Catching efficiency of multifilament trammel nets with different twisted twine for shrimp fishing in Kotabaru, Indonesia

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Abstract: Fishing experiments were carried out in Kotabaru of Indonesia to determine catching efficiency of double-twisted and triple-twisted multifilament trammel nets. A total of 10 nets were constructed with the same dimension and inner-outer mesh sizes (40-mm and 80-mm). Trials covered 160-net hauls/type with 1-hour submersion time. The shrimps were composed of Penaeus monodon, Penaeus merguiensis, Metapenalis monoserus, Penaeus semiculatus and Parapenaeopsis sculptilis. A total of 142.8 kg shrimp comprises 84.46 kg (59.15%) for double-twisted and 58.34 kg (40.85%) for triple-twisted were collected over 16-day trip sampling period, indicating double-twisted multifilament trammel net was 45% more efficient. The average weight of double-twisted (5.25±1.64 kg) was considerably higher than that of triple-twisted (3.65±1.41 kg) as well as total YPUE of double-twisted (1.056±0.02 kg) was considerably higher than that of triple-twisted (0.729±0.02 kg) (P<0.05). Some recommendations for improving performances and efficiency of trammel nets are made, for example, by inserting the additional bag collector along the lower part of the nets, placing selvedge between the lead line and the net or using underwater lamps associated with the net.

Keywords: double-twisted, triple-twisted, trammel net, weight, YPUE, Kotabaru

INTRODUCTION

The development of fishing technology in Indonesia is in line with the progress of fishing science, including the knowledge of the gear efficiency and catch handling. This knowledge is essential for efficient fishing and better fisheries resource management. Pauly & MacLean (2003) stated that transferring fishing effort from industrial fisheries to small-scale fisheries will have benefits for the socio-economy of the fisheries sector as well as for the ecosystems supporting the fisheries. However, in order for this to be realized, the level of information availability for small-scale fisheries should at least be as high as that of their industrial counterparts. Thus, the need to improve knowledge of small-scale fisheries is urgent.

Recently trammel nets are the most common type of fishing gears that are being used to collect shrimps from different habitats for both research and commercial purposes (Akyol, 2008; Metin et al., 2009; Aydin et al., 2013). Other comprehensive studies in shrimp fisheries sector are also conducted for trawls (Hannah et al., 2015, Xing et al., 2015, Wong et al., 2015; Osawa et al. 2015), liftnet (Abdussamad, 2006; Puspito & Suherman, 2012; Puspito et al., 2015), traps (Calado & Narciso, 2004); lighted trap (Øresland, 2007; Ahmadi, 2012; Ahmadi & Rizani, 2013), and fyke nets (Barko and Habik, 2004; Jin et al. 2007; Zamyatina & Semik, 2015). Trammel nets are also often used to sampling of populations both marine fishes (Hunt et al., 2012) and freshwater fishes (Balik, 2001). This is because trammel netting is widely considered to be a nonlethal capture technique (Hubert, 1996).

Dealing with catching efficiency, multifilament trammel nets caught on average two times more prawns than monofilament gill nets (Thomas et al., 2003). In trammel net fisheries, the length of net is more important than the height of net for enhancing the weight of shrimp catch, which is similar with the shrimp trawl net (Engas & God, 1989; Dickson, 1993; Ahmadi et al. 2005; De Rezende et al. 2015).

Trammel nets were firstly introduced in Kotabaru District around 1980s in respond to the Presidential Decree No. 39/1980 concerning trawl ban in Indonesia. Prohibition against trawls had an adversely impact on the shrimp exporter industries. Practically, the use of mini trawls is still allowable under the local regulation to support shrimp industries. At the same time, the like of mini trawls (e.g. cantrang, arad) are also being operated in other provinces bring all consequences. Nowadays, all things considered, the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia issued the Ministerial Regulation No. 2/2015 to again prohibit fish trawl for the reason of fish resources protection from and against overfishing practices. Trammel nets-based shrimp fisheries
presented opportunity and challenge for replacing trawls in Kotabaru and are considered as alternative environmentally friendly fishing gear. Fishing with trammel nets is on-going throughout the year regardless of the seasonal periods indicating shrimp in this region are available in great abundance. Table 1 clearly shows that the annual production of shrimp in Kotabaru increases proportionally with increasing the number of trammel nets. Thus, improving the catch efficiency of the trammel nets for shrimp fishing in Kotabaru is really necessary.

![Figure 1. Map showing the location of fishing experiments in Kotabaru, South Kalimantan](image)

There are two types of trammel net twines used in Kotabaru, namely monofilament and multifilament-nylon twines. Recently most of fishermen using multifilament trammel nets for catching shrimp. They believe that the netting twines affecting on the number of shrimp to be caught. For this reason, we conducted actual investigation on trammel nets with double-twisted and triple-twisted multifilament net twines to compare its relative efficiency. Scientifically, catching efficiency of such trammel nets in Kotabaru is still poorly studied.

**MATERIALS AND METHODS**

The field experiments were carried out in Kotabaru waters located at 02°20’S and 115°15’E (Figure 1). In the present study, a total of 10 trammel nets consisted of 5 double-twisted and 5 triple-twisted multifilament nylons were simultaneously tested for collecting shrimp species from the sea at 12-13.5-m deep. Such treatments give equal chance of success for both nets in terms of catching efficiency. Each type was constructed with two outer walls of 80-mm PA multifilament nylon and one inner wall of 40-mm PA multifilament nylon. The twine diameters of outer and inner walls are 110D/9 and 210D/3 respectively. Individual nets had 30-m long and 2-m deep with hanging ratios of E=0.50 for outer wall and E=0.45 for inner wall. Each net attached to the head rope and foot rope 32 m long, 2 mm. The float made of foam, circle-shape, 74 pcs; while the sinker made of lead, oval-shape, 74 pcs plus extra 5 kg weigh of cast-cement on otter board.

![Table 1. The trend status of shrimp fishing in Kotabaru District during 2011-2015](image)

Table 1. The trend status of shrimp fishing in Kotabaru District during 2011-2015

<table>
<thead>
<tr>
<th>Variables</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual production (ton)</td>
<td>192.94</td>
<td>337.64</td>
<td>590.87</td>
<td>709.04</td>
<td>4,830</td>
</tr>
<tr>
<td>Capture fishery households</td>
<td>5,492</td>
<td>5,495</td>
<td>5,945</td>
<td>4,591</td>
<td>9,393</td>
</tr>
<tr>
<td>Fishing boats (&lt;5 GT)</td>
<td>3,966</td>
<td>3,970</td>
<td>3,970</td>
<td>3,982</td>
<td>6,749</td>
</tr>
<tr>
<td>Number of trammel nets</td>
<td>1,618</td>
<td>2,962</td>
<td>3,368</td>
<td>3,668</td>
<td>3,778</td>
</tr>
</tbody>
</table>

On each sampling date, ten replicates were arranged randomly with the same method and deployed in different locations following day using outboard wooden motor boat (6.5-m long, 1.5-m wide, 1.5-m high, engine of Tianli Dompeng 20, China). The fishing spots were about 2-mile from coastal line and the nets left at the bottom sea for about 1-hour. All fishing operations were conducted in the morning and supported by professional fishers. The trials consisted of 160-net hauls/gear type with 1-hour submersion time. Both net types were standardized to a yield per unit effort (YPUE) of total catch (kg) per 16-daytrip. On landing site, the catches were removed separately from each net and then identified for species and measured for weight to determine and compare the YPUEs of trammel net types. The YPUE was calculated using the following equation (Godoy et al., 2003), which is adapted for this study:

\[
YPUE = \frac{\sum_{i=1}^{n} \text{number of nets} \times \sum_{j=1}^{m} \text{fishing trials}}{\sum_{i=1}^{n} \text{weight}}
\]

The daily total and average of all catches are stated in mean ± standard deviation. The weight data analyzed met the assumptions of Lilliefors normality test. The t-test was used to examine whether or not significant difference occurred between the catch weight of individual nets in the same type or that of two trammel nets types tested. All statistical analyses were considered significant at 5% \( (P<0.05) \) using SPSS-16.0 software.

**RESULTS**

A total of 142.80 kg shrimp comprises 84.46 kg (59.15%) for double-twisted multifilament trammel nets and 58.34 kg (40.85%) for triple-twisted were collected over 16-daytrip sampling periods as shown in Table 2. The daily total and average of all catches were also recorded as 8.93 kg and 4.44 kg respectively. The average weight of 160-net hauls/gear type of shrimp captured by double-twisted and triple-twisted
multifilament nets was 5.28±1.64 kg and 3.65±1.41 kg. There was statistically significant difference in the percentage of daily average weight between double-twisted and triple-twisted multifilament nets (t=5.530, df=30, P<0.01). The percentage of daily average weight for double-twisted ranged from 35.31 to 78.30 % and from 21.70 to 64.69 % for triple-twisted multifilament.

The total weight of the captured shrimp was 1.45 times higher for double-twisted multifilament nets than triple-twisted ones (t=3.022, df=30, P<0.05).

Table 2. The descriptive comparison of caught shrimp (kg) between double-twisted (DT) and triple-twisted (TT) multifilament trammel nets over 16-day sampling periods. (YPUE = Yield per Unit Effort)

<table>
<thead>
<tr>
<th>Number of Trial</th>
<th>Double-twisted multifilament</th>
<th>Triple-twisted multifilament</th>
<th>Daily all catches</th>
<th>Daily average of all catches</th>
<th>DT : TT</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.6</td>
<td>1.48</td>
<td>4.08</td>
<td>2.04</td>
<td>1.76 : 1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>2</td>
<td>4.02</td>
<td>2.44</td>
<td>6.46</td>
<td>3.23</td>
<td>1.65 : 1</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>3</td>
<td>3.27</td>
<td>2.66</td>
<td>5.93</td>
<td>2.97</td>
<td>1.23 : 1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>4</td>
<td>5.1</td>
<td>4.72</td>
<td>9.82</td>
<td>4.91</td>
<td>1.08 : 1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>6.65</td>
<td>12.65</td>
<td>6.33</td>
<td>0.90 : 1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>6</td>
<td>3.45</td>
<td>6.32</td>
<td>9.77</td>
<td>4.89</td>
<td>0.55 : 1</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>1.94</td>
<td>8.94</td>
<td>4.47</td>
<td>3.61 : 1</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>8</td>
<td>4.3</td>
<td>3.06</td>
<td>7.36</td>
<td>3.68</td>
<td>1.41 : 1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>9</td>
<td>5.25</td>
<td>3.99</td>
<td>9.24</td>
<td>4.62</td>
<td>1.32 : 1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>3.7</td>
<td>11.7</td>
<td>5.85</td>
<td>2.16 : 1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>11</td>
<td>5.75</td>
<td>3.28</td>
<td>9.01</td>
<td>4.51</td>
<td>1.76 : 1</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>12</td>
<td>7.25</td>
<td>4.06</td>
<td>11.31</td>
<td>5.66</td>
<td>1.79 : 1</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>13</td>
<td>3.42</td>
<td>2.68</td>
<td>6.08</td>
<td>3.04</td>
<td>1.29 : 1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>14</td>
<td>7.3</td>
<td>4.15</td>
<td>11.45</td>
<td>5.73</td>
<td>1.76 : 1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>3.26</td>
<td>9.26</td>
<td>4.63</td>
<td>1.84 : 1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>16</td>
<td>5.75</td>
<td>3.99</td>
<td>9.74</td>
<td>4.47</td>
<td>1.44 : 1</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Total (kg) 84.46 58.34 142.8 71.4 1.45 : 1 P<0.05
Average (kg) 5.28 3.65 8.93 4.44 1.45 : 1 P<0.01
YPUE (kg) 1.056 0.729 0.893 0.888 1.45 : 1 P<0.05

Dealing with the ratio of all catches, the double-twisted was considerably higher than triple-twisted across all trials (P<0.05), except for the fifth- and sixth-trial (see Table 2). There was significantly difference in the YPUE rate between double-twisted and triple-twisted multifilament (t=3.041, df=30, P<0.05). The total YPUEs gained for double-twisted and triple-twisted multifilament nets were 1.056±0.02 kg and 0.729±0.02 kg respectively. In addition, it was also clearly visible in the ratio of daily average YPUEs to the mesh size of inner wall where double-twisted was significantly higher than triple-twisted (t=3.023, df=30, P<0.05) as plotted in Figure 2.

The relationships between the relative efficiency and the ratio of YPUEs to mesh size of double-twisted and triple-twisted were expressed in the following linear equations: $y = 0.4599x - 0.3336$ ($R^2 = 0.9818$) and $y = 0.5131x - 0.1596$ ($R^2 = 0.8963$), respectively. Figure 3 shows the daily total weight of both typical nets and percentage of daily YPUE gained over 16-day periods. The data points of daily total weight spread on the figure didn’t seem to be linear ($R^2 = 0.1825$) and implied that the abundance of shrimp is different from one to other fishing spots. Meanwhile the data points of percentage of daily YPUE seem definite linear regression ($R^2 = 1$), which meant that the proportion of weight of double-twisted was considerably higher than triple-twisted. It was determined in this study that the effect of double-twisted multifilament net twine on efficiency of trammel nets was found to be 45% more efficient than triple-twisted multifilament net twine for catching shrimp in this region. The weight of shrimp catch between individual nets within the same type of trammel nets were not found statistically different (P>0.05).

The catches composition included tiger prawn (Penaeus monodon Fabricius, 1798), white shrimp (Penaeus merguiensis De Man, 1888), brown shrimp (Metapenalis monoseros Fabricius, 1798), green tiger prawn (Penaeus semiculatus de Haan, 1844), and rainbow shrimp (Parapenaeopsis sculptilis Heller, 1862). All shrimp species are readily available.
market particularly for shrimp processing industries in Kotabaru as shrimp frozen export products.

![Graph showing daily catches of double-twisted and triple-twisted multifilament trammel nets](image)

**Figure 3.** The daily all catches of double-twisted and triple-twisted multifilament trammel nets (△) and percentage of daily YPUE (○) of double-twisted over triple-twisted during 16-daytrip periods

**DISCUSSION**

The catching efficiency of trammel nets is much influenced by the twine materials, the colour of material, mesh size, hanging ratio, tension acting on the net due to buoyancy of floats, visibility of netting, change in the shape of netting by the current and others (Klust, 1982; Koike & Matuda, 1988). The twine material should be carefully chosen in order to have a flexibility of netting structure, high breaking strength, lesser visibility, softness, and knot strength. However, there is no ideal material having all the desired properties, and therefore, the selection of the best available material for a specific purpose is important.

In the present study, double-twisted multifilament trammel net is 45% more efficient than triple-twisted due to the higher elasticity and flexibility of the thinner twine. It is practically accepted that the diameter and material of twine can influence visibility, elasticity and flexibility of both gillnet and trammel net (Balik & Çubuk, 2000; Holst et al., 2002). Typically, monofilament is more elastic and more efficient than multifilament due to smaller twine diameter (Karslen & Bjarnason, 1986, Ayaz et al., 2011) and is less visible (Backiel & Welcomme, 1980; Radhalakshmi & Gopalan Nayar, 1985) explaining the primary differences in efficiency between these twine materials. Thus, the catching efficiency of multifilament trammel nets is higher than multifilament for catching fish species (Wudianto et al., 1988; Balik, 2001). Meanwhile Matsuoka (1995) explained that the catch ability of the multifilament nylon was better than the monofilament nylon for gilled capture of croaker species. Thus, information on the catching efficiency of trammel nets is inconsistent, which is depending on the targeted species, net webbing, selectivity mechanism or experimental conditions.

In our observation, trammel net fishing with double-twisted multifilament seemed to be more suitable for keeping the catch shrimp with intact condition. Despite many benefits of using double-twisted multifilament, they may not be appropriate in all situations. This typical net has also limitations like all sampling devices. It was less durable and not repairable. Fishermen said that the use of such net only for about one month, while another prevail up to three months. Therefore, it is a great challenge for the local netting factory to produce multi-monofilament with high breaking strength, more elastic and more durable. According to Hovgard & Lassen (2000), nylon multifilament is made of a number of monofilament nylon thread or monofilaments in parallel. Multi-monofilament nets are generally considered the most efficient as the use of thin parallel threads make the net softer than monofilament or multifilament. It makes multi-monofilament nets more flexible underwater. Such type of net can be recently seen in the millennium gillnet fisheries (Rakhmadevi et al., 2008).

The size and type of trammel nets used in the present study are the same as those used by local fishermen. The inner panel mesh size of 40-mm of both net types is considered suitable for catching shrimp species in Kotabaru waters. Such mesh size is slightly larger than minimum mesh size regulation of 38-mm. We observed that the outer panel mesh size (80-mm) used in the trials did not significantly affect the catch characteristics in terms of catch weight and species composition as well as the size selectivity of the trammel nets. Its function is more or less as a temporary ‘bag’ when shrimp entangled in the net. Fujimori et al. (1996) observed the fishing mechanism on how kuruma prawn (Penaeus japonicus) becomes entangled in a trammel net with monofilament nylon in a small water tank. First, the prawn slowly crawls forward and approaches the edge of the trammel net. On contact with the inner and/or outer part of the net, the prawn jumped backwards to avoid the net. However, if in this process the rostrum or appendages entangles, then the prawn on further struggling tangles with the mesh and is caught. The probability that an appendage of the prawn touches and entangles with the net is assumed to be related to the body length and the mesh size.

Selectivity analysis is not performed in this study since both typical nets had the same mesh size (40-mm), and therefore a comparison within a mesh size is not possible. To the best knowledge of the authors, there is no study on the selectivity properties of trammel nets for shrimp fisheries in Kotabaru, so far. For this reason, we intend to conduct a series of the trammel net fishing with different mesh sizes. The observation includes the age class group corresponding to the mesh sizes as well as determination of allometric growth pattern and condition factor of shrimp. Practically trammel net or gillnet with the same nominal mesh sizes but different twine thicknesses will possibly result in different mesh openings during the fishing operation. Ayaz et al. (2011) investigated the effect of twine thickness on the selectivity of multifilament gillnet when targeting Bogue (Boops boops L.), and found that the 22 mm mesh size net (0.45 mm \( \Phi \)) captured significantly larger fish than the 23 mm mesh size net (0.54 mm \( \Phi \)), due to the higher elasticity and flexibility of the thinner twine. Park et al. (2011)
found that the size selectivity of the trammel net and gillnet was significantly different with only 0.2 cm difference in the modal length.

Among technical problem beyond our observation is that we cannot precisely estimate the amount of shrimp get out of the nets (after being caught) and then fall to the seabed particularly when the nets are being lifted on board. For this reason we plan to attach the additional net as ‘bag collector’ along the lower part of trammel nets to accommodate shrimp that released from the nets. By doing this, the catch ratio between shrimp entangled in the net and shrimp dropped into the ‘bag collector’ is comparable. This includes investigation of the effect of soaking time in such trammel net at different depth of the sea, and the results are still open for discussion. Placing selvedge between the lead line and the net is also good option to reduce discards. Metin et al. (2009) used selvedge to decrease discards of crustaceans and gastropods in prawn (Melicertus kerathurus) trammel nets in Izmir Bay of Turkey, and successfully reduced discards by 40%. More site-specific studies for testing trammel net models would be required to determine the optimum fishing levels that would satisfy fisheries and nature conservation interests in Kotabaru. Innovation in this fishery can also be served through the use of LED underwater lamps associated with trammel net during nighttime produces many predictable results. This is a great challenge for us (Ahmadi, 2012) since there are no reports on the phototactic response in shrimp and its application in Kotabaru, so far. It is also greatly possible to increase the efficiency of trammel net by changing the way of catching from passive to active method, where the trammel nets (with various mesh sizes or different webbing materials) towed encircling and swept over the sea bottom of fishing ground. In Banten of West Java, the sweeping method had been proved to have a better catch than the passive method (Wudianto, 1985), while in Kotabaru, it has not been reported. In doing so, more detailed data are needed to analyze the factors leading to these variations. For better fisheries management, the development of the trammel net fishery must not only be addressed to increase its productivity but also directed to improve its selectivity performance as well as to reduce the bycatch (non-targeted species).

CONCLUSION

The present study clearly demonstrates that trammel nets fishing with double-twisted multifilament net twine was 45% more efficient than triple-twisted multifilament net. This is because double-twisted multifilament net is softer and more flexible resulting in the catches is entangled. The twisting reduces the elasticity of triple-twisted multifilament. The YPUE gained for double-twisted was considerably higher than triple-twisted multifilament nets. The use of double-twisted multifilament trammel net will create more economic fishing activity for the local fishermen in supporting shrimp processing industry in Kotabaru, but it should be controlled regularly by the local authority to make sure over-fishing is not happened.

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