RESEARCH AND ENGINEERING APPROPRIATE BRDs FOR DEVELOPING THE ECO-FRIENDLY TRAWL NET IN INDONESIA

FINAL REPORT

COLLABORATION RESEARCH

FOOD AND AGRICULTURAL ORGANIZATION,
MINISTRY OF MARINE AFFAIRS AND FISHERIES, AND
FISHING TECHNOLOGY DEVELOPMENT CENTER SEMARANG

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ABSTRACT

Research and engineering appropriate BRDs for developing the eco-friendly trawl net in Indonesia were conducted on fishing ground around Dolak islands waters in Arafura sea from November 29 to December 9, 2007. The flume tank demonstration was performed at Fishing Technology Laboratory, Department of Fisheries Resources Utilization, Bogor Agricultural University. The objectives of the research were to evaluate technical performance of BRDs (TED super shooter, square mesh window, and fish eye); to collect baseline data on the catch composition of trawl net without BRD; to compare effectiveness of three different types of BRDs tested in reducing the by-catch from a commercial shrimp trawl fishery in Arafura sea in term of changes in catch composition, catch weight and catch value; and to demonstrate the BRDs performance in the laboratory flume tank.

The result of the study showed that the square mesh window and fish eye showed similar good technical performance in comparison with the US-TED. Although the US-TED has low technical performance, it was better than the standard TED, particularly from the view point of material used that give a little bit simple in handling compared to the standard TED. The total of 26 hauls were carried out successfully consisted of 45 species of fish, 2 species of shrimp, and some species of crabs. From those species of fish, 21 species of economic fish was utilized by the fishers. The fish eye has high effectiveness in reducing bycatch up to 13.36%, and then followed by square mesh window (reduced the bycatch up to 5.98%). The US-TED, however, failed to reduce the bycatch (conversely increased the bycatch by 4.66%). All the BRDs used have influenced on the shrimp loss i.e., 21.25% for the fish eye, 22.13% for the square mesh window, and 32.29% for the US-TED.

Flume tank observation from the three different types of BRDs showed a significant technical performance and escaping behaviour of fish. The highest escapement of fish was from square mesh window. Whilst the and fish eye and US-TED and fish eye have low escapes. The position of fish eye and exit hole of the US-TED has an effect to the escapement process. The grid angle of 57.1º was suitable for allowing the unwanted animal to escape.

It is recommended that three BRDs can be implemented. Although there are needed further study to increase the effectiveness of the square mesh and fish eye, mainly to decide the appropriate position of those BRDs on the codend for optimum function of the BRDs to reduce the bycatch. Further research need to be conducted in long duration of fishing trials that representing the fishing season.

Keywords: appropriate BRDs, eco-friendly, technical performance, catch composition, effectiveness, by-catch, Arafura sea

Research Team

1. Prof. Dr. Ir. Ari Purbayanto, M.Sc.
   Team Leader, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor.

2. Ir. Ronny Irawan Wahyu, M.Phil.
   Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor.

3. Ir. Suhariyanto
   Fishing Technology Development Center, Semarang.

4. Drs. Widodo.
   Fishing Technology Development Center, Semarang.

5. Suparman Sasmita, S.Pi, M.Si.
   Fishing Technology Development Center, Semarang.

6. Mochammad Riyanto, S.Pi.
   Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor.

Supporting Team

1. Ir. Tyas Budiman, MM.
   Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries. Jakarta.

2. Ir. Jainur Manurung, MM.
   Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries. Jakarta.

3. Imron Rosyidi, S.Pi.
   Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries. Jakarta.

4. Muklis, S.Pi.
   Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries. Jakarta.

5. Adi Susanto, S.Pi.
   Faculty of Fisheries and Marine Sciences, Bogor Agricultural University. Bogor.

6. Indra Supiyono Solihin, S.Pi.
   Faculty of Fisheries and Marine Sciences, Bogor Agricultural University. Bogor

Resource Persons

1. Dr. Ir. Dedy H. Sutisna, M.Si.
   Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries. Jakarta.

2. Ir. Suardoyo, M.Si.
   Fishing Technology Development Center, Semarang.

3. Prof. Dr. Ir. Mulyono S. Baskoro, M.Sc.
   Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor.

4. Dr. Ir. Wudianto, M.Sc.
   Capture Fisheries Research Center, Marine and Fisheries Research Agency, Ministry of Marine Affairs and Fisheries. Jakarta.

PREFACE

As the followed up of signing Letter of Agreement between Food and Agriculture Organization of the United Nations and Fishing Technology Development Centre (BBPPI) Semarang on carrying out "Research and Engineering Appropriate BRDs for Developing the Eco-friendly Trawl net in Indonesia", we submit a final report. This report explains research background, review on by-catch reduction devices, research methods, results and discussions, conclusions and recommendations.

The fishing trials using double rigged trawl nets with four different types of BRDs (standard TED supper shooter, US-TED super shooter, fish eye, and square mesh windows) in comparison with trawl nets without BRD (control net) were successfully conducted in Arafura sea on December 1-8, 2007. A commercial shrimp fishing boat, i.e., M.V. Laut Arafura owned by PT. Sinar Abadi Cemerlang was used during trials. The flume tank demonstration on BRDs performance and behaviour of fish inside the net codend was conducted at Fishing Technology Laboratory, Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University in January 21-28, 2008.

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We hope this final report is useful as scientific data for setting regulation on the development of eco-friendly trawl fisheries in Indonesia. Critics and comments to improve this report are welcome.

Thank you.

Research Team Leader,

Prof. Dr. Ir. Ari Purbayanto, M.Sc

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INTRODUCTION

1.2 Background

In recent years, there has been increased global concern over the impacts of fishing activity on non-target species termed as “by-catch”. Most of the conventional shrimp trawl typically are poorly selective fishing gears and so retain large quantities of by-catch (Saila 1983). In particular, shrimp trawl fisheries in tropical waters have come under increased scrutiny due to the capture and drowning of turtles caught in trawl nets.

The by-catch may include undersized individuals of target species, and non-target species. These include mixed fish and trash fish, which comprised of small individual fish and almost of the fish discarded at sea. There are major concerns on discarding of the by-catch: (1) wastes potentially good food; (2) reduces stocks of target and commercially valuable non-target species and (3) disrupts ecological process on the seabed (Saila 1983; Gulland and Rothschild 1984).

Trawling for shrimp occurs throughout the majority of the world’s oceans, providing a total catch of up to 2.9 million tones per year (FAO 1992), about 3.5 % of the total production from the world’s marine fisheries (82.5 million tones). In 1994, by-catch from shrimp trawl was estimated to be around 11.2 million tones worldwide (Alverson et al. 1994). Whilst the by-catch from legal shrimp trawlers in Arafura sea Indonesia was estimated around 332,186 tones per year (Purbayanto et al. 2004).

The mortality of large quantities of the by-catch has resulted in the introduction of stringent legislation requiring the implementation of measures to prevent this problem. According to presidential decree No.39/1980, the trawl was banned in all over Indonesia waters since it was issued in 1980. Only the trawl equipped with By-catch Excluder Device (BED) that is allowed to be operated in Arafura sea and its adjacent waters. These shrimp trawls were used to capture shrimp as target species and demersal fish as the by-catch.

Discarding of the by-catch and catching juvenile fish are serious regional problem in fisheries management. The situation today is that many fish stock are grossly over exploited and unwanted catch contributes to the reduction of fish stocks. It is now vital that the natural resources must be harvested selectively to improve the yield. Future fishing development is governed by the availability of sustainable fish stock, which dictates the need for the juveniles and immature fish to be released. These must be released to reach maturity and reproduce to maintain harvestable numbers of stock.

Development of selective fishing techniques that has been used to achieve ecosystem objectives for example Turtle Excluder Device (TEDs) in commercial trawling in Arafura sea has reduced the by-catch for more than 40%, eventhough the shrimp losses were still occurred about 5% (Nasution 1997). Actually, the small reduction in amount of shrimp caught can be reduced by changes in the net design to accelerate the water, and shrimp, flow through the TED's (Sainsbury 1996).

There are some well developed By-catch Reduction Device (BRD) designs (such as fish eye, square mesh windows, and nordmore grid) available to be implemented on the shrimp trawls in Arafura sea with the better performance that can maximize the escape probability of the by-catch while minimize shrimp loss. However, the implementation of the BRDs and its effectiveness on Indonesian shrimp trawl fisheries should be investigated through laboratory as well as field experiments. The implementation of these devices in fishing practices is expected to optimize yield, and minimize the by-catch and wastage.

The Ministry of Marine Affairs and Fisheries (MOMAF) is in the process of developing a management plan for the trawl fishery. In relation to improve the trawl net selectivity, MOMAF will release the recommendation to increase the minimum mesh size and to implement the appropriate BRDs for shrimp trawl fisheries in order to develop the eco-friendly trawl fisheries in Indonesia.

1.2 Objectives

1) To evaluate technical performance of BRDs (TED super shooter, square mesh window, and fish eye) used on shrimp trawl net.
2) To collect baseline data on the catch composition of trawl net without BRD.
3) To compare effectiveness of three different types of BRDs tested in reducing the by-catch from commercial shrimp trawl fishery in Arafura sea in terms of changes in catch composition, catch weight, and catch value.
4) To demonstrate the BRDs performance in the laboratory flume tank.

2
REVIEW ON BY-CATCH REDUCTION DEVICES

2.1 World View

Unwanted catch of fish and other species in shrimp trawling were perceives as a problem mainly in the south-eastern of United States during 1970s. In the shrimp trawls operated in the Gulf of Mexico, sea turtles were recognized as by-catch, in addition to jellyfish and fish species (Shiode and Tokai 2004). Against this background, the US National Marine Fisheries Service (NMFS), in collaboration with others, developed the TED (Watson *et al*. 1986). The technological improvement of TEDs advanced as they were developed and introduced to other countries in the world.

The experiment in Tampa Bay, Florida in 1996-1997 using two BRDs-the Extended Mesh Funnel (EMF) and the Florida Fish Eye (EFE)- were evaluated in otter trawls with net mouth circumferences of 14 m, 17 m, and 20 m and total net areas 45 m2. The by-catch principally composed by finfish (44 fish were captured); horseshoe crabs and blue crabs seasonally predominated in some trawls. Ten finfish species composed 92% of the total finfish catch; commercially or recreationally valuable species accounted for 7% of the catch (Steele *et al*. 2002)

Several research projects have evaluated some types of TED and BRD in the Queensland east coast trawl fishery in Australia (Robins-Troeger 1994 cited by Robins et al. 1999). These research trials suggested varying degrees of efficiency of the by-catch reduction technology. However, the location of the trials and the associated quantity and composition of the by-catch was probably the most influential factor determining the efficiency of the particular location. As expected, TEDs were very efficient in excluding large animals such as rays *Rhynchobatus* spp. and *Dasystis kuhluii*; sea turtles, and sharks. The effect of TEDs upon catch rates of other by-catch species, such as unwanted fish and sea snakes, was more variable, as indicated in the large range of by-catch rates observed during research and commercials tests. Types of TEDs including AusTED, AusTED II, and the Seymour TED were given a significant reduction of by-catch in the Queensland east coast fishery.

TEDs introduced to Southeast Asian countries, including Thailand, Malaysia, and the Philipines in order to cope with the US regulation, and mainly by initiatives of the Southeast Asian Fisheries Development Centre (SEAFDEC). Chokesanguan et al. (1997) tested two types of TEDs (Thai-ku and Thai Turtle Free Device TTDF) that had been jointly developed by Thailand and SEAFDEC, in addition to three types of US-developed TEDs (Anthony Weedless, Super Shooter, and Bent pipe) and two types of Mexican-developed TEDs (Georgia Jumper, Mexican). It resulted that TTFD was the best in experiments and training programmes aimed at promoting diffusion of TEDs among fishers were carried out in Malaysia, the Philippines, Indonesia, and Brunei, and the effectiveness of TTFD was widely recognized. However, fishermen did not venture to use TEDs because: (1) little or no by-catch of sea turtles occur in ordinary shrimp trawling operations in the region; (2) there is a danger in handling fishing gear due to the additional heavy-weight device, and (3) large quantities of marine debris entering into the net block the grid mesh thus lower shrimp catch rate (Shiode and Tokai 2004). In Indonesia, more than 1000 TEDs were employed in the fishing operations conducted by joint ventures with Japan in the western area, and the fishing gear specialists were sent to NMFS for training (Watson et al.1986).

2.2 Indonesian View

2.2.1 Existing by-catch reduction devices (BRDs)

Research on selective devices in industrial shrimp fishing- BED (by-catch excluder device) or TED - had been carried out by Research Institute for Marine Fisheries (RIMF). Introducing BED or the first type TED to shrimp fishing companies, was began with a collaborative scientific trial on BED between Agency for Assessment and Application of Technology, Bogor Agricultural University (IPB), Directorate General of Fisheries, and RIMF in the Arafura Sea in September-October 1982 (AAAT 1982). Then a scientific trial was carried out by RIMF in the Cilacap waters, southern coastal waters of Central Java in October 1982 (Nasution et al. 1983). The trial in the Arafura sea resulted in *a statistically significant reduction of by-catch* in the BED-net by 80.11 kg (42.51 %) per towing (one hour) and *a statistically insignificant loss of shrimp* in the

BED-net by 4.27 kg (27.48 %) per towing. The trial in the Cilacap waters resulted in a statistically significant reduction of by-catch in the BED-net by 86.21 kg (63.92 %) per towing (one hour) and a statistically insignificant, loss of shrimp in the BED-net by 1.80 kg (31.41 %) per towing. However, statistically insignificant, the loss of shrimp in the BED-net appears to be rather high (27.48-31.41 %). Considering in the actual fishing if two net towed within two hours, the shrimp loss will be 17.08 kg/towing in the Arafura sea, and 7.20 kg/towing in the Cilacap. These results could not prove the potential benefit of BED to be promoted to industrial shrimp fishing in the Arafura sea. Further scientific trials are needed for improving design and construction of the BED so as to minimize the shrimp loss. Since then, however, no more scientific trials are conducted until introducing a new type TED, Super Shooter TED came introduced 1996. It could be understood if the shrimp fishing companies rejected the BED, as many of American shrimpers also complained that it was too cumbersome and dangerous to use, especially in the rough sea and were reluctant to use it (Oravetz and Grant 1986) in addition the BED was heavy, large and difficult to handle (Prado 1993).

In relation to FAO Cooperative Research Network in Asia and Indian Region on Selective Tropical Shrimp Trawling, a preliminary fishing trial on the use of the Super Shooter TED in industrial shrimp fishing in the Arafura sea was carried out by RIMF in cooperation with a shrimp fishing company in Ambon on 1-10 April 1997 (Nasution, 1997). Two of four-seam trawl nets of the same size (one equipped with and another without TED) were continuously towed within every two hours in the Aru and Dolak waters of 15-25 m deep by a double rigger trawler of 180.70 GT and powered 600 HP. The trials in the Aru waters (15 hauls) resulted in *a statistically significant loss of tiger shrimp* in the TED-net by 3.427 kg (34.07 %) per towing, *a statistically insignificant loss of banana shrimp* in the TED-net by 2.591 kg (33.59 %) per towing and a statistically significant reduction of by-catch in the TED-net by 128.419 kg (41.15 %) per towing. The trial in the Dolak waters (20 hauls) resulted in *a statistically insignificant loss of banana shrimp* in the TED-net by 9.226 kg (33.09 %) per towing (tiger shrimp were not caught in this waters), and *a statistically significant reduction of by-catch* in the TED-net by 196.590 kg (45.65 %) per towing. However the TED super shooter reduce the by-catch, the shrimp loss appeared to be rather high, while significant loss of tiger shrimp occurred in the Aru waters. These results still could not prove the potential benefit of the TED to be promoted into industrial shrimp fishing in the Arafura sea. The reasons of high loss of shrimp might be due to the position of the exit hole, where the tested TED equipped with bottom exit hole, while top exit hole appeared to be better than bottom exit hole (Mitchell *et al*. 1995), the material and weight of TED and its size in relation to the circumference of cod-end, as well as the flotation. Unlike the BED, which has been rejected by most American shrimpers, the super shooter TED should not be complained as it showed a statistically insignificant loss of shrimp when trawling in USA (Renaud et al. 1992), as well as in Australia (Robins and Campbell 1997).

Whilst trialling in the Aru waters, the endangered sea turtles were not caught, but in the Dolak waters two sea turtles were caught in different hauls, one in the TED-net trapped in the TED then could escape alive by itself and another in the net without TED which released alive into the water. Furthermore, Mahiswara (2004) found that TED super shooter reduced the by-catch/towing/hours between 5% (12 cm grid spacing) and 60% (4 cm grid spacing), This reduction of the by-catch still be followed by the catch of shrimps between 13% (6 cm grid spacing) and 59% (10 cm grid spacing).

According to Eayrs (2004) there are some points to be considered of the successful introduction and development of TEDs in prawn-trawl fishery. First, is by extension and enforcement due to the willingness of fishermen to adopt new technology. The initiatives used to extend the results of testing programmes on both research and commercials boats played a major rule in this success. Second, is by selecting the correct TED. The most important aspect to TED selection is the decision to orientate the grid either upwards to exclude large animals through the top of the cod-end or downwards to exclude this animals through the bottom of the cod-end. Third, is the over-turning TEDs. Over-turning TEDs is a term coined to describe excessive and inappropriate modifications to the TED to reduce shrimp loss. This loss typically arises from poor design, rigging or maintenance of a TED, or the poor selection of a TED for particular fishing ground. And the last is by testing protocol. Testing protocol was required that allowed innovative fishermen the opportunity to test and develop their own TEDs and BRDs.

2.2.2 Potency and composition of by-catch in Arafura sea

Potency of by-catch in Arafura sea (the waters of Dolak Island, Aru island and the waters around Avona) has been reported by Purbayanto et. al. (2004). The potency was 332,186 ton/year based on the observer data from shrimp trawl netters as shown in Table 1.

Table 1
Estimation of by-catch potency in Arafura sea

Fishing ground	Average of by-catch volume		
	(ton/haul)	(ton/day)	(ton/trip)
Dolak island	1.03	7.21	216.3
	0.93	6.5	195.09
Aru island	0.37	2.57	77.07
Avona	0.04	0.31	9.24
	0.23	1.61	48.3
Average	0.52	3.64	109.2
Number of registered (unit) trawlers			336
Potency of by-catch (ton/year)			332.186

Source : Purbayanto et. al. (2004)

There are several reports about the by-catch from shrimp trawl fisheries in Arafura sea. Evans and Wahju (1996) reported that 34 species of fin-fish and 5 invertebrate taxa were identified as the by-catch from non BED trawl net in Arafura sea during sampling on February 1992. The dominant by-catch species by percent weight and number composed of queen fish (*Carangidae*), slimy fish (*Leioghnathus insidiator*), ornate threadfin (*Nemipterus hexadon*), banded grunter (*Therapon theraps*), and small head hair (*Trichiurus savala*) as shown in Table 2.

Table 2
The by-catch in samples taken from a trawler fishing in Arafura sea

Taxon	English name	Weight (%)	Number (%)
Carangidae	Queen fish	9.5	11.9
Formio niger	Black pomfret	1.7	2.1
Johnius dussumieri	Silver pennah	1.3	2.4
Leioghnathus insidiator	Slimy fish	6.9	4.4
Lethrinus lentjan	Red-spotted emperor	2.2	1.1
Lutjanus carponatus	Gold-stripped snapper	1.3	2.1
Nemipterus hexadon	Ornate threadfin	5.2	4.2
Pampus argentus	Silver pomfret	4.6	2.5
Sardinella spp.	Sardine	1.7	3.3
Stolephorus indicus	Anchovy	1.3	3.0
Therapon theraps	Banded grunter	8.7	8.9
Trichiurus savala	Small head hair	10.8	0.8
Upeneus sulphurous	Goatfish	1.3	6.7
Valamugil speigleri	Mullet	3.9	2.6
Melo spp.	Whelk	2.2	0.1

Source: Evans and Wahju (1996).

Mahiswara and Widodo (2005) reported that the by-catch from 180 GT double-rigged non TED shrimp trawl operated around Unu island waters in Arafura sea on July 2004 was 38 species of fin-fish, crustacean, snakes, and turtles. The most caught fish were pony fish (Leiognathidae), anchovies (Engraulidae), grunt (Haemulidae), rays, sardine (Clupeidae), and croaker (Sciaenidae) as shown in Table 3.

Table 3

Composition of fish caught by shrimp trawl in Arafura sea

No.	Family	Local/Indonesia name	Percent (%)
1.	Leiognathidae	Petek	44.39
2.	Engraulidae	Teri	6.49
3.	Haemulidae	Gerot-gerot	6.28
4.	Rays	Pari	5.55
5.	Clupeidae	Sardin	4.16
6.	Sciaenidae	Gulamah/tigawaja	4.19
7.	Mullidae	Biji nangka	2.19
8.	Lactaridae	Ikan susu	2.05
9.	Synodontidae	Beloso	2.00
10.	Trichiuridae	Layur	1.78
11.	Drepanidae	Ketang-ketang	1.65
12.	Shark	Hiu-cucut	1.53
13.	Ariidae	Manyung	1.20
14.	Polynemidae	Senangin-kuro	1.19
15.	Carangidae	Bubara/kuwe	1.12
16.	Centropomidae	Kakap putih	0.78
17.	Crabs	Kepiting	0.73
18.	Lutjanidae	Kakap merah	0.60
19.	Soleidae		0.51
20.	Sphyraenidae	Barakuda	0.48
21.	Cuttle	Sotong	0.48
22.	Harpadontidae	Nomei	0.42
23.	Squids	Cumi-cumi	0.29
24.	Sillagidae	Jerum	0.28
25.	Scombridae	Tenggiri	0.26
26.	Muraesocidae	Belut laut	0.22
27.	Theraponidae	Kerong-kerong	0.10
28.	Platycephalidae		0.07
29.	Nemipteridae	Kurisi	0.07
30.	Gerridae	Kapas-kapas	0.04
31.	Menidae	Semar	0.02
32.	Chirocentridae	Pedang-pedang/Parang-parang	0.01
33.	Rachycentridae		0.01
34.	Lobster	Udang barong	0.07
35.	Snake	Ular	0.11
36.	Invertebrate	Moluska	0.05
37.	Shrimp	Udang	7.27
38.	Turtle	Penyu	0.60

Source: Mahiswara and Widodo (2005)

From deck observation result on the by-catch species caught by shrimp trawl in Arafura sea showed 44 species, comprised of 24 demersal fish, 12 pelagic fish, 3 molluscs, and 5 crustaceans (Purbayanto et al. 2004). The Indonesian name, English name, and scientific name of the by-catch in detailed is shown in Table 3.

Table 4
Catch species of shrimp trawl (MV. Aru Pearl) during observation in Arafura sea

No.	Indonesia name	English name	Scientific name
	Demersal species		
1.	Bambangan	Red snapper	*Lutjanus spp*
2.	Bawal hitam	Black pomfret	*Formio niger*
3.	Beloso	Lizard fishes	*Saurida tumbil*
4.	Biji nangka	Goat fishes	*Upeneus sulphureus*
5.	Cucut	Shark	*Sphyrhinidae*
6.	Gulamah	Croaker	*Argyrosomus amoyensis*
7.	Gerot-gerot	Swept lips	*Johnius sp.*
8.	Kakap	Barramundi	*Lates calcarifer*
9.	Kerapu	Groupers	*Ephinephelus spp*
10.	Kerong-kerong	Banded grunter	*Terapon theraps*
11.	Kurisi	Threadfin breams	*Nemipterus spp*
12.	Kuro (Senangin)	Giant threadfish	*Eletheronema tetradactylum*
13.	Layur	Hairtail	*Trichiurus savala*
14.	Lidah	Long-tongue sole	*Cynoglossus sp*
15.	Manyung	Marine catfishes	*Arius thalassinus*
16.	Pari	Rays	*Trigonidae*
17.	Peperek	Pugnose ponyfishes	*Secutor ruconis*
18.	Sembilang	Canine catfishes	*Plotosus canius*
19.	Swanggi	Big eye	*Priacanthus spp.*
20.	Tiga waja	Bearded-croaker	*Johnius dussumieri*
21.	Buntal	Smooth golden toadfish	*Legochepalus inermis*
22.	Buntal besar	Starry pufferfish	*Arothtron stellatus*
23.	Nomei	Bombay duck, Saury	*Harpadon micropectoralis*
24.	Gampret	Plataks	*Platax batavianus*
	Pelagic species		
25.	Alu-alu	Barracudas	*Sphyraena spp*
26.	Daun bambu	Queen fishes	*Chorinemeus tala*
27.	Kembung	Long-jawed mackerel	*Rastrelliger kanagurta*
28.	Kuwe	Crevallies	*Caranx sexfasciatus*
29.	Layang	Scads	*Decapterus russelli*
30.	Lemuru	Indian oil sardinella	*Sardinella longicep*
31.	Parang-parang	Wolf herrings	*Chirocentrus spp*
32.	Selar	Blue-spotted trevally	*Caranx bucculentus*
33.	Tembang	Fringe scale sardinella	*Sardinella fimbriata*
34.	Tenggiri	Narrow barred spanish mackerel	*Scomberomorus comersonii*
35.	Tengiri papan	Indi pacific spanish mackerel	*Scomberomorus guttatus*
36.	Tetengkek	Hardtail	*Megalapis cordyla*
	Molluscs		
37.	Cumi-cumi	Squid	*Loligo spp.*
38.	Sotong	Cuttle fish	*Sepia spp.*
39.	Gurita	Octopus	*Octopus sp.*
	Crustacean		
40.	Kepiting	Crabs	*Scylla sp.*
41.	Rajungan	Swimming crabs	*Portunus pelagicus*
42.	Udang Ronggeng	Manthis shrimp	*Squilla sp.*
43.	Udang Jerbung	Banana shrimp	*Penaeus merguensis*
44.	Udang Windu	Tiger prawn	*Penaeus monodon*

Source: Purbayanto et al. (2004)

3
RESEARCH METHODS

3.1 Time and Location

Fishing trials for comparing effectiveness of three different types of BRDs were conducted on fishing ground around Dolak island waters in Arafura sea from November 29 to December 9, 2007. The geographical position of fishing ground was about 7º03’ - 8º43’ S and 137º20’ - 138º45’ E as shown in Figure 1. The flume tank demonstration was performed at Fishing Technology Laboratory, Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University in January 18-28, 2008.

3.2 Materials and Methods

The fishing trials in Arafura sea were carried out using a commercial double rig shrimp trawler (MV. Laut Arafura) owned by PT. Sinar Abadi Cemerlang. This trawler has 24,95 m overall length, 166 GT, and an engine power of 402 HP. Three different BRDs design (US-TED super shooter, square mesh windows, and fish eye) were constructed and attached on the cod-end of shrimp trawl nets for comparative fishing trials. Data and information of technical performance of BRDs during operation, catch composition, and effectiveness of each BRD for reducing by-catch were obtained. These data and information were further used to consider the development of eco-friendly trawl net in Indonesia.

The flume tank demonstration was performed to show an underwater technical performance of the BRDs and fish behaviour inside the codend. The BRDs used were small-scaled BRDs as to be used in the sea trials. Information obtained during flume tank demonstration supported the sea trials results especially for public understanding of the underwater BRDs technical performance. Flow chart diagram of the research in detail is shown in Figure 2.

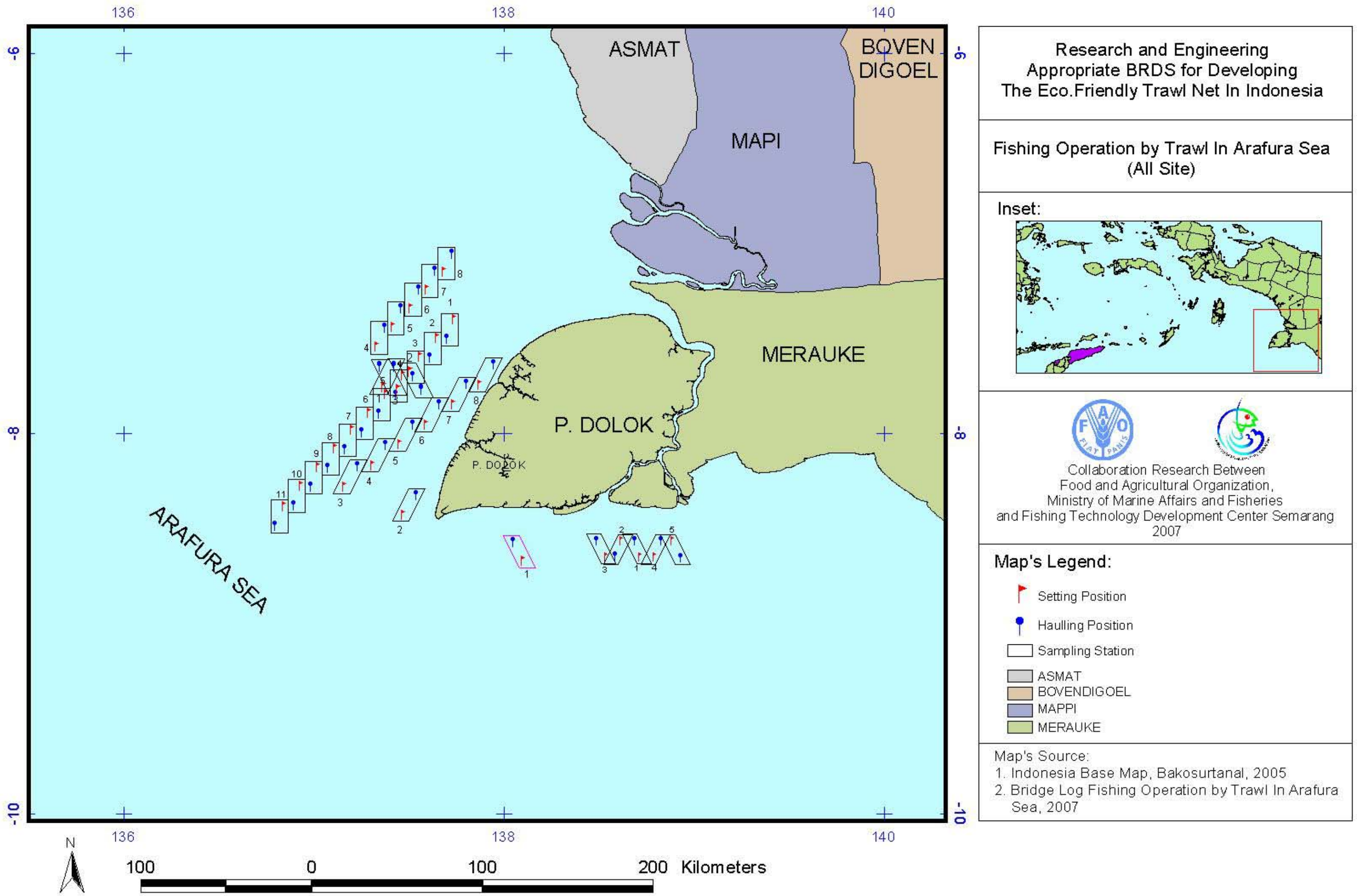

Figure 1. Map of fishing ground during sea trials around Dolak island waters in Arafura sea

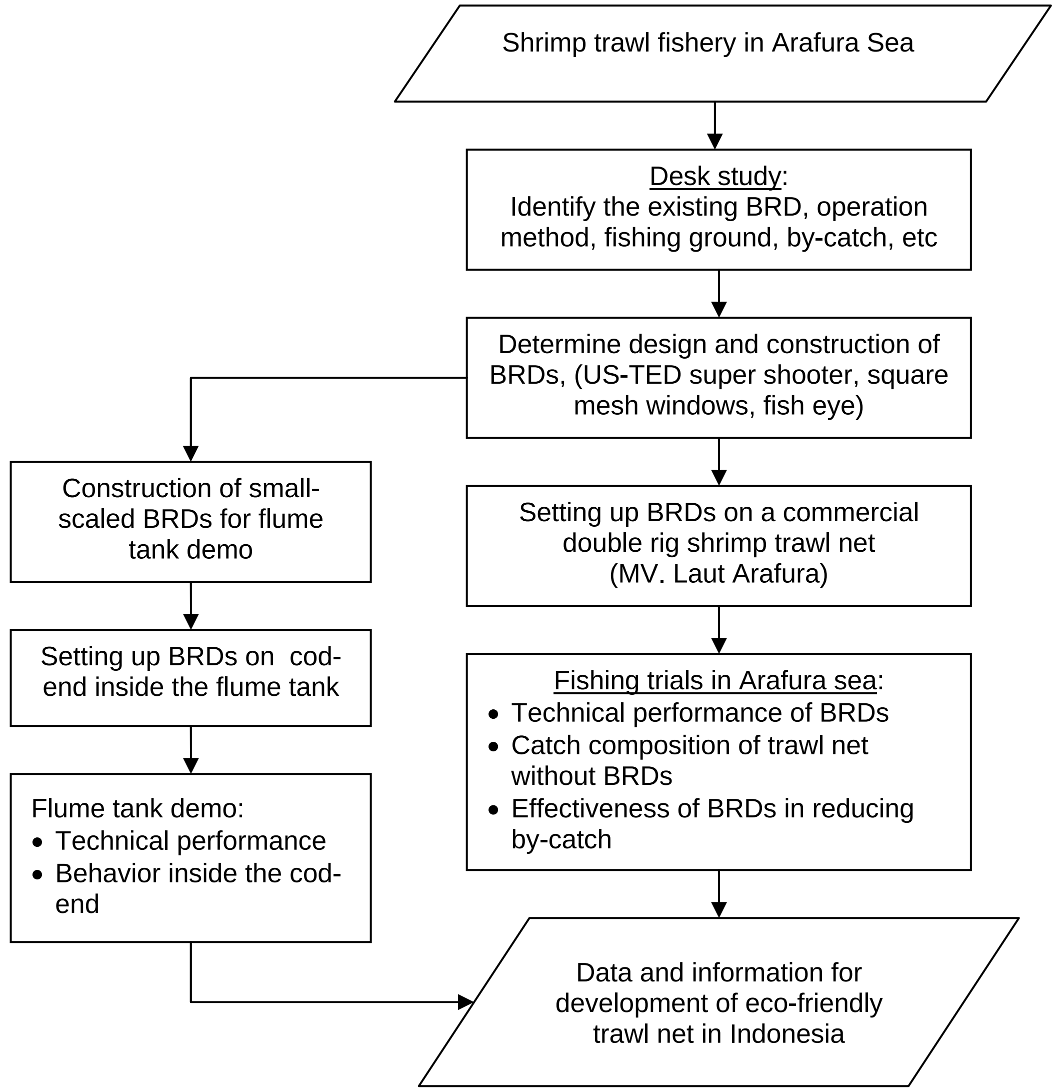

Figure 2. Flow diagram of research and engineering for development of eco-friendly trawl net in Indonesia

3.2.1 Field experiments

(1) Material and equipment

Materials and equipments used during the fishing trials in Arafura sea as follow :

1) a commercial double-rig shrimp trawler (MV. Laut Arafura) 166 GT (Table 5)
2) a commercial shrimp trawl net installed with BRDs such as TED super shooter, square mesh windows, and fish eye, (Figure 3 and Figure 4)
3) measuring board
4) container for fish sample
5) fish species identification book
6) balance
7) data sheet for catch composition
8) fishing log book

9) digital camera
10) handycam, and
11) all equipments available in the vessel (radar, GPS, echo sounder, binocular, radio communication, etc.).

Table 5

General specification of MV. Laut Arafura

Vessel name	**MV. Laut Arafura**
Research/commercial	Commercial
Length overall (m)	22,56 meters
Breadth (m)	7,79 meters
Depth (m)	4,26 meters
GRT	166 RT
Main Engine (HP)	402 HP

The specification of trawl nets used in the experiment is shown in Table 6, while the trawl net design is attached in the Appendix 1.

Table 6

Specification of trawl net used in the fishing trials

A. Gear data

Code	**TBS.03.1.5 (ISSCFG – FAO)**
Type of gear	Double rig trawl, 4 seam
Number of gears	2 (two) units
Net mouth circumference (a)	29 meters
Total length (b)	24.9 meters
Head rope (l)	18.6 meters
Ground rope (m)	22.0 meters
Upper wing (c)	6.6 meters, 85 ML, PE 380, 30 Fly
Lower wing (d)	8.6 meters, 77 ML, PE 380, 30 Fly
Square (d-c)	2.0 meters, 220 ML, PE 380, 30 Fly
Body (baiting/belly) (e)	9.1 meters, 220/40 ML (Baiting), PE 380, 30 Fly 200/20 ML (belly), PE 380, 30 Fly
Side panel (n)	17.7 meters, 80 ML/20 ML, PE 380, 30 Fly
Cod end (f)	7.1 meters, 160 ML, PE 380, 60 Fly
Length of ground chain	41.0 meters
Otter board type	Flat rectangular
Otter board size	2.5 m (L) x 1.1 m (B)
Weight of otter board	250 kgs

B. Codend data

Mesh size (mm)	44,5 mm (1¾ “)
Number of open mesh round	160 ML
Cod end length in m	7.1 meters
Cod end length in no of meshes	160 MD
Mesh type	Diamond mesh
Cod end material	PE 380 d/60 (fly)
Knotted/knotless	Knotted
Twine type	Multifilament
Twisted/braided twine	Twisted
Single/double twine	Single
Twine diameter (mm)	2,30 mm
Twine colour	Dark green

The specification of three different BRDs i.e., US-TED super shooter, square mesh windows, and fish eye that used in the experiment is shown in Table 7, while the designs and constructions are shown in Figure 3, 4, and 5.

Table 7

Specification of BRDs: US-TED super shooter (A), square mesh panel (B), and fish eye (C) used in the experiment

A1. US-TED super shooter

Grid length (cm)	120 cm
Grid breadth (cm)	90 cm
Grid bar shape and size	45 º
Grid material	Iron
Diameters of grid (mm)	16 mm
No of element	8
Bar distance (cm)	10 cm
Grid setting angle (º)	47,5 º
Grid position	Front part of cod end

A2. TED super shooter (FAO)

Type	Oval
Grid length (cm)	120 cm
Grid breadth (cm)	90 cm
Grid bar shape and size	45º
Grid material	Aluminium mix steel
Diameter of frame	38.1 mm
Diameter of grid	25.4 mm
Number of element	8
Bar distance	10 mm
Grid setting angle (º)	57,1 º
Grid position	Front of codend

B. Square mesh windows

Mesh type	Square mesh window
Window positioning	-
Window length	A = 42 bar, B = 11 bar
Window breadth	A = 34 bar, B = 9 bar
Mesh opening (mm)	A = 76,1 mm, B = 38,1 mm
Netting material	A = PE 380, 60 Fly, raschel net
Knotted/knotless	A = knotted, B = knotless
Twine type	Multifilament
Twisted/braided twine	A = Twisted, B = braided
Single/double twine	Single
Twine diameter (mm)	1,60 mm (A,B,C) and 2,30 mm (D)
Twine colour	A = dark green, B = black

C. Fish eye

Code	**-**
Fish eye material	Stainless steel
Diameter of fish eye (mm)	12,7 mm
Length of frame (cm)	55 cm
Breadth of elliptical opening (cm)	20 cm
Width of elliptical opening (cm)	45 cm
Fish eye position	-

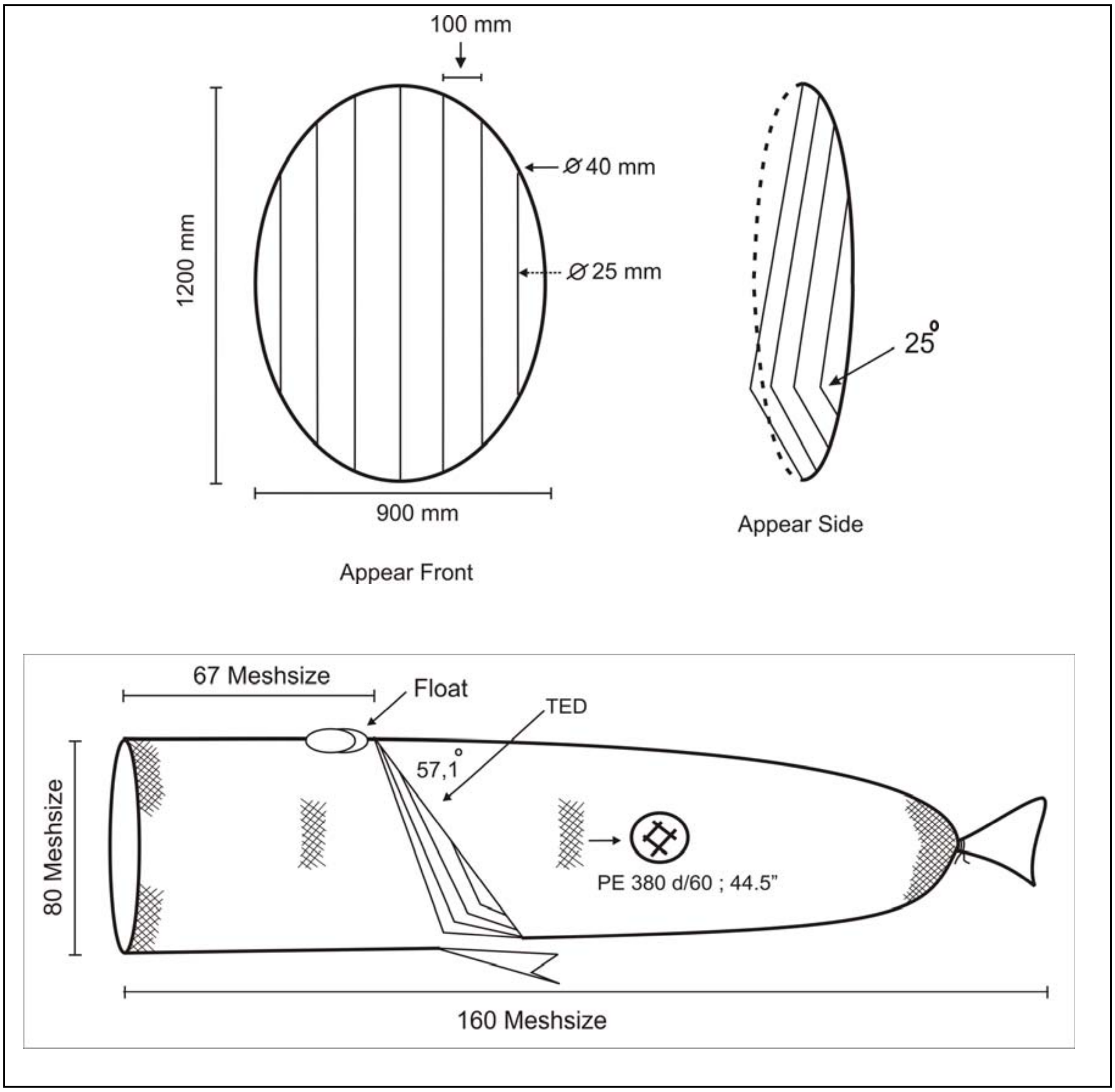

Figure 3. Design and construction of US-TED super shooter and setting position on the codend

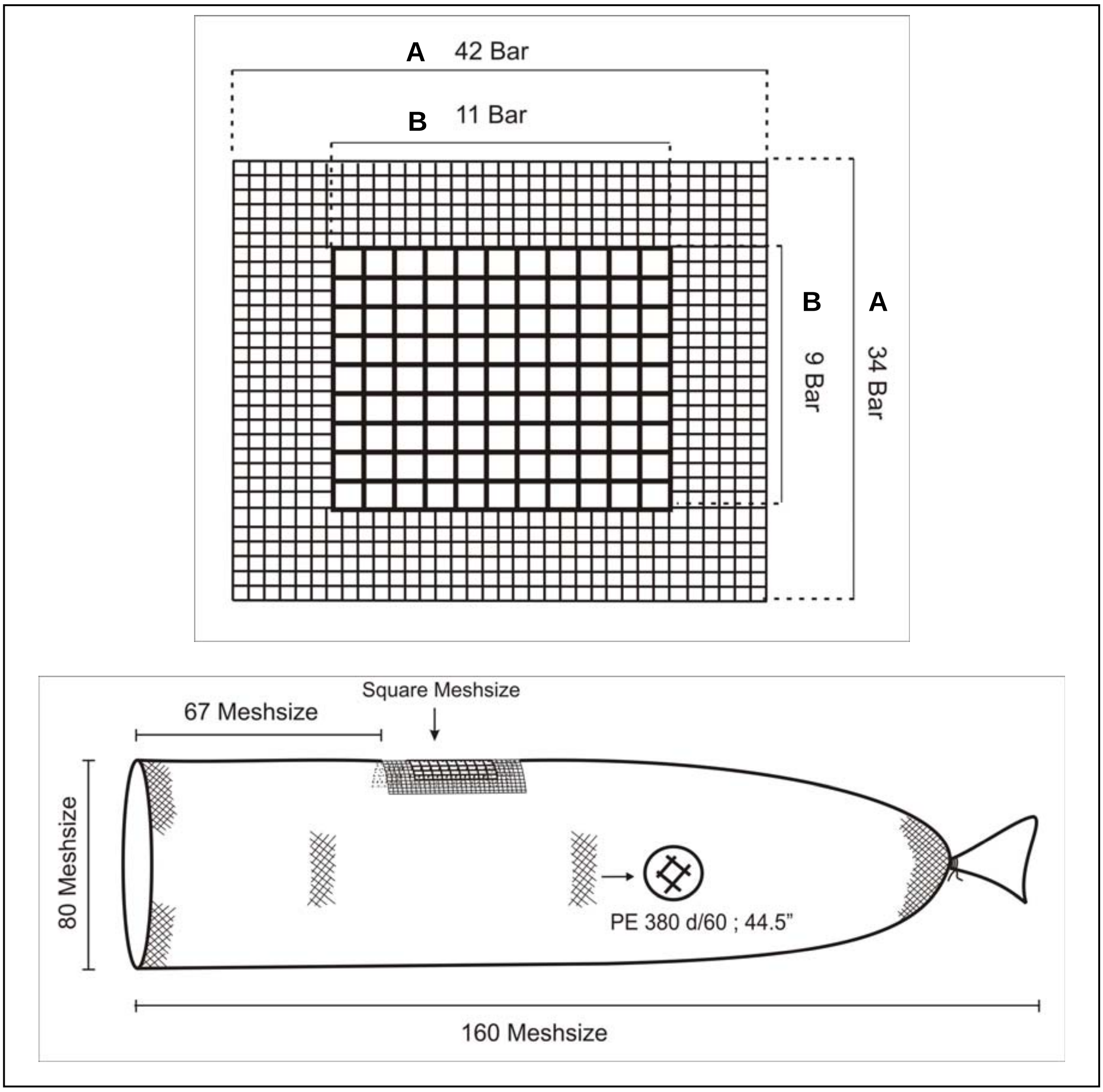

Figure 4. Design and construction of square mesh windows and setting position on the codend

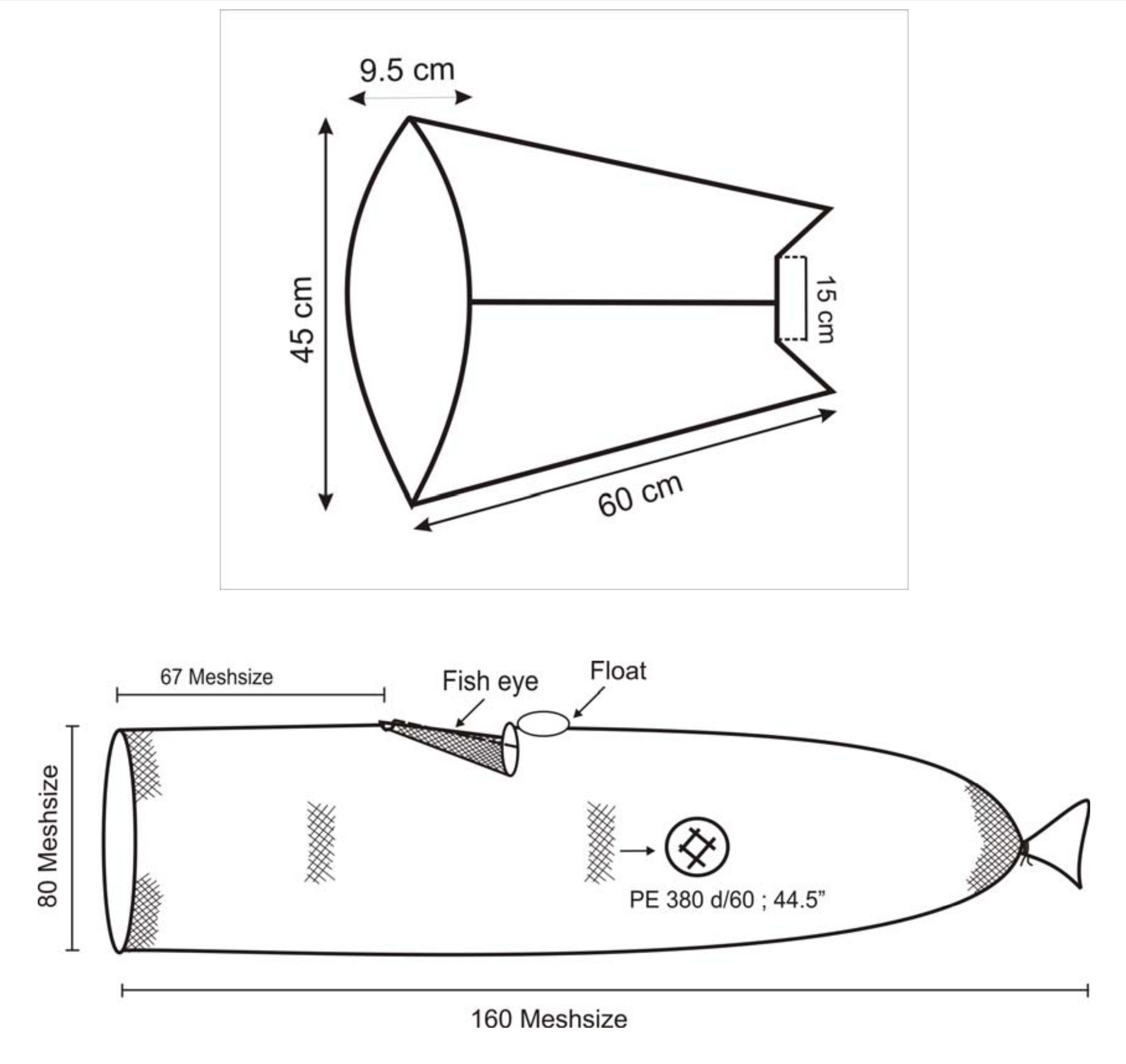

Figure 5. Design and construction of square mesh windows and setting position on the codend

(2) Experimental procedure

The sea trial was started from on boarding the researchers into MV. Laut Arafura in Merauke fishing base, Papua Province. Fishing operation was carried out in the fishing ground around Dolak island waters (Figure 1), it tooks about one-day sailing from the fishing base. The actual fishing operation for the experiment was 6 days, with 6-8 hauls for sampling purpose per day. The total hauling per day for a common commercial fishing operation is around 10 hauls.

The BRD effectiveness was determined using the twin trawl net method (Wileman et al. 1996). One trawler tows two similar trawl nets with and without BRD simultaneously side by side using special rigging. The tested BRD was attached to the other trawl net cod-end that towed together with trawl net without BRD (control net) to compare the total number of catch. Thus the reduction of catch by trawl net with BRD could be estimated.

The effects of three different types of BRD (US-TED super shooter, square mesh windows, and fish eye and) were compared their effectiveness to reduce the by-catch. Totally, 26 successfully hauls for catch sampling were carried out during day and night fishing operation with a towing duration of 2 hours as similar to the common commercial shrimp trawl fishing operation. The number of hauls according to the sea trials for sampling and date is shown in Table 8.

Table 8

The number of hauls according to the sea trials for sampling and date

Date	Fishing trials for sampling			
	Standard TED vs US-TED	Control Net vs US-TED	Control Net vs Fish Eye	Control Net vs Square Mesh
2 Dec. 2007	5 hauls			
4-5 Dec. 2007		6 hauls		
6 Dec. 2007			7 hauls	
7 Dec. 2007				8 hauls

The towing speed during trials was between 2.3 and 3.5 knots and the warp length was 5-12 times the water depth. The trawl net used was the net usually operated by MV. Laut Arafura with the design as shown in Appendix 2.

(3) Data collection

The catch data from trawl nets equipped with three different BRDs, trawl equipped with standard TED super shooter used by a commercial fleet in Arafura sea, and trawl net without BRD (control net) were investigated. The data composes of information regarding catch weight, number of fish, average catch number per shooting and species composition, BRD type, and cruise and positional information for each shot. The sub-sample of each tow was standardized to catch per hour, both in weight and numbers of individuals. The average catch weight from three different BRDs was sorted into taxonomy groups for comparison.

After sorting the catch were subdivided into three catch fractions:

1) The large by-catch fraction containing the larger fishes, crabs, starfish, debris etc.
2) The commercial shrimp fraction containing endeavour, tiger, and penaeidae.
3) The non-commercial shrimp.
4) The commercial by-catch containing the larger economic fish.

The body length was measured for all fish to the nearest centimetres. The 10% sub-sample of the total weight was taken from the tested and the control net.

(4) Data analysis

The technical performance of BRDs during fishing trials was descriptively analyzed based on information obtained through interviewing fishers and observation data obtained from direct observation during fishing trials. Four evaluation indicators were used such as (1) easiness for setting the BRD onto the codend, (2) easiness for hauling the net for each BRD used, (3) operation successful, and (4) acceptability by fishers. Scoring method was applied to quantify each technical performance of BRD according to each valuation indicator. The scores were given based on the scientist justification.

An analysis of non-parametric statistic (Wilcoxon sign test) was performed to test the significant differences in the average catch from three different BRDs in comparison to the control net at 95% significant level. From this analysis, the effectiveness of each BRD to reduce the by-catch was clarified. The analyzed data were presented in tabulation and graphical format.

3.2.2 Laboratory demonstration

The small scaled codends were installed with three different types of BRDs such as TED super shooter, square mesh panel, and fish eye (each of 1 set). Three different types of BRDs was fitted into ¾” mesh codend measuring 80 meshes length and 90 meshes circumference. Observations of the towing geometry of the three different types of BRDs and behaviour of fish inside the cod-end were conducted in the flume tank (Figure 7). The water velocity inside the flume tank was measured by using low atch. An investigation of the three different types of BRDs was conducted based upon the escapement process of fish and the performance of the BRDs in the flume tank.

Figure 6. Laboratory flume tank at Department of Fisheries Resources Utilization, Bogor Agricultural University

Simulation of fish escapement process was conducted by using freshwater fish, i.e. tilapia (*Oreochromis niloticus*), catch fish (*Pangasius pangasius*), and carp (*Cyprinus carpio*). The process of fish escapement from TED super shooter, square mesh windows, and fish eye was observed using handy cam and digital camera.

Table 9.

Laboratory flume tank dimension

Length	10 m
Width	4 m
Height	1.9 m
Channel size	1.2 x 1.2 m
Water capacity	48,000 lt
Water speed	0.5 – 3 m/s
Observation window	3 m x 1m

(1) TED super shooter

The model of TED super shooter was set in the flume tank with the water velocity 0.7 m/s. The outer frame of the grid constructed from 6 mm steel. The outer height and width of the grid were measured 26.7 mm and 21.5 mm, respectively. The bars of the grid were constructed from steel bars of 4 mm diameter. The grid consisted of seven bars, length of grid 200-270 mm. The TED was an oval shaped grid fitted to the trawl at an angle of about 57^o, with bars spacing of 1.9 cm. The two floats Y3H was attached to the top of the grid frame and measuring buoyancy force 28 grf (to provide slightly positive buoyancy). Specification of the TED model as shown in Figure 7.

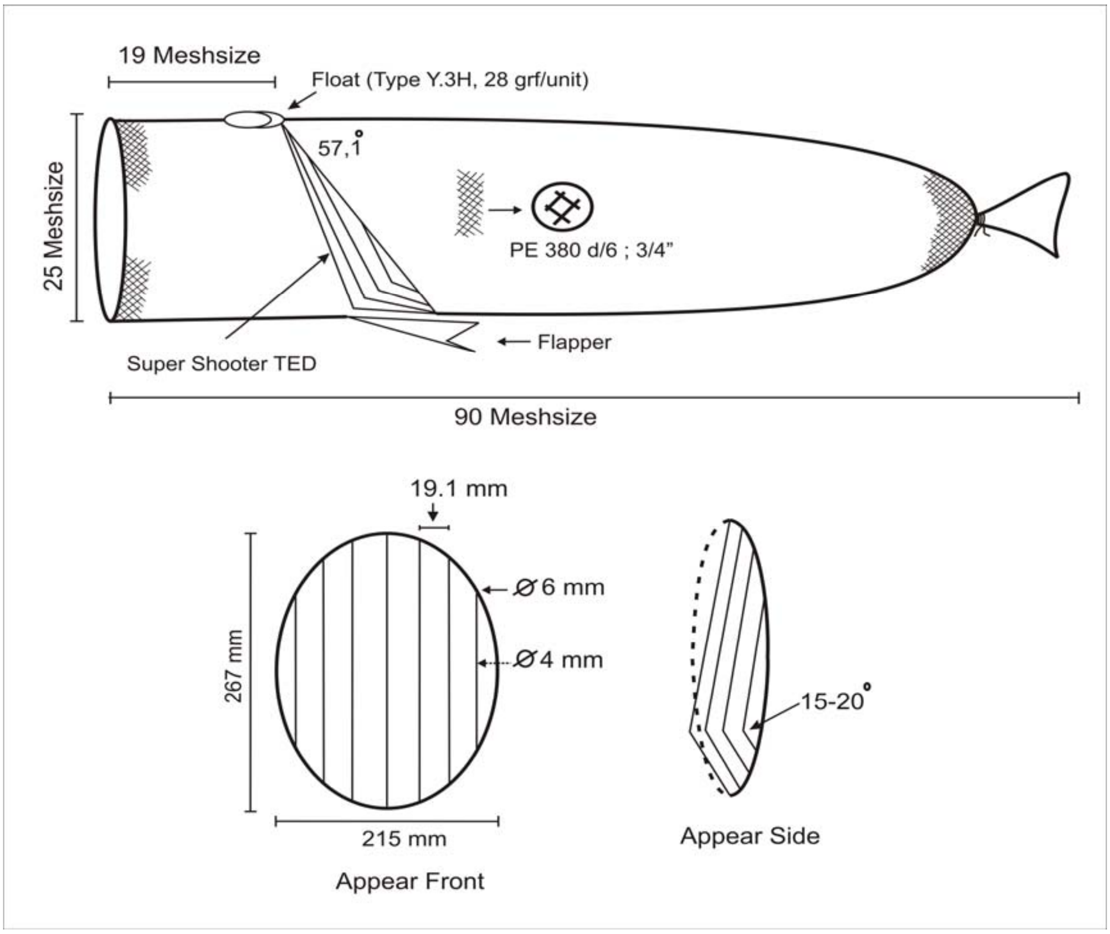

Figure 7. The small-scaled TED Super Shooter fitted in the codend

(2) Fish eye

The fish eye was constructed from 4 mm steel. The internal opening of the ellipse measured 215 mm and the circumference measured 285 mm. The length and height of the fish eye were measured 145 mm and 50 mm, respectively. The one plastic float Y3H was attached to top of the sides of the ellipse to counter the weight of the steel and hold the fish eye upright and level. The fish eye was fitted into the codend counted forward 17 ½ meshes and 38 meshes backward as shown in Figure 8.

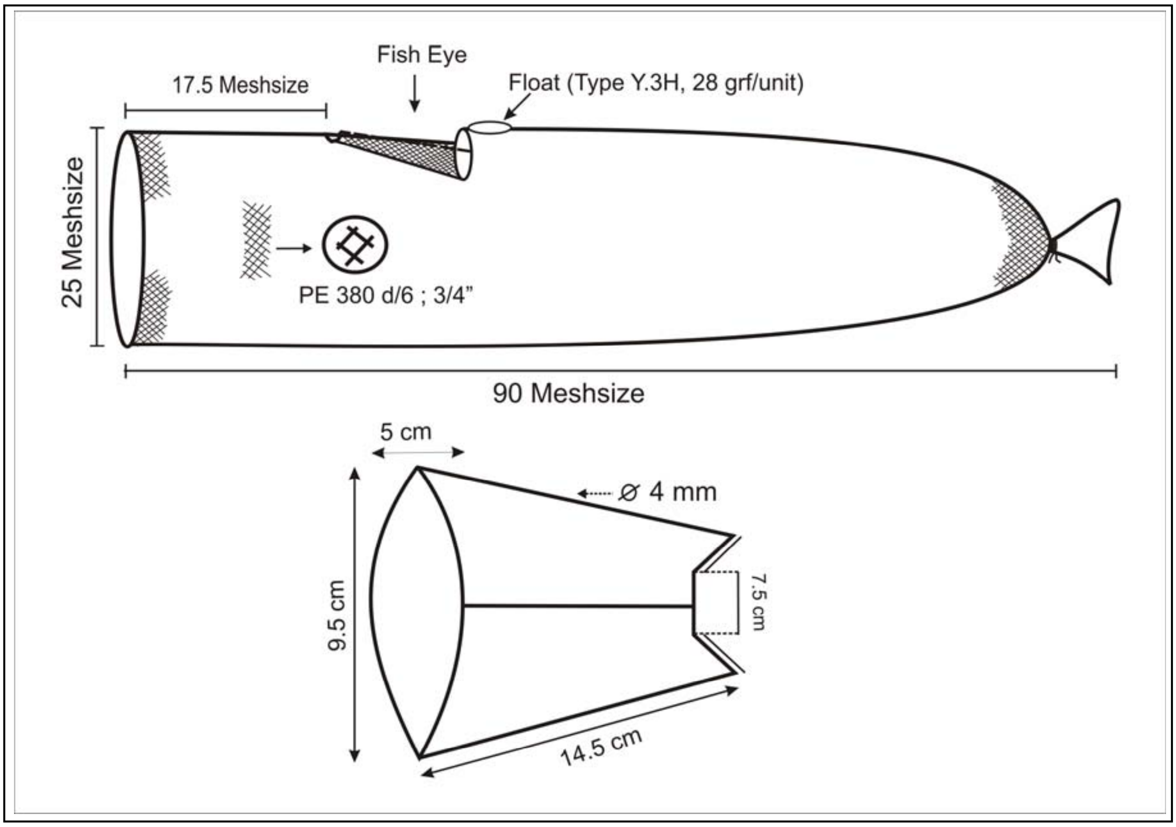

Figure 8. The small-scaled fish eye fitted in the codend

(3) Square mesh windows

The small-scaled square mesh window was constructed from 2.5" PE 380 d/30 square mesh measuring 4 x 6 bar length in the middle part. The square mesh 10 b x 15 b from PE 380 d/30 with the mesh size 1.5 " was set surrounding the square mesh. Square mesh was fitted into the codend counted forward 25.5 meshes and 12 meshes backward as shown in Figure 9.

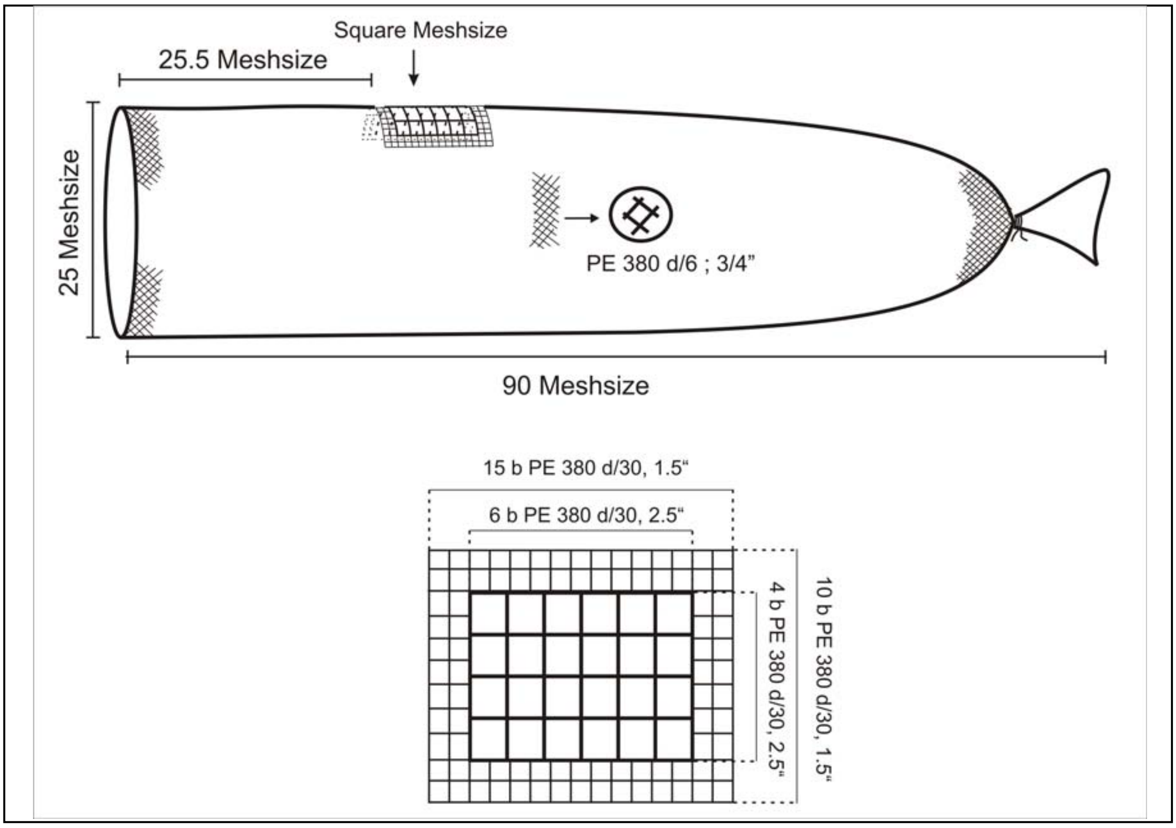

Figure 9. The small-scaled square mesh window fitted in the codend

4
RESULTS

4.1 Technical Performance of BRDs during Fishing Trials

The technical performance of BRDs (US-TED, square mesh window, and fish eye) was visually observed during sea trials. All fishing operation stages i.e., from setting the BRD into codend, shooting, towing, hauling, and releasing the catch from codend, were recorded. We observed that during a successful 26 hauls for sampling the catch, technically the BRDs showed good performance. The evaluation of technical performance of BRDs during fishing trials is shown in Table 10.

Table 10
Evaluation of technical performance of BRDs during fishing trials

No.	Evaluation indicators	US-TED	Square Mesh Window	Fish Eye
1.	Easiness for setting BRD into the codend	4	6	7
2.	Easiness for hauling the net for each BRD used	5	7	7
3.	Operation successful (no twisted net, no empty haul, etc.)	7	7	7
4.	Acceptability by fishermen	4	7	6
	Total Score	20	27	27

Note: Score 1-2 : very low
3-4 : low
5-6 : medium
7-8 : high
9-10 : very high

Considering Table 10, we can explain that for easiness setting and hauling aspects, the fish eye and square mesh has the highest score, and then followed by US-TED. The acceptability of BRDs by fishermen showed highest score for square mesh window, followed by fish eye, and US-TED. Therefore, an overall evaluation result showed that the best technical performance was fish eye (score 27) and square mesh window (score 27), and then US-TED (score 20).

4.2 Catch Composition of Trawl Net Without and With BRDs

4.2.1 Catch composition of control net and trawl net with US-TED

Catch composition of discarded fish from the control net during fishing trials on 4-5 December 2007, were dominated by *Loligo* spp 10.85 kg (19%), *Terapon theraps* 8.95 kg (15%), *Trichiurus lepturus* 5.4 kg (9%), *Johnius* spp 4.90 kg (8%), *Pellona ditchela* 4 kg (7%), *Polydactillus* spp 3.53 kg (6%) and the others species of fish (Figure 10). The total weight of fish sample was 58.6 kg.

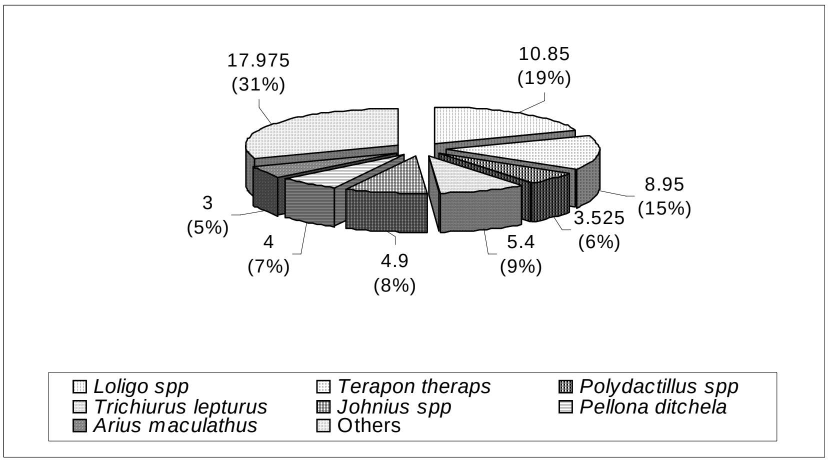

Figure 10. Catch composition of discarded fish from control net

The US-TED super shooter influenced on the composition of discarded fish catch. The catch was dominated by crab 16.10 kg (26%), and followed by *Terapon theraps* 12 kg (19%), *Trichiurus lepturus* 5.45 kg (9%), *Johnius* spp 4.375 (7%), *Pellona ditchela* 3.9 kg (6%) and others species of fishes such as *Carangoides* spp, *Polydactillus* spp, etc. with the total of 28%. The total weight of fish sample was 62.68 kg (Figure 11).

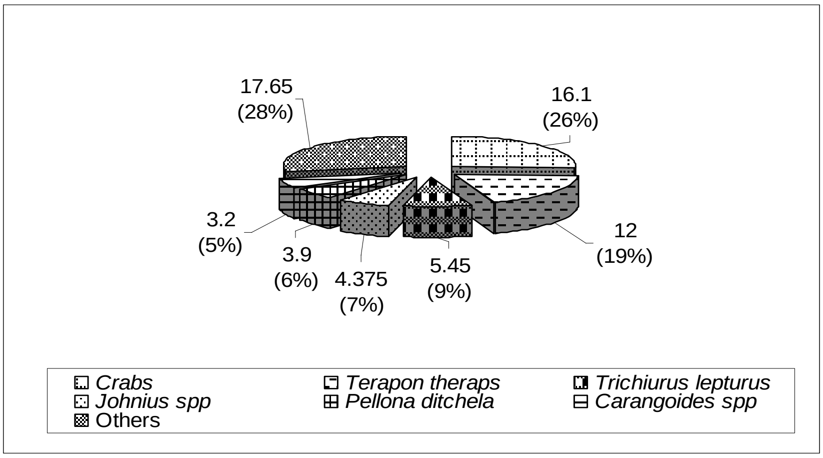

Figure 11. Catch composition of discarded fish from trawl net with US-TED

The total weight and species of fish caught by the US-TED showed increasing weight for certain species in comparison to the control net. However, some species were decreased such as *Loligo* spp from 10.85 kg to 0.25 kg (reduced by 10.6 kg), *Dasyatis kuhlli* was reduced by 1.33 kg and *Pomadasys maculatus* was reduced by 2.1 kg.

The catch composition of economic fish caught by the control net is shown in Figure 12. The fish comprised of *Trichiurus lepturus* 133.6 kg (52%), *Formio niger* 43.95 kg (17%), and *Otolites* spp 21.95 kg (8%). The other economic fish caught by the control net were such as *Cynoglossus spp*, *Caranx iqnobilis*, etc. amounted 13.25 kg (approximately 5% from the number of fish sampled).

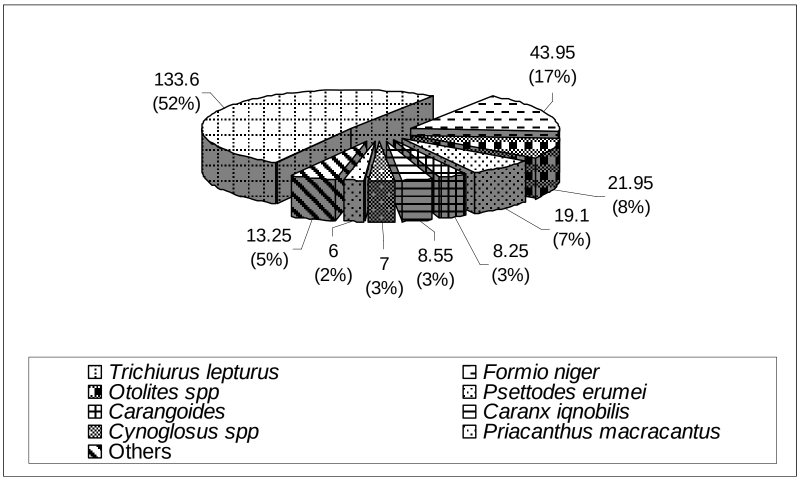

Figure 12. Catch composition of the economic fish from control net

The installment of US-TED influenced on the number and species of economic fish caught. The fish retained in the codend consisted of *Trichiurus lepturus* 84.75 kg (41%), *Formio niger* 29.6 kg (14%), *Otolites* spp 19.95 kg (10%), *Urapsis urapsis* 12.65 kg (6%), and *Psettodes erumei* 12.25 kg (6%). Meanwhile, the others fish caught consisted of *Alepes melanoptera*, and *Scomberomorus commersonii* ancounted10% or 19.95 kg (Figure 13).

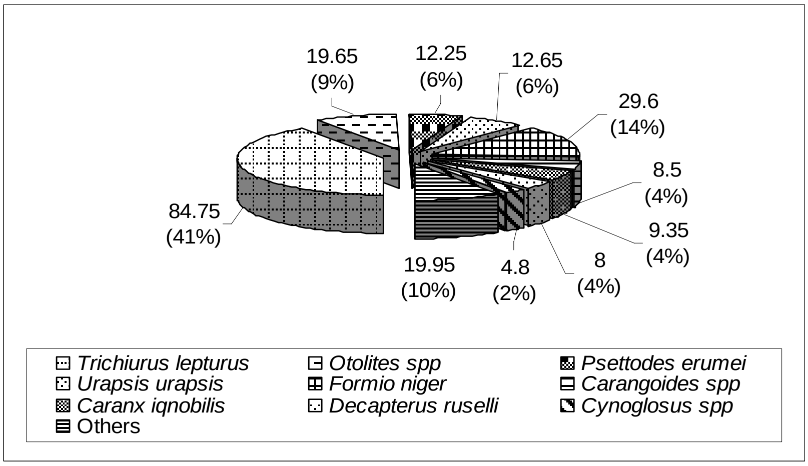

Figure 13. Catch composition of economic fish from trawl net with US-TED

4.2.2 Catch composition of control net and trawl net with square mesh window

Catch composition of discarded fish from the control net during fishing trials on 6-7 December 2007 was dominated by crab 25.4 kg (35%), *Setipinna* spp 9.45 kg (13%), *Pellona ditchella* 9 kg (13%), *Johnius* spp 4.7 kg (7%), *Trichiurus lepturus* 3.9 kg (5%), and some other fish species approximately 21% from the total fish sampled (Figure 14).

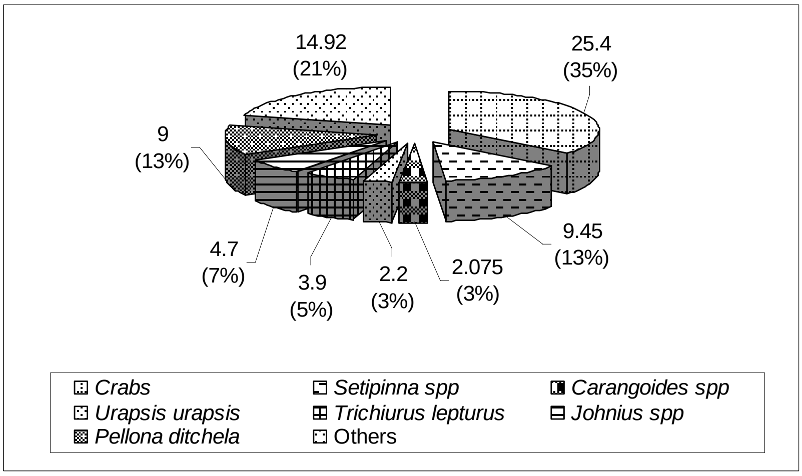

Figure 14. Catch composition of discarded fish from control net

The use of square mesh window influenced on the total weight and number of discarded fish species. The total catch was dominated by crab 45.5 kg (58%), *Setipinna* spp 7 kg (9%), *Johnius* spp 4.18 kg (5%), *Pellona dicthella* 3.9 kg (5%), *Trichiurus lepturus* 3.55 kg (4%), and others species of fish approximately 16% from the total fish sampled (Figure 15).

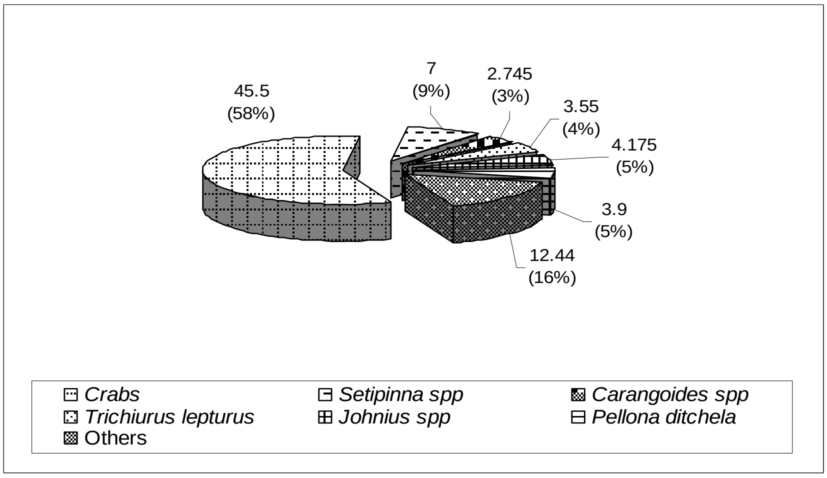

Figure 15. Catch composition of discarded fish from trawl net with square mesh window

The catch composition of economic fish from the control net was dominated by *Otolites* spp 68.75 kg (35%), *Cynoglossus* spp 40.9 kg (20%), *Trichiurus lepturus* 33.6 kg (17%), *Platycephalus* spp 10.15 kg (5%), and some other fish such as *Megalaspis cordila*, and *Urapsis urapsis* approximately 6% (200.25 kg) from the total weight (Figure 16).

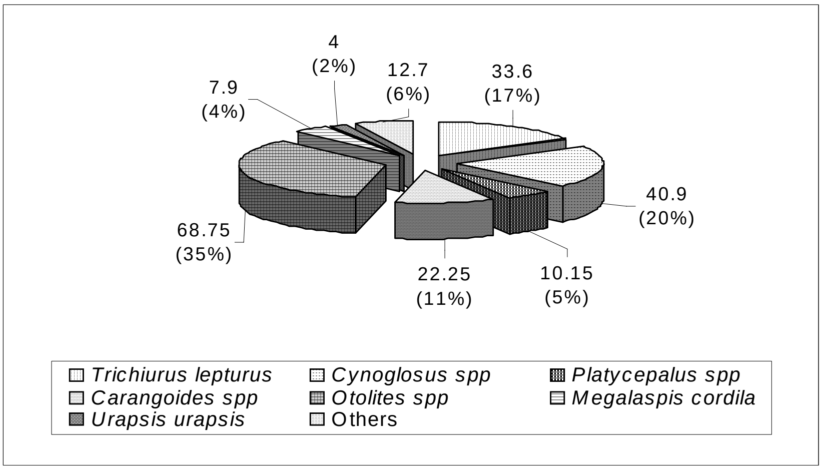

Figure 16. Catch composition of economic fish from control net

The installment of the square mesh window on the trawl net codend has influenced on the total weight of economic fish. The total catch was dominated by *Otolites* spp 44.1 kg (31%), *Trichiurus lepturus* 27 (19%), *Alepes melanoptera* 19.4 kg (14%), *Cynoglossus* spp 17.4 kg (12%), *Platycephalus* spp 11.7 kg (8%), *Megalaspis cordila* 10.55 kg (7%), and other species of fish such as *Muraenesox bagio*, and *Ephinephelus* spp approximately 143.6 kg (16%) from the total weight (Figure 17).

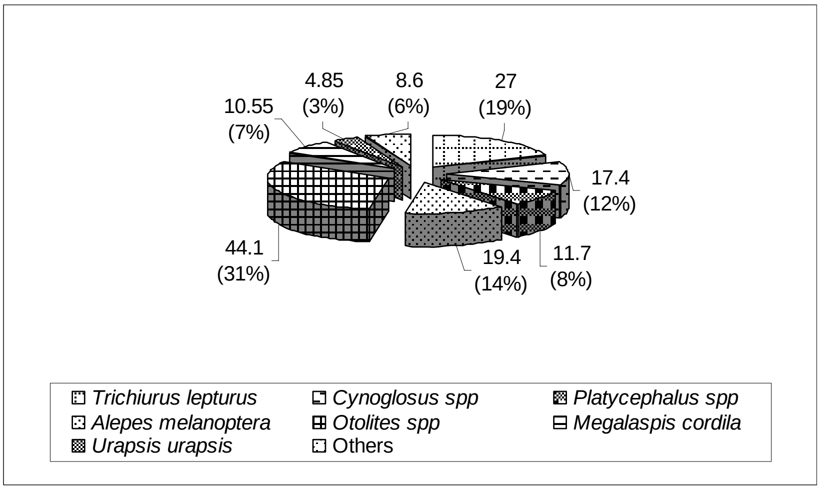

Figure 17. Catch composition of economic fish from trawl net with square mesh window

4.2.3 Catch composition of control net and trawl net with fish eye

The catch composition of the control net during fishing trials were dominated by crab 49 kg (54%), *Thryssa setrirostris* 8.25 kg (9%), *Johnius* spp 6.55 kg (7%), *Pellona ditchela* 4.4 kg (5%), *Illisa melastoma* 4.03 kg (4%), and others species such as *Leiognathus* spp, *Harpadon nehereus*, *Terapon theraps*, and *Arius maculatus* approximately 15% from the total weight of by-catch (Figure 18).

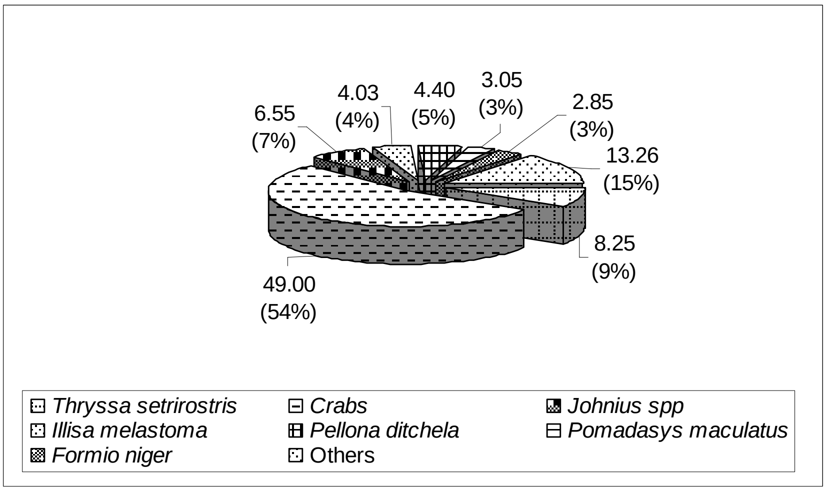

Figure 18. Catch composition of discarded fish from control net

The installment of fish eye on the trawl net has influenced on the catch composition of discarded fish. The catch was dominated by *Urapsis urapsis* 35.65 kg (51%), *Arius maculatus* 8.3 kg (12%), *Setipinna* spp 5.65 kg (8%), *Illisa melastoma* 4.63 kg (7%), *Apogon* spp 2.5 kg (4%), and other species approximately 15% from the total fish sampled (Figure 19).

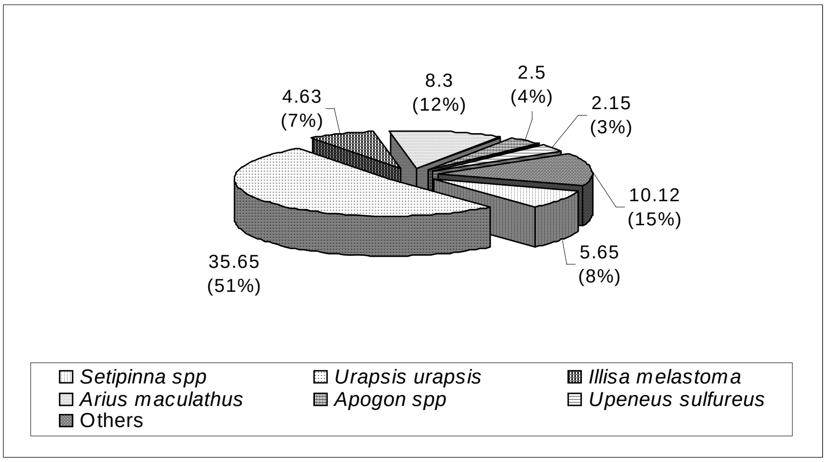

Figure 19. Catch composition of discarded fish from trawl net with fish eye

The catch composition of economic fish from the control net comprised of *Trichiurus lepturus* 26 kg (38%), *Polidactylus* spp 11.7 kg (17%), *Megalaspis cordila* 9.85 kg (15%), *Cynoglosus* spp 5.9 kg (9%), *Carcharinus* spp 5.1 kg (8%), and other species such as *Formio niger*, *Epinephelus* spp, *Carangoides* spp, and some other fish in small quantity (Figure 20).

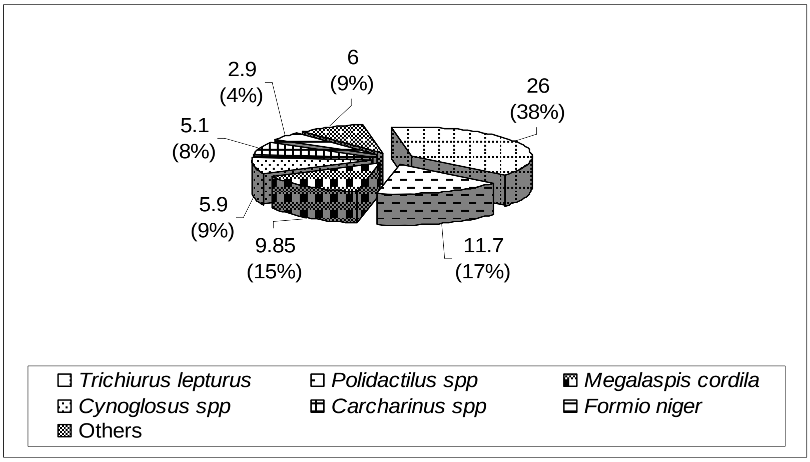

Figure 20. Catch composition of economic fish from control net

The installment of fish eye on the trawl net has influenced on the catch composition of economic fish retained. The catch composition was dominated by *Trichiurus lepturus* 28.40 kg (42.77%), then followed by *Otolites* spp 22.35 kg (33.66%), *Carcharinus* spp 5.15 kg (7.76%), *Cynoglossus* spp 3.40 kg (5.12%), and other species in a small quantity (Figure 21).

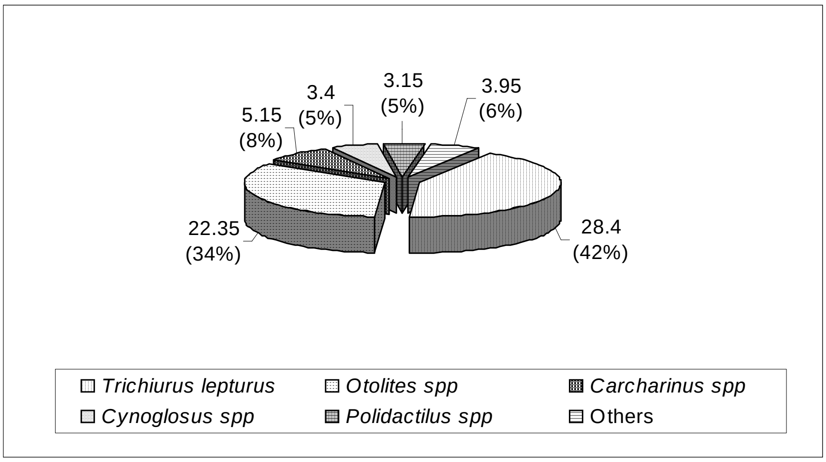

Figure 21. Catch composition of economic fish from trawl net with fish eye

4.3 Effectiveness of BRDs in Reducing By-catch

4.3.1 Catch composition

On the comparison of catch between trawl net without BRD (control net) and trawl net with US-TED showed the numbers of species identified from the control net were 24 species. Whilst, the numbers of species identified from the trawl net with US-TED were 28 species (Figure 22). There was decreasing in weight of fish from total sampled for three species i.e., *Loligo* spp. (99.79%, from 10.86 kg to 0.25 kg), *Rastrellliger kanagurta* (100%, all being escaped), and *Dasyatis kuhlli* (81.29%, from 2.9 kg to 1.6 kg). The decreasing fish weight number was occurred for 4 species i.e., *Formio niger* (98.47%, from 43.95 kg to 29.6 kg), *Muraenesox bagio* (100%), *Psettodes erumei* (96.64%, from 19.1 kg to 12.25 kg), and *Carangoides* (95.59%, from 8.25 kg to 3 kg).

The comparison of total catch between control net and trawl net with fish eye showed the number of species in a control net were 31 species, while for the trawl net with fish eye were 26 species (Figure 22). The number of fish catch was decreased for 10 species i.e., *Formio niger* (93.23%, from 2.85 kg to 0.55 kg), crabs (99.88%, from 49 kg to 2.95 kg), *Pomadasys maculatus* (99.46%, from 3.05 kg to 0.05 kg), *Trichiurus lepturus* (88.75%, from 2.45 kg to 0.67 kg), and *Pellona ditchela* (99.48%, from 4.4 kg to 4.1 kg). Meanwhile, *Thryssa setrirostris*, *Cynoglossus* spp, *Harpadon nehereus*, *Carangoides* spp, *Euristhmus lepturus*, and *Johnius* spp were not found in the codend.

The total weight of fish was decreased for 6 species i.e., *Polydactilus* spp. (97.70%, from 11.7kg to 3.14 kg), *Megalaspis cordila* (98.40%, from 9.85 kg to 1.55 kg). While, the others species such as *Formio niger*, *Priachantus* spp, *Carangoides* spp, and *Alepes melanoptera* were not found in the codend.

The comparison between control net and trawl net with square mesh windows showed the number of species in the control net were 33 species. While, the numbers of species in the trawl net with square mesh windows were 33 species (Figure 22). The total weight of fish was decreased for 5 species i.e., *Setipinna* spp. (92.16%, from 9.45 kg to 7 kg), *Urapsis urapsis* (97.93%, from 2.2 kg to 0.1 kg), *Megalapsis cordila* (65.73%, from 1.57 kg to 0.85 kg, *Pellona ditchela* (95.19%, from 9 kg to 3.9 kg, and *Leiognathus* spp. (23.61%, from 0.6 kg to 0.27 kg).

The number of fish weight was decreased for 5 species i.e., *Carcharinus* spp. (95.15%, from 3.8 kg to 0.7 kg), *Trichiurus lepturus* (97.61%, from 33.7 kg to 27 kg), *Cynoglossus* spp (98.96%, from 40.9 kg to 17.4 kg), *Carangoides* spp (99.60%, from 22.25 kg to 2 kg), *Otolites* spp (99.07%, from 68.75 kg to 44.1 kg), and *Rachicentron canadus* were not found in the codend.

The comparison of species number between standard trawl net used by Indonesian shrimp trawler in Arafura sea and trawl net with US-TED, showed the number of species for the standard TED was 38 species. Meanwhile, the number of species from the trawl net with US-TED was 37 species (Figure 22). The number of fish catch was decreased for 4 species i.e., *Thryssa mistax* (95.79%, from 9.25 kg to 3.6 kg), *Arius thallasinus* (91.72%, from 6.95 kg to 4 kg), *Dasyatis kuhlli* (96.15%, from 8.9 kg to 3.05 kg, and *Pellona ditchela* (98.44%, from 16.3 kg to 4.15 kg).

The numbers of fish weight was decreased for 5 species i.e., *Formio niger* (97.84%, from 13 kg to 3.65 kg), *Carcharinus* spp (92.23%, from 7.65 kg to 4.55 kg), *Lates calcarifer* (98.05%, from 16 kg to 5 kg), *Polydactilus* spp. (98.63%, from 39.55 kg to 21.4 kg), *Otolites* spp. (98.07%, from 26.95 kg to 14 kg). The reduction of species number within BRDs can be seen in Figure 23.

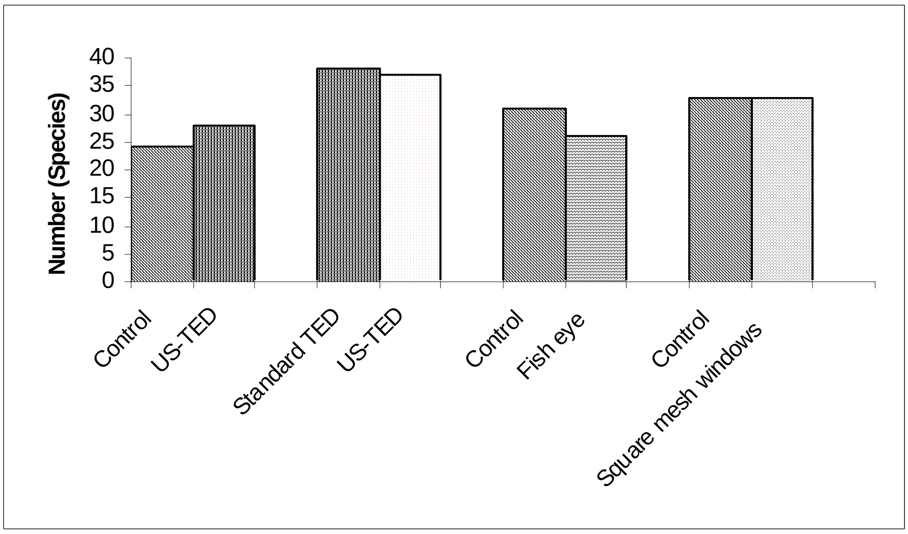

Figure 22. Comparison of species number reduction by BRDs used in trawl net

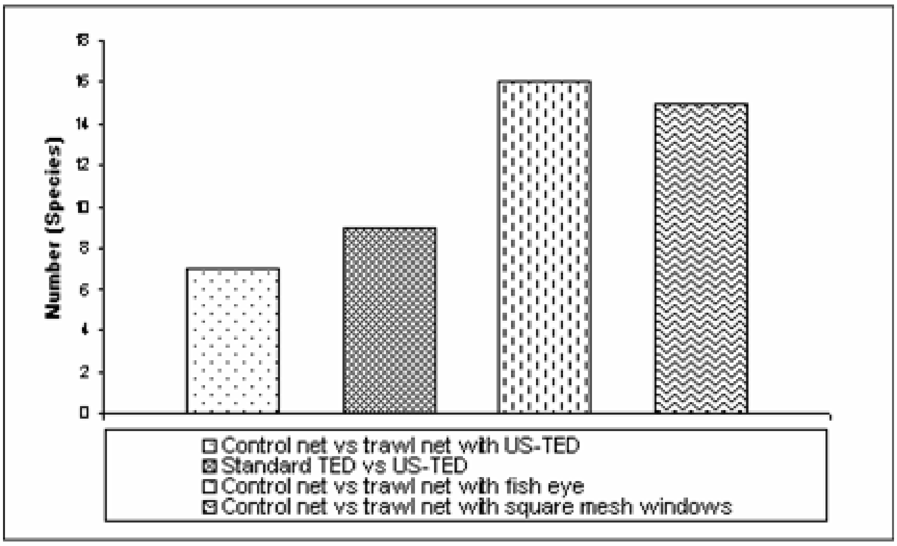

Figure 23. The reduction of species number within BRDs

4.3.2 Catch Weight

(1) Catch comparison between control net and trawl net with US-TED

From the comparison of average catch obtained during 7 hauls showed that the catch of trawl net without BRD (control net) was 382.32±27.15 kg, lower than the catch of trawl net with US-TED (395.05±20.16 kg) as shown in Figure 24. The average catch from every towing showed that the lowest catch occurred on the towing number 6 (216.75 kg) (Figure 25).

From the statistical analysis (Wilcoxon sign test) showed that the comparison of catch between control net and trawl net with US-TED was not significant difference (Asymp. sig. (2-tailed) 0.753 > α (0.05)).

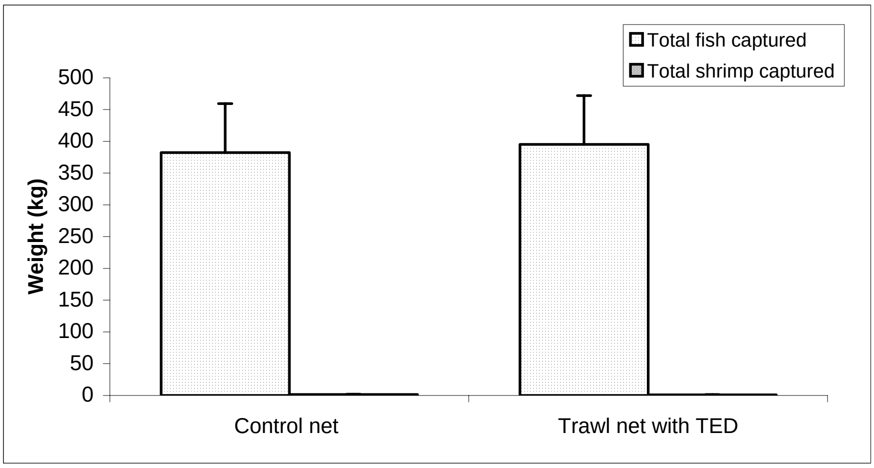

Figure 24. Average catch of control net and trawl net with US-TED

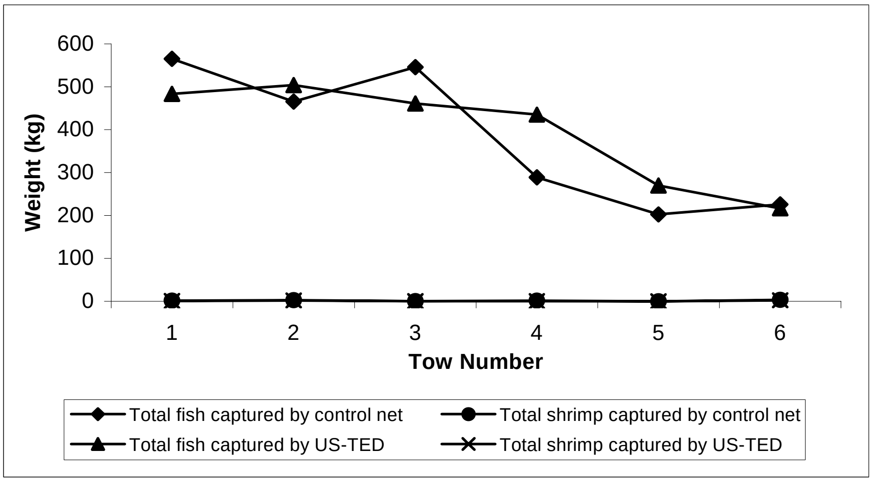

Figure 25. Catch of control net and trawl net with US-TED according to towing number

Comparison of the average weight of shrimp catch between control net and trawl net with US-TED showed that the catch from control net (1.5±0.21 kg) was insignificantly different to the catch from trawl net with US-TED (1.01±0.17 kg) as show in Figure 26.

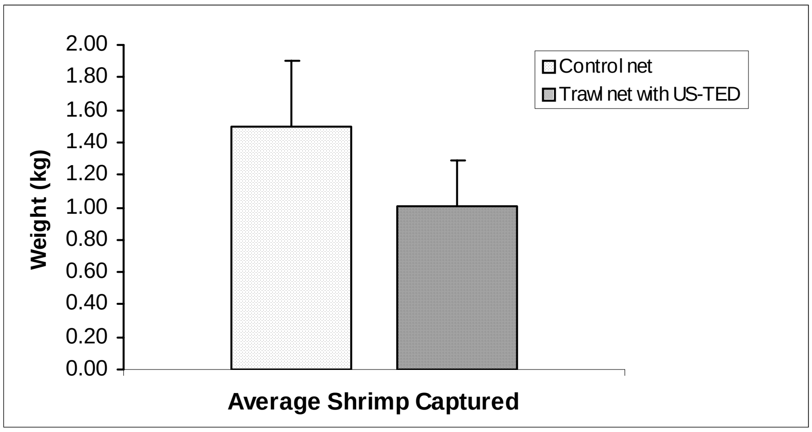

Figure 26. Average catch of shrimp from the control net and trawl net with US-TED

The total weight of shrimp catch for every towing showed a fluctuation with the highest catch of 3.25 kg for towing number 6 (Figure 27). Conversely, shrimp was not found on towing number 5.

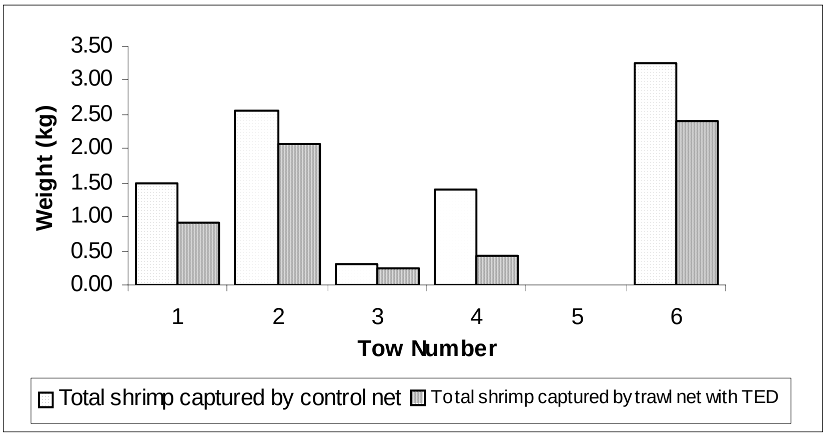

Figure 27. The catch of shrimp from control net and trawl net with TED per towing

(2) Comparison of catch weight between control net and trawl net with fish eye

The comparison of average catch weight obtained during 7 hauls showed that the catch from control net was 346.95±8.53 kg, higher than the catch weight from trawl net with fish eye (299.94±13.33 kg) as shown in Figure 28. The average catch of fish according to towing number showed the lowest catch was on towing number 7 (230.77 kg) as presented in Figure 29.

Statistical analysis (Wilcoxon sign test) between control net and trawl net with fish eye showed a significant difference as indicated by test value of Asymp. sig (2-tailed) 0.237 > α (0.05).

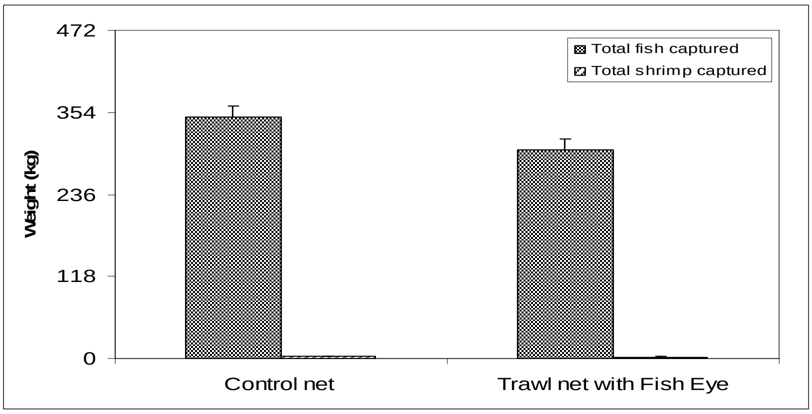

Figure 28. The average catch of control net and trawl net with fish eye

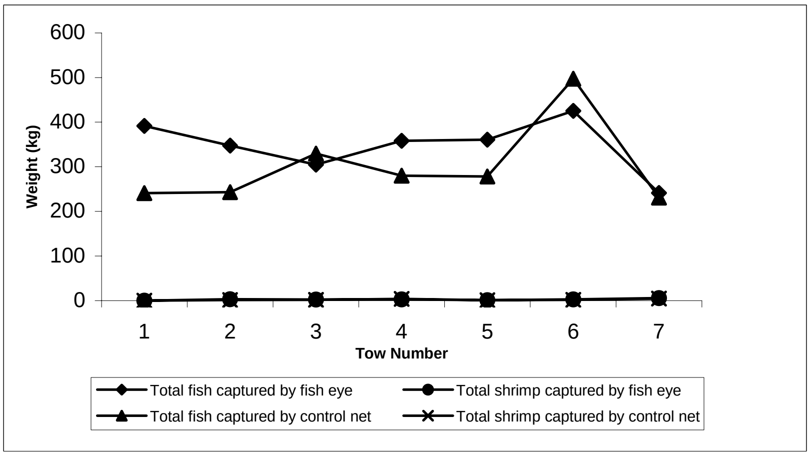

Figure 29. The comparison of catch between control net and trawl net with fish eye according to towing number

The average catch of shrimp for control net was 2.60±0.26 kg, insignificantly different compared to the average catch of trawl net with fish eye (2.10±0.51 kg) as shown in Figure 30.

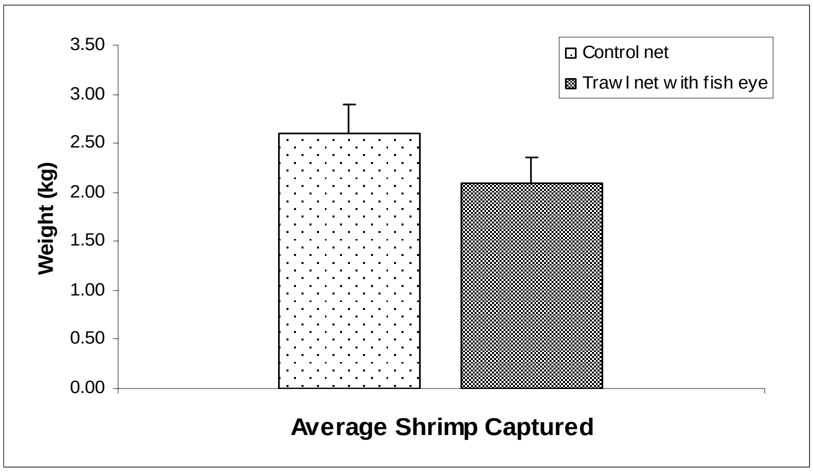

Figure 30. The average catch of shrimp from control net and trawl net with fish eye

The total weight of shrimp for every towing showed variation with the highest catch was 5 kg for towing number 7. Conversely, the shrimp caught were not found on towing number 1 (Figure 31).

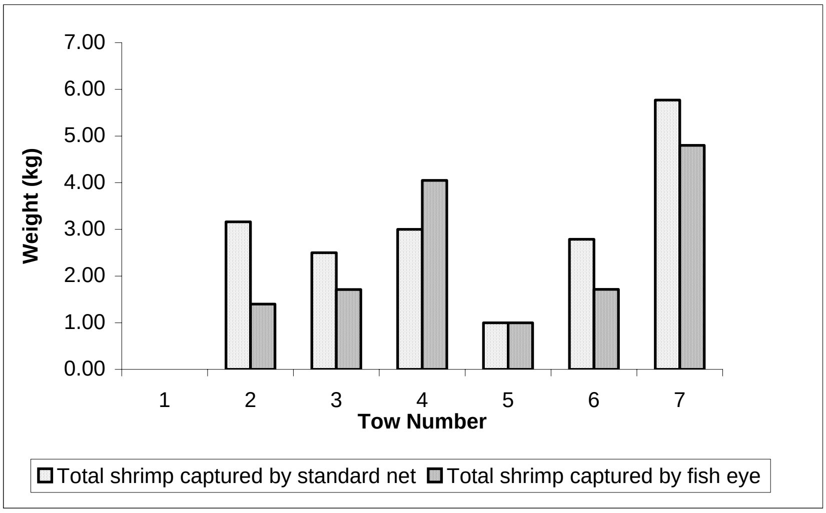

Figure 31. The catch of shrimp from control net and trawl net with fish eye for every towing

(3) Comparison of catch weight between control net and trawl net with square mesh window

The comparison of average catch between control net and trawl net with square mesh window obtained during 8 hauls showed that the catch of control net was 382.88±13.65 kg, higher than the catch of trawl net with square mesh windows (369.65±8.44 kg) as shown in Figure 32. The average fish catch for every towing showed the lowest catch number on towing number 4 (237.37 kg). The average catch for every towing is presented in Figure 33.

Statistical analysis (Wilcoxon sign test) showed that the comparison of catch from control net and trawl net with square mesh windows was not significant different as indicated by Asymp. sig. (2-tailed) 0.484 > α (0.05).

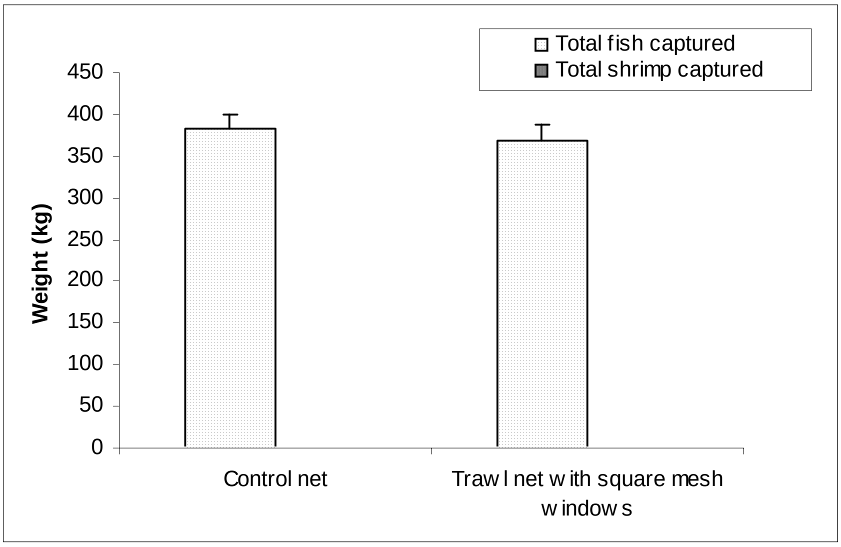

Figure 32. Average catch of control net and trawl net with square mesh windows

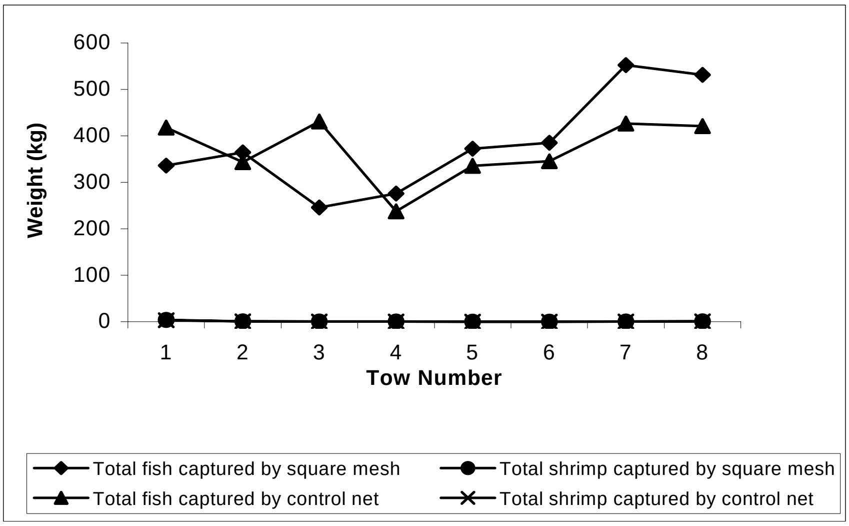

Figure 33. Catch of control net and trawl net with square mesh window for every towing

The average catch of shrimp from control net (0.80±0.15 kg) was insignificant different in comparison to the catch of trawl net with square mesh windows (0.62±0.12 kg) as shown in Figure 34.

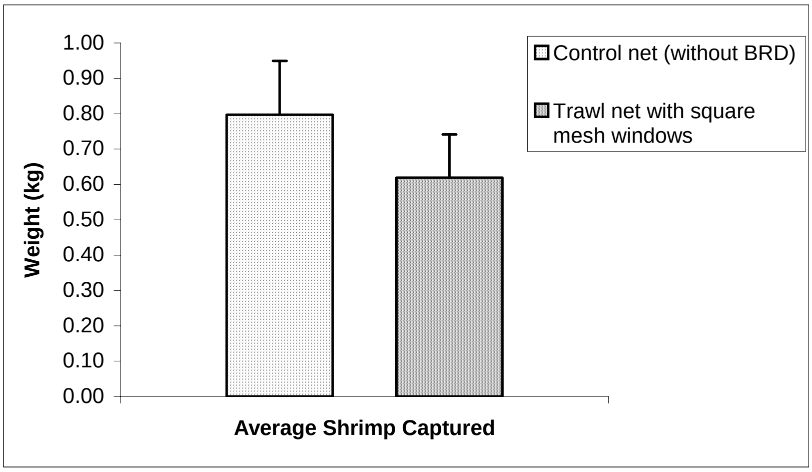

Figure 34. The average catch of shrimp from control net and trawl net with square mesh windows

The catch of shrimp for every towing showed a variation with the highest catch was 3.71 kg on towing number 1, while shrimp was not found on towing number 5 and 6 (Figure 35).

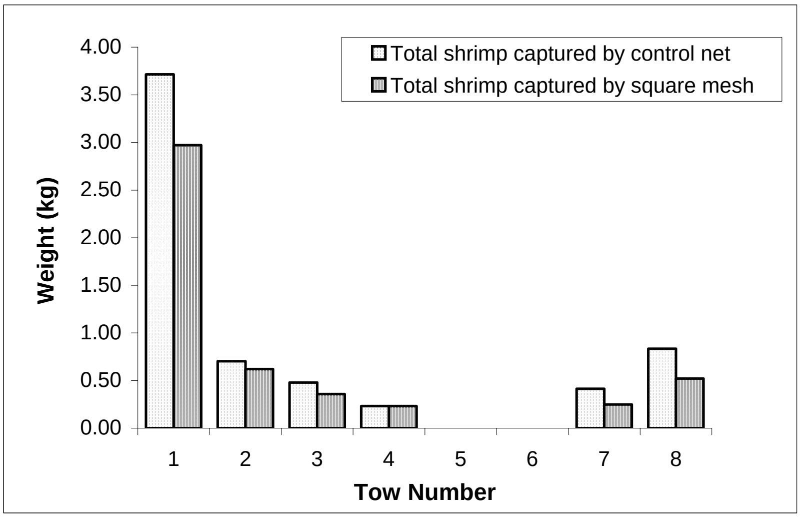

Figure 35. The catch of shrimp from control net and trawl net with square mesh windows for every towing

(4) Comparison of catch weight between trawl net with standard TED and US-TED

The comparison of average catch weight obtained during 5 hauls showed that the catch weight of trawl net with standard TED was 183.63±14.53 kg. It was higher than the catch weight of trawl net with US-TED (154.93±12.18 kg) as shown in Figure 36. The average catch weight for every towing showed that the lowest average catch was 171.3 kg for towing no. 3 (Figure 37).

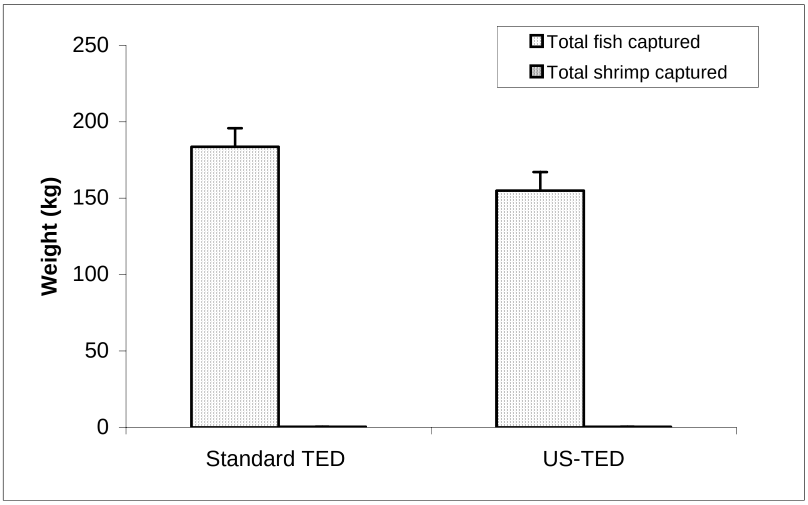

Figure 36. The average weight of trawl net with standard TED and US-TED

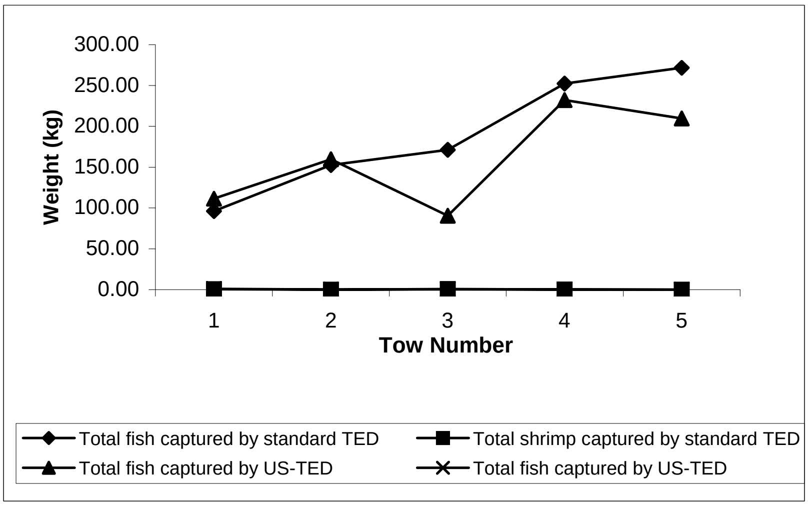

Figure 37. The total weight of trawl net with standard TED and US-TED for every towing

The average weight of shrimp from trawl net with standard TED (0.365±0.07 kg) was insignificantly different compared to the average weight from trawl net with US-TED (0.355±0.07 kg) as shown in Figure 38.

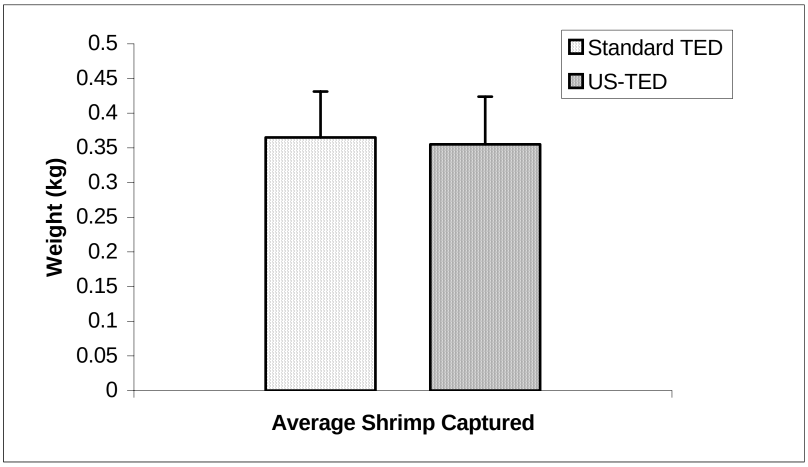

Figure 38. The average weight of shrimp from trawl net with standard TED and US-TED

The weight of shrimp for every towing showed a variation with the highest shrimp catch was 0.90 kg on towing no. 1, while shrimp was not found on towing no. 5 (Figure 39).

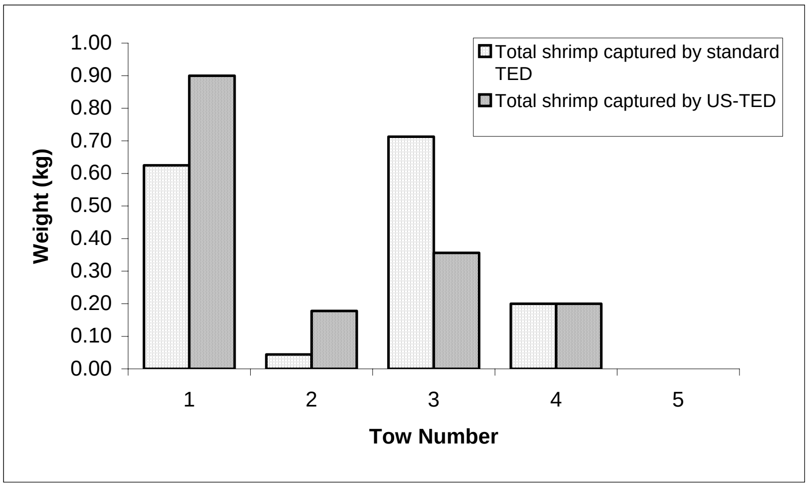

Figure 39. The weight of shrimp from trawl net with standard TED and US-TED for every towing

4.3.3 Catch Value

(1) Comparison of catch value between control net and trawl net with US-TED

The total weight of catch from trawl net without BRD (control) was 1.468, 68 kg, consisted of main target catch (shrimp) and by-catch. The by-catch of economic valued fish was utilized and non economic valued fish was discarded. From the Figure, it can be seen that proportion of shrimp catch was 0.46% (6.72 kg). The utilized of by-catch was 261.65

kg or 17.82% from the total catch. The number of discarded by-catch was higher than those shrimp and utilized by-catch mentioned above which reached 81.72% or 1200 kg.

The use of TED on trawl net has influenced on the catch number for both main target catch and the by-catch. The total catch was 1,534.25 kg, consisted of 0.30% (4.55 kg shrimp), 13.34% fish that was utilized such as economic value fish (204.70 kg), and discarded by-catch that was not utilized (86.36% or 1,325.00 kg).

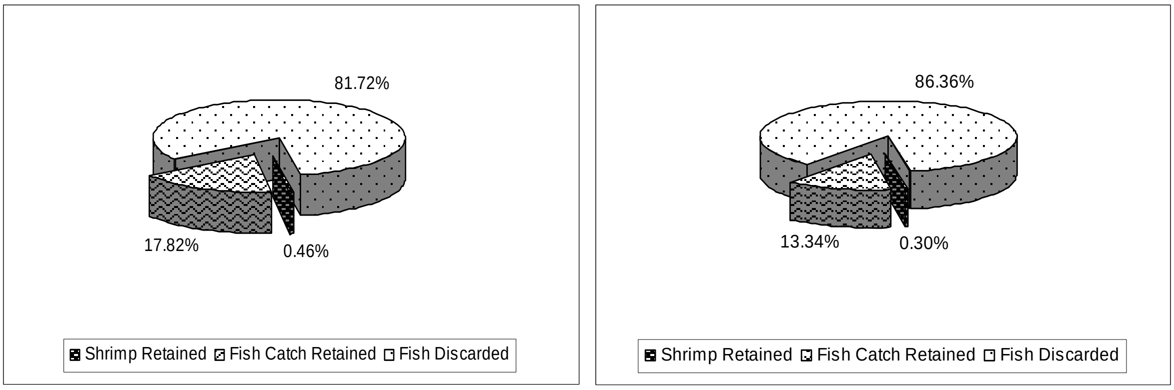

Figure 40. The comparison of catch value between control net and trawl net with US-TED

According to the catch values mentioned above, the catch was not significantly different between the control net and trawl net with US-TED. However, there was decreasing in number of economic fish species on trawl net with US-TED by 56.95 kg (21.77%).

(2) Comparison of catch value between control net and trawl net with fish eye

The total catch of control net was 2,642.75 kg, composed of the main catch and the by-catch species. The main catch of shrimp was 19.95 kg (0.75%) from the total catch. While, the utilized by-catch was 168.80 kg (6.39%), and the rest of 2.454 kg (92.86%) was discarded by-catch.

The use of fish eye influenced on the total catch. This fact can be seen from the decreasing in total catch number that reached 354.54 kg. The total catch from trawl net with fish eye was 2,288.21 kg, composed of 15.71 (0.69%) kg shrimp, 88.05 kg (3.85%) utilized by-catch, and 2,181.45 kg (95.47%) discarded by-catch.

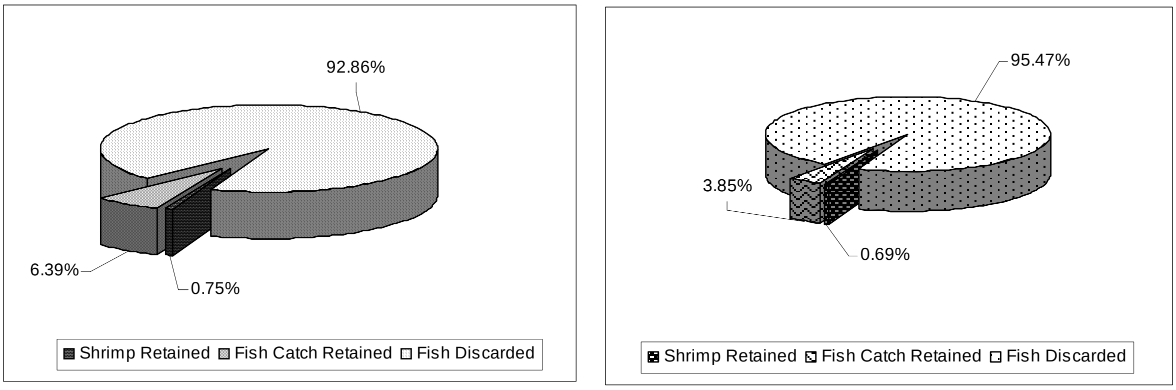

Figure 41. The comparison of catch value between control net and trawl net with fish eye

Considering the comparison of total catch number, the use of fish eye influenced on the decreasing in fish catch number by 13.36%. Partially, the use of fish eye decreased the number of important economic fish with amount of 47.84% and decreased discarded by-catch species by 10.94%. The use of fish eye also decreased the average catch number by 13.215 % per towing.

(3) Comparison of catch value between control net and trawl net with square mesh windows

The catch of control net was 3,456.35 kg consisted of shrimp as main catch and fish as by-catch. The shrimp catch was 6.10 kg (0.18%) from total catch, while number of utilized fish was 200.25 kg (5.79%) and unutilized by-catch was 3,250 kg (94.03%).

The use of square mesh windows influenced on the number of catch. Total catch weight was 3,248.35 kg, composed of shrimp 4.75 kg (0.15% from total catch). While, economic fish that entered into the cod-end was 143.60 kg (4.42%). The total weight of unutilized or as categorized non economic fish reached 3,100 kg (95.43% from the total catch).

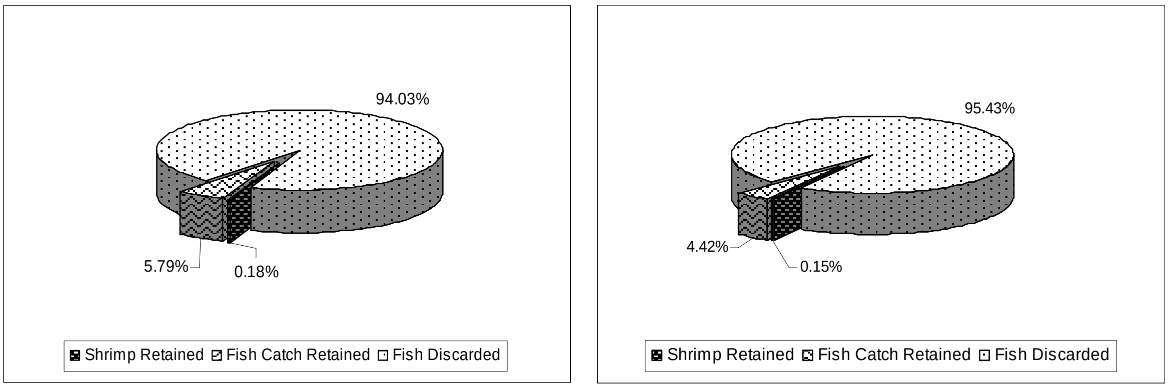

Figure 42. The comparison of catch value between control net and trawl net with square mesh window

According to the data mentioned above, the use of square mesh windows in general could decrease the number of fish caught until 5.99%. Moreover, the number of economic fish was decreased by 28.29%, while for non economic fish was only 4.62% decreasing.

(4) Comparison of catch value between trawl net with standard TED and US-TED

The total catch of trawl net with standard TED was 1,014.45 kg, comprising of shrimp as main catch and fish as the by-catch. The catch of shrimp from the trawl net with standard TED was 4.2 kg (0.41% from total catch). While, total catch of fish was 1,010.25 kg of which the utilized fish was 123.35 kg (12.16%), and discarded fish was 886.9 kg (87.43% from the total catch).

The use of US-TED on trawl net could reduce the total catch. The total catch of trawl net with US-TED was 817.18 kg, comprising of shrimp 4.93 kg (0.6%), utilized fish 93.65 kg (11.46%), and unutilized fish 718.6 kg (87.94% from the total catch).

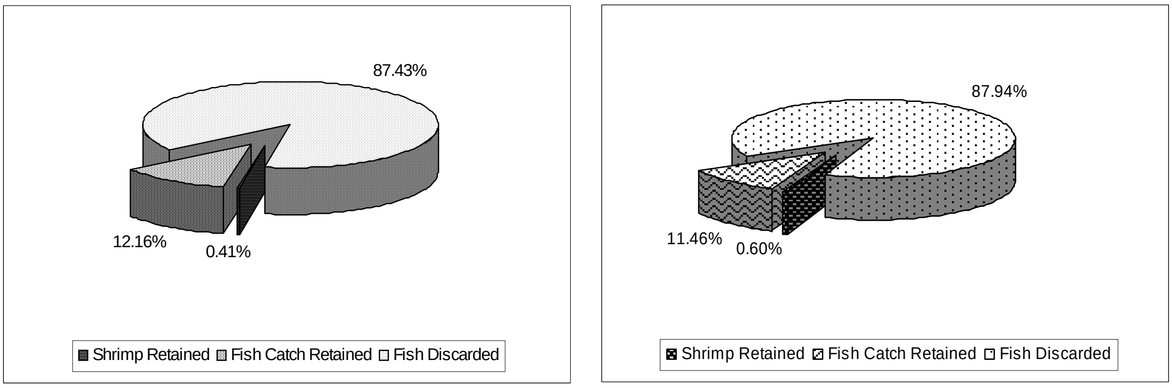

Figure 43. The comparison of catch value between trawl net with standard TED and US-TED

From Figure 43, it can be explained that the use of US-TED could reduce the catch by 198 kg (10.86%) in total, and also the utilized fish decreased by 29.7 kg (13.69%), while non economic fish decreased by 168.3 kg (10.48%).

Overall evaluation on the effectiveness of BRDs tested (US-TED, Square Mesh Window, Fish Eye) to reduce the by-catch can be explained by comparing the by-catch reduction level among the BRDs. The US-TED failed to reduce bycatch, therefore it increased the bycatch up to 4.66% in comparison to the control net. The square mesh window could reduce the by-catch up to 5.98%, and the fish eye reduced the bycatch up to 13.36%. All the BRDs, however, influenced to shrimp lost with the highest percentage occurred on the US-TED, followed by the square mesh window, and the fish eye as shown in Table 11 and Appendix-16 to Appendix-19.

Table 11.

The by-catch reduction and shrimp loss of the BRDs tested compared to the control net

Percent reduction by weight	US-TED	Square Mesh Window	Fish Eye
By-catch reduction	-(4.66)*	5.98	13.36
Shrimp loss	32.29	22.13	21.25

*) The bycatch increase compared to the control net.

4.4 Flume Tank Demonstration

Flume tank demonstration on the performance of three different types of BRDs showed a significant technical performance and escaping behavior of fish. The function of grid in TED super shooter directed for large animals and the unwanted animal to be excluded from the trawl. The grid angle has a strong relationship with grid size and is one of the most critical factors influencing TED efficiency. Typically grid angle is between 45º and 60º (Eayrs 2005). The small-scaled TED super shooter was 57.1^o, suitable for allowing the unwanted animal to escape. From the observation showed that the grid angle was not changed by increasing the water velocity. The grid was constructed with an outer frame to which parallel bars were welded. During the observation some small fish pass through the grid and enter into the codend. The downward excluding grid seemed to be difficult for fish to escape. Moreover, the double flapper also obstructing the fish to escape. This may be caused by the thickness of the double flapper from PE 380 d/6.

4.4.1 Escapement level of fish

Observation on the escapement level of fish for each BRD were carried out by estimating the numbers of fish for both released and retained fish by each BRD. The observation was conducted by different size of fish which categorized into (T, K, S and B) with 3 times replications for each type of BRD. The total of 40 fish was investigated with the same proportion for each type of BRD.

The result of observation in the flume tank showed that the square mesh could release more fish than fish eye and TED with the numbers of fish 17, 15, and 12 individuals, respectively. The escapement level of fish from the square mesh window was 42.5%, fish eye 37.5% and TED 30% from the total of experimental fish. The escapement level data on the flume tank can be seen in Table 9.

The square mesh codend has the higher escapement level compared with the fish eye and TED. This probably due to the different position of the exit hole from each type of BRDs. The square mesh window consists of 24 exit hole with remain opened during the observation that made easily for fish to release. Meanwhile, the fish eye construct only from one ellipse exit hole. This condition make difficult for fish to escape mainly for the fish which visual axis fore-upper. The escapement mechanism of TED super shooter is totally different compared with square mesh and fish eye.

Table 12
The average escapement level of experimental fish from three different type of BRDs

Length	TED			Square mesh			Fish eye		
	Released	**Retained**	**%**	**Released**	**Retained**	**%**	**Released**	**Retained**	**%**
T	2	8	20	3	7	30	2	8	20
K	4	6	40	5	5	50	3	7	30
S	3	7	30	4	6	40	5	5	50
B	3	7	30	5	5	50	5	5	50

Whereas :

T : the total length of fish 0-30 mm, height 0-10 mm and width 0-5 mm
K : the total length of fish 30-50 mm, height 10-15 mm and width 5-7mm
S : the total length of fish 50-65 mm, height 15-20 mm and width 7-12 mm
B : the total length of fish 65-95 mm, height 20-25 mm and width 12-17 mm.

4.4.2 Behavior of the experiment fish

(1) TED super shooter

Fish behavior of experimental fish during escape from the net equipped by three different types of BRDs was observed in the flume tank. Response of fish approaching the TED divided into two categorized involves of response of fish with the width of fish smaller than grid space and response of fish with the width of fish bigger than grid space.

The escapement mechanisms of fish with body width smaller than the grid space divided into : (1) fish passing through the grid and retained in the codend, (2) fish passing through the front part of grid than escape through the exit hole, (3) fish release pass through the exit hole because of a big size of fish blocking the grid, (4) fish blocking onto the grid horizontally or caudal ventral of fish, (5) fish blocking onto the grid then release from exit hole. The escapement process of experimental fish from the TED can be seen in Figure 44.

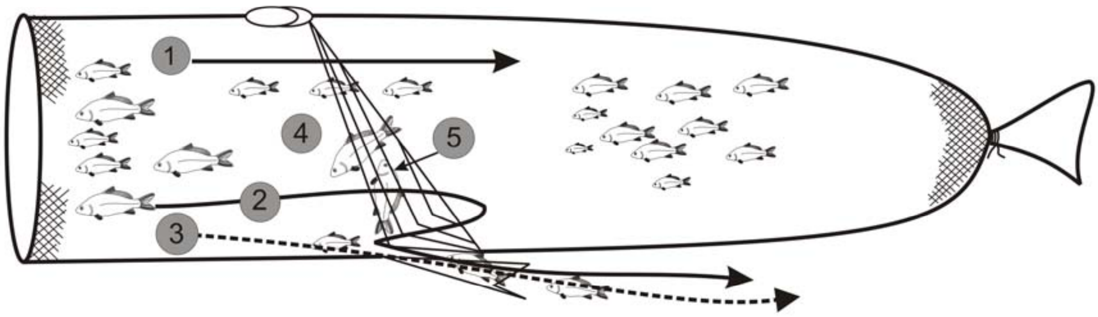

Figure 44. The escapement process of experimental fish from the TED

The group of fish with the body width bigger than the grid space can be categorized into: (1) fish pass through the codend by using the nasal part, (2) fish pass through the codend by using the ventral part then rotate the body 90^0 and push forward by the current and retained in the codend, (3) fish approaching the TED then push forward by the current, and release through the exit hole. The process of fish with the body width bigger than the grid space can be seen in Fugure 45.

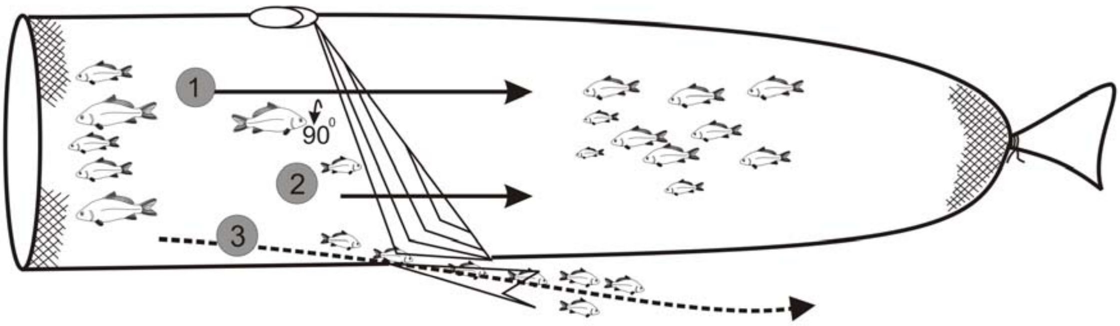

Figure 45. The process of fish with the body width bigger than the grid space

(2) Square mesh window

Response of fish approaching the square mesh to release could be divided into four categorized such as (1) fish release through the exit hole mainly by fishes with the small size (T and K) by swimming vertically without changing position the body against x axis, (2) fish pass through the exit hole from the codend with the escapement angle between $30\text{-}60^0$ against x axis, (3) fish released pass through the square mesh from the front part with the escapement angle between $30\text{-}60^0$ and, (4) fish can not pass through the square mesh because the body width bigger than the square mesh. The escapement process of experimental fish during the observation can be seen in Figure 46.

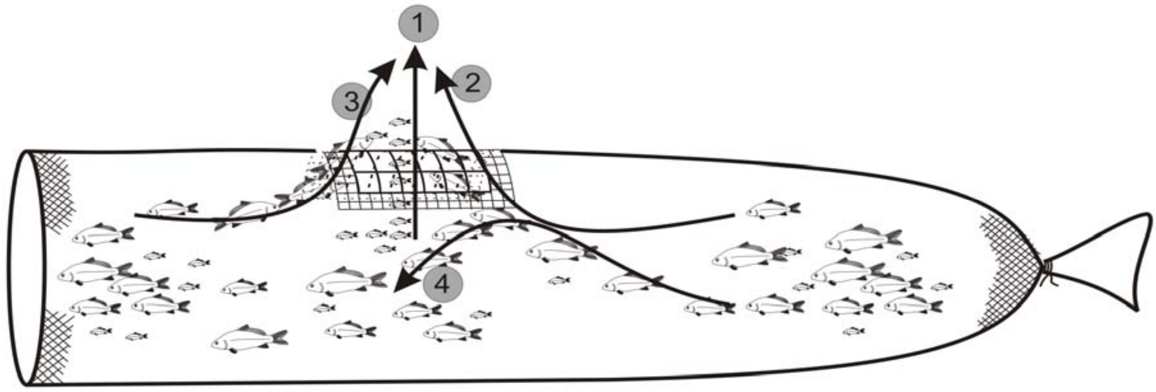

Figure 46. Escapement process of experimetal fish from the square mesh window

(3) Fish eye

The escapement process of fish from the fish eye is relatively similar with the others types of BRDs. The response of fish in the fish eye showed not too much variation compared with TED and square mesh. In the fish eye consisted of two different responses of fish during approaching the exit hole : (1) fish escape through the exit hole from the back part, (2) fish approaching the fish eye then turn around the swimming direction to the bottom part of the fish eye. The escapement process of fish from the fish eye can be seen in Figure 47.

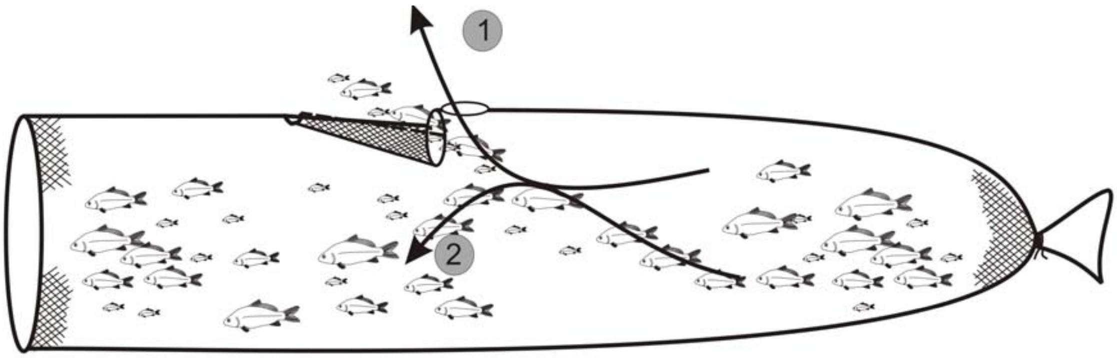

Figure 47. The escapement process of fish from the fish eye

5
DISCUSSIONS

5.1 Technical Performance of BRDs during Fishing Trials

Trawl net equipped with the by-catch reduction device (BRD) here in after referred as shrimp trawl ("pukat udang" in Indonesia language) has been used legally based on the Presidential decree No. 85/1982 that took effect from 24 December 1982. This decree explain that shrimp trawl was permitted to use in the waters of Kei island, Tanimbar, Aru, Irian Jaya, and Arafura sea with geographical coordinate of 130º E to the eastern, except for coastal waters of those islands limiting by 10 m isobath. The first introduced BRD in Indonesia shrimp trawl fishery was by-catch excluder device (BED), a modification of box-shaped US-TED. In line with development of new BRD design and construction in the world, recently the used of BED has been changed with a new type of turtle excluder device (TED) super shooter. Even with the new developed TED super shooter, however, most of the shrimp trawler abuses this law by taking out the device during fishing operation, except for inspection needed only by the government fisheries authority. Concerning this, there are some identified obstacles and problems of TED implementation, such as technically, the use of TED frequently cause fail of the net operation; weakness of monitoring, controlling, and surveillance (MCS) as well as law enforcement (Purbayanto et al. 2004); decrease significantly the catch of shrimp as main target species (Evans and Wahju 1996; Nasution 1997; DJPT-DKP, 2005).

The explanation mentioned above can be the reason why technical performance of US-TED during fishing trials was not good compared to square mesh window and fish eye as shown in Table 10. The low technical performance of the US-TED is due to low scores in easiness setting and hauling, and acceptability by the fishers. Beside that, US-TED has a similar design and construction with standard TED recently used by Indonesian shrimp trawler in Arafura sea. The different was on material used which was aluminum pipe for US-TED and massive iron for standard TED. The lighter US-TED gave a little bit simple in handling compared to the standard TED. While, the square mesh window and fish eye showed similar good technical performance due to their high scores in mostly valuation criteria.

5.2 Catch Composition of Trawl Net without and with BRDs

Demersal marine fish resource inhabiting near coastal water have a high diversity compared to pelagic fish resource (Mahiswara 2004). The biodiversity of marine resource can be a determinant factor of catch composition of the shrimp trawl. It can be clarified from the catch composition of the trawl that is not only caught shrimp as a target species but also fish as by-catch. Instead of the biodiversity of marine resource, the operation method of trawl which is swept and towed over the sea bottom also supports this condition.

The number of fish and crustacean caught in the codend can be an indication of diversity of the marine resource in sampling sites. The total number of species identified consisted of 45 species of fish, 2 species of shrimp and some species of crab. From 45 species of fish, 21 species included economic species and highly price fish that can be utilized for income generating to the fishermen instead of the main catch.

5.2.1 Trawl without and with TED

Implementation of BRD namely TED super shooter have no significant effect to the composition of the total catch. This can be shown from the number of species caught from the trawl net without BRD (control net) in comparison to the trawl net with TED super shooter. The objective of installing the TED is to reduce the unwanted catch. However, the result of this research showed that the total catch of the trawl net with TED was higher than the total catch of the control net. The 36 species was caught in the trawl net with US-TED consisted of 23 species of utilized fish and 13 species of fish categorized as economic fish. Meanwhile, the 41 species fish was caught from the control net comprised of 25 species of discarded non-economic fish and 16 species of economic retained fish.

This is probably due to the construction of TED super shooter was designed to release turtle and other large animal. So the TED super shooter was not effective to release the small fish with body girth smaller than the grid space used. Escaping mechanism of fish from the TED occurred for fish with high swimming ability and the ability to escape was from the bottom part of the TED. Moreover, for the fish with the body girth was bigger than the grid space, they may hit the grid then sustained swim for a while to escape from the exit hole.

For the small fish with low swimming ability, they will swim passively into the codend. Even though, installment of the TED on trawl net has an effect in reducing a certain species of fish and the total weight of economic fish caught. The three species were reduced in term of total weight such as *Formio niger*, *Trichiurus lepturus*, and *Loligo* spp.

5.2.2 Trawl without and with square mesh window

The mechanism of square mesh windows are directed to fish with fore-upper visual orientation to escape from the square mesh window. The square mesh windows in the trawl net have no significant effect to the composition of fish caught. The 41 species of fish were caught from the control net consisted of 25 species of discarded and 16 species of retained fish. Meanwhile, in the trawl net with square mesh windows the numbers of species caught were 43 species consisted of 27 species of discarded and 16 species retained fish.

The square mesh window installed in the upper part of the codend may give possibility for fish with good swimming and resistant against the current to escape from the codend during towing. Some species of fish caught involved demersal fish of low swimming ability, so they could not escape through the square mesh windows on upper part of the codend. Even though, the square mesh windows showed that some retained fish species were decreased in term of the total weight such as *Cynoglossus* spp, *Carangoides* spp, and *Otolites* spp.

5.2.3 Trawl without and with fish eye

The fish eye that installed in trawl net has an affect to the number of species caught. The numbers of species caught were 38 species which consisted of 25 species of fish discarded and 13 species of fish retained. Meanwhile, the install of fish eye have an affect to the numbers of species caught. The 31 of species were caught from the trawl net with fish eye, which consisted of 20 species of fish discarded and 11 species of fish retained.

The escape mechanisms of fish are relatively similar with the square mesh window. For both BRD are depended upon the swimming ability of fish to escape from the exit hole. The fish eye constructs only a single hole. During towing, the water flow will open the codend and in the same time the fish eye also opened. In that time the fish with high swimming ability escape through the exit hole. The position of fish eye may influence to the numbers of fish released.

Referrring to the numbers of species of fish being released was higher than the TED and the square mesh windows. The fish eye was reduced 7 species of fish such as *Thryssa* *setrirostris, Harpadon nehereus, Johnius* spp*, Alepes melanoptera, Formio niger, Euristhmus lepturus* and *Triachantus* spp.

5.3 Effectiveness of BRDs in Reducing By-catch

In general, most of capture fisheries contributes the by-catch, some fisheries especially shrimp trawl, however contribute a large quantity of the by-catch compare to other fisheries. This condition is due to that the shrimp trawl categorized as more effective gear for capturing shrimp as well as demersal fish. From the construction aspect, shrimp trawl has a codend with relatively small mesh size so that many other marine organism of various size are caught as the by-catch.

The dominant by-catch of shrimp trawl is mostly demersal fish species of high economic value. A high by-catch number can be influenced by factor of population number of each fish species caught. Beside that, the fishing operation is conducted by sweeping and dragging the net over sea bottom that cause many shrimp and also demersal fish species are caught. This demersal fish inhabit sea bottom area together with penaeid shrimp in one ecosystem due to their interaction on food web (Riyanto 2005).

Problems occurred on trawl fisheries are due to many by-catch discarded to the sea. To reduce these by-catch, the trawl net equipped with By-catch Reduction Device (BRD) so that to increase it's selectivity performance. From the research reported by Chokesanguan et al. (1996) in Thailand and Renaud et al. (1993) in USA showed that the use of BRD could significantly reduce the by-catch volume. The use of TED super shooter type could reduce 40% by-catch, but loss of shrimp as main target catch reached 30% (Nasution 1977).

From the fishing trials that have been successfully done in the water around in Dolak Isaland, Arafura Sea showed that the use of BRD could reduce the catch species composition especially for pelagic fish species such as *Carangoides*. This species has a better swimming ability than demersal fish species of small sized fish. The BRD construction has been made to give high probability of by-catch for escaping due to the occurrence of current mechanism or collision to grids (Mahiswara 2004). Moreover, Day (1996) in his research revealed that during operation there are current turbulence inside the trawl net, further being directed to grids frame. This condition support large sized fish and fish with high swimming speed to escape through opening window. While, small fish with low swimming speed are drifted by current to enter into the codend part.

From the observation during research showed that there is some other factors influence by-catch number that escaped from trawl, namely grids covering (masking effect). The grids covering are mainly due to sea bottom trash/garbage or big sized fish. This condition can not be avoided by the trawl because shrimp as target species inhabit in the sea bottom habitat associated with other demersal fish species.

The catch during fishing trials gave figure on high diversity of fish species caught by the trawl, which was 45 species could be identified. Factor of position and water depth station for fishing operation supposed to influence the number, kind, and size of catch. On the shrimp trawl fishery, some factors such as shape and size of mesh, codend diameter, hanging ratio, fish availability, water condition, speed and duration of towing can be influenced to the by-catch number. During fishing operation, the shape and size of mesh of the trawl net will change, for instant the mesh of net will close when towing process. The mesh opening as the influence of given hanging ratio value will be changed in shape due to towing and weighing effect on the codend part. Beside the mesh opening, other factor that also give influence to the by-catch is a blocking effect on the codend part due to catch inside the codend part (Ferno and Olsen 1994).

Comparison between shrimp and fish catch is a fishing ratio. This ratio is the comparison between shrimp caught and by-catch in every hauling. Based on the analysis result from 26 hauls, it can be estimated that the fishing ratio of retained shrimp, retained fish, and discarded fish between the control net and trawl net with US-TED was 1:13:86, the control net and trawl net with square mesh window was 1:4:95, and the control net and trawl net with fish eye was 1:4:95. The high comparison value between shrimp and by-catch can be due to some following factors (Purbayanto and Riyanto 2005);

(1) Shrimp trawl has an active character, that is to catch fish by towing the net so that many non target fish also caught,
(2) Fishing operation is conducted in shallow water of 10-35 m depth, it means that mouth opening of shrimp trawl net is able to sweep most of waters column, indicated by pelagic fish caught.
(3) Shallow water is a habitat of fish for feeding, spawning, and nursery activities, so that many young and small fish to be caught.
(4) The bottom of Arafura sea to have a flat surface condition because of continental shelf and muddy bottom substrate that is a habitat for demersal fish species, and
(5) Fishing operation of shrimp is generally not implemented the use of By-catch Reduction Device (BRD) especially Turtle Excluder Device as the government regulation, so that many non target fish become caught.

There are no decreasing in total catch number on trawl without BRDs (control net) and trawl with US-TED. This condition due to the construction of TED with bigger grids will effective only for turtle and big sized fish for being able to escape from the trawl, while small fish still enter into the codend.

Decreasing in total catch occurred on the trawl with fish eye against the control net by 350.30 kg (13.36%), the trawl with square mesh window against the control net by 206.65 kg (5.99%). This condition supposed that the construction of fish eye having enough bigger the escape hole so that giving the possibility for fish with good visual acuity and swimming ability to escape through the escape hole. While, during towing process, the mesh of square mesh window still kept opening so that the swimmer fish with size less than the square mesh opening can escape from the codend side.

6
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

1. The square mesh window and fish eye showed similar good technical performance as indicated by high scores of three observation indicators i.e., the easiness setting of BRD into the codend, easiness hauling the net, and acceptability by the fishers in comparison with the US-TED. The US-TED has better technical performance compared to the standard TED, particularly from the view point of material used that give a little bit simple in handling compared to the standard TED.

2. The total number of species identified during sea trials of 26 successful hauls consisted of 45 species of fish, 2 species of shrimp, and some species of crabs. From those species of fish, 21 species categorized as the economic fish that were utilized by the fishers.

3. The fish eye has high effectiveness in reducing bycatch up to 13.36%, and then followed by square mesh window (reduced the bycatch up to 5.98%). The US-TED, however, failed to reduce the bycatch (conversely increased the bycatch by 4.66%). All the BRDs used influenced on the shrimp loss i.e., 21.25% for the fish eye, 22.13% for the square mesh window, and 32.29% for the US-TED.

4. Flume tank observation from the three different types of BRDs showed a significant technical performance and escaping behavior of fish. The highest escapement of fish was from square mesh window. Whilst the TED super shooter and fish eye have low escapes. The position of fish eye and exit hole of the TED super shooter has an effect to the escapement process. The TED grid angle of 57.1º was suitable for allowing the unwanted animal to escape.

6.2 Recommendation

Based upon the result of the study it can be recommended that three different BRDs can be implemented. Although we need further study to increase the effectiveness of the square mesh and fish eye mainly to decide the appropriate position of those BRDs on the codend for optimum function of the BRDs to reduce the bycatch. Further research need to be conducted in long duration of fishing trials that representing the fishing season.

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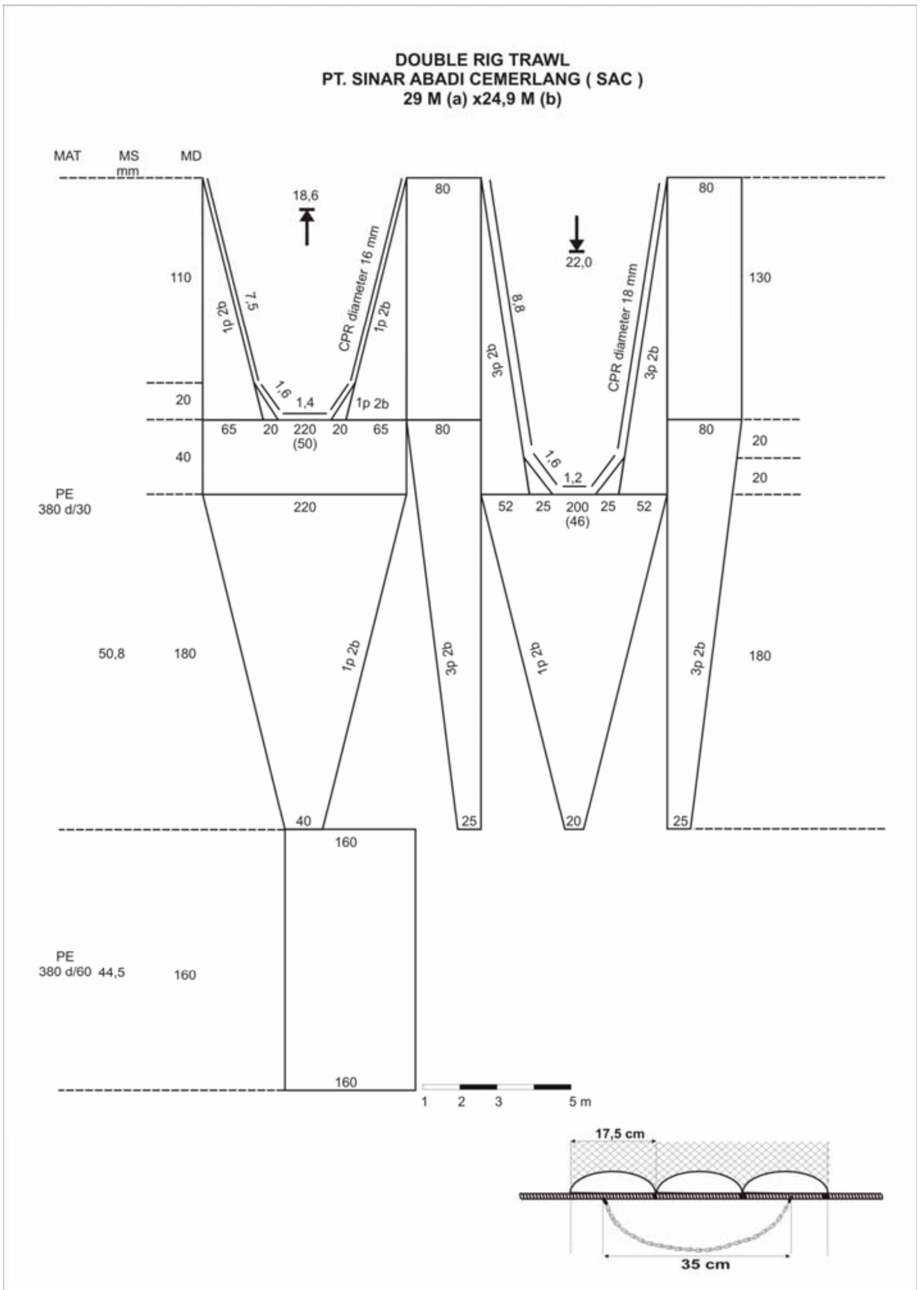
APPENDICES

Appendix-1. Fishing unit specification used during sea trials

Vessel Name:	KM Laut Arafura		Date start: 01/12/ 2007		Date end : 08/12/2007	
Vessel Identification Number	1990 MMa NO. 303/N		Number of tows completed	32	Vessel HP	402 HP
Vessel Length (m)	24.95 x 7.7 x 3.4					
Commercial fishing vessel	Y	N	Type of trawl arrangement used		Single trawl	
	√				Double rig trawl	√
Net type	Semi ballon		Headrope (m)	18	Quad rig trawl	
Mesh size in trawl	2 inch		Mesh size in codend	1 3/4 inch	Ground rope length (m)	21.5
Chafing gear:			Length of codend (meshes)	160	Codend material (PE or PA)	PE
Pendant rope length	Upper 7 m Lower 7.30 m		Otter board (LxH) m	250 x 125	Circumference of codend (meshes)	520
Towing Speed (knots)	2.5 – 3.3		Water depth range	8 - 48	Otter board weight (kg) in air	600
Name of fishing ground	Dolak Island waters, Arafura Sea		Approx. Latitude	S 7°01’		
			Approx. Longitude	E 137°20’		

Appendix-2. Design of double rig shrimp trawl net used in fishing trials



Appendix-3. BRDs (US-TED, square mesh window, fish eye) construction

Name of BRD in local language	Alat penyaring ikan (API)	Mata jaring segi empat	Mata ikan
Name of BRD in English	TED Super shooter	Square mesh window	Fish eye
Primary material used to construct fish BRD	Aluminum steel	Knotless (raschel net)	Aluminum steel
Describe the overall dimensions of the BRD	120 x 91 cm Type : oval Grids : 4 inch	Bar : 3 inch Outer : 2½ inch	Length 60 cm, Height 20 cm Opening fish eye 55 cm

Diagram showing location of US-TED in trawl

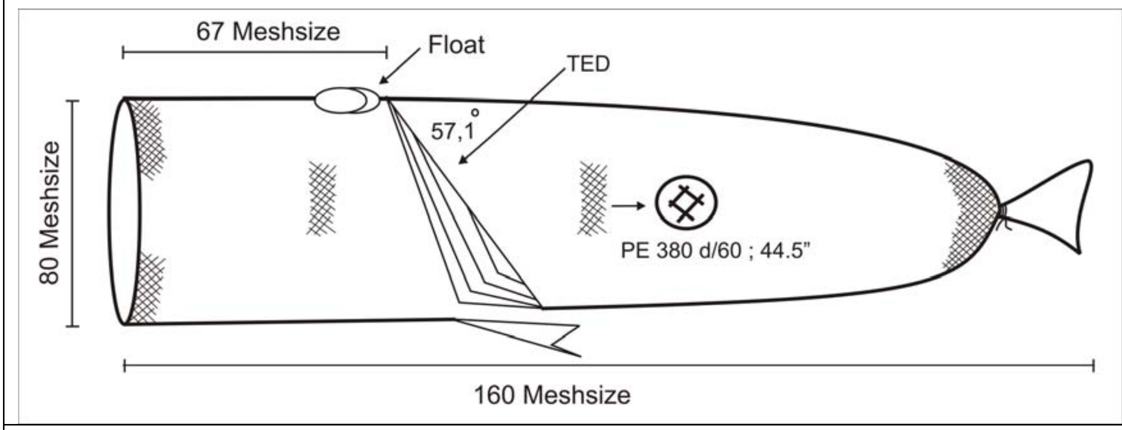
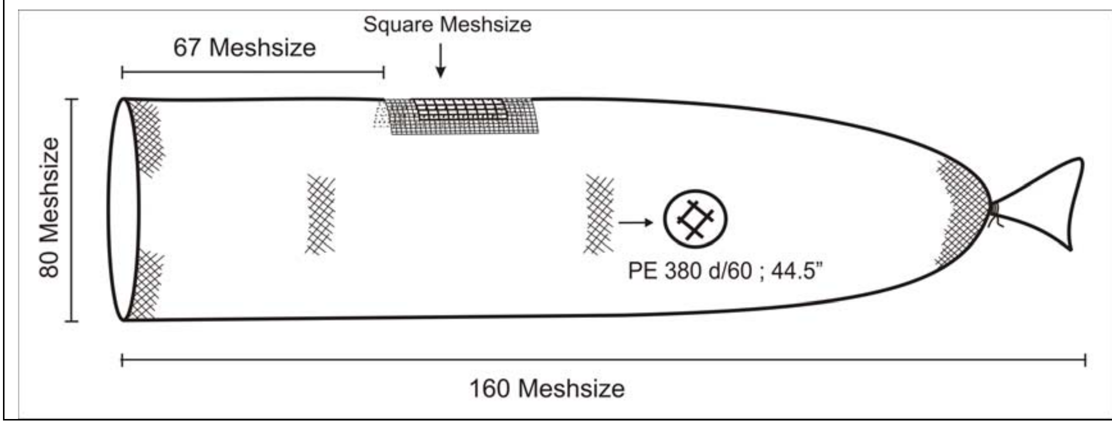
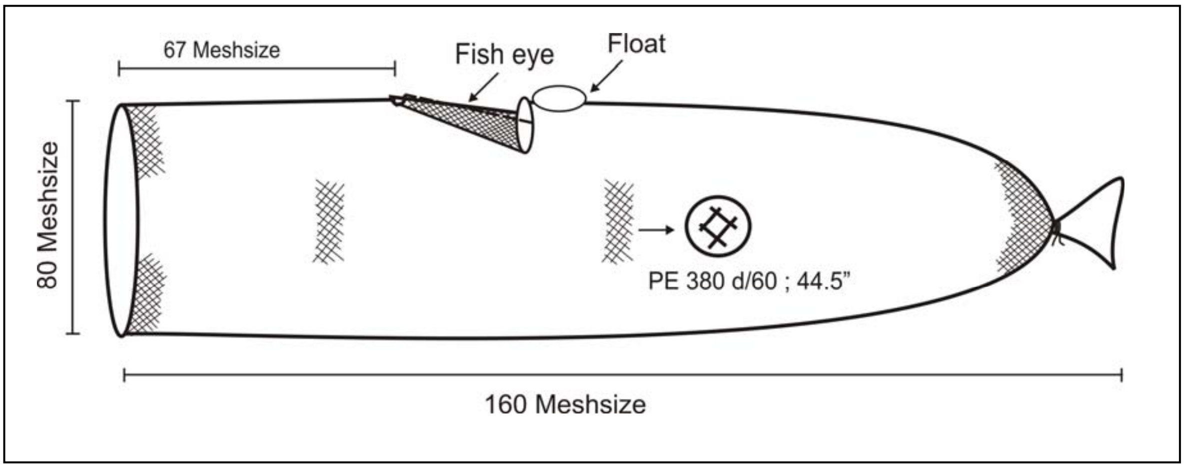


Diagram showing location of Square Mesh Window in trawl

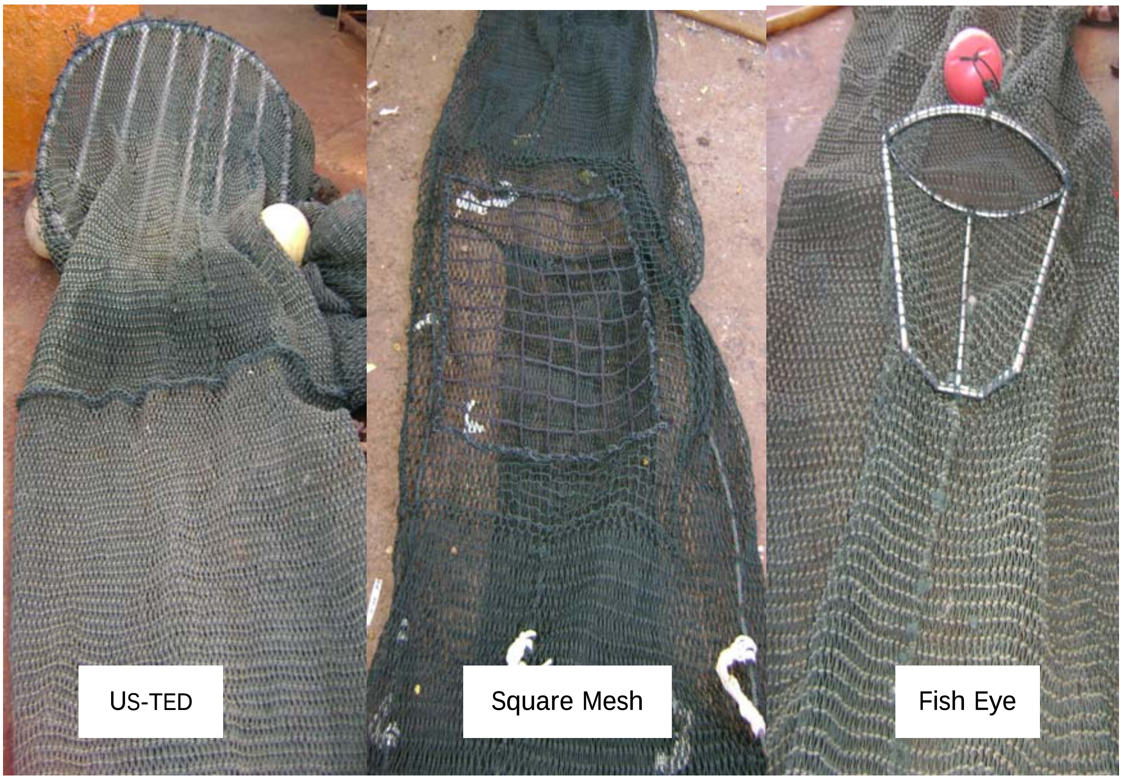


Appendix-3. (continued)

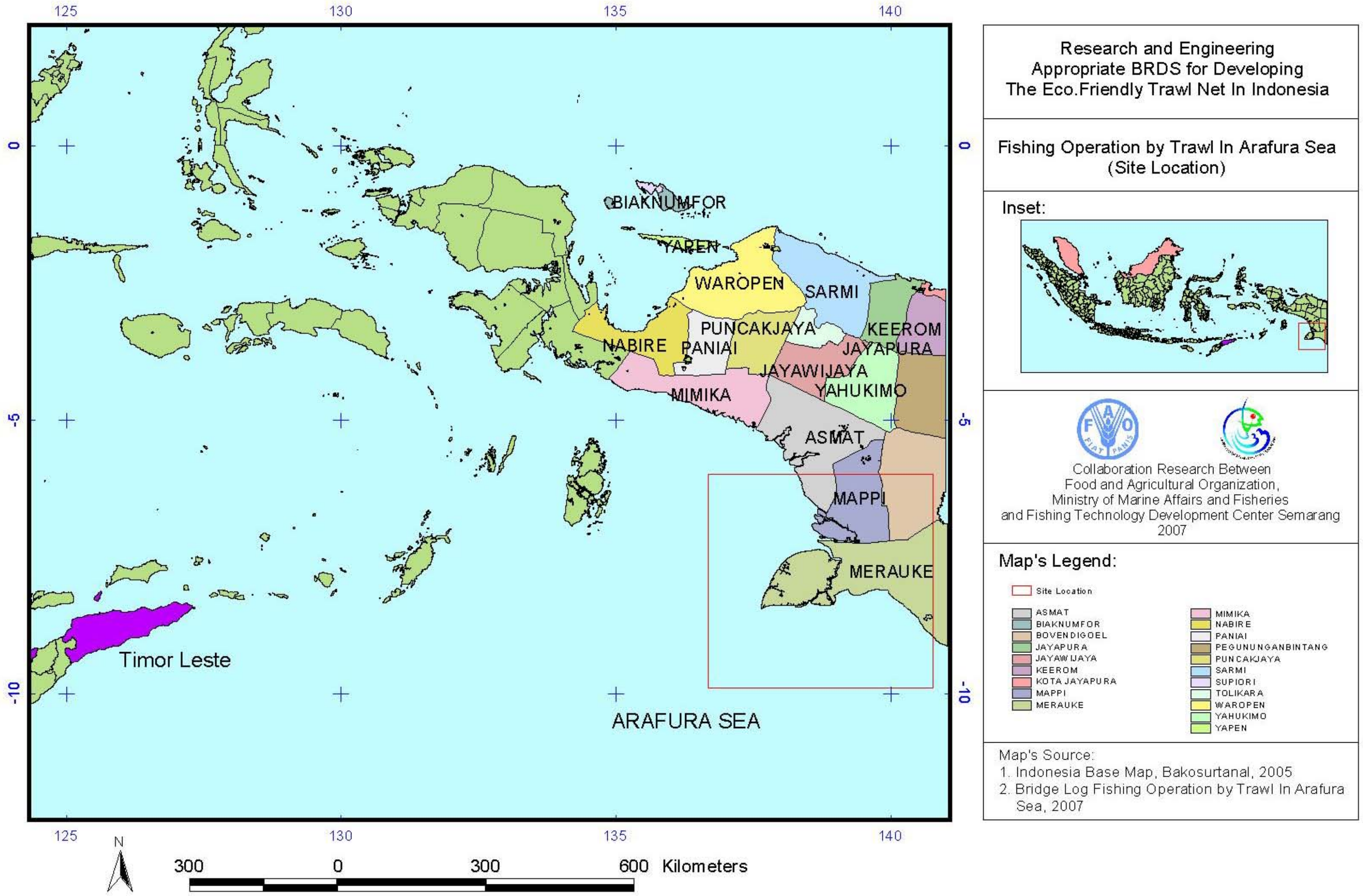


Appendix-4. Vessel (MV. Laut Arafura) used during sea trials

Appendix-5. The BRDs (US-TED, square mesh window, and fish eye) set in the codend



Appendix-6. Fishing ground in Arafura sea



Appendix-7. Bridge Log Fishing Operation by Trawl in Arafura Sea

Date	Station	Time			Setting position		Haulling position		Warp	Deepth	Speed	Weather	Information
		Setting	Haulling	Towing Duration (h)	Latitude	Longitude	Latitude	Longitude					
TED Amerika													
12/2/2007	1	05.15	7.15	2.00	08º38'069"	138º28'244"	08º37'750"	138º26'243"	150	27	2.5	C	sampling
	2	07.30	9.45	2.15	08º37'353"	138º26'475"	08º35'861"	138º23'505"	110	16	3	C	sampling
	3	10.00	12.4	2.40	08º35'701"	138º23'443"	08º34'310"	138º30'900"	100	10	3.1	C	sampling
	4	12.30	14.3	2.00	08º34'302"	138º31'019"	08º32'364"	138º36'832"	80	8.8	3.3	C	sampling
	5	15.30	16.45	1.15	08º32'134"	138º40'660"	08º32'483"	138º45'295"	80	9.1	3.5	C	sampling
TED													
12/4/2007	1	09.15	10.20	1.05	08º43'104"	138º23'600"	08º43'900"	138º20'360"	195	47.9	3.5	C	sampling
	2	21.00	22.10	1.10	08º08'195"	137º25'104"	08º04'902"	137º27'080"	80	8.9	3.2	C	sampling
12/5/2007	3	23.20	00.30	1.10	07º58'942"	137º28'731"	07º56'237"	137º29'810"	100	11.2	2.6	C	sampling
	4	02.30	03.40	1.10	07º45'525"	137º29'081"	07º42'691"	137º29'272"	100	13.8	2.6	B	Not sampling
	5	03.50	05.15	2.05	07º42'263"	137º29'430"	07º40'776"	137º32'724"	110	14.1	2.7	B	Not sampling
	6	05.25	06.50	1.25	07º40'746"	137º33'746"	07º39'804"	137º36'406"	110	15	2.6	B	sampling
	7	07.10	08.30	1.20	07º38'907"	137º35'581"	07º37'533"	137º34'019"	110	15	2.8	C	sampling
	8	11.40	13.40	2.00	07º29'054"	137º52'310"	07º28'403"	137º57'838"	110	14	2.8	C	sampling
FISH EYE													
12/5/2007	1	14.25	16.30	2.05	07º27'613"	137º59'597"	07º25'829"	138º01'063"	110	14	3.1	C	sampling
	2	16.40	18.30	2.30	07º26'350"	138º00'530"	07º29'610"	137º57'747"	110	15	2.6	C	sampling
	3	18.45	20.45	2.00	07º29'000"	137º57'110"	07º25'910"	137º59'662"	110	14	2.5	C	sampling
	4	21.15	23.15	2.00	07º24'895"	138º02'051"	07º22'148"	138º07'555"	110	15	3	C	sampling
12/6/2007	5	00.30	02.30	2.00	07º15'273"	138º09'715"	07º09'962"	138º10'028"	125	19.3	2.7	C	sampling
	6	02.40	04.30	2.30	07º09'211"	138º10'068"	07º04'704"	138º10'427"	125	19.5	2.8	C	Not sampling
	7	04.45	06.25	2.20	07º04'217"	138º10'933"	07º02'783"	138º11'270"	125	21.7	2.7	C	sampling
	8	07.00	08.30	1.30	07º03'359"	138º07'812"	07º06'050"	138º02'802"	130	22	3.1	C	sampling

Appendix-7. (continued)

Date	Station	Time			Setting position		Haulling position		Warp	Deepth	Speed	Weather	Information
		Setting	Haulling	Towing Duration (h)	Latitude	Longitude	Latitude	Longitude					
SQUARE MESH													
12/6/2007	1	09.10	10.55	1.45	07º06'569"	138º01'725"	07º10'395"	137º56'905"	130	21	3.2	C	sampling
	2	11.15	13.00	2.25	07º11'078"	137º56'138"	07º16'080"	137º53'355"	130	20	2.8	C	sampling
	3	13.10	14.50	1.40	07º16'588"	137º53'043"	07º20'848"	137º50'227"	125	18	3.1	C	sampling
	4	15.35	17.30	2.35	07º25'269"	137º41'778"	07º29'068"	137º45'639"	110	15.8	2.5	H	sampling
	5	18.40	20.35	2.35	07º34'675"	137º42'708"	07º39'048"	137º41'195"	110	16	2.4	C	sampling
12/7/2007	6	23.45	00.35	0.55	07º52'366"	137º21'972"	07º58'340"	137º26'635"	110	14.5	3.1	C	Not sampling
	7	01.50	04.05	2.55	07º59'271"	137º20'421"	07º02'182"	137º22'319"	110	15.4	3.3	C	Not sampling
	8	04.15	06.10	2.35	07º01'533"	137º21'430"	07º00'065"	137º20'638"	110	14.9	2.5	C	sampling
	9	07.30	09.15	2.25	08º07'883"	137º25'188"	08º11'900"	137º26'137"	80	10	3.5	C	sampling
	10	09.45	11.00	1.55	08º12'175"	137º26'695"	08º14'050"	137º27'080"	75	6	2.3	C	sampling
	11	16.15	18.15	2.00	08º40'057"	137º31'980"	08º41'769"	137º36'312"	150	26	2.5	C	Not sampling

Appendix-8. Catch sampling composition of control net and trawl net with TED on December 4-5, 2007

No.	Indonesian Name	Scientific Name	Control Net		Trawl Net with TED	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Beloso	*Saurida* spp	0.525	0.90	0.95	1.52
2.	Bulu ayam	*Setipinna* spp	0	0.00	0	0.00
3.	Bulu ayam	*Thryssa setirostis*	2.75	4.69	1.9	3.03
4.	Carangid	*Urapsis urapsis*	0	0.00	0.275	0.44
5.	Crab	-	0.275	0.47	16.1	25.69
6.	Cumi	*Loligo* spp	10.85	18.52	0.25	0.40
7.	Gerot-gerot	*Pomadasys maculatus*	2.2	3.75	0.1	0.16
8.	Japuh	*Dussumieria acuta*	0	0.00	0.025	0.04
9.	Kembung	*Rastrelliger kanagurta*	0.25	0.43	0	0.00
10.	Kerong	*Terapon theraps*	8.95	15.27	12	19.15
11.	Kuniran	*Upenus sulphureus*	0.65	1.11	0.2	0.32
12.	Kurisi	*Nemipterus nematophorus*	0.15	0.26	0.25	0.40
13.	Kuro	*Polydactillus* spp	3.525	6.02	2.425	3.87
14.	Layur	*Trichiurus lepturus*	5.4	9.22	5.45	8.70
15.	Lidah	*Cynoglosus* spp	1.7	2.90	1.2	1.91
16.	Manyung	*Arius maculathus*	3	5.12	2.2	3.51
17.	Mata Besar	*Priacanthus maculatus*	0.25	0.43	0.625	1.00
18.	Nomei	*Harpadon* spp	0.85	1.45	0.95	1.52
19.	Pari	*Dasyatis kuhlli*	2.925	4.99	1.6	2.55
20.	Petek	*Leiognathus* spp	0.4	0.68	1.075	1.72
21.	Selar	*Alepes melanoptera*	0.7	1.19	0.7	1.12
22.	Selar	*Carangoides* spp	1.55	2.65	3.2	5.11
23.	Sembilang	*Eurithalmus lepturus*	0	0.00	0	0.00
24.	Slengseng	*Megalaspis cordila*	0	0.00	0	0.00
25.	Tembang	*Illisa melastoma*	0	0.00	0.025	0.04
26.	Tiga waja	*Johnius* spp	4.9	8.36	4.375	6.98
27.	-	*Herklotsichtis* spp	1.8	3.07	1.4	2.23
28.	-	*Pellona ditchela*	4	6.83	3.9	6.22
29.	-	*Platycephalus* spp	0	0.00	0	0.00
30.	-	*Polynemus* spp	1	1.71	1.5	2.39
Total fish sampling			58.6		62.675	

Appendix-9. Catch sampling composition of economically species from control net and trawl net with TED on December 4-5, 2007

No.	Indonesian Name	Scientific Name	Control Net		Trawl Net with TED	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Bawal hitam	*Formio niger*	43.95	16.80	29.6	14.46
2.	Carangides	*Urapsis urapsis*	0	0.00	12.65	6.18
3.	Cucut	*Carcharinus* spp	0	0.00	2.7	1.32
4.	Kerapu	*Ephinephelus* spp	0	0.00	0	0.00
5.	Kue	*Caranx iqnobilis*	8.55	3.27	9.35	4.57
6.	Kuro	*Polidactilus* spp	4.35	1.66	3.35	1.64
7.	Layang	*Decapterus ruselli*	2.9	1.11	8	3.91
8.	Layur	*Trichiurus lepturus*	133.6	51.06	84.75	41.40
9.	Lidah	*Cynoglosus* spp	7	2.68	4.8	2.34
10.	Mata besar	*Priacanthus macracantus*	6	2.29	4	1.95
11.	Parang-parang	*Rachicentron canadus*	0	0.00	0	0.00
12.	Remang	*Muraenesox bagio*	1.5	0.57	0	0.00
13.	Sebelah	*Psettodes erumei*	19.1	7.30	12.25	5.98
14.	Selar	*Alepes melanoptera*	0.9	0.34	0.45	0.22
15	Selar	*Carangoides* spp	11.85	4.53	11.5	4.15
16.	Slengseng	*Megalaspis cordila*	0	0.00	0	0.00
17.	Tenggiri	*Scomberomorus commersoni*	0	0.00	1.25	0.61
18.	Tiga waja	*Otolites* spp	21.95	8.39	19.65	9.60
		Platycepalus	0	0.00	0.4	0.20
Total fish catch			261.65		204.7	

Appendix-10. Catch sampling composition of control net and trawl net with square mesh windows on December 6-7, 2007

No.	Indonesian Name	Scientific Name	Control Net		Trawl Net with Square Mesh Windows	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Beloso	*Saurida* spp	0.1	0.14	0.31	0.39
2.	Bulu ayam	*Setipinna* spp	9.45	13.19	7	8.83
3.	Bulu ayam	*Thryssa setrirostris*	0.29	0.40	0.65	0.82
4.	Buntal	*Diodon* spp	0	0.00	1	1.26
5.	Carangid	*Urapsis urapsis*	2.2	3.07	0.1	0.13
6.	Crab		25.4	35.45	45.5	57.37
7.	Gerot-gerot	*Pomadasys maculatus*	1.125	1.57	0.425	0.54
8.	Kembung	*Rastrelliger kanagurta*	0	0.00	0	0.00
9.	Kerong	*Terapon theraps*	0.125	0.17	0.05	0.06
10.	Kuniran	*Terapon theraps*	0.875	1.22	0.05	0.06
11.	Kuro	*Polydactillus* spp	0.925	1.29	0.675	0.85
12.	Layur	*Trichiurus lepturus*	3.9	5.44	3.55	4.48
13.	Lidah	*Cynoglosus* spp	1.915	2.67	1.26	1.59
14.	Manyung	*Arius maculathus*	2.65	3.70	2.25	2.84
15.	Mata Besar	*Priacanthus maculatus*	0.05	0.07	1.025	1.29
16.	Nomei	*Harpadon nehereus*	0.1	0.14	0.25	0.32
17.	Pari	*Dasyatis kuhlli*	0.35	0.49	0.86	1.08
18.	Petek	*Leiognathus* spp	0.6	0.84	0.275	0.35
19.	Selar	*Alepes melanoptera*	0.4	0.56	0.4	0.50
20.	Selar	*Carangoides* spp	2.075	2.90	2.745	3.46
21.	Sembilang	*Euristhmus lepturus*	0	0.00	0.2	0.25
22.	Slengseng	*Megalaspis cordila*	1.575	2.20	0.85	1.07
23.	Tembang	*Illisa melastoma*	2.68	3.74	1.225	1.54
24.	Tiga waja	*Johnius* spp	4.7	6.56	4.175	5.26
25.		*Herklotsichtis* spp	0.36	0.50	0.125	0.16
26.		*Pellona ditchela*	9	12.56	3.9	4.92
27.		*Platycephalus* spp	0.05	0.07	0.06	0.08
28.		*Polinemus* spp	0.75	1.05	0.4	0.50
Total Sampling			71.645		79.31	

Appendix-11. Catch sampling composition of economically species from control net and trawl net with square mesh windows on December 6-7, 2007

No.	Indonesian Name	Scientific Name	Control Net		Trawl Net with Square Mesh Windows	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Bawal hitam	*Formio niger*	0.6	0.30	1.35	0.94
2.	Carangid	*Urapsis urapsis*	4	2.00	4.85	3.38
3.	Cucut	*Carcharinus* spp	3.8	1.90	0.7	0.49
4.	Kaakan	*Pomadasys* spp	0	0.00	0.25	0.17
5.	Kerapu	*Ephinephelus* spp	1.25	0.62	1.75	1.22
6.	Kuro	*Platycepalus* spp	10.15	5.07	11.7	8.15
7.	Layur	*Trichiurus lepturus*	33.6	16.78	27	18.80
8.	Lidah	*Cynoglosus* spp	40.9	20.42	17.4	12.12
9.	Mata besar	*Priacanthus macracantus*	0.575	0.29	0.85	0.59
10.	Parang-parang	*Rachicentron canadus*	0.35	0.17	0	0.00
11.	Remang	*Muraenesox bagio*	0.95	0.47	0.2	0.14
12.	Selar	*Alepes melanoptera*	3.175	1.59	19.4	13.51
13.	Selar	*Carangoides* spp	22.25	11.11	2	1.39
14.	Slengseng	*Megalaspis cordila*	7.9	3.95	10.55	7.35
15.	Tenggiri	*Scomberomorus commersoni*	0.5	0.25	1.25	0.87
16.	Tiga waja	*Otolites* spp	68.75	34.33	44.1	30.71
17.		*Platycepalus* spp	1.5	0.75	0.25	0.17
Total fish catch			200.25		143.6	

Appendix-12. Catch sampling composition of control net and trawl net with fish eye on December 5-6, 2007

No.	Indonesian Name	Scientific Name	Control Net		Trawl Net with Fish Eye	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Bawal hitam	*Formio niger*	2.85	3.12	0.55	0.80
2.	Beloso	*Saurida* spp	0.55	0.60	1.5	2.17
3.	Bulu ayam	*Thryssa mistax*	0.35	0.38	0.05	0.07
4.	Bulu ayam	*Setipinna* spp	0.45	0.49	5.65	8.19
5.	Bulu ayam	*Thryssa setrirostris*	8.25	9.03	0	0.00
6.	Carangid	*Urapsis urapsis*	0.075	0.08	35.65	51.67
7.	Crab		49	53.62	2.95	4.28
8.	Gerot-gerot	*Pomadasys maculatus*	3.05	3.34	0.05	0.07
9.	Kembung	*Rastrelliger kanagurta*	0.05	0.05	1.3	1.88
10.	Kerong	*Terapon theraps*	2.725	2.98	0.25	0.36
11.	Kuniran	*Upenus sulphureus*	0.45	0.49	2.15	3.12
12.	Kuro	*Polidactilus* spp	0.6	0.66	0.2	0.29
13.	Layur	*Trichiurus lepturus*	2.45	2.68	0.675	0.98
14.	Lidah	*Cynoglosus* spp	0.6	0.66	0	0.00
15.	Manyung	*Arius maculathus*	1.1	1.20	8.3	12.03
16.	Nomei	*Harpadon nehereus*	1.1	1.20	0	0.00
17.	Pari	*Dasyatis kuhlli*	0.7	0.77	1.7	2.46
18.	Petek	*Leiognathus* spp	0.125	0.14	0.55	0.80
19.	Selar	*Carangoides* spp	0.325	0.36	0	0.00
20.	Sembilang	*Euristhmus lepturus*	0.7	0.77	0	0.00
21.	Slengseng	*Megalaspis cordila*	0.3	0.33	0.05	0.07
22.	Srinding	*Apogon* spp	0	0.00	2.5	3.62
23.	Tembang	*Illisa melastoma*	4.035	4.42	4.625	6.70
24.	Tiga waja	*Johnius* spp	6.55	7.17	0.00	0.00
25.		*Pellona ditchela*	4.4	4.81	0.1	0.14
26.		*Polinemus* spp	0.6	0.66	0.2	0.29
Total sampling			91.385		69.00	

Appendix-13. Catch sampling composition of economically species from control net and trawl net with fish eye on December 5-6, 2007

No.	Indonesian Name	Scientific Name	Control Net		Trawl Net with Fish Eye	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Alu alu	*Spryraena* spp	0	0.00	0.35	0.53
2.	Bawal hitam	*Formio niger*	2.9	4.30	0.00	0.00
3.	Carangid	*Urapsis urapsis*	1.05	1.56	1.00	1.51
4.	Cucut	*Carcharinus* spp	5.1	7.56	5.15	7.76
5.	Kerapu	*Epinephelus* spp	0.8	1.19	0.40	0.60
6.	Kuro	*Polidactilus* spp	11.7	17.35	3.15	4.74
7.	Layur	*Trichiurus lepturus*	26	38.55	28.40	42.77
8.	Lidah	*Cynoglosus* spp	5.9	8.75	3.40	5.12
9.	Mata besar	*Triachantus* spp	0.05	0.07	0.00	0.00
10.	Remang	*Muraynesox bagio*	1	1.48	0.40	0.60
11.	Selar	*Carangoides* spp	0.45	0.67	0.00	0.00
12.	Selar	*Alepes melanoptera*	1.95	2.89	0.00	0.00
13.	Slengseng	*Megalaspis cordila*	9.85	14.60	1.55	2.33
14.	Tiga waja	*Otolites* spp	0	0.00	22.35	33.66
15.		*Platicephalus* spp	0.7	1.04	0.25	0.38
Total fish catch			67.45		66.4	

Appendix-14. Catch sampling composition of trawl net with standard TED and USA TED on December 2-4, 2007

No.	Indonesian Name	Scientific Name	Trawl Net with standard TED		Trawl Net with USA TED	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Beloso	*Saurida micopectoalis*	2.95	2.89	0.825	1.05
2.	Bulu ayam	*Thryssa settirostris*	2.275	2.23	1.7	2.16
3.	Bulu ayam	*Setipinna* spp	10.8	10.59	12.45	15.84
4.	Bulu ayam	*Thryssa mistax*	9.25	9.07	3.6	4.58
5.	Buntal	*Lagocephalus spadiceus*	0.45	0.44	0.35	0.45
6.	Crab		6.275	6.15	9.8	12.47
7.	Cucut	*Carcharinus* spp	0	0.00	0	0.00
8.	Cumi-cumi	*Loligo* spp	0.6	0.59	0.75	0.95
9.	Gerot-gerot	*Pomadasys maculatus*	6.9	6.77	5.85	7.45
10.	Ikan Sebelah	*Psettodes erumei*	0	0.00	1	1.27
11.	Japuh	*Dussumieria acuta*	0.9	0.88	0.3	0.38
12.	Kembung	*Rastrelliger kanagurta*	0	0.00	0	0.00
13.	Kerong	*Terapon theraps*	0.15	0.15	0.1	0.13
14.	Kuniran	*Upenus sulphureus*	0.15	0.15	0.2	0.25
15.	Kuro	*Polydactillus* spp	9.55	9.37	4.9	6.24
16.	Layur	*Trichiurus lepturus*	0.7	0.69	2.8	3.56
17.	Lidah	*Cynoglosus* spp	1.55	1.52	1	1.27
18.	Manyung	*Arius thallasinus*	6.95	6.82	4	5.09
19.	Nomei	*Apogon* spp	1.75	1.72	0.75	0.95
20.	Nomei	*Harpadon nehereus*	0	0.00	0	0.00
21.	Pari	*Dasyatis kuhlli*	8.9	8.73	3.05	3.88
22.	Petek	*Leiognathus* spp	1.15	1.13	1.75	2.23
23.	Selar	*Alepes melanoptera*	0.1	0.10	0	0.00
24.	Selar	*Carangoides* spp	0.4	0.39	0.8	1.02
25.	Sembilang	*Euristhmus lepturus*	1.35	1.32	1.35	1.72
26.	Tembang	*Illisa melastoma*	3.85	3.78	9.65	12.28
27.	Teri	*Stolephorus devisi*	2.85	2.79	0.15	0.19
28.	Tiga waja	*Johnius* spp	3.95	3.87	4.3	5.47
29.	Udang krosok		0.625	0.61	0.6	0.76
30.		*Herklotchsichtis* spp	1.05	1.03	2.3	2.93
31.		*Pellona ditchela*	16.3	15.98	4.15	5.28
32.		*Platycephalus endrachtensis*	0.25	0.25	0.1	0.13
Total Sampling			101.975		78.575	

Appendix-15. Catch sampling composition of economically species from trawl net with standard TED and USA TED December 2-4, 2007

No.	Indonesian Name	Scientific Name	Trawl Net with standard TED		Trawl Net with USA TED	
			Weight (kg)	Percent (%)	Weight (kg)	Percent (%)
1.	Bandeng laki	*Elops machnata*	8.6	6.11	6.85	6.87
2.	Bawal hitam	*Formio niger*	13	9.24	3.65	3.66
3.	Beloso	*Saurida micopectoalis*	0.65	0.46	0	0.00
4.	Cucut	*Carcharinus* spp	7.65	5.44	4.55	4.57
5.		*Ephippus orbis*	0.3	0.21	0.4	0.40
6.	Ikan Sebelah	*Psettodes erumei*	0.4	0.28	1	1.00
7.	Kakap putih	*Lates calcariver*	16	11.38	5	5.02
8.	Kue	*Caranx iqnobilis*	1.9	1.35	2	2.01
9.	Kuro	*Polidactilus* spp	39.55	28.12	21.4	21.48
10.	Layang	*Decapterus ruselli*	0	0.00	0	0.00
11.	Layur	*Trichiurus lepturus*	2.8	1.99	12	12.04
12.	Lidah	*Cynoglosus* spp	3.9	2.77	2.95	2.96
13.	Mata besar	*Priacanthus macracantus*	0	0.00	0	0.00
14.	Parang-parang	*Rachicentron canadus*	9.5	6.75	13.6	13.65
15.	Remang	*Muraenesox bagio*	0.95	0.68	0.1	0.10
16.	Selar	*Alepes melanoptera*	0	0.00	0	0.00
17.	Selar	*Carangoides* spp	0.5	0.36	0.15	0.15
18.	Skiper	*Scatophagus argus*	2.65	1.88	2.15	2.16
19.	Slengseng	*Megalaspis cordila*	0	0.00	0	0.00
20.	Tenggiri	*Scomberomorus commersoni*	5.1	3.63	9.35	9.38
21.	Tiga waja	*Otolites* spp	26.95	19.16	14	14.04
22.		*Platycepalus* spp	0.25	0.18	0.5	0.50
Total fish catch			140.65		99.65	100

Appendix-16. Catch weight (kg) comparison of trawl net with standard TED and trawl net with US-TED

Tow Number	Trawl Net With Standard TED						Trawl Net With US-TED						Fish Reduction (%)	Shrimp Lost (%)
	Shrimp Retained	Shrimp Discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured	Shrimp Retained	Shrimp discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured		
1	3.00	-	1.00	36.90	3.00	357.90	4.05	-	11.40	268.60	4.05	280.00	21.77	-35.00
2	0.05	-	1.75	50.00	0.05	171.75	0.20	-	29.55	150.00	0.20	179.55	-4.54	-300.00
3	0.95	-	8.40	00.00	0.95	228.40	0.48	-	20.65	100.00	0.48	120.65	47.18	50.00
4	0.20	-	2.20	00.00	0.20	252.20	0.20	-	32.05	200.00	0.20	232.05	7.99	0.00
5	-	-	9.80	50.00	-	169.80	-	-	6.00	125.00	-	131.00	22.85	-
Total	4.20	-	43.15	1,036.90	4.20	1,180.05	4.93	-	99.65	843.60	4.93	943.25	20.07*	-17.26*
Average	0.84	-	8.63	207.38	0.84	236.01	0.99	-	19.93	168.72	0.99	188.65	4.01*	3.45*-

* Total and average were calculated from the total data of fish and shrimp captured

Appendix-17 Catch weight (kg) comparison of control net and trawl net TED

Tow Number	Trawl Net Without BRD						Trawl Net With US-TED						Fish Reduction (%)	Shrimp Lost (%)
	Shrimp Retained	Shrimp Discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured	Shrimp Retained	Shrimp discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured		
1	0.80	-	106.20	200.00	0.80	306.20	0.50	-	61.90	200.00	0.50	261.90	14.47	37.50
2	1.50	-	21.55	250.00	1.50	271.55	1.20	-	19.00	275.00	1.20	294.00	-8.27	20.00
3	0.17	-	18.45	300.00	0.17	318.45	0.15	-	19.05	250.00	0.15	269.05	15.51	11.76
4	1.00	-	54.55	150.00	1.00	204.55	0.30	-	58.15	250.00	0.30	308.15	-50.65	70.00
5	-	-	35.00	100.00	-	135.00	-	-	29.85	150.00	-	179.85	-33.22	-
6	3.25	-	25.90	200.00	3.25	225.90	2.40	-	16.75	200.00	2.40	216.75	4.05	26.15
Total	6.72	-	261.65	1,200.00	6.72	1,461.65	4.55	-	204.70	1,325.00	4.55	1,529.70	-4.66*	32.29*
Average	1.12	-	43.61	200.00	1.12	243.61	0.76	-	34.12	220.83	0.76	254.95	-0.78*	5.38*

* Total and average were calculated from the total data of fish and shrimp captured

Appendix-18. Catch weight (kg) comparison of control net and trawl net with square mesh windows

Tow Number	Trawl Net Without BRD						Trawl Net With *Square Mesh Window*						Fish Reduction (%)	Shrimp Lost (%)
	Shrimp Retained	Shrimp Discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured	Shrimp Retained	Shrimp discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured		
1	3.25		18.98	275.00	3.25	293.98	2.60		15.65	350.00	2.60	365.65	-24.38	20.00
2	0.85		65.35	375.00	0.85	440.35	0.75		39.65	375.00	0.75	414.65	5.84	11.76
3	0.40		4.95	200.00	0.40	204.95	0.30		9.05	350.00	0.30	359.05	-75.19	25.00
4	0.30		6.13	350.00	0.30	356.13	0.30		6.60	300.00	0.30	306.60	13.91	-
5	-		31.25	450.00	-	481.25	-		8.05	425.00	-	433.05	10.02	-
6	-		47.50	450.00	-	497.50	-		45.90	400.00	-	445.90	10.37	-
7	0.50		17.00	650.00	0.50	667.00	0.30		15.20	500.00	0.30	515.20	22.76	40.00
8	0.80		9.10	500.00	0.80	509.10	0.50		3.50	400.00	0.50	403.50	20.74	37.50
Total	6.10	-	200.25	3,250.00	6.10	3,450.25	4.75	-	143.60	3,100.00	4.75	3,243.60	5.99*	22.13*
Average	0.76		25.03	406.25	0.76	431.28	0.59		17.95	387.50	0.59	405.45	0.75*	2.77*

* Total and average were calculated from the total data of fish and shrimp captured

Appendix-19. Catch weight (kg) comparison of control net and trawl net with fish eye

Tow Number	Trawl Net Without BRD						Trawl Net With *Fish Eye*						Fish Reduction (%)	Shrimp Lost (%)
	Shrimp Retained	Shrimp Discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured	Shrimp Retained	Shrimp discard	Fish Catch Retained	Fish Discarded	Total Shrimp Captured	Total Fish Captured		
1	-	-	7.70	400.00	-	407.70	-	-	1.00	250.00	-	251.00	38.44	-
2	3.95	-	9.20	425.00	3.95	434.20	1.75	-	3.85	300.00	1.75	303.85	30.02	55.70
3	2.50	-	4.60	300.00	2.50	304.60	1.71	-	4.85	324.45	1.71	329.30	-8.11	31.60
4	3.00	-	21.50	336.40	3.00	357.90	4.05	-	9.70	270.30	4.05	280.00	21.77	(35.00)
5	1.00	-	43.00	317.60	1.00	360.60	1.00	-	19.40	258.60	1.00	278.00	22.91	-
6	3.25	-	46.40	450.00	3.25	496.40	2.00	-	30.35	550.00	2.00	580.35	-16.91	38.46
7	6.25	-	36.40	225.00	6.25	261.40	5.20	-	18.90	231.10	5.20	250.00	4.36	16.80
Total	19.95	-	168.80	2,454.00	19.95	2,622.80	15.71	-	88.05	2,184.45	15.71	2,272.50	13.36*	21.25*
Average	2.85	-	24.11	350.57	2.85	374.69	2.24	-	12.58	312.06	2.24	324.64	1.91*	3.04*

* Total and average were calculated from the total data of fish and shrimp captured

Appendix -20. Fitted US-TED, square mesh window and fish eye into the codend

US-TED

TED Standard

Appendix-20 (continued)


Square mesh window


Fish eye

Appendix -21. Shrimp capture during fishing trials in Arafura sea

Penaeus merguensis

Metapenaeus spp

Appendix -22. By-catch during fishing trials in Arafura sea

Crabs

Formio niger

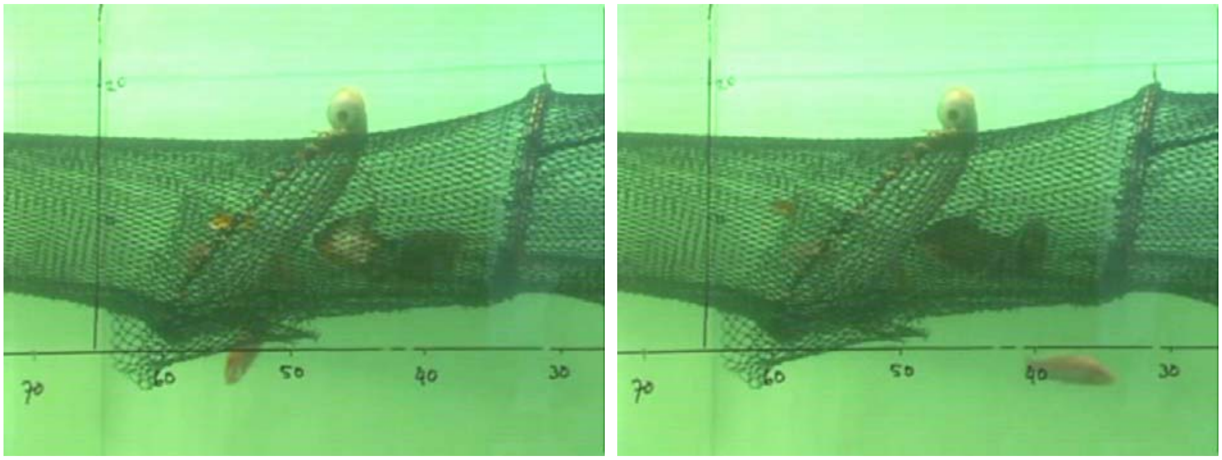
Trichiurus lepturus

Elops machnata

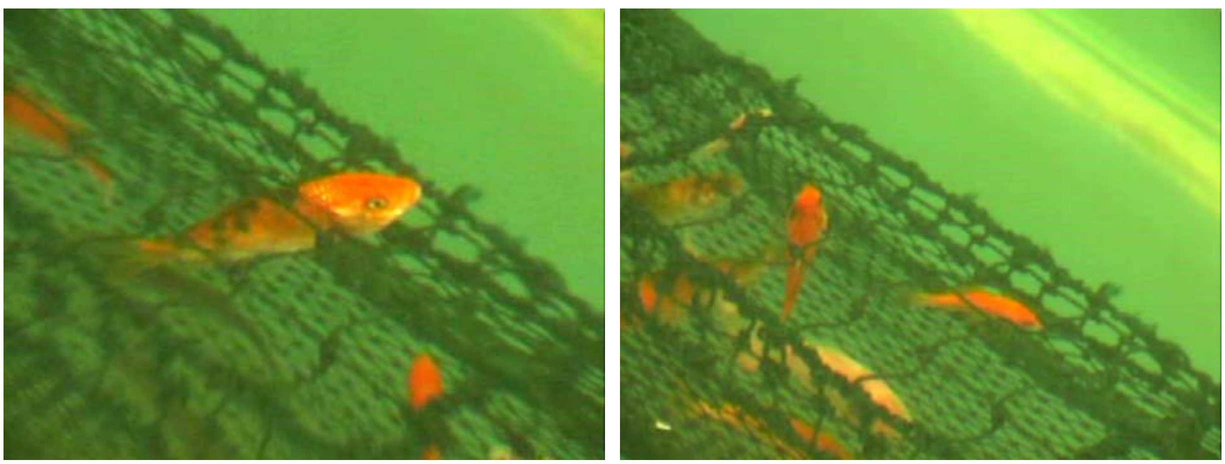
Cynoglossus spp

Carcharinus spp

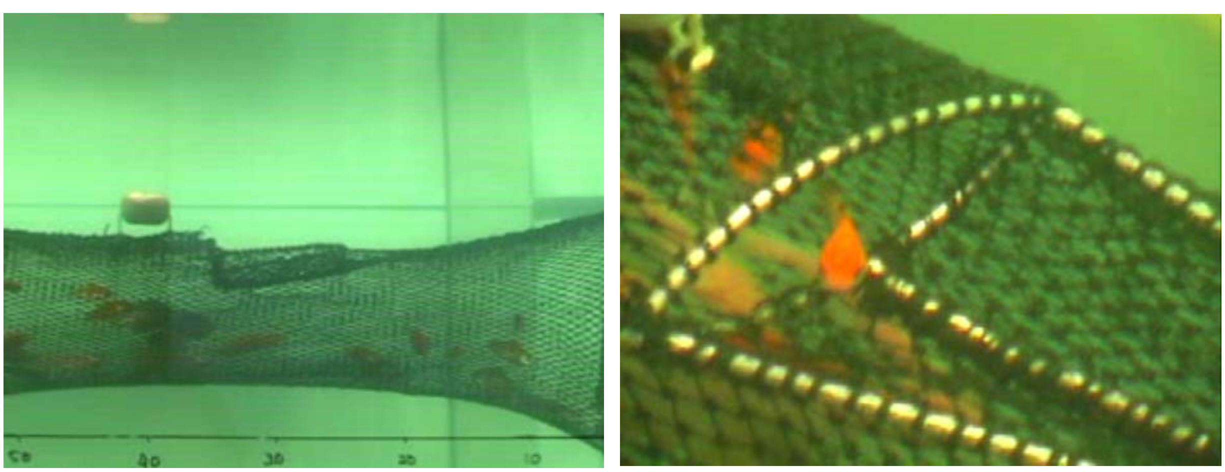
Appendix -23. Behavior of the experiment fish in flume tank



TED super shooter



Square mesh window



Fish eye