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RESEARCH PAPER

The effectiveness of the Jones/Davis type by-catch reduction device (BRD) to reduce unintended catch of trawl fisheries

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ABSTRACT

Reduction by-catch of commercial fishing is become a major concern, especially prawn trawl fisheries. By-catch reduction device developed to address that issue. However, there were trade-off problems regarding the implementation the BRD in trawl fisheries that is the effectiveness of the BRD. The performance of BRD was questionable on the effectiveness in term of reduction the by-catch and maintenance amount of target catch. This essay examines the performance of Jones-Davis type BRD to reduce by-catch and its impact on prawn catch in Cleveland Bay. An experimental fishing has been conducted (control-net and BRD-net; Pair-trawl method) to assess the effectiveness of by-catch reduction which examined with Wilcoxon Rank Test. The result shows that trawl equipped by BRD significantly reduce by-catch by 22.2% (Z = -4.6406, p-value = 0.0001) and retained prawn catch which was no significant difference in prawn catch between BRD and control nets (Z = -1.9218, p-value = 0.0546). Therefore, that evidence could be argued to convince about the BRD benefits to commercial prawn trawl fisheries.

Keywords: Jones-Davis type BRD; by-catch; prawn trawl; effectiveness; Queensland

INTRODUCTION

By-catch is the catch that being an unintended catch of fisheries(Kumar and Deepthi, 2006), such as fish, turtles, marine mammals, and sea-birds. Almost by-catch is discarded from the net and a few portions have been processed as by-product, such "surimi"(Blanco *et al.*, 2007). By-catch is due to a lack of fishing gear to be selective on its target, especially trawl fisheries (Broadhurst *et al.*, 2006). By-catch is becoming a major issue in fisheries management by considering to ecological disturbance of ecosystem balance (Broadhurst *et al.*, 2006; Eayrs, 2007; Lewison *et al.*, 2004), such as unwanted harvest of vulnerable species (i.e. turtle, dolphin and dugong) and predator species (sea lion and shark). By-catch possibly also generated an economic loss, wasting fishing cost by throwing back the unintended catches(Broadhurst *et al.*, 2007). The effect of by-catch lately recognized in 1885 which was indicated by the rapid decline of fish stock (Blanco *et al.*, 2007).

By considering the negative impact of by-catch, people started to develop techniques that possibly reduce amount of by-catch significantly, such as selecting a fishing gear based on selectivity (Cooke and Wilde, 2007), modification (He, 2007), operation (Crawford *et al.*, 2011; Gaspar and Chícharo, 2007; Manjarrés-Martínez *et al.*, 2015) and community engagement (Hall *et al.*, 2007). Various fishing gear-based methods have been developed to reduce unintended catch, such as longline (Løkkeborg, 1992), gillnet(Baremore *et al.*, 2012) and traps (Stewart, 2007). However, the major concern on the shrimp trawls fisheries(Andrew and Pepperell, 1992; Broadhurst, 2000; Broadhurst *et al.*, 2006; Davies *et al.*, 2009; Gray, 2001)was due to the significant ratio between target catch (shrimp) and its by-catch (fish)(Harris and Poiner, 1990). There was around 1.8 million ton of by-catch per year that discarded from shrimp trawl (Kelleher, 2005) and increases significantly in the recent decade by 7 million ton per year (Eayrs, 2007).

An increase in concern on by-catch reduction has been initiated by US in early 1990s by amending the Magnuson Fishery Conservation and Management Act. This amendment was followed by the increase of by-catch reduction research, specifically to develop an effective by-catch reduction device (BRD). BRD is the recent terminology for tools which have a purpose to reduce the by-catch number, formerly BRD was called as the Turtle Excluder Device (TED) due to the specific objective to reduce turtle from trawling. There are various types of BRD has been developed, such as fisheye-mesh, side opening TED, extended funnel, snake-eye, Morrison TED, Andrews TED and Jones-Davis. Those BRDs show dissimilar performance to reduce by-catch and to optimize target catch (Watson *et al.*, 1999).General methods to assess the efficiency of BRD are by comparing the different performance of BRD by measuring catch composition, fishing gear selectivity (Eayrs, 2002) and survival rate of by-catch (NOAA, 2011). There were different trawl operations to measure the effectiveness, such as alternate haul trawl, trouser trawl (Eayrs, 2002) pair-trawl (Brewer *et al.*, 1998), and underwater video (Jaiteh *et al.*, 2014).

Prawn trawl industry in the northern waters of Australia faces similar trade-off on improving the effectiveness of BRD in order to optimize target catch along with reducing unwanted catch(Gullett, 2003; Robins and McGilvray, 1999). The AusTED/ Australian trawl efficiency device(Mounsey *et al.*, 1995) was developed to reduce unwanted catch and could reduce by-catch by up to 55% of total catch(Robins-Troeger *et al.*, 1995). Jones-David BRD also commonly used by the Northern Prawn Fisheries in the Coral Sea. The efficiency of Jones-David BRD depends on places (Andrew and Pepperell, 1992). Studies reported that in Cleveland Bay northern Australia, Jones-Davis BRD could reduce by-catch about 25% of total catch and increased prawn ratio by around 10% (Fingerlos, 2012). The development of BRD need to consider several issues, such as industry acceptances that require high efficiency of BRD (reduce by-catch and increase target catch), simple installation, secure in an application and low cost. Therefore, this report examines the recent update on the effectiveness of Jones-Davis type BRD to reduce unintended catch and to optimize target catch.

MATERIALS AND METHODS

Time and location

The study was conducted in Cleveland Bay, Townsville-Queensland during 7-8 March 2015 using RV James Kirby. The pair-trawl method was used to assess the efficiency of Jones-Davis type BRD (Figure 1a) by comparing with control trawl (trawl without BRD) (NOAA, 2008).

Data collection

A pair-trawl method trawled both nets (control and BRD trawl; Figure 1b) at the same time and assumed that the nets swept the same density of demersal fish population (Eayrs, 2007; Warner *et al.*, 2004). The trawls used were standardized for commercial prawn fishery that has 1.5-inch mesh size. Every single trawl has 24 repeating times and same condition, such as vessel speed at 4.2 km/hr and the towing period for 10 minute which means the coverage was 6,000 m^2/trawling. Every catch grouped at least by family or genus and weighted. This catches also measured the maximum weight and length of 5 fishes per trawl bag.

Data analysis

Those pooled-catch data used to examine the BRD effectiveness by comparing various kinds of catches between control and BRD trawl, such as prawn, total fishes, invertebrate-fish ratio, pony fish (*Leiognatus* sp.), Lizard fish (*Saurida pectoralis*), other fishes, mean of maximum fork length, and mean of maximum weight. The null hypothesis (H_0) stated that there is no difference between the median of two samples (catches of control and BRD trawl). This hypothesis will be tested by Wilcoxon Rank Test in S-Plus. This non-parametric test was assumed that data was not normal distributed and the variance was not equal (Whitlock and Schluter, 2009).

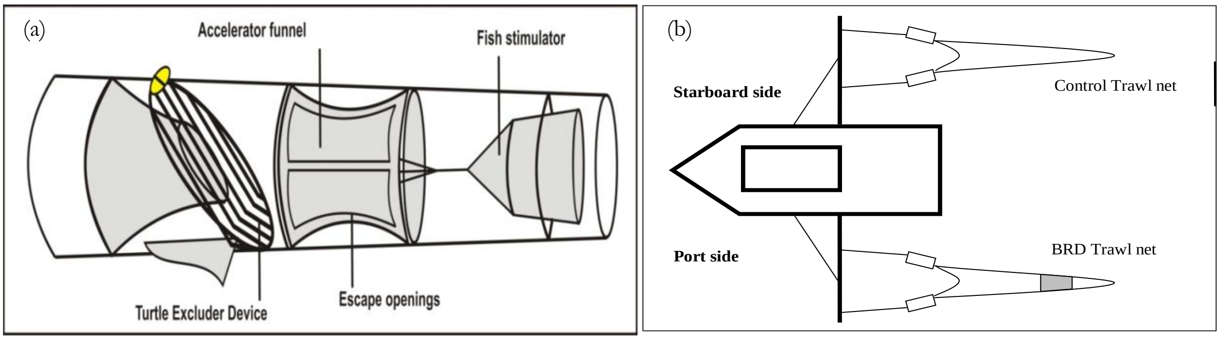

Figure 1. (a) Installation scheme of Jones-Davis type BRD (Watson *et al.*, 1999), (b) and pair-trawl method

RESULTS

The ratio of target catches (prawn) and by-catch for different treatments (BRD and control) showed significant different using Wilcoxon rank-sum test (Z = -2.1922, p-value = 0.0284). This ratio for BRD net was higher (1:384) than control net (1:331). This condition probably was due to a lot of prawn absences during sampling. However, comparison of prawn as target catch between BRD (0.02 ± 0.02 kg) and control (0.03 ± 0.02 kg) nets were not significant different (Z = -1.9218, p-value = 0.0546) (**Error! Reference source not found.** and Figure 2a).

Moreover, other catches showed that there were significant differences of catch quantity between BRD and control nets ($P < 0.05$) (Table 2). By using BRD, by-catch of trawl (total fishes, pony fish, lizard fish and other fishes) were reduced significantly by 22.2%, 12.8%, 31.9%, and 34.8% respectively. Total fish catches between BRD (6.0 ± 1.5) and control (9.4 ± 3.2) nets were significantly (Z = -4.6406, p-value = 0.0001) different where total fish in BRD net was lower than control net (**Error! Reference source not found.** and Figure 2b). Both pony and lizard fish catches (Table 2 and Figure 2c-d) of BRD net (pony fish: 3.8 ± 1.0; lizard fish: 0.2 ± 0.2) were lower than control net (pony fish: 4.9 ± 1.9; lizard: 0.3 ± 0.3) and showed significant differences (Z_{pony} = -2.7525, p-value$_{pony}$ = 0.0059; Z_{lizard} = -2.7569, p-value$_{lizard}$ = 0.0058). Similarly, carangid fishes and other fish (Table 2 and Figure 2e-f) in BRD net (carangid fishes: 0.1 ± 0.2; other fish: 1.9 ± 1.1) was lower than control net (carangid fishes: 0.2 ± 0.2; other fish: 4.0 ± 2.7) and showed significant differences ($Z_{carangid}$ = -2.3293, p-value$_{carangid}$ = 0.0198;Z_{other} = -3.6741, p-value$_{other}$ = 0.0002).

Other attributes of trawl catch i.e. the average of maximum fork-length and weight for 5 fish samples showed contrary results (Figure 3a-b). The average of maximum fork length for BRD net (15.6 ± 2.1) was lower than control net (17.9 ± 2.3) and reported significant differences (Z = -2.1549, p-value = 0.0312). However, there were no differences between the average of maximum weight from 5 fish samples (Z = -0.5258, p-value = 0.5990) of BRD (56.9 ± 21.3) and control (62.5 ± 28.6) nets.

Table 1. Summary statistics of catches between BRD and control nets

Statistic	Prawn	Total fishes	Pony fish	Lizard fish	Carangid fishes	Other fishes	Mean of max fork length	Mean of max weight
	(kg/6,000 m^2)						(cm)	(g)
BRD								
Mean	0.02	6.0	3.8	0.2	0.1	1.9	15.6	56.9
SD	0.02	1.5	1.0	0.2	0.2	1.1	2.1	21.3
Var	0.0003	2.2	1.1	0.02	0.02	1.3	4.3	454.8
Min	-	4.5	2.4	-	0.03	0.8	12.4	26.0
Max	0.05	10.2	6.8	0.7	0.8	6.2	20.6	111.2
Control								
Mean	0.03	9.4	4.9	0.3	0.2	4.0	17.9	62.5
SD	0.02	3.2	1.9	0.3	0.2	2.7	2.3	28.6
Var	0.0004	10.3	3.7	0.1	0.03	7.2	5.4	819.5
Min	-	6.4	2.6	0.1	0.03	1.1	11.5	22.1
Max	0.08	18.7	11.2	1.2	0.6	13.2	21.3	153.6
Differences between amount of catches of BRD and control nets*								
Value (%)	-29.3	-22.2	-12.8	-31.9	-33.3	-34.8	-4.2	-4.7

* : minus (-) value means there an decrease in catch quantity by using BRD

Table 2. Summary of Wilcoxon Rank Test on Control and BRD Trawl Catches

No.	Variate of control and BRD trawl	Z value	p-value	Result
1	Ratio prawn and by-catch*	-2.1922	0.0284	**
2	Prawn	-1.9218	0.0546	
3	Total fishes	-4.6406	0.0001	**
4	Pony fish	-2.7525	0.0059	**
5	Lizard fish	-2.7569	0.0058	**
6	Carangid fishes	-2.3293	0.0198	**
7	Other fishes	-3.6741	0.0002	**
8	mean of maximum fork length	-2.1549	0.0312	**
9	mean of maximum weight	-0.5258	0.5990	

* : other marine species except prawn, ** : Significantly different at 0.05

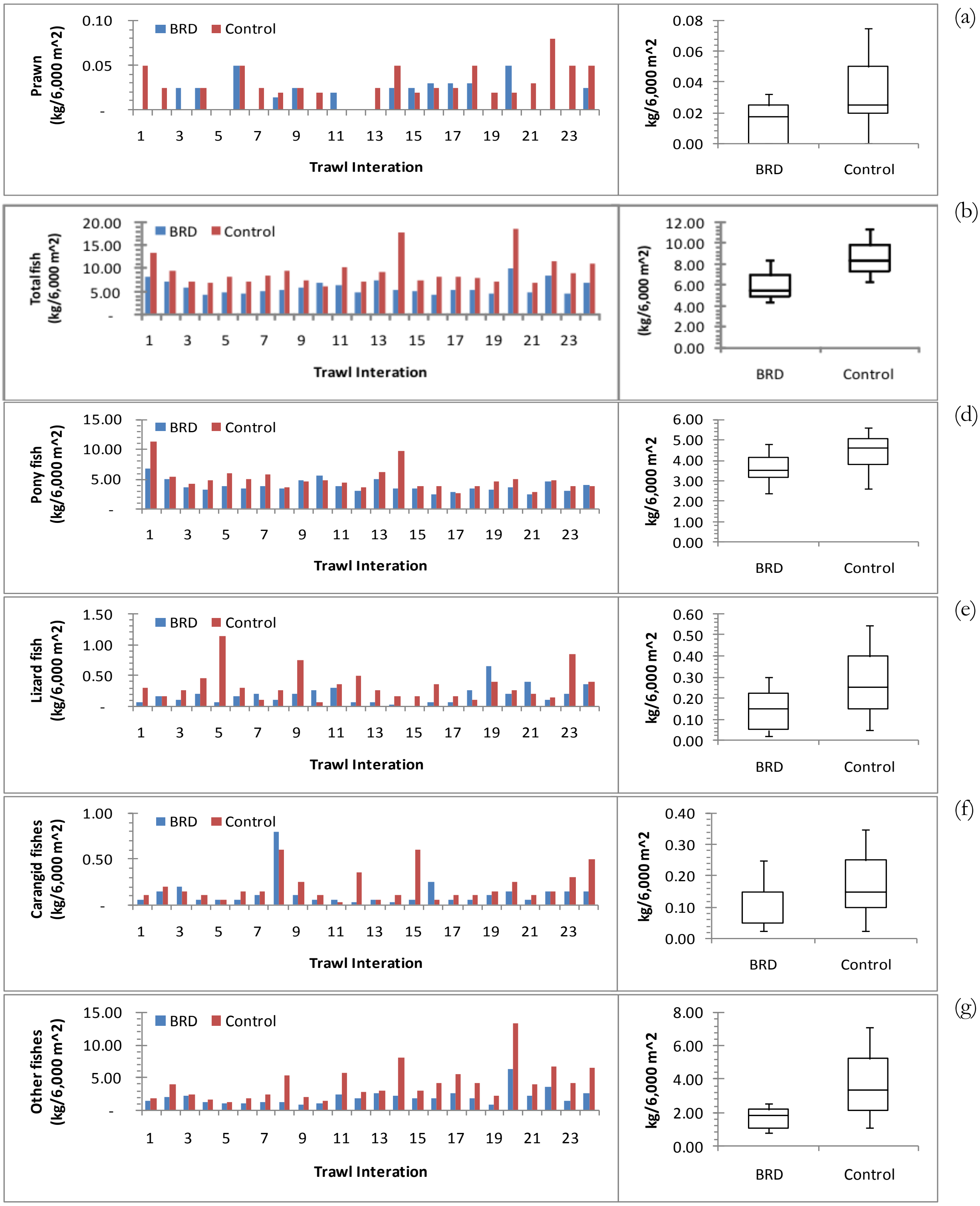

Figure 2. Comparison of catch between BRD and control nets by commodities namely, (a) prawn, (b) total fish, (c) pony fish, (d) lizard fish,(e) carangid, (f) other fishes

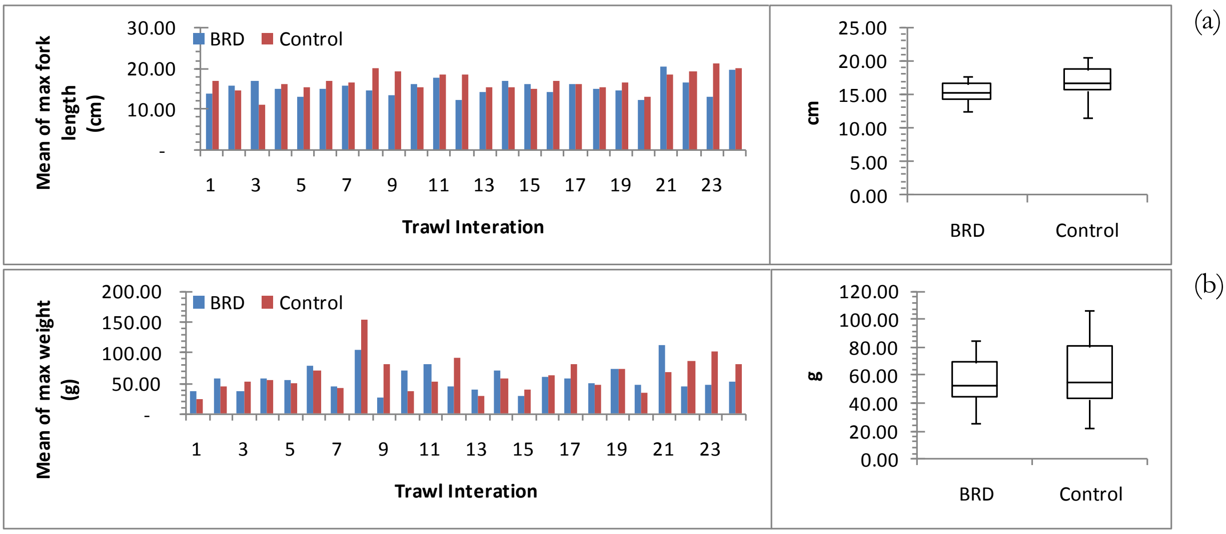

Figure 3. Comparison of catch attributes between BRD and control nets (a) by mean of maximum fork length, (b) and mean of maximum weight

DISCUSSION

Prawn catch is an important consideration to assess the efficiency of applying BRD in a trawl net, especially to persuade commercial prawn a trawler. As a target catch, prawn quality also needs to be secured when BRD was applied by trawler. The assessment of the effectiveness of Jones-Davis type BRD showed that there was significant similarity of prawn catches between BRD and control nets and significantly effective to reduce by-catch of prawn trawl. Similarly, other studies stated that prawn catch between BRD and control nets were no differences (Brewer *et al.*, 1998; Courtney *et al.*, 2006; Fingerlos, 2012; Watson *et al.*, 1999). This condition would increase industry acceptance on BRD enforcement due to the advantages of BRD, such as sorting time reduction that leads to good treatment for better prawn quality and reduction of energy loss from reduction drag force of unwanted catch(Gullett, 2003; Hoagland, 1999). Those benefits probably increase the probability to gain more catch due to an increase in fishing time. Some studies on trawlers in Cleveland Bay reported that by using Jones-Davis type BRD, the prawn catch increased around 20% (Fingerlos, 2012). Reduction rate may vary due to environmental conditions, such as inclination (Brewer *et al.*, 1998)fish composition (Andrew and Pepperell, 1992), wave (Robins-Troeger *et al.*, 1995), vessel propeller force (O'Neill *et al.*, 2003).

There seems limitation of Jones-Davis type BRD that this BRD less effective to reduce fish species that small and slow swimmer, such pony fishes (12.8%). However, BRD showed a significant reduction in a relatively good swimmer, such as carangid fishes (33.3%)(Gemballa and Treiber, 2003). It explained that good swimmer fishes have a high probability to escape from a trawl through BRD than slow swimmer due to different swim behaviors. Carangid fishes physiology in their organ that allowed them to maintain dynamic motion (Gemballa and Treiber, 2003).

This study showed that there was significant reduction in lizard fish (*Saurida pectoralis*) and pony fish (Leiognathidae) as a weak swimmer by using Jones-Davis type BRD. Lizard fish was known as demersal predator and their physiological organ put them highly vulnerable to prawn trawl fisheries (Brewer *et al.*, 2006) due to lack of maintenance burst speed for long period (Sfakiotakis *et al.*, 1999).Similarly, pony fish (Leiognathidae) was ineffective physiologically to escape from fish stimulator and swim against tunnel which leads to high vulnerability to prawn trawl fisheries (Staunton-Smith *et al.*, 1999). In contrast, other studies reported installation of BRD had no significant reduction in lizard fish and Pony fish catch (Fingerlos, 2012). It could argue that lizard and pony fish had seasonal abundance over the period; therefore it's difficult to measure the effectiveness of BRD.

Originally, Jones-Davis BRD attempted for red snapper fisheries in the Gulf of Mexico and showed a total fish reduction by 58% (J. W. Watson & Foster, 1997). Other studies on BRD in Cleveland Bay reported that reduction by-catch by 19-24% (Fingerlos, 2012). The low effectiveness of by-catch reduction of Jones-Davis BRD was influenced by fish composition. Therefore, BRD showed less effective to reduce small fishes in tropical fisheries than sub-tropical fisheries (Brewer *et al.*, 2006; Fingerlos, 2012). However, type of BRD and BRD configuration showed a different kind of performance to reduce the by-catch (Brewer *et al.*, 2006; Broadhurst *et al.*, 2002; NOAA, 2011; Watson *et al.*, 1999; Watson and Foster, 1997). Further study needed to assess the performance of examines time series data, by-catch survival rate and gear selectivity.

CONCLUSIONS

The result shows that trawl equipped by BRD significantly reduce by-catch by 22.2% (Z = -4.6406, p-value = 0.0001) and retained prawn catch which was no significant difference on prawn catch between BRD and control nets (Z = -1.9218, p-value = 0.0546). Therefore, that evidence could be argued to convince about the BRD benefits to commercial prawn trawl fisheries.

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