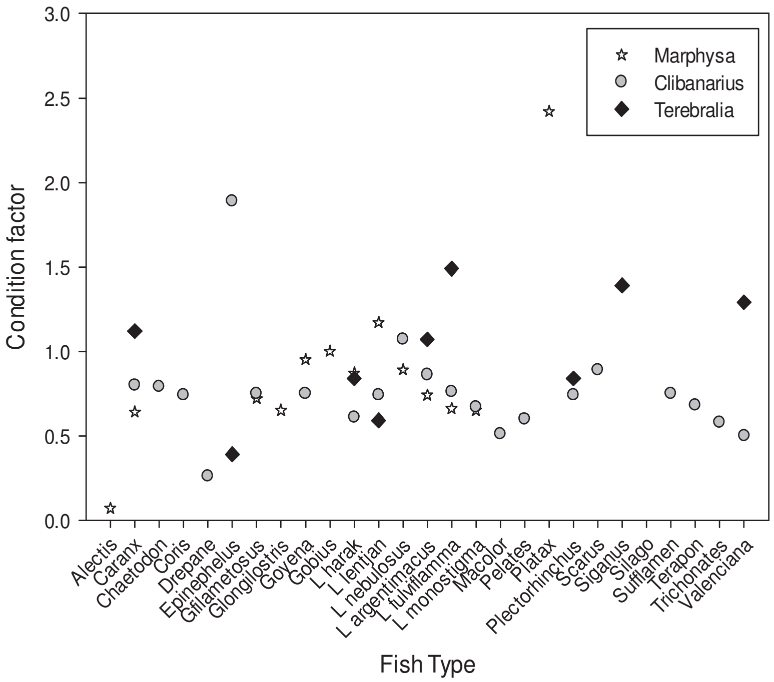

Figure 2. Variation in condition factor among the bait and fish types landed by fishers at Mida creek, Kenya.

Comparison of GSI among the species and bait types

Comparison of GSI among the species indicate no significant differences (χ^2=2792, df-2795, p<0.0001). Less than 20% of the fish species landed had a GSI above unity (Figure 3). The highest GSI was recorded *Drepane punctata* (2.08*), L. nebulosus* (1.66), *L. lentjan* (1.39), *Sufflamen* (1.37), *Pelates* (1.35) which recorded GSI above unity. On the other hand, *S. sutor, Silago sihama, Terapon jarbua, Coris, Gerres oyena, Lethrinus argentimacus, Platax* and *Alectis* had the lowest GSI of below 0.1. Other species such as *Caranx ignobilis, Epinephelus, Gerres filamentosus, Gerres longilostris, L. harak, Lutjanus fulviflamma, Lutjanus monostigma, Trichonates* and *Valenciana* had between 0.1 to 0.5. *Chaetodon, Gobius, Lutjanus argentimacus, Macolor niger, Plectorhinchus,* and *Scarus sodidus* had between 0.5 and 1.

Among *Terebralia* fishers, the highest GSI was *L. lentjan*, and the lowest *Epinephelus* and *Siganus*. Among *Marphysa* fishers *Drepane* was the highest while the lowest was for *G. oyena* and *L. fulviflamma*. Among *Clibanarius* fishers, *L. nebulosus* was the highest while *Terapon, Plectorhinchus* and *Drepane*, the lowest (Figure 3).

Variation in fishing index among the species and gear employed

Comparison of fishing index among the species landed were significantly different (χ^2=3323, df-2184, P<0.0001). Only two fish species *Valenciana* (50.9) and *Gobius* (90.9) had a fishing index of above 50% (Figure 4). *Chaetodon, Epinephelus, L. argetimacus, L. monostigma, Platax,* and *Plectorhinchus* were harvested before achieving 10% of adult size, while other species had 10 to 50% of adult body dimensions (Figure 4).

Among hook users, three fish taxa had above 40% fishing index; *Gobius keiensis* (91%), *T. jarbua* (43%) and *Valenciana* (45%), while five species (*Caranx, Epinephelus, L. fulviflama, Macolor*) were landed prior to achieving 10% of adult's body dimension (Figure 4). Among trap gear users, the highest FI was recorded for *Valenciana* (58%), while four species had less than 10% the lowest (*C. ignobilis, Epinephelus, L. argentimacus, Plectorhinchus*).

Variation in fishing index among fish species and bait types

Comparison of fishing index among fish types landed by the different bait revealed that among *Marphysa* fishers, the highest fishing index was 91% for *Gobius,* while two species *Caranx* (9.6), and *L. fulviflama* (8.8) and *Plectorhinchus* (8.3) had below 10% (Figure 5). Among *Clibanarius* fishers *Valenciana, Terapon*, had the highest fishing index while 4 species *Caranx, Epinephelus, Macolor, Siganus* had less than 10%. Among *Terebralia* fishers only *Valenciana* had above 40% of normal size.

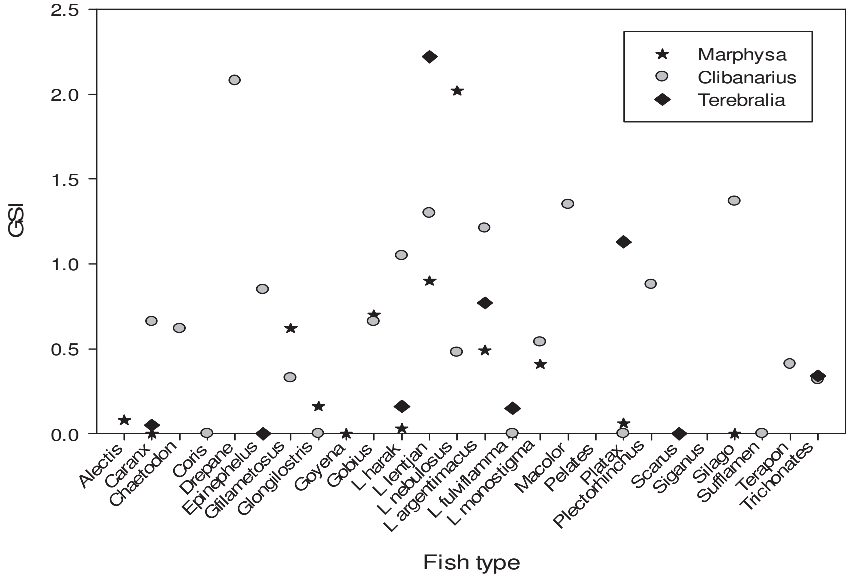

Figure 3. Variation in fish species GSI among the bait and fish types landed by fishers at Mida creek, Kenya.

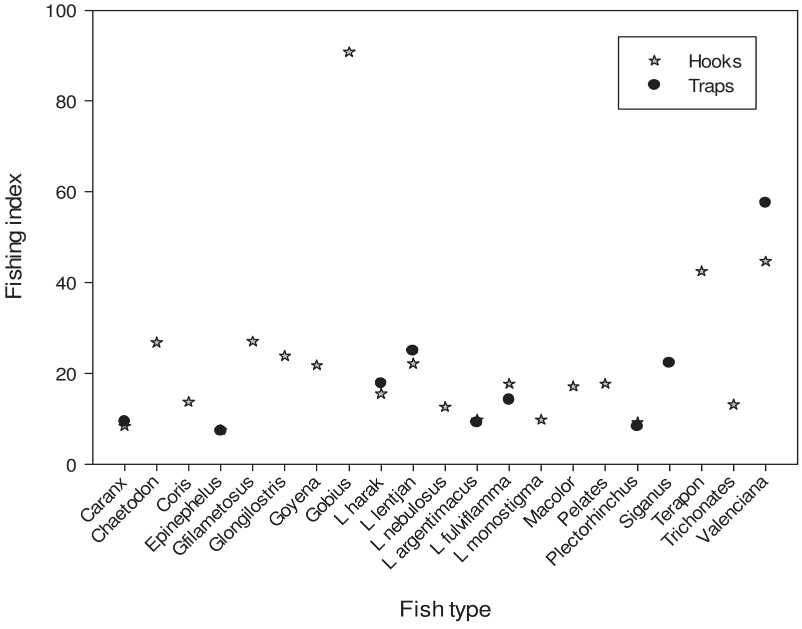

Figure 4. Variation in fishing index among species landed by baited hook and trap users at Mida.

DISCUSSION

Fish landed by bait fishers at Mida were of moderate to low condition and GSI of less than unity. The fishes landed were harvested after achieving approximately 22% of their potential adult size. Hence the fishery at Mida, targets immature sub-adult growth stages of relatively large marine fish from over 20 species. These results suggests that the fishery lands immature fish. The immediate impact of excessive harvesting of immature may be collapse of the fishery, due to failure to recruit new cohorts. Increasing fishing effort among jobless local communities will compound the current situation as reported by Verleysen and Hoorweg (2008), since bait

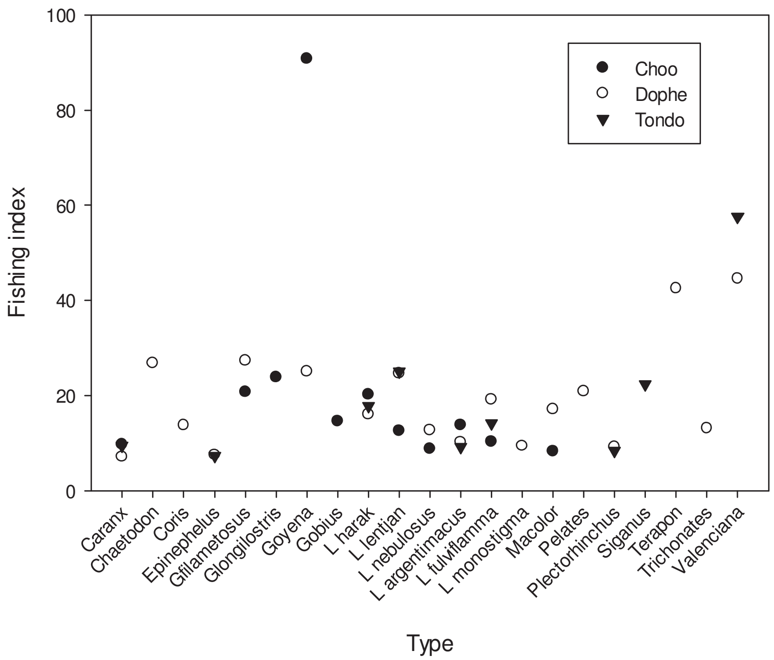

Figure 5. Variation in fishing index with fish and bait type among Mida creek fishers.

fishing in nearshore areas is the cheapest and easiest fishing livelihood strategy (Cinner et al., 2008). In addition, future deep water fish stocks may be depleted due to limited recruitment of immature back to the open sea, and hence affect both the open sea ecosystem and commercial fishery potentials therein.

Bait fishers along the Kenyan coastline land approximately 4Mt of fish valued at 8 million dollars annually with a calculated earning per fisher of between 1 to 2 million $ annually. Assuming all bait fishers land sub-adults (20% of adult weight), it can be estimated that continued harvesting of immature (20% of adult weight) would represent a loss to ecosystem of over 32 million dollars annually, as prospective future earnings from mature fish. Furthermore, this would be augment earnings for the estimated 4,000 to7,000 bait fishers to approximately 5 to 7 million dollars per fisher annually and potentially enhance fisher livelihoods. This could potentially lift the artisanal fisher from the poverty trap that characterizes their livelihoods.

Ninety percent of the fish types landed by all the gears and bait types were immature. The most developed fish type landed was *G. keiensis* which achieved up to 90% of their adult dimension. High commercial value top predator species such as carangidae, Serranidae, Siganidae and Lutjanidae, were landed at less than 10% of their potential adult dimensions. The harvesting of immature high value fish by bait fishers may limit the earning ability of the fishers since such small fishes are of limited market value. While fishers sell fresh landed fish to local fish traders and brokers at about 2$.kg^{-1}, selling fresh high value fish directly to local tourist hotels may earn fishers double that amount. Tourism is an important foreign exchange earner in Kenya, and the Kenyan coast hosts a large number of tourist hotels (GOK, 2009; Mclean et al., 2014). Direct marketing of freshly landed high value fish to coastal tourist hotels may be an important market for locally landed fish, however, penetration into this market may require the fishers to offer more suitable specimen. Ideally reduction in fishing pressure through effort controls may allow larger mature fish to dominate landings and hence leverage penetration into the lucrative tourism industry and further improve livelihoods.

Landing immature fish reported here emanate from a combination of fishing within fish nursery grounds and ovefishing. Mangrove forest fringed zones are important nursery grounds for marine fish and crustaceans and mangrove forest extent is closely correlated to marine landings (Gadjzik, et al, 2014). Similarly, landing of small immature fish may be an indicator of overfishing pressure.

While trap fishers land significantly heavier fish, no significant differences in condition factor, GSI and fishing index were detected among the gears employed. This implies that, while trap gear land larger fish, the condition and developmental stages of the fish were similar to hook gears. While trap fishers land 9 fish taxa, hook user land over 15 taxa. Difference in fish sizes and taxa landed may be attributed to gear selectivity and habitat utilization of the fish. The mesh of the basket traps allow smaller fish to escape but in addition, the traps are soaked overnight and fish retrieved live, which allows more time for smaller fish to escape. Similarity in fish morphometric index may be attributed to interconnectivity between mangrove forest, seagrass beds and coral reefs habitats utilized by the fish(Garrison et al, 2004; Gadjzik et al, 2014), that cancels out these apparent differences. Mangrove forests, apart from housing permanent residents, are also renowned for harboring transiting predatory and breeding adult fish (Krumme and Saint-Paul, 2010; Gajdzik et al., 2014).

Wambiji et al. (2008) and also Agembe et al. (2010) report higher condition factor of 0.9 to 1.2 for Siganids captured using basket trap and other gears, in the south coast of Kenya. On the other hand, Mbaru et al. (2010) report condition factors of 0.01 to 0.4 for *L. lentjan* and *L. fulviflamma* caught using nets, which are lower than values reported here. Nandikeswan and Ananda (2013) report GSI of over 4.0 in *Terapon puta* from Asia, which is higher than levels reported here. Zeyl et al. (2013) report GSI cutoff points for a gobid (*Neogobius melanostostonus*) of 1.0 and 8.0 for adult males and females respectively, which are higher than those reported here for *G. keiensis*. Apart from differences in derivation of respective morphometric parameters used in this and comparable studies, variations in distribution patterns and also fishing pressure on the fish populations, are implied. It is plausible that deployment of artisanal gears in different habitats (apart from within mangrove, and creek) may explain the observed results. In addition, anecdotal evidence from Uyombo, a landing beach used by migrant Pemba fishers at Mida creek, indicates that these fishers use larger traps, to land relatively larger fish from the open sea, than local fishers. It is possible that facilitating local baits fishers to venture into alternative fishing grounds, may improve landings, while reducing pressure from the immature creek fish population; however additional data is needed before implementation of such interventions.

Although heavier fish are landed using *tondo* bait, similarity in the condition, gonadal development and fishing index among the bait types tested are reported here. This indicates that the different baits used by artisanal fishers attract and catch fish with similar morphometric characteristics. This differs with results presented by Jacobsen and Joensen (2004) in a longline bait fishery that showed difference in catches among the baits tested at Faroe Islands. However, in the same study, Jacobsen and Joensen (2004) report higher catch using whelk than squid bait in longline fishery, but no differences in shoreline handline fishery, similar to results reported here. Chemical and visual cues emitted by baits, are crucial to ensuring catching fish (Kasumyan and Doving, 2004), hence, exposure to unfamiliar bait cues may arouse fish curiosity, leading to higher catch in novel habitats. It is possible, that deployment of nearshore benthic invertebrate bait familiar to fish may result in lower but similar catch. Pemba fishers at Uyombo seem to employ similar bait (*tondo*) to target larger fish in the open sea. This is an issue that requires further experimentation to compare landings and thereafter, identify alternative fishing grounds suitable for local fishers.

It was expected that fish caught by trap fishers operating within mangrove forest would be less abundant, since they primarily respond to chemical cues. This is because, in shaded and also highly turbid aquatic habitats, visual predation is limited and hence tactile, electrical and chemical cues are more commonly used. On the other hand, fish caught from the open creek fishing ground, used by hook fishers, where both visual and chemical cues operate, would be more abundant. Results presented here indicate that although the variety of fish caught in the open creek grounds was higher, their morphometric parameters were similar to those landed from mangrove habitats. This may imply that sustained fishing pressure has depleted large mature adults from both fishing grounds. Anecdotal evidence from the fishers indicates that, fishes at the creek were previously larger and more abundant, than the current situation. Verleysen and Hoorweg (2008) suggest the massive increase in fishers at Mida, was precipitated by conversion of the largely agricultural Mijikenda into fishers, due to lack of suitable alternative livelihoods. In addition, a significant proportion of artisanal fishers is partime fishers, that also takes up farming, business or employment in the tourism industry (Mr. Anyembe- Watamu –Turtle Watch, Personal Communication). Thus improvement in alternative livelihood options may provide respite for a depleted fishery.

Fish types landed by bait fishers at Mida have similar condition factor that ranged from 0.2 to 2.4. This indicates that most of the fish landed by bait fishers at Mida are in a sub-optimal condition. Additionally, over 80% of the fish landed had limited gonadal enlargement, especially carangidae (e.g. *D. punctata*) and Lethrinidae (e.g. *L. nebulosus, L lentjan*). The lowest gonadal development was reported for Siganid (*S. sutor*), Gerrid, Labrid (*Coris*), Lethrinid (e.g. *L. argentimacus*). Of special interest are the low GSI reported for mangrove dwelling fishes, such as gobids and mangrove snapper, which presumably spend most of their lives in the vicinity of mangrove. It is important to note that GSI values change significantly with seasonal breeding patterns and hence results on GSI differences presented here need to be taken as an indicator of potential impacts. More elaborate longer term studies of variation in GSI are needed to concretize the findings.

Only Gobid and V*alenciana* are harvested at an advanced stage of development having achieved over 50% of their adult size. The observed species difference in condition factor, GSI, and fishing index may indicate differences in habitat utilization among the species. It was expected that permanent residents within the creek would record higher levels of the indicators monitored.

Knowledge of exploited species breeding and habitat utilization strategies may shed more light on this aspect.

Minimum size restriction and catch-release of immature and juveniles, for high value large top predatory species, such as *Serranidae, Lethrinidae, Lutjanidae*, and *Carangidae* with fishing indices below 10% of their potential adult dimension may improve future landings. Such intervention is commonly employed in temperate angler recreational fishery (Alos et al., 2009) and may require investigation in tropical regions. Similarly, the use of small mesh basket trap and also small hooks need to be evaluated and regulated. While initial resistance from resource poor fishers may be anticipated, future improved earnings within participatory management frameworks, may be essential to sustaining livelihoods in the semi-enclosed Mida creek basin. Inadequate administrative authority policing of remote shorelines, may require concerted local community participation through strengthened Beach Management Units.

Conclusion

The study revealed that bait fishers at Mida use basket traps baited with *tondo* and hooks baited with *choo* and *dophe* to catch similar immature fish, with moderate to low condition factor, GSI and fishing index. This is the first record describing the characteristics of fish landed using specific types of bait in a tropical multi-bait fishery. The differences in landed fish characteristics observed are largely attributed to overfishing, species specific growth characteristics and habitat utilization patterns. Only small bodied fishes, such as Gobidae are landed at significantly higher developmental status, while potentially larger top carnivores such as carangid, are landed as immature of low condition and gonadal development. Reduction in fishing pressure, through voluntary catch-release of juveniles and immature, minimum size restriction, coupled with identification of alternative fishing grounds and livelihoods may allow improvement in morphometrics of landings and offer a respite and sustainability to the Mida creek fishery.

Conflict of Interest

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

This study was financed by a National Council of Science and Technology, Kenya grant. Laboratory and facilities were provided by Nairobi and Egerton Universities and Kenya Marine and Fisheries Institute. Members of the Mida Creek Conservation Community, especially J. Mwamure, facilitated interactions with fishers. This paper formed part of a BSc thesis by Hendrick Y. (Egerton University). A. Nthiga and V. Njuguna (MSc Students, University of Nairobi), participated in field and laboratory analysis, while, J. Ngatia, S. Muhamed and M. Abutrika (BSc students, University of Nairobi), participated in fieldwork. B. Otieno (KMFRI, Mombasa), assisted in field identification of fish. The contributions and suggestions made by anonymous reviewers are also appreciated.

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