Factors affecting the efficiency and selectivity of the Andaman Sea demersal sampling trawl

By

Chalermchat Arunrojprapai

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Abstract

The average catch per unit of swept area (CPUE) from bottom trawl surveys by research vessels are used as an index of abundance for the demersal fish resources of the Thai waters of the Andaman Sea. The surveys are carried out under the assumption of constant swept area and catch efficiency. However, preliminary investigations showed that the geometry varied by depth and based on other studies it is likely that this may affect CPUE.

To reduce the variability in trawl geometry by depth, the constrictor rope technique was applied. The length of the rope (6 m) and its position (between the warps; 100 ahead of the trawl doors) were based on trials without rope at the shallowest depth trawled during the routine surveys (20 m).

Using the constrictor rope at deeper depths gave similar trawl geometry as obtained at the reference depth of 20 m. When the trawl was fished with the constrictor rope 75 m depth, the mean door distance was reduced by 23% compared to the door distance obtained for hauls without a constrictor rope. Similarly, wing distance was reduced by 18% and the angle of the sweep/bridles was reduced from 20.3 to 15 degrees (26% reduction). The vertical trawl opening was increased marginally (0.12 m; 6.5 %)

Despite the difference in trawl geometry, catch rates and catch composition did not differ significantly between the hauls made with and without the constrictor rope. The reason for this is unclear, but it is suggested that the larger area swept when no rope is used is offset by increased escape below the fishing line due to the trawl being overspread.

Observations by underwater video cameras in the net mouth area during hauls at shallow depth and without constrictor rope, indicated proper bottom contact of the fishing line. It is therefore suggested that the trawl will have similar bottom contact at all depths when the constrictor rope is used. However, this needs to be verified. Observations of fish showed that fish took up position slightly in front of the fishing line, swimming in the direction of towing. Except for a few rays, no fish were observed to escape below the fishing line. Observations of trawl’s fish lock showed that this did not function as intended as fish were observed to swim forward out of the codend during haul back of the trawl.

Sections of gillnet panels mounted to the outside of the top panel of the trawl, showed only marked escape during one haul and only close to the codend. The catch is this haul was approximately an order of magnitude higher than in the remaining hauls, suggesting a density dependent escape.

1. Introduction

1.1 Background

Marine fisheries are very important to food supplies worldwide. To avoid that fish populations are overexploited or depleted, it is therefore important to tune fishing activities with fluctuations in fish stocks due to natural conditions.

The main purpose of stock assessment is to estimate the status of fish stocks and to estimate how the stocks will respond to different harvesting strategies. The need for reliable stock assessment has increased in recent years. A number of fisheries have collapsed. FAO (2009) reported that 28% of global fish stocks were overexploited or depleted in 2007. This may lead to severe economic problems. There can be several reasons that fish stocks have been overexploited or depleted, but one reason is lack of control by fisheries management authorities.

Fisheries resource assessment is generally based on data from the fisheries (fishery-dependent data) and/or from scientific surveys (fishery-independent data). Fishery-dependent data are collected from the fisheries through such as log-books and data collection by observers onboard. The collected data are used to estimate the historical stock level and the rate of removals from stocks using age-based methods (Hilborn and Walters, 1992). Accurate fisheries-dependent data may give the cohort strength if reliable estimates of natural mortality and catch composition are obtained through collection of biological data collected either during fishing or during portside sampling. The age of fish is determined from scales or otoliths. However, there is considerable uncertainty related to data from the fisheries due to factors such as misreporting (area, species and quantity), discard/unaccounted mortality, technological creeping that make it difficult to establish a correct fishing effort, as well as uncertain biological sampling and change in fishing strategy. These uncertainties led to the development of scientific surveys in the 1960s.

Scientific surveys are carried out using sampling gear such as trawls, longlines and pots and can be designed to target a group of several species or a single species. The survey data may provide an index of fish abundance such as the number of fish caught per haul and is an important tool for assessing the present state of fish stocks once times series have been established (Gunderson, 1993).

Scientific demersal surveys play an important part in managing several demersal fish stocks worldwide. Due to the importance of scientific trawl surveys for stock assessments, considerable effort has been directed at standardization of survey trawls, monitoring trawl performance during surveys, identifying factors that affect the catch efficiency and selectivity of survey trawls and at improving the survey routines.

1.2 Limitation of bottom trawl surveys

The main purpose of bottom trawl surveys is to obtain indicators of stock abundance and also to monitor changes in population structure and distribution. Nowadays fishery-independent data from research surveys are an important tool for assessing the present state of most of the commercial important stocks (Pennington and Brown, 1981). Most scientific surveys are carried out on the assumption that the catch efficiency is constant from haul to haul and between years. Under this assumption, catch rates are considered proportional to the true stock density. Thus, an important aspect is to minimize sampling variability by standardizing the fishing gear and the fishing operations. However, it is well documented that factors such as trawl geometry and performance, and fish behavior may vary from haul to haul (Godø and Engås, 1989). This may lead to biased estimates of the stock.

Several aspects of geometry and performance of the gear have been shown to affect efficiency of the sampling gear for different species and size-groups (Engås, 1994). Rose and Walters (1990) showed that warp to depth ratio affects the net spread. Engås and Godø (1989a) found that catch rates increased with increasing sweep length. Moreover, escapement of fish below the fishing line has been shown to be both species and size dependent Engås (1989b). Vessel and gear generated noise have been shown to influence the behaviour and thereby the efficiency. Ona and Godø (1990) reported instances when large cod dived some 50–100 m after passage of the vessel. Environmental factors such as temperature (affecting swimming performance of fish) and light level (affecting vision)

(Wardle, 1993) may also have an effect on the catch efficiency of the gear. Furthermore, the difference in fish distribution between day and night, losses of catch during trawl's hauling or from fish penetrating through the net during towing are factors that may affect the survey results.

1.3 Development of bottom trawl survey in Andaman Sea

The Andaman Sea Fisheries Research and Development Center (AFRDEC) in Phuket, Thailand conduct annual bottom trawl surveys to monitor abundance, distribution and population structure of a number of Andaman Sea demersal fish stocks. The information is used by the Department of Fisheries of Thailand to develop a time series of data to monitor the state of the stocks and to provide management actions such as harvesting strategies.

The first survey in Thai coastal waters of the Andaman Sea was conducted in 1968. One vessel participates in the survey. Initially the R/V "Pramong 3" was used. The sampling area extends from the border with the Republic of the Union of Myanmar south to the border with Malaysia (see Figure 1). In 2004, R/V "Pramong 3" was replaced by R/V "Pramong 4", and this vessel has been used to conduct all bottom trawl survey since then. The survey area is divided into four subareas with a total of 22 trawl station (Figure 1). Sampling is conducted systematically from year to year during four cruises a year, each at a fixed time of the year. The cruises are run in the period November till May to avoid the rough weather (high waves and storm) during the Southwest monsoon.

Samples are obtained by trawling for sixty minutes. The survey trawl, an"Engel trawl" (Tiews, 1973) has been used since the start of the surveys. It was rigged with wooden trawl doors until 2008 after which Thyborøn trawl doors have been used (for more details about trawl and trawl doors, see material and methods). Hydroacoustic trawl instruments to measure the trawl geometry during sampling tows have been used since 2004. The dimensions measured include the vertical opening of the trawl at the centre of the headline and the horizontal distance between the trawl doors.

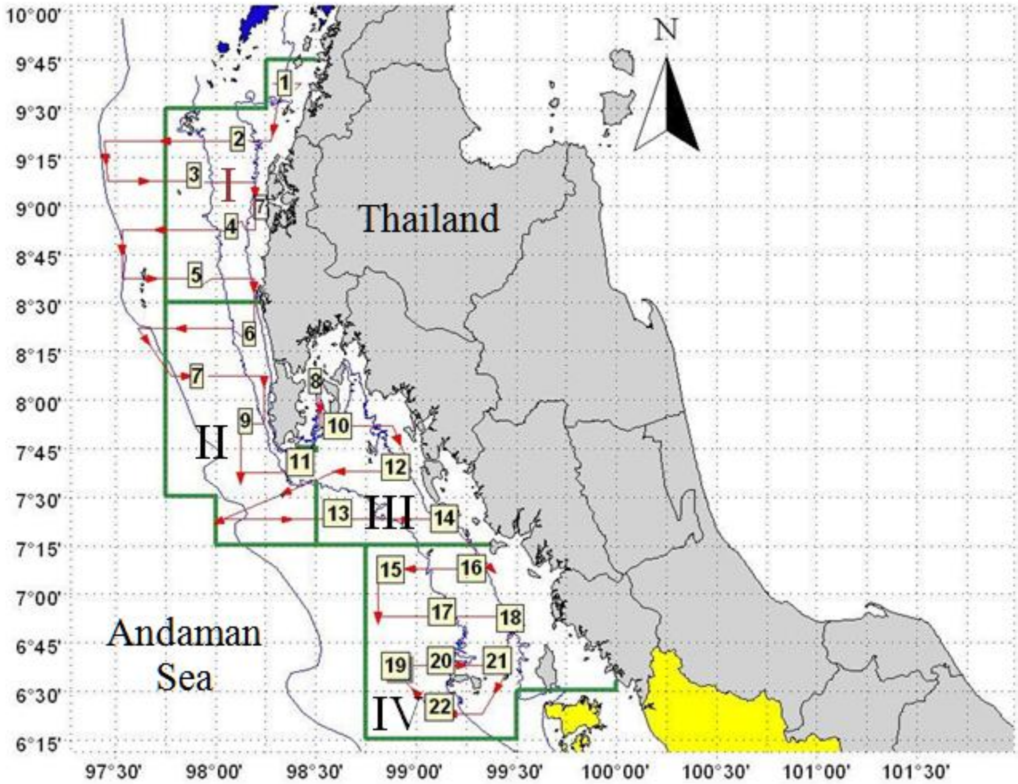


Figure 1: Survey area with 4 subareas and 22 stations for bottom trawl sampling in the Andaman Sea, Thailand.

The time series of cpue from the trawl surveys in the period 1968 – 1983 and 2003 - 2009 are presented in Figure 2. The CPUE declined markedly from 350 kg/hr in 1968 to 50 kg/hr in 1979. This coincides with increased effort resulting from a large buildup of the fishing fleet (NSO, 1985; DOF, 1997). Since 1980, catch rate has been relatively stable in range 50-80 kg/hr.

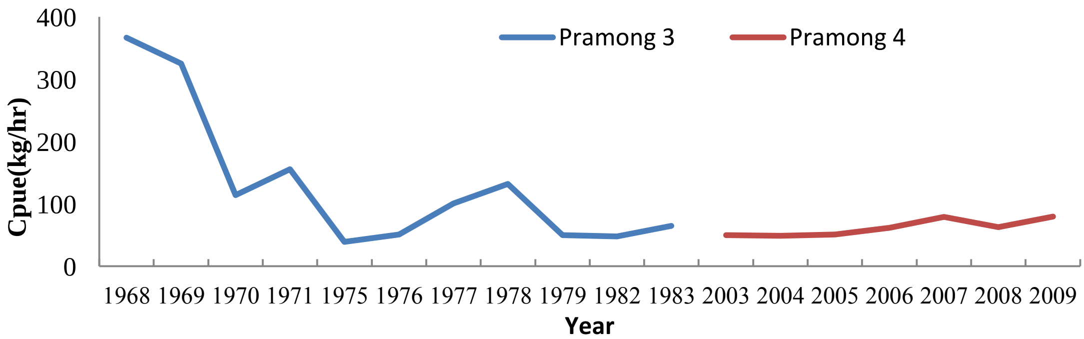


Figure 2: The overall Catch per unit effort in 1968-1983 and 2003-2009, no data available between 1983 and 2003.

Approximately 30 families, comprising over 300 species have been recorded during the surveys (Nootmorn et al., 2003). The most common families of demersal fish were Leiognathidae (pony fish), Nemipteridae (Threadfin Bream), Synodontidae (Lizardfish), Priacanthidae (Bigeye) and Mullidae (Goatfish). All are commercial fish except Leiognathidae (pony fish) that is a trash fish (Figure 3). The proportion of demersal fish was 56 percent.

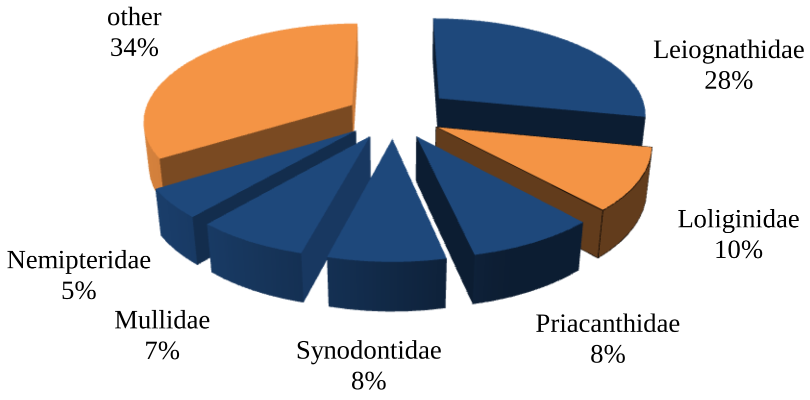


Figure 3: Average catch composition from bottom trawl survey in 2002-2009

1.4 Challenges for the bottom trawl survey in the Andaman Sea, Thailand

In the Andaman Sea bottom trawl survey, the depth of trawling stations varies from approximately 20 m to 80 m. The warp length-to-depth ratio used is approximately 5 and 4 in shallow and deep waters, respectively. Measurements of trawl door spread and vertical opening of the net have been carried out during the surveys since 2004. These measurements show that the door spread is reduced from approximately 70 m in deep waters to approximately 50 m in shallow waters (Figure 4). The effect of this to the area swept by the trawl is not adjusted for. Thus, the estimates of abundance may be significantly biased.

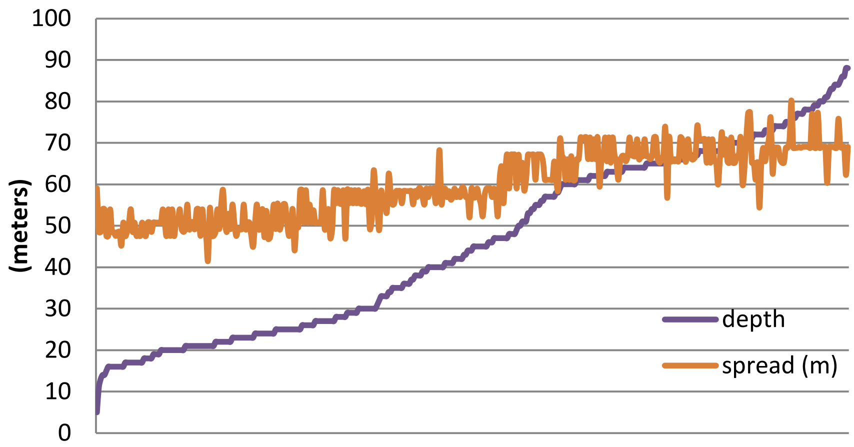


Figure 4: Doors spread versus depth measured during the routine surveys.

While the trawl spread measurements can be used to adjust for the effects of difference in swept area, this geometrical adjustment does not necessarily account for changes in the proportion of fish encountering the trawl which are actually retained in the catch. The shape of the trawl and its components affect how fish respond to it (Godø and Engås, 1989). In addition, an overspread trawl will have lower vertical opening, less bottom contact and have a large gap between the edges of the net and the sand cloud generated behind the doors (Rose and Walters, 1990).

1.5 Objectives

The aim of this study is to identify factors affecting the efficiency and selectivity of the Andaman Sea demersal sampling trawl. The first step was to evaluate if a constrictor rope minimized the variability in the horizontal and vertical opening of the trawl between deep and shallow water. Specifically, the study will test the hypothesis that there should be no difference in the catch rates and catch composition between hauls made with and without the constrictor rope (Engås and Ona, 1991; Engås and Ona, 1993).

Initial trials were carried out to identify if fish were escaping through the belly of the trawl using gill net panels attached to the outside of the top panel. Furthermore, direct underwater video observations are carried out to examine if the ground rope had proper bottom contact and to study the behaviour of fish in the net mouth area. Finally, the efficiency of the trawl lock during haul back operations was studied using video observation. The results from this investigation will be used to improve the Andaman Sea demersal trawl survey.

2. Materials and Methods

2.1 Study area and vessel

The experiments were carried out on board the R/V "Pramong 4" (Figure 5), belonging to AFRDEC, Department of Fisheries, Thailand. This is the same vessel that is used during the standard surveys run by AFRDEC. The vessel is 23.5 m long (LOA), and the hull material is steel. She has a main engine of 500 KW, a displacement of 96.84 gross tons, and a maximum speed of 11 knots.

Figure 5: The research vessel Pramong 4 used during the experiments.

All experiments were conducted in the Phang nga Bay and coastal water south of Phuket, Thailand, in February 2011 (Figure 6). An area with a water depth of approximately 70 m was selected for the experiments comparing trawl geometry and catch composition between the trawl rigged with and without a constrictor rope (Figure 6, area 1). The main reason for selecting the chosen area was that the difference in trawl geometry with and without constrictor rope will be higher in deep than in shallow water. Running the experiment in deep waters will therefore improve the probability of detecting an effect of the constrictor rope. In order to carry out combined video observations of behavior of fish in the net mouth area without artificial light and to verify if the center fishing line had proper bottom contact, an area in Phang nga Bay with a water depth of approximately 20 m was selected (Figure 6, area 2). Preliminary experiments to study escape of fish from the top panel of the belly of the trawl was conducted in area 1 and partly in an area located in Satun province (Figure 6, area 3). The bottom sediment in all areas was sandy mud.

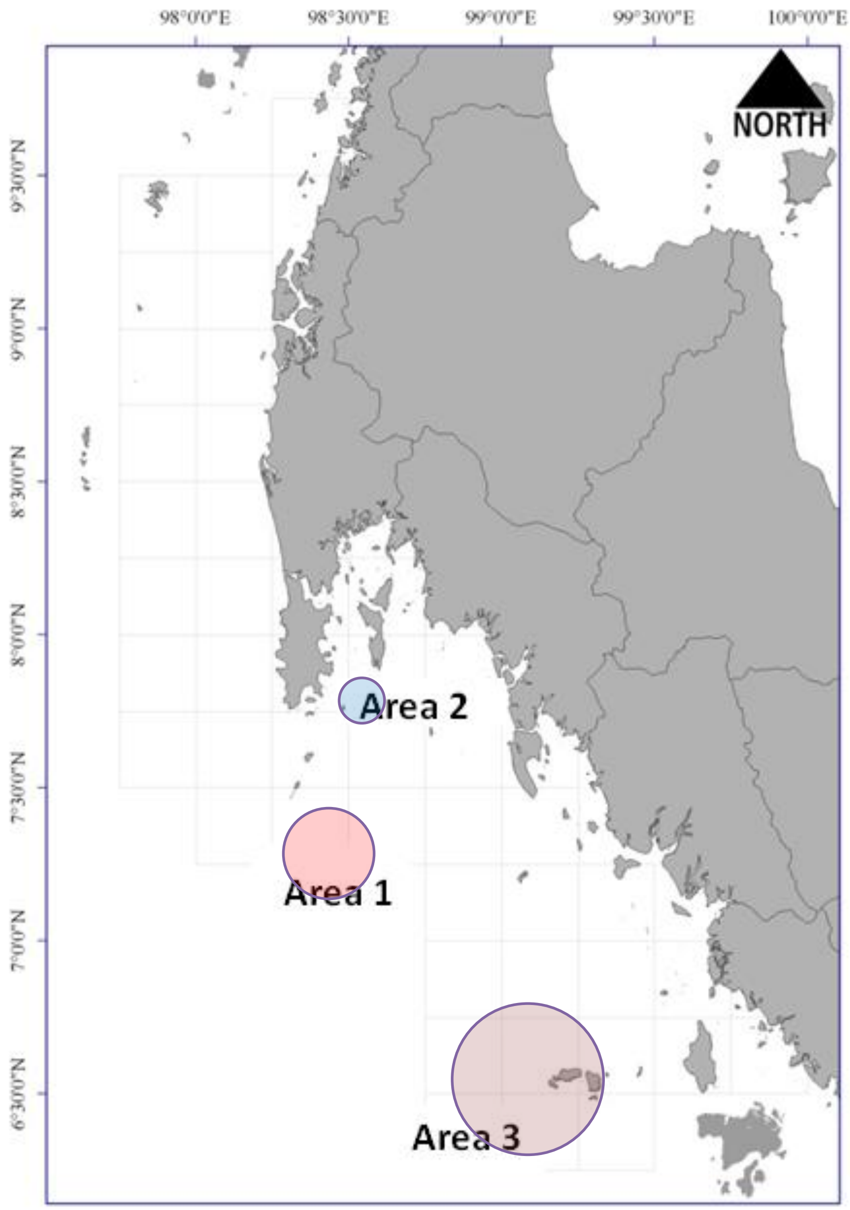


Figure 6: The experimental areas used during the study. Area 1: Comparison of trawl geometry and catch rates and catch composition for hauls made with and without the constrictor rope including fish lock observations and fish escapement through the belly of the trawl; Area 2: Hauls to determine target door spread as well as hauls to study fish behaviour, bottom contact and fish lock observations; Area 3: Investigations of fish escapement through the belly of the trawl.

2.2 Sampling gear

AFRDEC's standard demersal sampling trawl (an "Engel trawl"; Tiews (1973)) was used during the experiments (Figure 7). The trawl is a two panel trawl constructed of polyethylene netting with a mesh size ranging from 160 mm in the wing part to 40 mm in the codend. A cover with a mesh size of 25 mm was fitted on the outside of the codend (used as a standard during the surveys). The fishing line (measured at 45.40 m) was equipped with a chain (dimension 3/8", total weight of 30 kg) to obtain bottom contact. Headline length was measured at 36.26 m and it had 21 floats (Ø=8 inch). Total length of the trawl was 30.91 m (top side) and 26.86 m (bottom side).

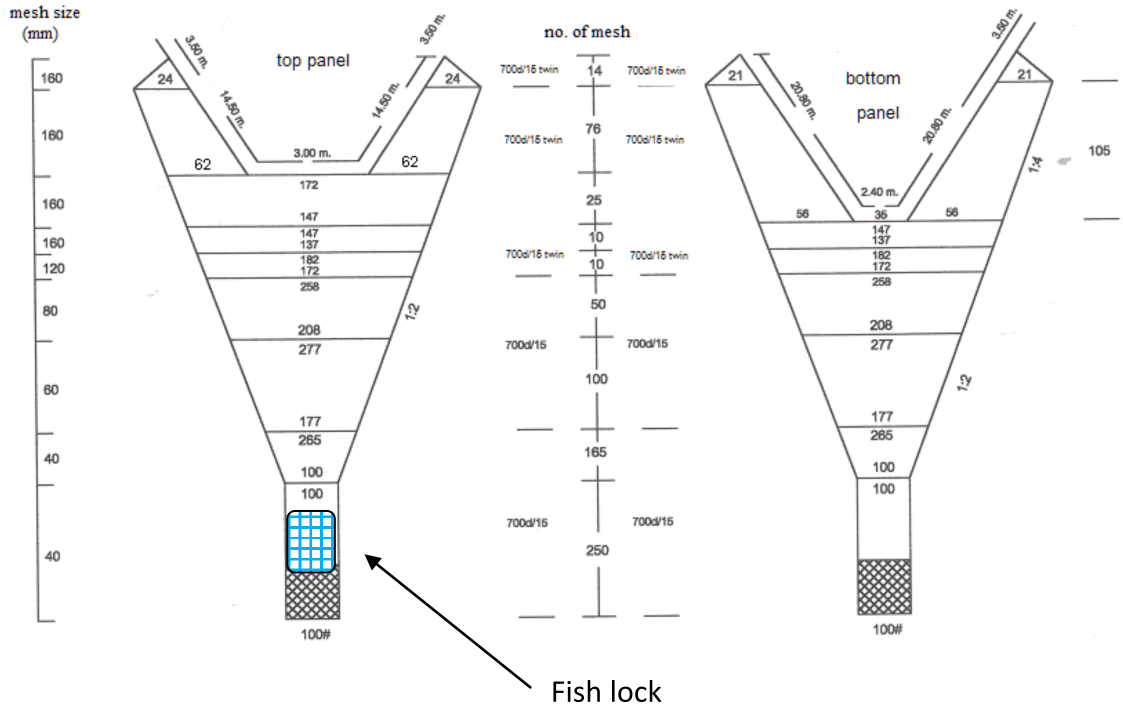


Figure 7: Construction drawing of the Engel trawl used as the standard demersal sampling trawl by the AFRDEC. Position of fish lock (blue hatching) is shown, as well of the cover on the outside of the codend (black hatching).

The trawl net was kept open during fishing operation by Thyborøn trawl doors (Figure 8). Each door was rigged with 57 m bridles and sweeps (Figure 9). The towing warps (wire) had a diameter of 20 mm

Figure 8: Thyborøn Type 12 trawl doors. Each door weighs 387 kg and measures 2.22 m^2.

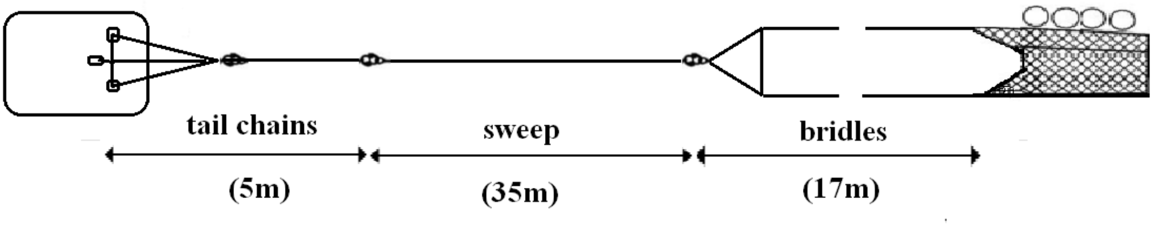


Figure 9: Rigging of bridles, sweeps and tail chains.

A fish lock with a mesh size of 45 mm is used as a standard during the surveys. It is mounted to the ceiling of the upper panel (like a flapper) and installed in the extension (Figure 7).

2.3 Experiment design and implementation.

2.3.1 Experiments with and without constrictor rope

To compare hauls with and without the constrictor rope, alternate hauls were carried out. Each pair consisted of one tow with a constrictor rope and one without. In each pair both hauls were conducted from the same position and in the same towing direction. The constrictor rope unit consisted of a purse ring (BOSS SR40) that had a special wheel inside the ring and a 6 m long rope (PE, 3 strands and Ø = 13 mm) (Figure 10).

Figure 10: Purse seine ring.

The constrictor rope was affixed to the starboard warp 100 m ahead of the doors (Figure 11, left panel). The other end was attached to the port warp with the purse seine ring (Figure 11, right panel). During the routine surveys the shallowest hauls are made at a depth of approx 20 m using a warp length of 100 m. Therefore the constrictor rope was attached 100 m ahead of the doors. Trawl geometry at this depth was therefore taken as a standard.

Figure 11: Constrictor rope installed between the warps 100 m ahead of the doors. Left: Constrictor rope affixed to the starboard warp; Right: Purse seine ring attached to the port warp.

The warp length-to-depth ratio used in this study was 4, i.e. a warp length of 320 m at approximately 75 m depth. All hauls were conducted during daylight (08:00-17:00) for 60 minutes. Towing speed was determined by a constant propeller revolution of 1000 rpm. Paired tows were started within 1 hour of each other (the time needed to go back to the same start position for the next operation).

Display unit   Spread sensors   Height sensor

Figure 12: The SIMRAD trawl monitoring PI44 used during the experiments.

All observations of trawl geometry were made with the Simrad PI44 trawl monitoring system (Figure 12). A height sensor measuring vertical opening of the trawl was mounted at the center of the headline while sensors measuring distance between the trawl doors were mounted on the backstops of the trawl doors. As only one set of distance sensors was available, measurements of distance between the wings could not be carried out simultaneously with the measurements of the distance between the trawl doors. During hauls no. 7-10, 15-18 and 25-26, the spread sensors were moved from the trawl doors to the wing tip and mounted on the upper wings (20 cm in front of wing tip). Trawl geometry was logged continuously throughout the hauls. GPS positions of the start and the stop of the haul were also logged and later used to calculate towing speed over ground.

Sampling and measurements of the trawl catches were carried out as during routine surveys (Sparre and Venema, 1998). Each catch was sorted to determine the number and weight of each species present. Length composition was determined for each commercial species by measuring the total length of all fish caught to the nearest 0.5 centimeter below. A total of 20 hauls were carried out. Catch rates (catch in numbers per hour of trawling) were calculated for each species for each tow.

2.3.2 Fish behaviour, bottom contact and fish lock observations.

A Navigator monochrome camera (Figure 13) was used without artificial light during one haul (10 February) to observe fish behavior in the net mouth area and to check if the fishing line had proper bottom contact. The housing was mounted within a frame. The frame was mounted at the center of the headline with the camera pointing down towards the fishing line. The haul was carried out as during the routine surveys.

Figure 13**:** The Navigator monochrome camera used to observe bottom contact of the fishing line and fish behavior in the net mouth area.

A Sony handy cam (HDR-CX350VE) camera (Figure 14) enclosed in an underwater housing was used during 6 hauls (haul no.11, 12, 13, 20, 24 and 26) to observe fish behavior in the vicinity of the fish lock. The housing was mounted to a frame and the frame attached in front of the fish lock. The camera pointed backwards to the fish lock in order to study the efficiency of the trawl lock during haul back operations.

Figure 14: The Sony Handy cam (HDR-CX350VE) used to observe the fish lock and fish behavior in the vicinity of the fish lock.

This experiment was carried out at a water depth of 25 m, located in the Phang-nga bay area. The trawl was rigged without a constrictor rope and a warp length-to-depth ratio of 4 was used. Measurements of trawl geometry (vertical opening and door spread) were carried out as described above.

2.3.3 Escapement of fish through the belly of the trawl

To investigate if fish pass through the belly of the sampling trawl, sections of the top panel of the trawl were covered with gillnet material on the outside of the trawl panels (Figure 15).

Figure 15: Gill net material on the outside of the trawl net.

The gillnet material was mounted to the trawl by sewing the edges of the gillnet panels to the selected trawl panels. Fish moving through the sampled panels would then become gilled. Four sections of gill nets material with mesh sizes of 35 mm (1 piece) and 50 mm (3 pieces), were selected to capture escaping fish (Figure 16). These mesh sizes were selected to target fish that can penetrate through the meshes of the trawl net. Both mesh sizes were made of monofilament (polyamide) with a twine thickness of 0.20 and 0.25 mm respectively. This investigation started at trawl no. 19 and lasted until the study finished.

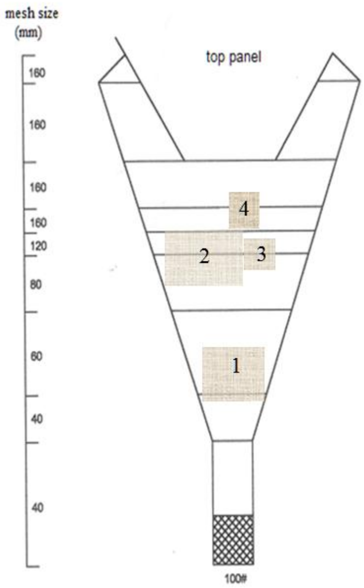


Figure 16: Position of gill netting panels at the top panel of the trawl, 1= 35 mm mesh size (5.5 × 3.0 m), 2 = 50 mm mesh size (5.5 × 4.5 m), 3 = 50 mm mesh size (2.0 × 2.0 m) and 4 = 50 mm mesh size (2.0 × 2.0 m).

2.4 Data analysis

Catches of species and groups were standardized to catch per unit of effort (CPUE):

$$\text{CPUE} = \frac{\text{total catch(kg)}}{\text{effort(hr)}}$$

where effort is trawl duration that was determined by the scientist (start = when trawl started fishing at the bottom, stop = when trawl started to lift from bottom).

Net geometry data from the PI44 system was converted and transferred to spreadsheets in Microsoft Excel 2007. A Wilcoxon two sample paired signed rank test was used to test the null hypothesis that there is not difference in catch rates between hauls made with and without the constrictor rope. Null hypothesis is that there was no difference between hauls made with and without a constrictor rope. The “R” package (version 2.13.0) was used to run the tests.

To calculate the bridle/sweep angle we need to know 1) distance from the trawl door to the wing tip, 2) door spread and 3) wing spread. The bridle angle can then be calculated as follows:

$$\text{Bridle angle(radians)} \quad = \sin^{-1} \frac{\langle \text{Door spread} - \text{Wing spread} \rangle}{2[\text{Total length from trawl door to wing tip(57 m)}]}$$

Convert bridle angle in radians to degrees by;

$$\text{Bridle angle(degrees)} \ = \text{Bridle angle(radians)} \times \frac{180}{\pi}$$

3. Results

3.1 Gear geometry measurements

The first two hauls during the survey were made at approximately 20 m, the shallowest depth trawled during the routine surveys, to establish the target door distance to be used with the constriction rope. The two hauls were towed in opposite direction to eliminate any effect of current direction. The mean door distance was measured at 45.9 and 44.4 m respectively (Table 1), using a warp length of 100 m. The reference door distance was therefore set at 45 m and will be obtained by attaching the constrictor rope at this warp length. The mean vertical opening of the trawl was measured at 1.97 and 2.02 m respectively (Table 1).

Table 1: Detail of net geometry and haul parameters.

Haul no.	Sensor position	Constrictor rope	Depth (m)	Warp (m)	SOG (kn)	COG (°)	Spread (m)	Height (m)	Catch ($kghr^{-1}$)
1	door	none	23.32	100	2.6	74	45.88	1.97	8.18
2	door	none	23.01	100	3.1	255	44.35	2.02	26.05
3	door	none	74.24	270	2.4	172	62.18	2.12	24.87
4	door	yes	75.15	300	2.7	162	47.69	2.23	26.07
5	door	none	74.86	350	3.1	3	68.08	1.69	56.53
6	door	yes	74.2	350	3.3	3	51.07	1.88	36.98
7	wing	yes	73.91	320	2.5	190	19.11	2.06	44.55
8	wing	none	74.96	320	2.6	185	23.48	1.97	45.38
9	wing	yes	75.39	320	2.8	5	19.41	2.02	32.01
10	wing	none	75.28	320	2.5	3	22.33	1.95	35.77
11	wing	none	17.25	100	2.3	165	16.62	1.85	900.21
12	wing	none	24.88	150	2.7	705	21.2	1.87	10.26
13	wing	none	44.55	200	2.3	261	28.46	2.36	19.75
14	wing	yes	44.46	200	2.4	260	18.43	1.93	29.94
15	wing	yes	74.71	320	2.6	190	17.82	2.07	52.58

Table 1(Cont.): Detail of net geometry and haul parameters.

Haul no.	Sensor position	Constrictor rope	Depth (m)	Warp (m)	SOG (kn)	COG (°)	Spread (m)	Height (m)	Catch ($kghr^{-1}$)
16	wing	none	74.09	320	2.6	190	21.99	1.95	51.4
17	wing	yes	73.95	320	2.6	20	18.29	2.07	47.98
18	wing	none	74.87	320	2.7	20	23.01	1.87	56.13
19	door	none	75.54	320	2.6	220	62.52	1.95	58.09
20	door	yes	74.91	320	2.9	220	48.17	2.01	65.15
21	door	none	74.88	320	2.9	40	63.04	2	19.71
22	door	yes	74.72	320	2.8	40	48.99	2.05	51.16
23	door	yes	73.55	320	2.5	195	47.31	2.13	32.73
24	door	none	72.99	320	2.6	195	61.49	1.95	35.27
25	wing	yes	73.22	320	2.4	15	18.84	2.01	23.74
26	wing	none	72.4	320	2.6	15	23.21	1.79	20.5
27	wing	none	64.22	260	3	305	21.9	1.61	64.48
28	wing	yes	65.16	260	2.5	310	18.43	1.91	31.67
29	wing	none	76.62	320	2.7	89	21.98	1.96	292.9
30	wing	yes	57.05	260	2.7	73	18.39	1.92	32.63
31	wing	none	57.27	260	2.6	78	21.53	1.85	27.12
32	wing	none	41.2	180	2.8	268	19.92	1.74	32.21
33	wing	yes	41	180	2.7	268	18.4	1.81	24.36

The paired hauls made with and without the constrictor rope were carried out at a depth of approx 75 m, near the deepest range of depths trawled during the routine surveys. A total of 5 paired hauls were obtained with the distance sensors mounted at the doors, and 5 with the sensors mounted at the wingtips. For two of the paired hauls (haul no. 3&4 and 5&6) made with the sensor mounted at the doors, the warp length differed from the standard of 320 m used at this depth. These pairs were therefore excluded from the analysis. Door distance was reduced by a mean value of 22.7% (14.2 m) when constraining rope was installed (Table 2). The reduction in distance between the wingtips was 18.7% (4.1 m). Vertical opening of the trawl increased 6.4% (0.1 m) when constraining rope was used.

Based on the mean door distance and mean wing distance the bridle/sweep angle was calculated. Attaching the constrictor rope reduced the bridle/sweep angle by 5.3 degrees (26 %) from 20.3 to 15.0 degrees.

Table 2: Trawl geometry comparisons. Measurements of door spread, wing spread and vertical opening are compared for paired hauls with and without constrictor rope. All measurements are in metres.

	pairwise	Without Const.R	Constrictor rope	diff	%
Door spread	no.19 and 20	62.52	48.17	14.35	22.95
	no.21 and 22	63.04	48.99	14.05	22.29
	no.23 and 24	61.49	47.31	14.18	23.06
	Average	**62.35**	**48.16**	**14.19**	**22.76**
Wing spread	no.7 and 8	23.48	19.11	4.37	18.61
	no.9 and 10	22.33	19.41	2.92	13.08
	no.15 and 16	21.99	17.82	4.17	18.96
	no.17 and 18	23.01	18.29	4.72	20.51
	no.25 and 26	23.21	18.84	4.37	18.83
	Average	**22.80**	**18.69**	**4.11**	**18.02**
Vertical opening	no.7 and 8	1.97	2.06	-0.09	-4.57
	no.9 and 10	1.95	2.02	-0.07	-3.59
	no.15 and 16	1.95	2.07	-0.12	-6.15
	no.17 and 18	1.87	2.07	-0.20	-10.70
	no.19 and 20	1.95	2.01	-0.06	-3.08
	no.21 and 22	2.00	2.05	-0.05	-2.50
	no.23 and 24	1.95	2.13	-0.18	-9.23
	no.25 and 26	1.79	2.01	-0.22	-12.29
	Average	**1.93**	**2.05**	**-0.12**	**-6.42**

3.2 Catch rate comparisons

The eight pairs of hauls that were used to study the effect of the constrictor rope on trawl geometry were also used to study the effects on catch rates and catch composition. A total of 94 species were caught during the 16 hauls (Appendix 1). Of these species, only a few were caught consistently across hauls and in numbers sufficient to make meaningful conclusions with respect to differences in catch rates between the two hauls of a pair. *Saurida undosquamis* was the most abundant demersal fish species, and on average accounted for 56% of the catch. Cephalopods made up 13% of the catch, families Priacantidae and Nemipteridae 7 and 3% respectively, and trash fish 6 %.

Table 3: Catch rates and catch composition of the paired hauls. Catch rates are in kg per hour.

Haul	**Constrictor**	**Catch rate (kghr^{-1})**					
no.	**rope**	**Total**	***S. undosquamis***	**Cephalopod**	**Trash fish**	**Priacanthidae**	**Nemiteridae**
7	**yes**	**44.55**	**29.80**	**3.73**	**0.94**	**4.69**	**1.07**
8	**none**	**45.38**	**34.00**	**2.58**	**3.00**	**1.49**	**0.65**
9	**yes**	**32.01**	**20.05**	**5.54**	**0.39**	**1.89**	**0.71**
10	**none**	**35.77**	**23.70**	**3.44**	**0.99**	**1.66**	**1.06**
15	**yes**	**52.58**	**30.44**	**9.72**	**2.00**	**2.63**	**3.49**
16	**none**	**51.4**	**27.18**	**5.79**	**1.91**	**1.62**	**1.33**
17	**yes**	**47.98**	**32.80**	**5.69**	**1.50**	**3.23**	**1.59**
18	**none**	**56.13**	**31.51**	**8.58**	**2.19**	**5.04**	**1.53**
19	**none**	**58.09**	**37.29**	**7.79**	**2.64**	**2.01**	**1.83**
20	**yes**	**65.15**	**31.35**	**9.12**	**3.34**	**12.97**	**1.94**
21	**none**	**19.71**	**6.07**	**4.97**	**2.42**	**1.59**	**1.46**
22	**yes**	**51.16**	**32.61**	**6.50**	**2.80**	**3.22**	**1.01**
23	**yes**	**32.73**	**14.08**	**3.38**	**4.22**	**2.21**	**0.72**
24	**none**	**35.27**	**16.16**	**6.39**	**3.74**	**1.49**	**0.87**
25	**yes**	**23.74**	**7.54**	**2.65**	**3.28**	**1.29**	**0.62**
26	**none**	**20.50**	**6.61**	**2.08**	**3.73**	**1.06**	**0.55**

Overall catch rates varied between 19.7 and 65.2 $kghr^{-1}$ and were generally consistent between the two hauls of a pair, except for pair no. 6 (haul no.21-22) (Figure 17, Table 3). Mean catch rate was 43.7 $kghr^{-1}$for the hauls with the constrictor rope and 40.3 $kghr^{-1}$ for the hauls without the constrictor rope. A pairwise comparison of overall catch rates showed no significant difference between the two riggings (Wilcoxon paired signed rank test, V= 20, p= 0.844). Exclusion of pair 6 gave estimates of 42.7 and 43.2 $kghr^{-1}$for hauls with and without the constrictor rope.

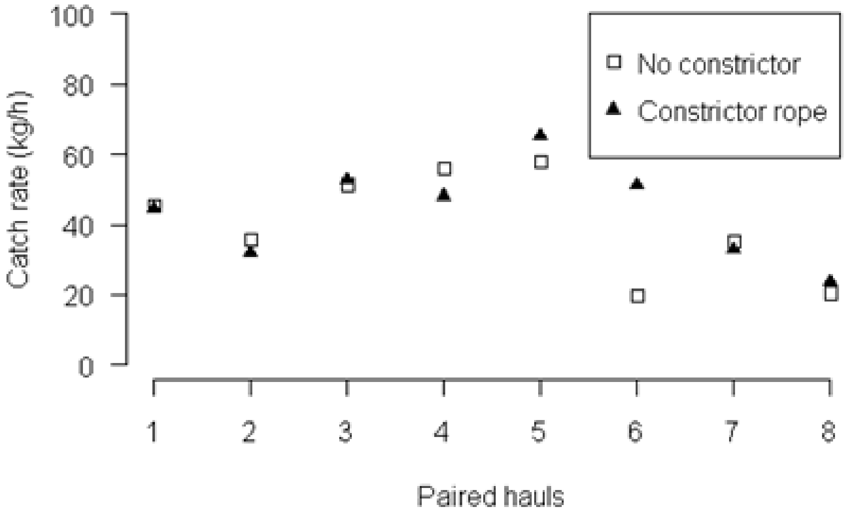
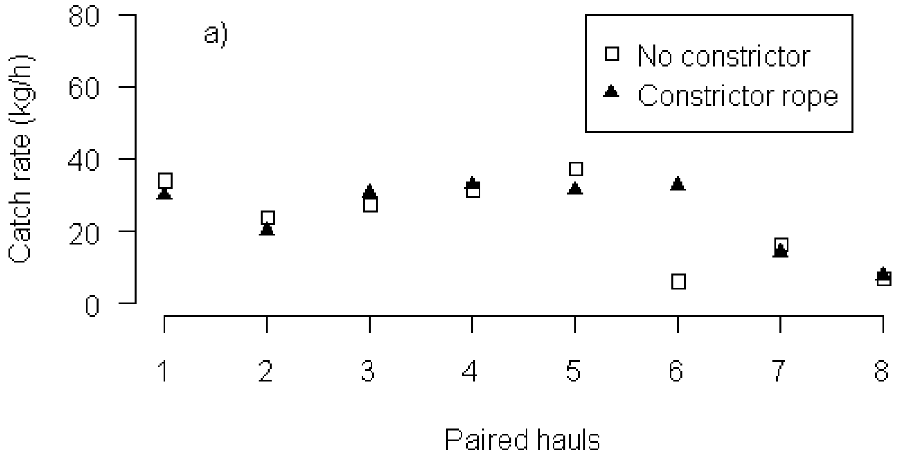
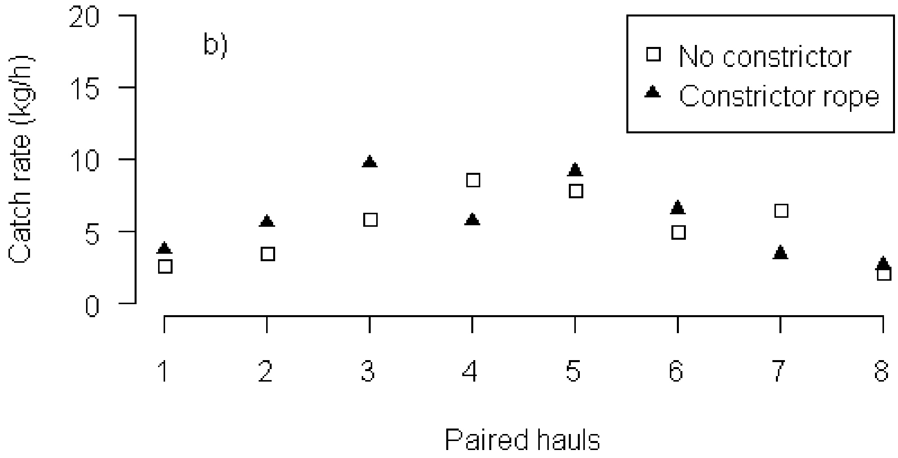
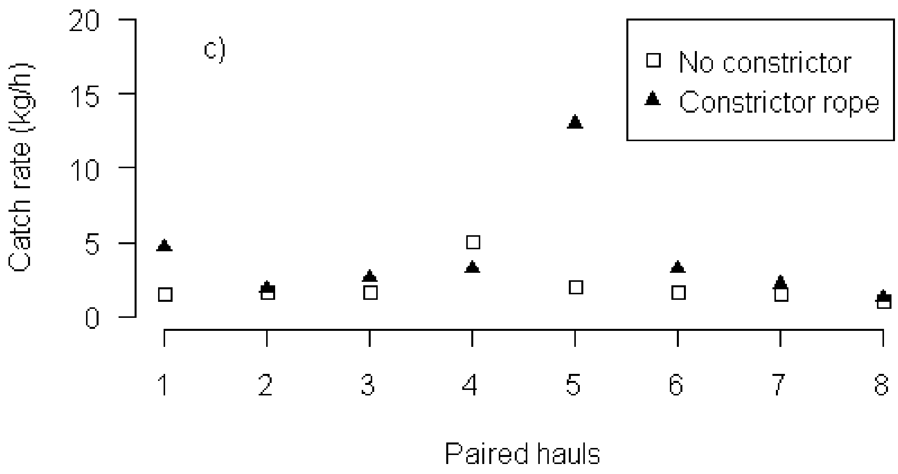


Figure 17: The pairwise comparison of overall catch rates between the two riggings

Saurida undosquamis was a dominant species. Mean catch rates for hauls with and without constrictor rope were 24.8 and 22.8 $kghr^{-1}$ respectively (Figure 18a) but the difference was not significant (Wilcoxon paired signed rank test, V= 15, p= 0.7422). Redoing the analysis without pair no.6 did not change the conclusion (V=7, p= 0.2969). For Cephalopods, mean catch rate was 5.8 $kghr^{-1}$ for the hauls with the constrictor rope and 5.2 $kghr^{-1}$ for the hauls without the constrictor rope (Figure 18b). The difference was not significantly different (V=23, p= 0.5469). Catch rates of *Priacanthidae* varied between 1.06 and 12.97 $kghr^{-1}$ and were generally consistent, except for pair no. 5. Mean catch rate was 4.02 $kghr^{-1}$ for the hauls with the constrictor rope and 2.0 $kghr^{-1}$ for the hauls without the constrictor rope (Figure 18c). A pairwise comparison of overall catch rates showed no significant difference between the two riggings but p value close to critical area (Wilcoxon paired signed rank test, V= 30, p= 0.107). Exclusion of pair no. 5 (haul no.19-20) gave estimates of 2.74 and 1.99 $kghr^{-1}$ for hauls with and without the constrictor rope. Finally, trash fish had mean catch rates of 2.31 and 2.58 $kghr^{-1}$ for hauls with and without the constrictor rope installed (Figure 18d). As for the other species these catch rate were not significantly different (V=14, p= 0.640).







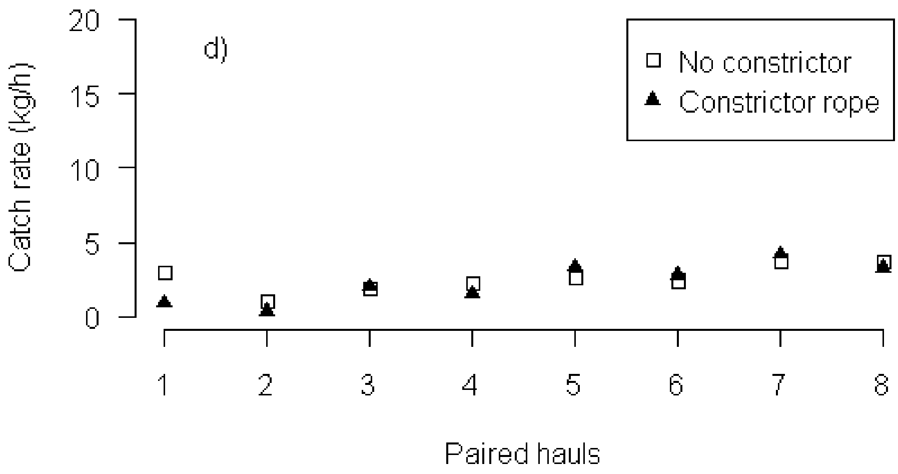


Figure 18: The catch rates of the paired hauls made to study the effect of constrictor rope on catch rates for; a) *Saurida undosquamis*, b) Cephalopods, c) Priacanthidae and d) Trash fish.

3.3 Comparison of length composition

The length frequency distribution of fish caught in the hauls where constrictor rope was used was compared with the distribution for those caught in hauls made without the rope. The comparison was made for the most abundant commercial species, *Saurida* *undosquamis* and *Pricanthus tayenus*. The cumulative length frequency distributions showed very similar results for *S. undosquamis* (average total length 12.61 cm and 13.17 cm for the catch made with and without the constrictor rope (Figure 19)) and *P. tayenus* (average length was 8.66 cm for hauls with constrictor rope and 8.61 cm for hauls without rope (Figure 20). For Nemipterus, the number of individuals was too small (the haul with constrictor rope had 32 specimens and the haul without constrictor rope had 36 specimens) for a comparison.

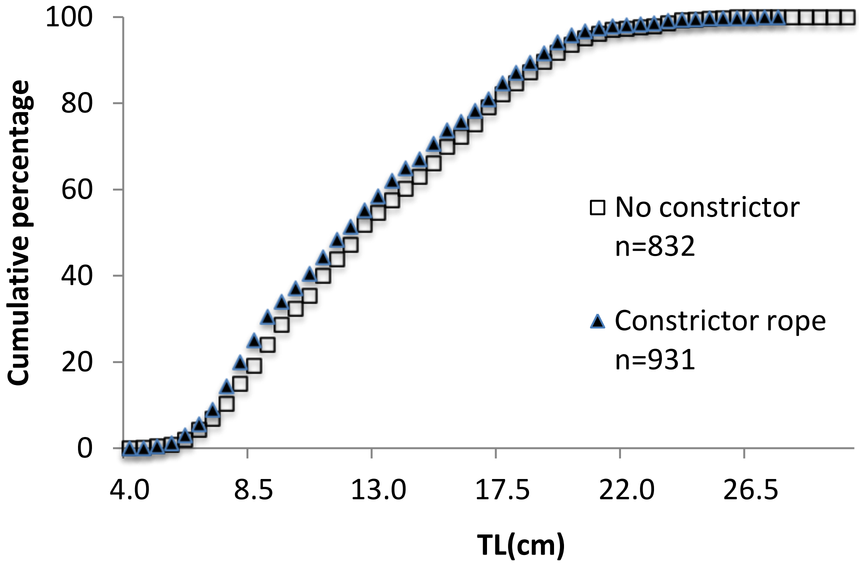


Figure 19: Length frequency of *Saurida undosquamis.*

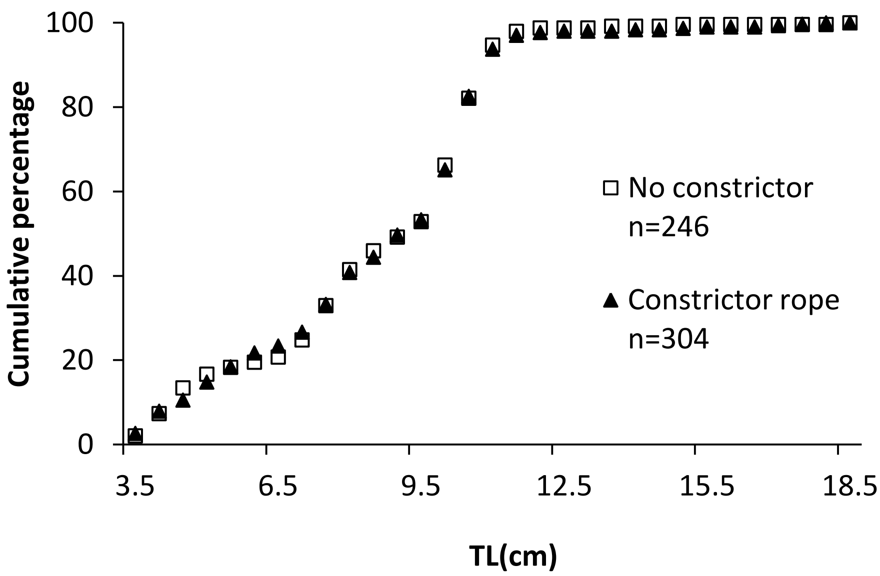


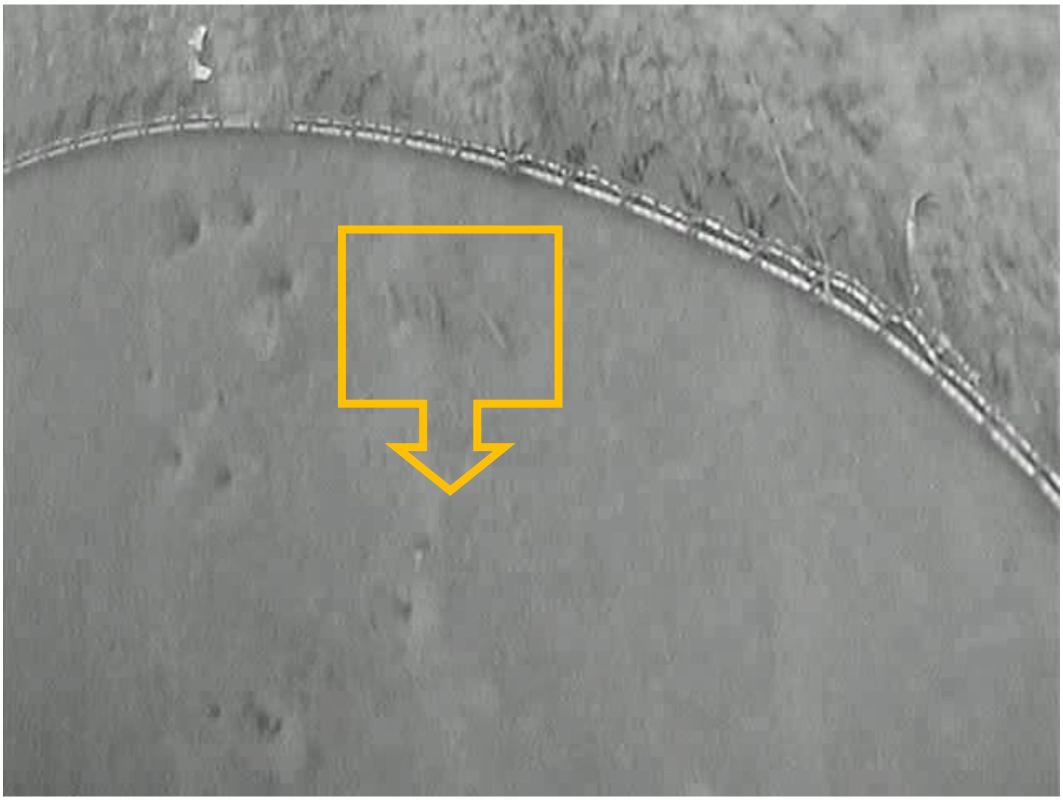
Figure 20: Length frequency of *Priacanthus tayenus.*

3.4 Fish escapement in the belly of the trawl

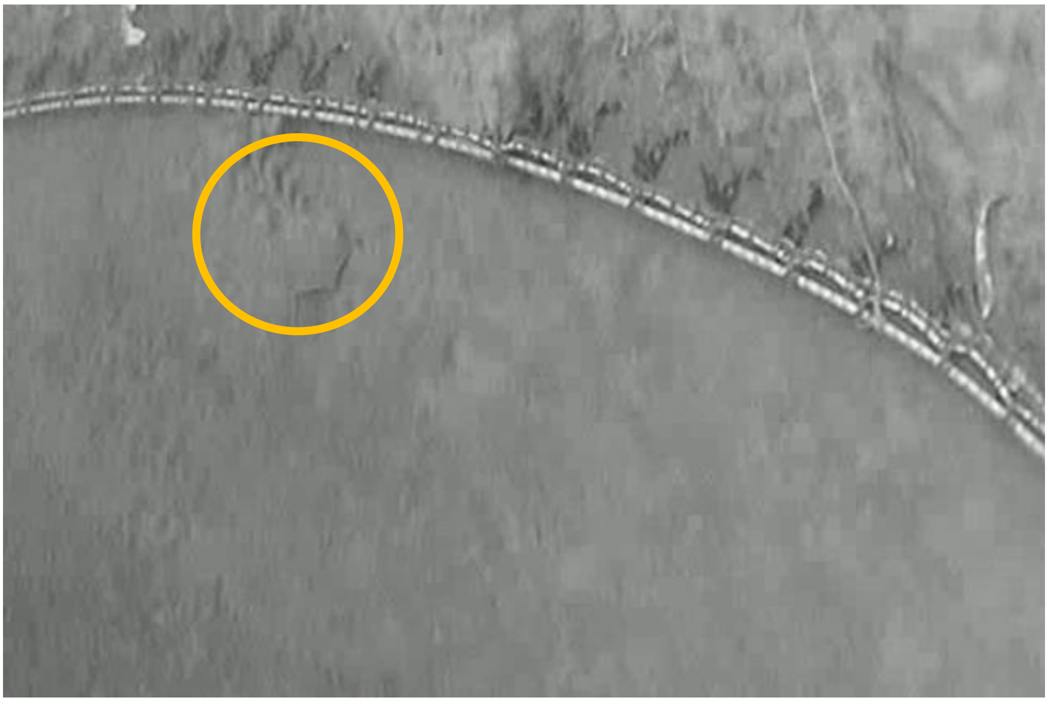
The gillnet panels that lined section of the outside of the belly of the trawl were used during 15 hauls. Fish were caught in the panels during two of the hauls (hauls 27 and 29), in both cases in gillnet no. 1 (Figure 16), which was installed in the extension. Mesh size of the trawl in this part was 80 mm. In haul 27 one specimen of *S. undosquamis* (TL 12.5 cm) was caught in the gillnet. Total catch rate in this haul was 63 $kghr^{-1}$. In haul 29, a total of 29 specimens of *P. tayenus* with an average length of 6.9 cm were caught in the gillnet. Catch rate in this haul was 292.90 $kghr^{-1}$ and most of catch (86%) were specimens of this species. The average length of *P. tayenus* in the codend was 6.8 cm.

3.5 Observations of fish behaviour, bottom contact and fish lock

We had 2 sets of underwater video camera recorders that each had a different objective: 1) A Navigator monochrome camera was used to study the bottom contact of the trawl gear and possible escape of fish below the ground rope. This video camera was attached to the ceiling of the upper panel overlooking the centre section of the ground rope. Recordings were made during a one hour haul (haul 12, Table 1) made in area 2 (Figure 6). The recordings indicated that the ground rope had good bottom contact throughout the haul (Figure 21). However, it was difficult to observe the behaviour of fish in the net mouth area due low contrast between the fish and the seabed. In addition, most fish observed were small and since the observational area only covered part of the centre net mouth area, it was difficult to follow the fish through the entire time they stayed in the net mouth area. Generally, fish entered from the wing area and took up positions shortly ahead of the fishing line, swimming in the direction of towing. Here they stayed for 15-20 s before they zig-zaged forward/sideways out of the observational area. Except for three rays, no fish were observed to escape (pass) below the fishing line. No fish were neither seen entering the trawl. 2) HDR-CX350VE camera was used to observe the fish lock performance during haulback. It was shown that the fish lock did not work as intended (Figure 22) and specimen of Bigeye (*P. tayenus*) were observed to swim forward out of the codend during haulback. It is unclear whether these fish actually escaped from the trawl as specimens of this species were caught in the same haul.

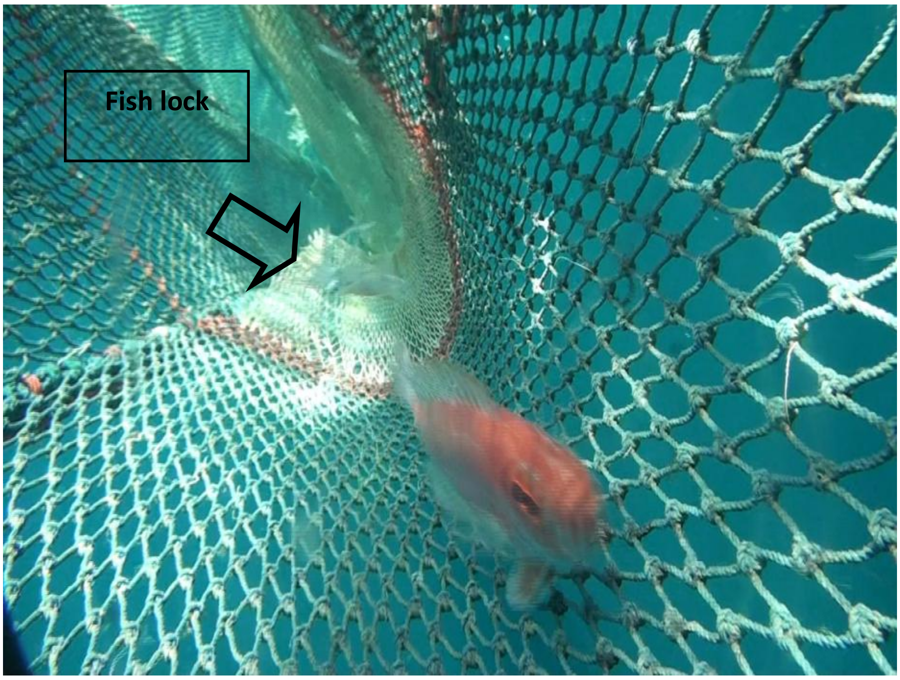


(a)



(b)

Figure 21: Bottom contact of trawl that was shown by underwater video recorder. (a); Four fish can be seen inside the area marked with the yellow box. The arrow of the box indicated the towing direction of the trawl, (b); Ray buried in the sediment that escaped under the fishing line. Yellow circle shows position of the ray.



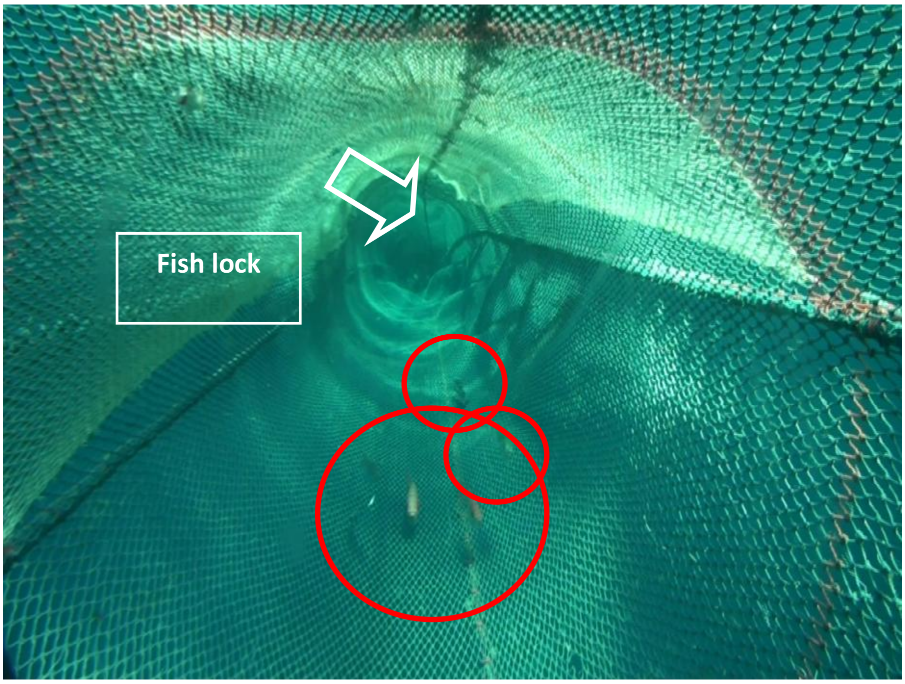


Figure 22: Fish that have passed the fish lock and swim forward towards the trawl mount. Specimens on the upper photo were identified as *P. tayenus.*

4. Discussion

To obtain the same door spread and trawl geometry across all fishing stations, a constrictor rope was used between the warps. Position and length of the rope was determined based on trials at the shallowest fishing depth used during the standardized surveys run in the area. The study showed that use of the rope in deep waters resulted in similar door distance and trawl geometry as obtained in shallow water without rope. At 75 m, the use of the constrictor rope reduced door spread by 22% compared to the situation when no rope was used. Similarly wing spread was reduced by 18%, while vertical opening of the trawl was increased by 6.5%.

The increase of door spread with depth are consistent with previous studies (Godø and Engås (1989); Engås and West (1987); Rose and Nunnallee (1998); Walsh (1996) and Pilling and Parkes (1995). Koeller (1991) showed that warp length and scope ratios affect to doors spread which itself is related to depth. The percentage reduction in door spread observed in this study at 70 m is higher than found in other studies at similar depth (Rose and Nunnallee 1998; Walsh and McCallum 1995). The reason for this is unknown but it may be due to factors such as the type of trawl, rigging configuration and bottom type. Main and Sangster (1979) showed an effect of bottom types on door spread. Thus, the assumption that the trawl efficiency has been independent of depth for the Andaman Sea trawl survey has not been fulfilled.

Despite the difference in trawl geometry, our results showed no significant difference in the catch rates and catch composition between hauls with and without constrictor rope. This is in agreement with results obtained by Walsh and McCallum (1997) who did not find a difference in catch rate for 6 groundfish and 2 pelagic species for fishing trials in the NW Atlantic. However, Rose and Nunnallee (1998) reported higher catch rates of walleye Pollock (*Theragra chalcogramma*), arrowtooth flounder (*Atheresthes stomias*), and flathead sole (*Hippoglossoides elassodon*) when the trawl width was restricted by cables than when it was unrestricted. The catch per area swept was significantly higher in the restricted configuration for the two flatfish species and a gadoid.

Dickson (1993) described the efficiency of trawl nets as composed of two components: net efficiency (the proportion of fish from the area between the wings of the net) and bridle efficiency (the proportion of fish from the area between the trawl wings and the otter doors that are herded into the net path by the action of the bridles, doors and sand clouds). If correct, then in our study, as both the wing and door spread increased with depth, net efficiency and especially bridle efficiency should increase with increasing water depth. The herding efficiency due to differences in bridle angles may also affect the catchability. Dickson (1993) and Main and Sangster (1981a) suggested that at high bridle angles, the sand-clouds pass well outside the wings of the trawl, thus reducing the important herding effects of sand-clouds, leading to reduced catch efficiency. This may also lead to a size-selection effect (Engås and Godø, 1986).

Korotkov (1984) found that when the height of the fishing line from bottom was increased, this resulted in increased escapement of fish. Von Szalay and Somerton (2001) reported catch rates to decrease significantly with increasing net spread for six of the seven species caught, despite the larger area swept at greater net spreads. They related this to reduced bottom contact at larger net spread. Similarly, Engås and Godø (1986) showed that an overspread trawl may affect the bottom contact and result in escape under the fishing line. If our trawl is overspread when fished at 70m depth without the constrictor rope, the higher swept area may be offset by reduced bottom contact. The 12 cm (6%) difference in vertical opening between hauls with and without constrictor is likely to be too small to substantially affect catch rates.

The video observations of bottom contact and fish behaviour in the net mouth area were only made in shallow depth (20 m). The recording indicated that the bottom contact was good. Except for rays, no escape of fish below the fishing line was seen. As we have the same gear configuration at deeper depths when using the constrictor rope, there is reason to believe that bottom contact is good also at greater depths when the constrictor rope is used. However, as no observations were collected at 70 m without a constrictor rope, we cannot (as mentioned above) rule out that bottom contact is reduced due to the trawl becoming overspread when fished at this depth.

Although the low catch rates at 20 m depth made it difficult to study fish behaviour in the net mouth area, there were indications that fish accumulated in front of the fishing line where they showed an optomotor response. Similar behavioural patterns have been observed for a number of species in other studies (e.g. Main and Sangster, 1981b). At 70 m the visibility was poor and artificial light would have to be used. However, this light may affect behaviour and observations were therefore not made.

Fish were caught in the gillnets lining sections of the trawl belly in only two of 16 hauls. In one of the hauls only one specimen of *S. undosquamis* was caught. In the other haul 29 specimens, all *P. tayenus*, were caught in the aftmost panel where the belly becomes narrow. This demonstrates that fish escape through the meshes of the top panel of the belly. The haul with the largest escape was characterised by a considerably higher catch rate than the other hauls. Size of the fish caught in the gillnet was similar to the size of fish caught in the codend. This may suggest that escapement is density dependent. No gillnetting was mounted to the lower belly due to the risk of damage to the netting. Escape may also take place here.

The video observations demonstrated that fish swim forward out of the codend during haulback. This is caused by the reduced towing speed (0.9-1.2 knots) during haulback, as the engine power the on the AFRDEC research vessel Pramong 4, is not sufficient to maintain standard towing speed (3 knots) during this phase. To prevent this, a fish lock has been installed. However, the video observations showed that the lock did not work as intended. Moreover, the mesh size of the netting used in the fish lock should be smaller to avoid fish becoming gilled in it.

5. Conclusion

This study has demonstrated that the area swept by the standard sampling trawl used by the Andaman Sea Fisheries Research and development Center increases considerably by depth, despite the relative narrow depth interval fished. To reduce this variability in trawl geometry by depth, the constrictor rope technique was applied. The length of the rope (6 m) and its position (between the warps; 100 ahead of the trawl doors) were based on trials without rope at the shallowest depth trawled during the routine surveys (20 m). Using the constrictor rope at deeper depths gave similar trawl geometry as obtained at the reference depth of 20 m. The constrictor rope technique is simple to apply and it is recommended that the restrictor rope should be used on a routine basis during the stock monitoring surveys in Thai waters.

Despite the difference in trawl geometry, catch rates and catch composition did not differ significantly between the hauls made with and without the constrictor rope. The reason for this is unclear, but it is suggested that the larger area swept when no rope is used is offset by increased escape below the fishing line due to the trawl being overspread. Observations by underwater video cameras in the net mouth area during hauls at shallow depth and without constrictor rope, indicated proper bottom contact of the fishing line. It is therefore suggested that the trawl will have similar bottom contact at all depths when the constrictor rope is used. However, this should be examined closer.

Observations of trawl's fish lock showed that this did not function as intended as fish were observed to swim forward out of the codend during haul back of the trawl. A new fish lock should be designed and installed. Its operation should be documented by new video footage.

Sections of gillnet panels mounted to the outside of the top panel of the trawl, showed only marked escape during one haul and only close to the codend. The catch is this haul was approximately an order of magnitude higher than in the remaining hauls, suggesting a density dependent escape. The escape of fish may be a potential source of bias and should be explored further. Possible mesh size reductions in the aft of the belly should be considered.

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7. Appendix

Table A1: Species composition and catch rate ($kg hr^{-1}$) in each haul

GROUP	Scientific name	Haul no.														
		7	8	9	10	15	16	17	18	19	20	21	22	24	25	26
Cephalopod	*Loligo chinensis*	1.50	1.12	2.05	1.14	0.90	0.43	0.75	1.92	0.92	2.60	0.53	1.42		0.40	0.24
	Loligo duvauceli	1.74	1.18	2.99	2.00	7.20	4.45	3.35	5.80	6.70	5.60	3.10	3.70	5.90	1.90	1.70
	Loliolus sumatrensis	0.09	0.01	0.02		0.01	0.09	0.01			0.07		0.08	0.04	0.04	0.03
	Octopodidae					0.18	0.21	0.25						0.02	0.04	0.04
	Sepia brevimana		0.03	0.02		0.17	0.06	0.08	0.01	0.09	0.11	0.02	0.06		0.07	
	Sepia pharaonis					0.13								0.16		
	Sepia recurvirostra		0.01		0.04	0.04	0.01		0.00	0.01	0.01	0.05	0.03		0.01	
	un_loliginidae	0.22	0.06	0.20	0.08	0.77	0.35	1.16	0.85	0.07	0.42	1.02	1.11	0.18	0.20	0.08
Crabs	*Charybdis miles*			0.02		0.03	0.18							0.13		0.12
	Podophthalmus vigil		0.04		0.13					0.07						0.05
	Calappidae	0.43	1.00	0.20	0.37	0.60	0.23	0.60	1.45	0.78	1.00		0.40	0.20	0.90	
	Charybdis truncata						0.00					0.02				0.01
	Charybdis variegata	0.06	0.06	0.05		0.02		0.03	0.06	0.04		0.00	0.14	0.02	0.04	
	Diogenidae										0.08				0.02	
	Dromiidae															0.16
	Majidae				0.04			0.16	0.17				0.02			
	Portunus hastatoides											0.02				

Table A1 (continued): Species composition and catch rate ($kghr^{-1}$) in each haul.

GROUP	Scientific name	Haul no.														
		7	8	9	10	15	16	17	18	19	20	21	22	24	25	26
Demersal fish	*Aluterus monoceros*	0.25	0.13	1.11		0.04	0.05			0.01	0.04				0.03	
	Cynoglossidae			0.01												
	Epinephelus bleekeri										0.30					
	Gazza minuta	0.02	0.04	0.06										0.06	0.05	0.09
	Labridae					0.03	0.06			0.04		0.02		0.02		0.02
	Lagocephalus sceleratus	0.03				0.08	0.12	0.15	0.03	0.12		0.10	0.31	0.10	0.05	0.05
	Lagocephalus spadiceus	0.44	0.15	0.30	0.46	0.25	0.20	0.05	0.31	0.32	0.06	0.08	0.30	0.45	1.69	0.99
	Lutjanus lutjanus		0.15													
	Menidae															0.17
	Muraenesox talabonoides		0.01			0.07	0.08					0.05				
	Nemipterus delagoae	0.09	0.03	0.22	0.18	0.35	0.18	0.06	0.64	0.36	0.46	0.54	0.29	0.07	0.22	0.22
	Nemipterus japonicus	0.12	0.08													
	Nemipterus nematophorus	0.38	0.09	0.18		0.96	0.30	0.50	0.30	0.70	0.90	0.15	0.29	0.38	0.18	0.07
	Nemipterus nemurus	0.43	0.41	0.28	0.83	2.06	0.81	0.75	0.59	0.77	0.52	0.70	0.41	0.42	0.22	0.26
	Nemipterus tambuloides							0.25								
	Parupeneus heptacanthus													0.27		
	Pinguipedidae	0.10		0.06	0.02	0.10	0.02	0.06	0.07	0.04	0.04	0.03	0.09		0.01	0.06
	Plotosidae						3.23									

Table A1 (continued): Species composition and catch rate (kghr^{-1}) in each haul.

GROUP	Scientific name	Haul no.														
		7	8	9	10	15	16	17	18	19	20	21	22	24	25	26
Demersal fish	*Priacanthus macracanthus*	3.81	0.98	1.46	0.90	0.55	1.02	2.45	3.20	0.70	1.50	0.80	1.80	1.30	1.06	0.77
	Priacanthus spp										0.03	0.02		0.02		0.01
	Priacanthus tayenus	0.65	0.41	0.34	0.68	1.99	0.55	0.73	1.84	1.31	11.01	0.69	1.36	0.15	0.23	0.29
	Pristipomoides spp.				0.03	0.02	0.17	0.06	0.11	0.03		0.02	0.11	0.02	0.05	0.01
	Rachycentron canadus										0.08			0.04	0.05	
	Saurida elongata	0.43		0.25	0.40		0.23							0.56	0.09	0.35
	Saurida micropectoralis															0.35
	Saurida tumbil	0.04												0.47	0.49	1.38
	Saurida undosquamis	28.31	31.74	19.05	22.52	29.42	26.27	32.25	31.51	37.29	30.31	5.76	32.07	15.89	7.54	6.61
	Scaridae											0.04				
	Scolopsis			0.01	0.02	0.12		0.03	0.01	0.01	0.00	0.01				
	Siganus canaliculatus		0.07			0.01	0.15		0.11	0.06						
	small platy				0.06	0.04		0.04	0.06	0.05	0.07	0.26	0.27	0.07	0.04	0.08
	small sphyraenidae	0.05	0.16	0.03	0.07	0.04			0.07	0.24	0.35	0.06	0.03	0.15	0.39	0.02
	Sphyraena jello											0.23				
	Synodus spp			0.03			0.10	0.23			0.03	0.06		0.04	0.03	0.15
	Trachinocephalus myops						0.02							0.06	0.04	
	Trichiuridae	0.16			0.51	0.53	2.19		0.11	0.17	0.14	0.04	0.47	0.96	2.45	1.31
	Upeneus bensasi	0.33	0.09	0.33	0.81	1.26	1.56	1.21	2.79	2.20	2.14	1.10	1.14	0.47	0.17	0.19
	Upeneus moluccensis	0.20	0.07	0.17	0.31	0.27	0.21	0.17	0.29	0.31	0.30	0.14	0.39	0.13	0.10	0.01

Table A1 (continued): Species composition and catch rate (kghr^{-1}) in each haul.

GROUP	Scientific name	Haul no.														
		7	8	9	10	15	16	17	18	19	20	21	22	24	25	26
Trash fish	Antennariidae						0.26	0.20				0.22			0.20	0.03
	blackfin_apogon							0.05		0.01	0.24		0.05	0.01		
	Bothidae	0.13	0.05	0.17	0.50	1.00	0.13	0.32	1.06	1.24	0.89	1.13	0.96	0.46	0.47	0.46
	Callionymidae									0.05						
	champsodon_spp	0.22	0.15	0.07	0.17	0.47	0.40	0.39	0.49	0.90	0.94	0.67	1.11	1.17	1.09	1.18
	Dactylopteridae	0.01			0.03			0.18	0.05	0.02			0.03	0.08	0.11	0.10
	Diodontidae														0.06	0.09
	Fistulariidae	0.03	0.14	0.03		0.06	0.07	0.04	0.05	0.02	0.00		0.04		0.03	0.06
	Leiognathus aureus					0.03			0.02	0.12	0.06	0.02	0.02	1.10	0.75	1.22
	Leiognathus bindus							0.02						0.00		0.03
	Pentaprion longimanus	0.04	0.03	0.03	0.02	0.08		0.15	0.18	0.01	0.42		0.05	0.74	0.21	0.21
	Pleuronectidae			0.06	0.02							0.01		0.05		0.02
	Pomacenthidae									0.08	0.21		0.14			0.01
	redtail_apogon		2.11		0.00				0.00	0.06	0.01	0.00	0.01			
	Scorpaenidae					0.03			0.07			0.01			0.01	0.08
	Soleidae	0.44	0.16	0.01	0.02	0.03	0.97	0.12	0.07	0.05	0.14	0.03	0.06	0.06	0.31	0.20
	strip_apogon	0.02	0.03		0.17	0.15	0.02		0.19	0.08	0.32	0.22	0.29		0.04	0.06
	Trash pterocaesio		0.14													
	Uranoscopidae					0.08								0.02		

Table A1 (continued): Species composition and catch rate (kghr^{-1}) in each haul.

GROUP	Scientific name	Haul_no														
		7	8	9	10	15	16	17	18	19	20	21	22	24	25	26
pelagic	*Atul mate*						0.06									
	Carangoides spp	0.40	0.73	0.18	0.30	0.35	0.20	0.08	0.49	0.72	0.23	0.15	0.60	0.20	0.15	0.04
	Decapterus maruadsi						0.05		0.04	0.15	0.14	0.03	0.03			
	Megalaspis cordyla						1.94			0.02	0.52		0.13			
	Other large pelagicfish						0.02									
	Rastrelliger kanagurta	0.76	0.48	0.06	0.17	0.19	0.50	0.02	0.70	0.75	0.55	0.36		1.10	0.60	0.55
	Scomberoides spp.													0.29	0.12	0.12
	Selar crumenophthalmus									0.18						
	Seriolina nigrofasciata								0.25							
	Stolephorus indicus	0.16	0.16	0.38	0.95	0.11	1.27	0.02		0.23	0.06	0.15	0.04	0.62	0.51	0.02
	Un_uraspis	0.04	0.03			0.01		0.17	0.13				0.20	0.10	0.18	0.09
shrimp	Other shrimp	0.02				0.01	0.02	0.02		0.01		0.02			0.00	
	Penaeus semisulcatus	0.18					0.24					0.07	0.20			
	un_metapenaeopsis	0.02	0.05	0.04	0.05		0.04	0.02	0.03		0.07		0.09	0.01	0.06	0.08
	Oratosquilla woodmasoni															0.02
	un_mantisshrimp								0.02					0.02		
others	giant murex ahell														0.05	0.04
	sea_dollars								0.01							
	sea_stars										0.01					
	sea_urchins														0.02	