BY-CATCH REDUCTION IN THE WHITE SHRIMP, *NEMATOPALAEMON HASTATUS* FISHERY OF NIGERIA USING CODEND WITH RIGID SEPARATOR PANEL.

Eyo E. Ambrose and Godwin N. Udom

Faculty of Agriculture, University of Uyo, PMB 1017, Uyo, Akwa Ibom State.

ABSTRACT

Sea fishing experiments with conventional and modified codends were conducted to reduce fish by-catch from shrimp beam trawl fisheries off Ibeno coast, Nigeria. The modified codend consist of a rigid grid with a guiding panel and bar spacing of 20 mm. Simultaneous paired fishing comparison against conventional codends showed that the modified codend significantly reduced the by-catch of juvenile fishes up to 72.06% (T-test, P<0.05;0.01) with no significant reduction (2.9%) in the quantity of the target shrimps, *Nematopalaemon hastatus* (T-test, p>0.05;0.01). Small size and fusiform shape fishes with total length of 4 to 10 cm were mostly retained by the modified codend, e.g. *Epinephelus aenus* (p>0.05;0.01) and *Pomadasys jubelini* (p>0.05;0.01), while large and flattened fish specimens with a total length range of 11 to 30 cm were mostly excluded (*Dasyatis margaritas* and *Carcharhinus brachyrus)* (p<0.05,0.01). The high percentage reduction of the three species of most abundance and prioritize croaker by-catch family, Sciaenidae: *Pseudotolithus elongatus (*72.73%, p<0.05;05;0.01), *P. senegalensis* (66.65%, p<0.05.01) and *P.typus* (68.33, p<0.05;0.01) makes the by-catch reduction device a conservation tool for commercial application. The potential of the separator panel to alleviate by-catch problems and its limitations in a developing economy is discussed in the study

Key words: By-catch reduction device, shrimp, Trawl fisheries, Sustainability Conservation tool, Nigeria.

Introduction

Artisanal beam trawl shrimping in Nigeria is daily fishery and is carried out throughout the year. The fishery is new and operates using planked canoe powered by 25 or 40 HP outboard engines in estuaries and nearshore part of the sea within 1 to 2 nautical miles from shoreline where their technology could permit. These zones are reserved for small scale fisheries exploitation by the Nigerian fisheries law and regulations and they form the nursery ground for juveniles of fin fishes. Like the majority of trawls, the conventional shrimp trawl typically are poor selective fishing gears and so retain large quantities of non-target species collectively termed by 'by-catch' (saila, 1983). By-catch in shrimp trawls become a significant problem for fishery managers who are mandated to maintain sustainable fish stocks when most are fully or over exploited. Shrimps by-catch often includes fin fish species with commercial importance incidentally killed. The mortality of these species is thought to reduce the recruitment, biomass and yield of stocks that form the basis of other fisheries and has been a global concern (Saila, 1983; Andrew and Pepperell, 1992; Alverson *et al.,* 1994). In 1994, by-catch from shrimp trawls was estimated to be around 11.2 million tones worldwide (Alverson, *et al.*, 1994).

A recent observer-based study of this fishery that quantified by-catch species and trawling gear components as a pre-requisite for trawling gear modifications to reduce by-catch species show that: (1) 25 species belonging to 20 families constituted the by-catch species and are juveniles with a total length range of 4 to 30 cm caught within their nursery grounds, the target shrimp is *Nematopalaemon hastatus* with carapace length range of 0.5 to 1.5 cm (Ambrose, *et al.*, 2005). (2) The fishing unit is simple; consisting of 7.5 to 9.5m LOA planked canoes powered by 25 or 40 HP outboard engine, the trawl condend mesh size is 10mm stretched (Ambrose and Williams, 2003). (3) The croaker family, scienidae is the most abundant and priortised by-catch family for reduction (Ambrose, 2003).

A global awareness of by-catch problems has led to various management strategies that attempt to alleviate some of the impacts of large by-catches (Andrew and Pepperell, 1992). Options such as restricting trawling to locations and times known to have relatively small amount of by-catches (High *et al.*, 1969; Canddy, 1982) and conversion of by-catch species to human/livestock feed (Peterkin, 1982) are to no avail on by-catch reduction. The most applied option throughout the majority of the worlds shrimp trawl fisheries focused on technological changes that involve modifications of conventional trawling gears and methods by incorporating by-catch reduction device (BRD) at the bunt to improve interspecific selectivity and so minimize by-catch of unwanted individuals (Watson *et al.*, 1989; Broadhurst and Kennelly 1994, 1995; Kendall, 1995; Isaksen *et al.*, 1992. Broadhurst (2000) classified BRDs under two broad categories according to the basic theory and methods used to facilitate the escape of by-catch. The first are those that separate by-catch from shrimps due to behavioural differences. The second are those that separate by-catch from shrimps by size partitioning. In this fishery, juvenile fishes (4-30cm, TL) and shrimps (0.5-1.5cm, CL) are exploited (Ambrose *et al*., 2005). The multiple by-catch species are larger than target shrimps and required mechanical separation. Such BRDs comprise of relatively simple oblique panels or grids usually located within or immediately anterior to the condend (Kendall, 1990; Andrew *et al.,* 1993; Isaksen *et al*., 1992; Broadhurst and Kennelly, 1996). Most BRDs in this category e.g. rigid grid are designed mainly to exclude those individuals that are larger than the openings in the separating panel.

The specific goals in this work were to complete a series of experiments under normal commercial fishing conditions to determine the shrimp retention and by-catch exclusion characteristics of rigid separation grid inserted in shrimp beam trawl that operates in Nigerian coastal waters.

Materials and methods

The study was performed from October 2020 to January 2021 by 2 men fishing crew with a wooden planked canoe of overall length 8.5m, powered by 25HP outboard engine. Nearshore Atlantic Ocean with depth ranging from 10 to 20m off Ibeno, South East Nigerian Coast (Latitude 4N to 6.30N and Longitude 8E to 10E) was trawled. The beam trawl net used is an improvised stow net rigged effectively for towing, vertical mouth lift, horizontal mouth spread and negative bouyancy. Detailed design and rigging of stow net to bestow for towing is given by Ambrose and Williams (2003). The codends employed for the study measured 454 meshes from anterior to posterior tip, 256 meshes from anterior to posterior tip, 256 meshes in circumstance and were constructed from 10mm mesh size netting with a thickness of R155 tex. The net has seven segments joined with a take up ratio of 0.5. Mouth re-inforced panel is thicker (R470 tex) and mesh size larger (38mm) to withstand towing stress form the warp and bridles.

Two codends designs were compared. The conventional codend was designed similar to fisher's net as described above. The second codend termed 'modified by inserting grid assemblage at anterior codend. It consisted of; (1) 400mm by 600mm aluminum grid with a bar spacing of 20mm (2) Guarding panel net with chain end and (3) Plastic.

The two codends were compared against each other in independent paired trials, that are in separate two hours' tows by two adjacent boats fishing at the same time (Thorsteinsson, 1992; High *et al*., 1969) on an established shrimping ground. Over 4 months, with completed a total of 30 replicate tows of each paired comparison.

After each tow in each paired experiments, the two condends were emptied into the midship deck of the canoe. On board sorting of fishes from shrimps started toward shore and was completed upon landing at shore. All organisms were sorted according to species and families. The following data were collected from each landing: (1) The total weight of shrimps (2) The total weight of by-catch in kilogram (3) The weight, number and size of commercially important fin and shell fish species were taken using flat head weighing balance and measuring board. Several commercially important by-catch species were caught in quantities to allow meaningful comparisons. These were; Pentanemus quinquarius, *Galeoides decadactylus, Callinectes aminicola, llisha africana, Pseudotolitithus elongatus, P. senegalenses, P. typus, Cynoglossus senegalensis, Drepane africana, Selene dorsalis, Chloroscombrus chrysurus, Lutjanus dentatus, Arius latiscutatus, Pomadasys jubelini, Trichiurus lepturus and Carchahinus brachyrus.*

Catch data from all the 30 replicate landings for each of the paired comparison were pooled for analysis. The total weight of by-catch species, target shrimps and the weightland numbers of commercially important by-catch species from both conventional and modified codends were compared. The hypotheses that the weights/numbers of landing (shrimps, total by-catch species and commercially important by-catch species) from conventional and modified codends do not differ were tested using one tailed paired T-test.

Results

Compared with the conventional codend, the modified codend significantly reduced the by-catch of juvenile fishes up to 72.09% (T-test, P<0.05;0.01) with no significant reduction (2.9%) in the quantity of the target shrimps *Nematopalaemon hastatus* (T-test, P>0.05;0.01, table 1). Sixteen out of 18 commercially important by-catch species that were caught in sufficient quantity showed high percentage weight reduction (50% and above) in modified condend, while large fish specimens with a total length range of 11 to 30cm that could not pass through the grid bar spacing of 20cm were highly excluded from modified condend.

The high percentage weight reduction of the 3 species of most abundance and priortised croaker by-catch family, sciaenidae e.g *Pseudotolithus elongatus.,* (72.73%, T-test, P<0.05;0.01), *P. senegalensis* (66.65%, T-test, P<0.05;0.01) and *P. typus* (68.33%, T-test, P<0.05;0.01 Table 2) makes the BRD a conservation tool for commercial application.

Reduction in the number of commercially important by-catch families were significant e.g. Clupeidea (P<0.05;0.01), Trichiuridea (P<0.05;0.01, Sciaenidae (P<0.05;0.01), Carangidae (P<0.05;0.01), Polynemidae (P<0.05;0.01, Table 3). However, the number of flattened fish species reduced in modified condend were not statistically significant e.g. Dasyatidae (T-test, P>0.05;0.01) and Carcharhinidae (t-test, P>0.05;0.01).

The mean catch (kg) of 13 commercially important by-catch species in modified codend were significantly lower (T-test, P<0.05;0.01) than in conventional condend and likewise total by-catch (T-test, P<0.05;0.01) while target shrimps was not significant (T-test, P>0.05;0.01).

Discussion

Coastal shrimp trawl by-catch in Nigeria like other developing countries has not attracted international attention and therefore is not being aggressively addressed by State and Federal Management Agencies. The local outcry about the unsustainable harvesting of juvenile fishes from fragile habitats (estuary, coastal seas) perceived to be the nursery ground for majority of fish species led to an observer study (Ambrose *et al*, 2005) and a successful development and introduction gear modification capable of significantly reducing shrimp trawl by-catch and provided tools to more effectively manage and utilize coastal fishery resources.

Like other studies (Broadhurst *et al.*, 1992), this study has shown that there is great utility for the separator grid in the conservation of 25 commercially important by-catch species (Ambrose *et al.*, 2005) and most abundance and prioritized croaker by-catch family, sciaenidea (Ambrose, 2004) incidentally killed in coastal shrimp trawls. The shrimp retention characteristics of the grid are attributed to its ability to remove jellyfish and marine debris more effectively, thus leading to high clean and quality shrimps. These were noticed at the end of two hourly tows. The design components enable the device to achieve these feats, the long guiding panel and smooth contours of the shrimps to detach from the jelly fish and thus enabled them to pass into the condend.

The low percentage in shrimps loss of 2.9% (Table 1) may promote its commercial application and endorsement by fishers, in contrast the high percentage reduction of commercially important by-catch species of 72.06% (Table 1) especially large sizes of total length 11-30cm make fishers skeptical in its wide spread adoption. Ambrose *et al.* (2005) have earlier reported that by-catch from this fishery falls within a total length range of 4-30cm, length range of 11-30 are marketable and consumed while length range of 4-10cm are discarded ashore. Based on catch utilization, the result therefore brings perception to different professional stakeholder in shrimp fisheries resources. To the economists and fishers, themselves, it is a loss of income while to the Biologist and environmentalist it is conservative.

Rigid grid, with bar spacing of 20mm retained nearly all species with total length of 4-10cm while most fishes with total length of 11-30cm were excluded because it could not pass through the 20mm bar spacing of the grid to the codend. The implications are that marketed sizes of fishes are lost while at the same time small sizes of fishes are killed incidentally. Since the percentage of shrimp retained is more (97.1%) it could be better to ignore the quantity of fish killed. Alternatively, secondary by-catch reducing device like square mesh panel or fish eye could be installed to further reduce the quantity of juveniles (4-10cm TL) retained in the fishery studies as reported in Australia (Broadhurst *et al.,* 1997). The rigid grid therefore has a great potential in by-catch reduction in fishery but with anticipated by-catch livelihood trades termination and loss of income to fishers. Further refinements of the design of grid assemblage for example; increase in the bar spacing of grid from 20mm to 40mm will allowed the retention of large sized fish for commercial use as well as incorporation of secondary BRD to facilitate the escape of small sized fish to grow and be recruited into the fishery in future years.

TABLE 1: Weights (kg) of target Shrimps and total by-catch Species from 30 replicates tows, each from conventional codend and modified codend (m) that was used in t- test comparison (m versus C; N = 30; XP, 0.05;XXP , 0.01)

No of Tows	Conventional Codend (C)		Modified Codend (M)	
	Target Shrimps	Total by-Catch	Target Shrimps	Total by-catch species
1	74.6	17.3	81.09	0.96
2	38	14.35	25.5	3.26
3	112.5	29.16	96.1	11.61
4	82.9	22.42	71.0	4.93
5	65.6	32.68	66.7	14.81
6	111.0	27.96	96.0	12.42
7	35.5	18.84	37.0	3.72
8	89.0	23.18	81.2	6.93
9	52.8	16.06	63.9	2.69
10	29.1	15.63	28.9	2.47
11	41.2	21.17	58.3	3.79
12	75.0	17.08	77.9	1.44
13	121.0	23.57	132.0	6.18
14	99.2	21.09	67.0	4.31
15	80.6	11.18	75.1	1.1
16	134.0	22.63	137.9	8.64
17	159.0	22.95	138.0	6.15
18	72.8	14.41	89.0	3.11
19	41.0	12.67	48.0	2.46
20	96.0	29.2	131.1	9.02

21	**36.6**	**22.09**	**29.1**	**6.64**
22	**85.2**	**31.94**	**86.9**	**13.16**
23	**77.0**	**23.64**	**89.0**	**10.94**
24	**82.0**	**20.3**	**66.7**	**5.54**
25	**32.1**	**14.58**	**29.0**	**3.5**
26	**41.8**	**22.94**	**42.5**	**6.48**
27	**53.0**	**20.91**	**44.0**	**5.89**
28	**63.0**	**20.08**	**50.9**	**3.17**
29	**28.1**	**24.67**	**26.5**	**8.65**
30	**31.0**	**25.39**	**33.4**	**5.09**
Total	**2140.6**	**640.07**	**2079.69**	**179.06**
Mean	**71.35**	**21.33**	**69.32***	**5.96*,****
% Retention	**100**	**100**	**97.1**	**27.94**

**P <0.01,

TABLE 2

Weights (kg) of commercially important by catch species from 30 replicate tows (N) from conventional codend and modified codend.

Name of Species	Family	C	M	Percentage Retention	Statistical Inference
IliSHA africana	Clupeidae	66.83	20.14	30.13	*,**
Trichiurus lepturus	Trichiuridae	100.63	32.98	32.77	*,**
Pseudotolithus elongatus	Sciaenidae	65.14	17.77	27.27	*,**
Pseudotolithus senegalensis	Sciaenidae	82.62	27.56	33.35	*,**
Pseudotolithus typus	Sciaenidae	84.37	26.72	31.67	*,**
Epinephelus aenus	Serranidae	1.6	1.28	80.00	ns
Cynoglossus senegalensis	Cynoglossidae	26.39	3.89	14.74	*,**
Drepane africana	Drepanidae	8.48	1.87	22.05	*,**
Pentanemus quinquarius	Polynemidae	53.11	14.83	27.92	*,**
Galeoides decadactylus	Polynemidae	40.97	8.51	20.77	*,**
Sepia elegans	Sepiidae	5.31	1.55	29.19	*,**
Callinectes amnicola	Portunidae	50.09	4.75	9.48	*,**
Selene dorsalis	Carangidae	6.72	1.36	20.23	*,**
Chloroscombrus chrysurus	Carangidae	9.08	2.05	22.57	*,**
Lutjanus dentatus	Lutijanidae	12.03	1.72	14.29	*,**
Dasyatis margarita	Dasyatidae	6.35	5.3	83.46	ns
Carcharhinus brachyrus	Carcharhinidae	3.12	0.98	31.41	ns
Pomadasys jubelini	Pomadasyidae	5.33	1.32	24.76	ns

*P <0.05 , **P <0.01, ns P > 0.01

TABLE 3: Summaries of one-tailed paired t-tests comparing the number of commercially important bycatch species from modified and conventional codends.

			M versus conventional		
Name of Species	**Family**	**Common Name**	**Paired T-Value (0.05)**	**P level**	**N**
Ilisha africana	Clupeidae	African Shad	8.4543	*,**	30
Trichiurus lepturus	Trichiuridae	Silver Fish	9.609	*,**	30
Pseudotolithus elongatus	Sciaenidae	Short Croaker	11.8254	*,**	30
Pseudotolithus senegalensis	Sciaenidae	Normal Croaker	13.6801	*,**	30
Pseudotolithus typus	Sciaenidae	Long Neck Croaker	10.5938	*,**	30
Epinephelus aenus	Serranida	Grouper	1.1028	ns	30
Cynoglossus senegalensis	Cynoglossidae	Sole Fish	5.7777	*,**	30
Drepane africana	Drepanidae	Spade Fish	8.2725	*,**	30
Pentanemus quinquarius	Polynemidae	Royal Thread	8.3897	*,**	30
Galeoides decadactylus	Polynemidae	Shiny Nose	7.5247	*,**	30
Callinectes amnicola	Portunidae	Blue Crab	9.8741	*,**	30
Chloroscombrus chrysurus	Carangidae	Caranx	6.0382	*,**	30
Selene dorsalis	Carangidae	Moon Fish	6.6609	*,**	30
Lutjanus dentatus	Lutijanidae	Red Snapper	1.3779	ns	30
Pomadasys jubelini	Pomadasyidae	Grunter	0.8965	ns	30
Carcharhinus brachyrus	Carcharhinidae	Shark	0.9410	ns	30
Sepia elegans	Sepiidae	Cuttle Fish	3.9911	*,**	30
Dasyatis margarita	Dasyatidae	Ray Fish	0.9235	ns	30

*P <0.05 , **P <0.01, ns P > 0.01

References

Alverson, D. L. Freeberg, M. H., Murawski S. A and Pope, J. G. (1994). A *global assessment of fisheries by-catch and discards FAO fish.* Tech. pap. No. 339 233PP

Ambrose, E. E. (2004). Comparative quantification of juvenile croakers *Pseodotolithus species* incidentally killed in coastal artisanal shrimp beam trawl fisheries off Lagos coast, Nigeria and management implications. *Journal of Aquatic Sciences* 19 (2): 77-84.

Ambrose, E. E. and Williams A. B. (2003). A study case of artisanal trawl gear design and catches in Nigerian coastal waters. *Journal of Science and Technology Research* 2(3): 18-23.

Ambrose, E. E. Solarin, B. Isebor, C. and Williams, A. (2005). Assessment of fish by-catch species from coastal artisanal shrimp beam trawl fisheries in Nigeria *Fisheries Research* 71: 125-132.

Andrew, N. L. and Pepperell, J. G. (1992). The by-catch of shrimp trawl fisheries. *Oceanography and marine Biology Annual Review* 30:527-565.

Andrew, N. L., Kennelly, S. J. and Broad Hurst M. K. (1993) an application of the Morrison soft TED to the offshore prawn fishery in NSW, Australia. *Fisheries Research* 16:101-111.

Averil, P. H. (1989). Shrimp/fish separator trawls for northern shrimp fishery. In, Campbell, C. M. (ed), *proceeding of the World symposium on Fishing gear and Fishing Vessels. Marine Institute, St.* Johns Canada, 42-47PP.

Brewer, D., Rawlinson, N., Eays, S. and Burridge, C. (1998). An assessment of by-catch reduction devices in a tropical Australian prawn trawl fishery. *Fisheries Research* 36:195-215.

Broadhurst, M. K. and Kennelly, S. J. (1994). Reducing the by-catch of juvenile fish (Mulloway) *Argyrosomus hololepidotus* using square mesh panels in codends in Hawkesbury River prawn trawl fishery, Australia. *Fisheries Research* 19:321-331.

Broadhurst, M. K. and Kennelly, S. J. (1995). A trouser-trawl experiment to assess condends that exclude juvenile Mulloway *Argyrosomus hololepidotus in the Hawkesbury River Prawn-trawl fishery Marine & Freshwater Research* 40:953-958.

Broadhurst, M. K. and Kennelly, S. J. (1999). Rigid and flexible separator panels in trawls that reduce the by-catch of small fish in the Clearance River Prawn-trawl fishery, Australian, *Marine & Freshwater Research* 47:991-998.

Broadhurst, M. K. and Kennelly, S. J. and Workman, I. (1997). Evaluations of the Nordmore-grid and secondary by-catch reducing devices (BRDs) in the Hunter River Prawn-trawl fishery, Australia *Fisheries Bulletin* 95.210-219.

Broadhurst, M. K. (2000). Modifications to reduce by-catch in Prawn trawls. A review and framework for development *Reviews in Fish Biology and Fisheries* 10:27-60.

Caddy, J. F. (1982). Management of shrimp fisheries. In fish by-catch bonus from the sea; *report of a Technical Consultation on shrimp by-catch utilization held in Georgetown, Guyana,* 27-30 October 1981, IDRC, Ottawa, (IDRC-198e) 120-124pp.

High, W. L., Ellis, I. E. and Lusz, L. D. (1969). A progress report on the development of a shrimp separator to separate shrimp from fish and bottom-dwelling animals. *Commercial Foisheries Review* 31:20-33.

Isaksen, B., Valdemarsen, J. W., Larsen, R. B and Karlsen, L. (1992). Reduction of fish by-catch in shrimp trawl using a rigid separator grid in the aft. Belly. *Fisheries Research* 13:335-0352.

Karlsen, L. and Larsen, R. (1989) *Progress in the selective shrimp trawl development in Norway. In cambell; C. M. (ed) proceedings of the World Symposium on Fishing Gear and Fishing Vessels.* Marine Institute St. John, Canada 30-38pp.

Kendal, D. (1990). Shrimp retention characteristics of the Morison soft, TED; inserted in a shrimp trawl net. *Fisheries Research* 9:13-21.

Peterkin, F. A. (1982). Developing a shrimp by-catch utilization program. *Proceeding, Gulf of Caribbean fisheries Institute* 34:112-119.

Rulifson, R. A. Murray, J. D. and Bahen, J. J. (1992). Fin fish by-catch reduction in South Atlantic shrimp trawls using three designs of by-catch reduction devices, *fisheries* 17:9-19.

Salia, S. B. (1983). Importance and assessment of discards in commercial fisheries *FAO Fisheries Circular* No. 765, 62pp.

Thorsteinsson, G. (1992). The use of square mesh condends in the Icelandic shrimp *Pandalus borealis Fisheries research* 13:255-266.

Watson, J. W., Mitchel, J. F. and Shah, A. K. (1986). Trawling efficiency device. A new concept for selective shrimp trawling *gear Marine Fisheries Review* 48:19.