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A Green Technology for Crab Fishery: Serial Collapsible Crab Trap

J. Amala Shajeeva[1]*, N. Neethiselvan[1], M. Kalaiarasan[1], N. Jayakumar[2], R. Shalini[3] and S. Archana[1]

[1]*Department of Fishing Technology and Fisheries Engineering, Fisheries College and Research Institute, Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Thoothukudi–628 008, Tamil Nadu, India*
[2]*Department of Fisheries Resource and Management, Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Thoothukudi–628 008, Tamil Nadu, India*
[3]*Department of Fish Quality Assurance and Management, Fisheries College and Research Institute, Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Thoothukudi–628 008, Tamil Nadu, India*

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Key words
Gill net, Serial collapsible crab trap, Indiscriminate fishing, Sustainable fishing, Gulf of mannar

ABSTRACT

Crab traps are generally considered an eco-friendly fishing gear with high selectivity and pose minimal damage to ecosystem upon proper usage. A study was conducted from April 2023 to March 2024 to evaluate the catching efficiency of serial collapsible crab traps (SCCT) and crab gill nets in the offshore waters of Gulf of Mannar along south east coast of India. Experimental SCCT was fabricated and tested to assess the catching efficiency with the commercial operated gill nets of the same location. The experimental traps exhibited 20.6-56.3% (1.31-2.11 kg) higher CPUE (catch per unit effort) in comparison to gill nets (1.04 – 1.35 kg). A significant difference ($p < 0.01$) in the catch rates recorded between the experimental traps and the gill net with *Portunus pelagicus* being the dominant species. This study also highlights the unique nature of SCCT and shed light on the indiscriminate fishing nature of crab gill nets in the region. The outcome of this research work demonstrate that the SCCT is an excellent alternative green technology for sustainable fishing in ecologically unique coastal region in India and elsewhere.

INTRODUCTION

A total of about 4,500 species of crabs are reported to be distributed worldwide. Crabs inhabits primarily in salt water ecosystems, although about 850 crab species are found to have distribution in fresh water bodies. Edible crab species are found in the bays, inlets, estuaries and brackish marshes in the world oceans. Saltwater Crabs are a must have cleaner for any reef aquarium. As far as India is concerned, although about 600 species of crabs are recorded, the commercially important carb species belong to 3 families such as Portunidae, Calappidae and Grapsidae.

Crabs contributed to 20% of all marine crustaceans captured worldwide. Despite a relatively modest contribution to landings volume (7.8%), crustaceans represent a disproportionate amount of global marine fisheries value (21.3%), making them the most valuable group by landed mass (FAO, 2020). The top four seafood types by price are all invertebrates, the top three of which are crustaceans such as lobsters, crabs, and shrimps and prawns (FAO, 2018). In recent years, prices for crustaceans have continued to rise. Crabs are economically important crustaceans as they are essential delicacies consumed worldwide and are also an excellent environmental indicator.

Historically these crab resources support the fisheries in India, though the contribution to total fishery has seen significant rise from 4% in 1996 to 12% in 2006 (Rao *et al*., 1973; Manissery and Radhakrishnan, 2003). The crab fishing in Gulf of Mannar and Palk Bay region along the southeast coast of India are being operated as artisanal sector through bottom set gill.

Portunidae is a family of swimming crabs with a total of 104 species representing 22 genera are coming under Indian Portunids. In the family Portunidae, species

* Corresponding author: jeeva.julin@gmail.com
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such as *Portunus sanguinolentus, P. pelagicus, Charybdis feriatus, C. annulate* and *C. natator* are notable for their commercial fishery (Manisseri and Radhakrishnan, 2003). In India, while making a comparison between East and West coasts, East coast has been reported to be more productive contributing about 56.7% of the national marine crab landings during the above period (Josileen et.al, 2019). Among the different maritime states, Tamil Nadu contributed 28,440 tonnes of crabs during the year 2023, which accounted for 5.03 % of the total marine fish landings of the state (CMFRI, 2024).

Globally crabs are being captured by using different gears such as crab gill nets, crab traps and pots. In China, exclusive crab setter vessels are used for capturing crabs. As far as India is concerning many species of crabs form fishery as a main catch in crab gillnets and as a by-catch in trawls operated all along the coast of India. All along the coast of Tamil Nadu, indiscriminate fishing of crabs including juveniles and berried crabs is the major biological problem caused by the fishermen while fishing the crabs with monofilament gill nets which capture them by entangling process. Even if the fishermen are willing to release back the juvenile and berried crabs considering their biological significance, the removal of such crabs in live condition from the monofilament gill nets without breakage of their body parts is found very difficult owing to complex entanglement.

Serial collapsible crab traps (SCCT) are widely used in different countries as an efficient and environmentally sustainable fishing gear for crab fisheries due to their passive mode of operation, high selectivity, and minimal impact on benthic habitats. In Japan, trap-based fisheries are extensively used for harvesting swimming crabs and other crustaceans, demonstrating high catch efficiency and economic feasibility (Yamamoto, 2000). In Southeast Asian countries such as Thailand and Indonesia, collapsible crab traps are a dominant gear in small-scale coastal fisheries targeting the blue swimming crab (*Portunus pelagicus*), where they allow the live release of undersized and berried crabs and contribute significantly to sustainable resource utilization (Kunsook *et al*., 2014; FAO, 2018). In India, experimental studies on SCCT have reported that trap design, funnel configuration, bait type, and soak time strongly influence catch rates, highlighting their potential as a selective and eco-friendly alternative to crab gillnets (Pravin *et al*., 2011). Similarly, in China and other East Asian fisheries, crab traps are promoted to improve size selectivity and reduce juvenile bycatch (Xu *et al*., 2017). In developed fisheries such as those of the United States and Europe, crab traps and pots are regulated with biodegradable escape panels and ghost-fishing mitigation measures, reinforcing their role as a low-impact fishing technology when supported by effective management frameworks (Guillory *et al*., 2001; FAO, 2016).

In the present study the current status of crab fishery was analysed from two different gears such as crab gill nets and SCCT and the difference in CPUE (catch per unit effort) of both the gears were analysed.

MATERIALS AND METHODS

Study area

The present study select one representative fishing village from Gulf of Mannar i.e. Vedhalai (Lat: 09° 27.23'N; Lon: 79° 10.40'E) and Thirupalaikudi (Lat: 09° 54.80'N; Lon: 78° 91.47'E) from Palk Bay along the Tamil Nadu coast, India. The fishers of these villages operate bottom set gillnets for fishing. To a very great extent fishers of these villages sustain their livelihood through crab fishing. In both the villages crab fishing operation has been carried out for approximately 20 days every month (Ameer-Hamsa, 1978; Josileen *et al*., 2019).

CPUE of crab gill nets

To estimate the catch and effort data of the gill net operation in both the villages catch data were collected for 12 months (April 2023 to May 2024). The collected catch data were expressed in terms of weights randomly during each sampling day. Each sampling day about 10 to 20% of the units were observed depending upon the number of units operated and the average daily catch was estimated. The average daily catch estimates were multiplied by the number of fishing days in a particular month to obtain the monthly catch. The total effort was expressed as the number of boat days per month. The CPUE was calculated as kg/day (Kumar *et al*., 2019). Each vessel will carry 10 to 15 nos. of gill net per operation. To compare the catch with single SCCT unit the CPUE was estimated as kg/net.

CPUE of SCCT

SCCT was fabricated as per the procedure explained by Karthy (2014). The SCCT was operated in the crab fishing grounds of Vedhalai and Thiruppalaikudi where the gill nets are being operated. The SCCT also operated for 12 months from April 2023 to April 2024 at the rate of 10 trials per month. The CPUE was estimated as kg/SCCT.

The composition of different species of crabs landed were also recorded in the landing centre itself.

Statistical analysis

SPSS software was used to carry out t-test based on the catch rate of traps and SCCT to know about the significance difference between two gears.

RESULTS AND DISCUSSION

Both at Vedhalai and Thiruppalaikudi, crab fishing at bottom set gill nets are carried out round the year. The details of the crab gill nets operated by both the villagers are presented in Table I and the fabricated SCCT and its design details are shown in Figure 1. Based on the results of crab fishing by SCCT and gill net, irrespective of the fishing village the catch was more in SCCT. In the fishing village of Vedhalai the CPUE was found to be more in the SCCT than bottom set gill net in both the fishing villages. It was estimated as 2.11 kg per SCCT and 1.35 kg per gill net. The CPUE of SCCT was 56.3% more than the CPUE of gill net (Table II). In Thiruppalaikudi also the CPUE was more (1.31 kg) in the SCCT than that of Gill net (1.04 kg). In Thiruppalaikudi SCCT showed 20.6% more catch than gill net (Table II). During the study period, peak landing was observed in the month of June 2023 at both the villages. But the highest CPUE was observed in August at Vedhalai and September at Thiruppalaikudi. Total annual catch in crab gill net was estimated as 133.7 tons in Vedhalai and 94.5 tons in Thiruppalaikudi.

Rajamani and Palanichamy (2010) reported *Portunus pelagicus* landings at Vedhalai and Thiruppalaikudi. They estimated the total catch of Vedhalai as 31 tons in 2007 and 27 tons in 2008, with the same CPUE of 5.3 kg/unit

Table I. Design details of crab gill nets.

S. No	Parameters	Fishing village: Vedhalai	Fishing village: Thiruppalaikudi
1	**Webbing**		
a.	Material	Monofilament nylon	Monofilament nylon
b.	Twine thickness	1.5 – 2.5 mm	2 mm
c.	Colour	Colourless	Colourless
d.	Length	700 to 1000 m	400 to 500 m
e.	Mesh size	75 – 85 mm	85 – 90 mm
f.	Hung depth	0.7 m	0.8 m
g.	No. of meshes in length	13,000–15,000	6500 – 8000
h.	No. of meshes in height	10	11
i.	Hanging co-efficient	0.75	0.75
2	**Head rope**		
a.	Material	Polypropylene	Polypropylene
b.	Thickness	3 mm	3.5 mm
3.	**Foot rope**		
a.	Material	Polypropylene	Polypropylene
b.	Thickness	3 mm	3.5 mm
4.	**Sinkers**		
a.	Material	Lead	Natural rope
b.	Weight	100g	-
c.	Interval	2m	Throughout foot rope

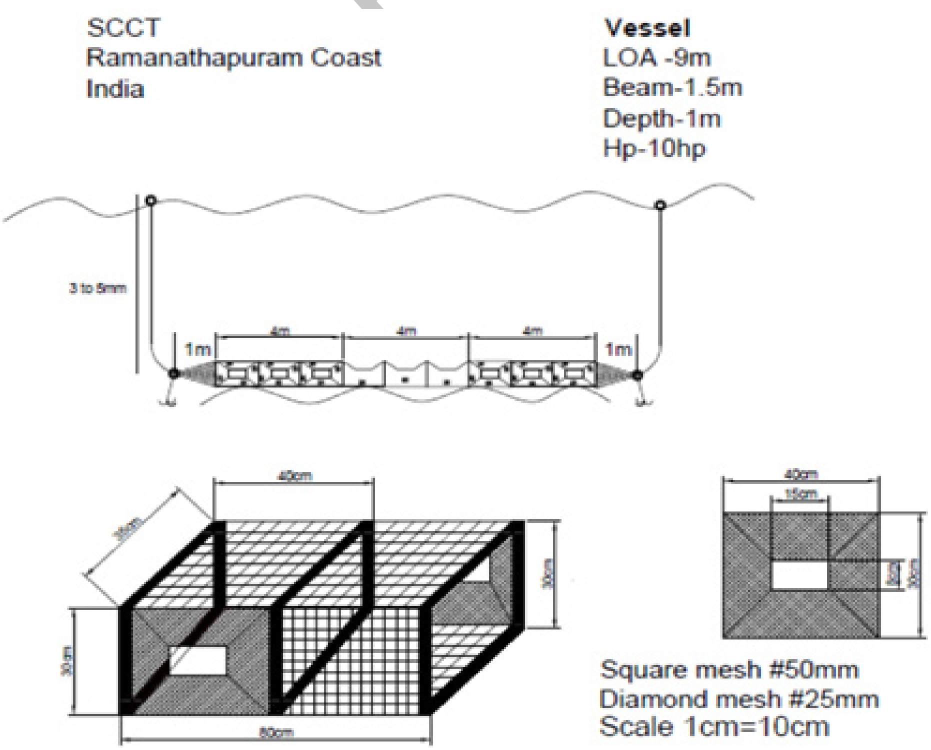

Fig. 1. Design details of fabricated SCCT.

Table II. Catch details of crab gill nets and SCCT in the fishing grounds of Vedhalai and Thiruppalaikudi.

Months	Crab gillnet				SCCT		
	AMBD	TMC	CPUE (kg/ boat day)	CPUE (kg/ gill net)	Monthly operations	Total catch	CPUE (kg/ SCCT)
Fishing grounds of Vedhalai							
April 23	810	8343.0	10.3	1.03	10	19.6	1.96
May	882	13582.8	15.4	1.54	10	23.4	2.34
June	986	20114.4	20.4	2.04	10	31.6	3.16
July	705	12549.0	17.8	1.78	10	28.3	2.83
Aug	812	17214.4	21.2	2.12	10	18.7	1.87
Sep	735	10510.5	14.3	1.43	10	23.1	2.31
Oct	884	13702.0	15.5	1.55	10	20.8	2.08
Nov	672	5846.4	8.7	0.87	10	9.6	0.96
Dec	522	2349.0	4.5	0.45	10	18.7	1.87
Jan 24	806	8463.0	10.5	1.05	10	19.1	1.91
Feb	854	5551.0	6.5	0.65	10	22.1	2.21
March	870	15486.0	17.8	1.78	10	18.8	1.88
	Total	133711.5	162.9	16.29	Total	253.8	25.38
	Mean	11142.63	13.5	1.35	Mean	21.15	2.11
Fishing grounds of Thiruppalaikudi							
April 23	1173	8914.8	7.6	0.76	10	7	0.7
May	1012	10828.4	10.7	1.07	10	17.7	1.77
June	1392	16843.2	12.1	1.21	10	14.3	1.43
July	1155	15823.5	13.7	1.37	10	22.5	2.25
Aug	1007	9868.6	9.8	0.98	10	17.5	1.75
Sep	980	13622.0	13.9	1.39	10	6.8	0.68
Oct	924	9240.0	10.0	1.00	10	12.7	1.27
Nov	738	6346.8	8.6	0.86	10	7.2	0.72
Dec	663	7359.3	11.1	1.11	10	10.7	1.07
Jan 24	1008	9172.8	9.1	0.91	10	17.4	1.74
Feb	990	8118.0	8.2	0.82	10	8.3	0.83
March	836	8861.6	10.6	1.06	10	15.1	1.51
Total	124999.0	125.4	12.54		Total	15.72	
Mean	10416.6	10.45	1.045		Mean	1.31	

AMBD, average monthly boat days; TMC, total monthly catch; CPUE, catch per unit effort; SCCT, serial collapsible crab traps.

and in Thiruppalaikudi it was estimated as 98 tons in 2007 and 57 tons in 2008, with CPUE values of 5.5 kg and 4.9 kg, respectively. This is also consistent with previous studies which have demonstrated the superior selectivity and catch rates of trap-based fishing methods for portunid crabs (de Lestang *et al*., 2003; Islam *et al*., 2021; Sudhagar *et al*., 2016).

The higher CPUE observed in collapsible crab traps may be attributed to their gear design, which reduces the escape of legally sized individuals while minimizing damage to crabs during capture. In contrast, crab gill nets exhibited lower CPUE and were found to indiscriminately capture crabs of various sizes, including juveniles and berried females. This aligns with the observations of Sukumaran and Neelakantan (1997), who reported that gill nets often result in high bycatch and post-capture mortality due to entanglement stress and physical injury.

Although both the Palk Bay and the Gulf of Mannar provide productive grounds for *P. pelagicus*, differences in fishing intensity and gear use between the two regions affect CPUE outcomes. Similar regional CPUE variations have been documented in other parts of India and Southeast Asia, reflecting the influence of localized fishing pressure, habitat type, and fisher behavior (Prasad *et al*., 1989; Ikhwanuddin *et al*., 2012). The successful use of collapsible traps in countries like Thailand, Indonesia, and Malaysia has prompted efforts to promote this gear in Indian small-scale fisheries, especially for export-oriented crab species (Ragavan *et al*., 2018; Islam *et al*., 2021).

In Southeast Asia, particularly in Malaysia, Indonesia, and Vietnam, collapsible traps have become the preferred gear for harvesting *Portunus pelagicus* and other portunid crabs. For example, Ikhwanuddin *et al*. (2012) reported CPUE values ranging from 2.5 to 5.0 kg/trap/day for *P. pelagicus* in Malaysian waters, depending on the season and fishing grounds. These values are significantly higher than those obtained through traditional gill nets or handlines, which often result in high bycatch and lower trap retention rates.

Similarly, in Thailand, research by Chaiyapechara *et al*. (2003) demonstrated that collapsible traps yielded 4.2 kg/trap/day during peak seasons in the Gulf of Thailand, with minimal damage to the catch and better market quality.

In Bangladesh, Islam *et al*. (2021) conducted a comparative study between gill nets and collapsible traps in *Scylla olivacea* fisheries and found that traps provided a 1.6-fold increase in CPUE, while also drastically reducing the capture of undersized crabs and non-target species. These results highlight the importance of trap design and placement in enhancing gear performance.

In Australia, de Lestang *et al*. (2003) reported that traps used in commercial *P. pelagicus* fisheries in Western Australia achieved CPUE values of 3.0–6.0 kg/trap/day, depending on site productivity and trap soak duration.

All the crabs caught in SCCT was found in a live condition (Fig. 2A). If any mishandling during the removal of crabs, it may damage the specimen. But the percentage of damage was < 1% only.

The SCCT has proven to be an efficient and eco-friendly fishing gear for the selective capture of commercially important crabs such as *Portunus pelagicus*. One of the key advantages of SCCT is its ability to retain crabs alive and uninjured, which is crucial for high-value live crab trade. The passive trapping mechanism eliminates the risk of physical damage that often occurs in entangling gears like gill nets. Crabs enter the trap voluntarily in search of bait and remain confined with minimal stress and abrasion. This ensures superior quality of catch suitable for live transport and export markets (Chaiyapechara *et al*., 2003; Thiagarajan *et al*., 2017). Furthermore, the collapsible design makes the gear easy to handle, store, and deploy, promoting its suitability for small-scale fishers seeking sustainable and value-added harvesting methods.

Fig. 2. (A) Live crab specimens captured using serial collapsible crab traps (SCCT). The gear ensures minimal injury and stress, making it suitable for live crab trade. (B) Dead and damaged specimens caught using crab gill nets.

Almost 99% of the crabs caught in the gill nets are found in a dead condition and with body parts (Fig. 2B). Gill nets, widely used along the southeast coast of India for crab fishing, are non-selective and frequently result in the entanglement of undersized and soft-shelled crabs. Crabs caught in gill nets are typically ensnared by their walking legs, chelae, or spines, leading to physical damage such as broken appendages and carapace injuries. This not only reduces their commercial value, particularly for the live crab trade, but also contributes to significant post-capture mortality. Moreover, the gear lacks size and species selectivity, often capturing juvenile and non-target species, thereby raising serious concerns over the sustainability of crab fisheries (Sukumaran and Neelakantan, 1997; Thiagarajan *et al*., 2017). Such indiscriminate capture practices underscore the need for more selective and eco-friendly alternatives, such as the SCCT, to ensure the long-term viability of crab resources in coastal ecosystems.

The catch from Vedhalai of Gulf of Mannar revealed the selective fishing efficiency of SCCT in capturing the swimming crabs such as *Portunus pelagicus*, *P. sanguinolentus, Charybdis natator* and *P. gladiator*. The catch was dominated by the swimming crab *P. pelagicus* in both the fishing gears. The species composition of different gears also noticed same during the study period.

However, *P. pelagicus* remained the dominant species throughout the observation period in both the fishing villages. In Vedhalai *P. pelagicus* contributed to 71% of total catch composition in both the fishing gears. *P. sanguinolentus* contributed to 12 % of total catch in SCCT and 16 % in gill net. *Charybdis natator* ranked third with 10 % of total catch in SCCT and 7% of total catch in gill net and *P. gladiator* ranked fourth with 7% and 6% of contribution in SCCT and gill nets respectively (Fig. 3A). In Thiruppalaikudi *P. pelagicus* contributed to 83 % of the SCCT catch and 97% of the gill net catch (Fig. 3B).

Rajamani and Palanichamy (2010) also recorded the single species fishery of *P. pelagicus* in Thiruppalaikudi and five species composition of *Portunus pelagicus*, *P. sanguinolentus, Charybdis natator, C. feriata* and *Scylla tranquebarica* in Vedhalai.

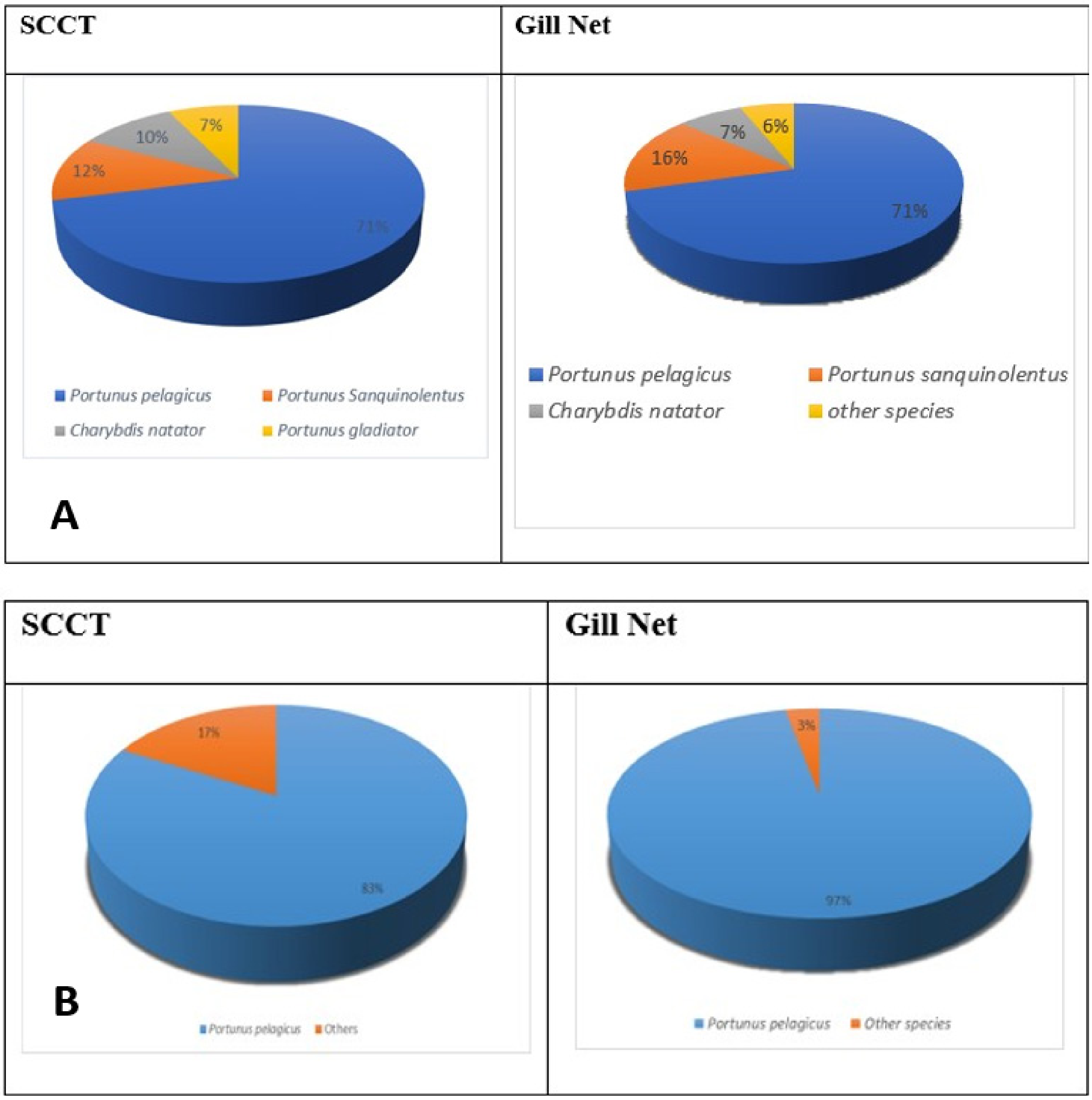

Fig. 3. Species composition of crabs at Vedhalai of Gulf of Mannar (A), and Thiruppalaikudi of Palk Bay (B).

Josileen *et al.* (2019) reported that *Portunus pelagicus* accounted for 98.3% of the crab landings from 2007 to 2017, highlighting its dominance during that period. Notably, *P. pelagicus* is widely distributed and is considered a significant commercial fishery resource in many parts of the world (Chande and Mgaya, 2003). Among the other species, the rock crab *Charybdis natator* ranked second in abundance, making up 2.1% of the total landings. *P. sanguinolentus*, which plays a moderate role in the fishery south of the Gulf of Mannar off Tharuvaikulam, contributed only 1.8% of the crab catches in the northern Gulf of Mannar off Vedalai (Rajamani and Manickaraja, 2007). *C. feriata* and *Scylla tranquebarica* were found in negligible proportions, each constituting < 1%, and were sporadically recorded, with some months showing no occurrences at all.

Across both regions, *Portunus pelagicus* emerged as the dominant species, accounting for over 70% of the total crab catch in Palk Bay and approximately 50–60% in the Gulf of Mannar. This pattern aligns with previous studies that identified *P. pelagicus* as the primary target species in the shallow coastal waters of southeastern India due to its high market value, fast growth rate, and wide distribution (Sukumaran and Neelakantan, 1997; Kizhakudan *et al.*, 2015).

The low species diversity in Palk Bay may be attributed to its semi-enclosed nature, predominantly sandy-muddy substrate, and relatively lower habitat heterogeneity compared to the Gulf of Mannar (Soundararajan and Varadharajan, 2009). Furthermore, targeted fishing practices using species-selective gears such as gill nets are more common in Palk Bay, further skewing the composition toward *P. pelagicus*.

In contrast, the Gulf of Mannar exhibited greater crab species richness. While *P. pelagicus* remained the dominant species, its share was relatively lower than in Palk Bay. Other significant contributors included *P. sanguinolentus* (15–20%), *Charybdis feriata* (5–10%), *C. natator* (3–5%), and *Scylla tranquebarica* (2–4%). This broader assemblage is consistent with the Gulf's ecological diversity, which includes coral reefs, seagrass beds, and mangrove patches, offering diverse habitats for different crab species (Ragavan *et al*., 2018; Sudhagar *et al*., 2016).

These findings are consistent with earlier observations by Prasad *et al.* (1989) and Varadharajan and Soundararajan (2012), who reported that while *P. pelagicus* forms the backbone of the crab fishery along the Tamil Nadu coast, species such as *P. sanguinolentus* and *Charybdis* spp. contribute significantly in less disturbed, biodiverse regions such as the Gulf of Mannar.

The results of the statistical analysis by using SPSS on the catch rate of commercial gill nets and experimental SCCT, through t-test (Table III) revealed significant difference ($P < 0.001$) between the catch rate of commercial gill net and experimental SCCT.

Table III. Statistical analysis on the catch rate of commercial crab gill nets and experimental SCCT by t-test.

S. No.	Parameters	Experimental SCCT	Commercial crab gill net
1	Mean	2136.8	1350.737
2	Variance	124052.7	45358.4
3	Observations	12	12
4	Degrees of freedom	22	
5	t Stat	6.61572	1.717 (1%) 2.508 (5%)
6	P(T<=t) one-tail	0.0000	
7	t Critical one-tail	1.717144	
8	P(T<=t) two-tail	0.0000	
9	t Critical two-tail	2.073873	

SCCT are superior to gill nets because they provide higher species and size selectivity with significantly lower bycatch and ecological impact while ensuring effective crab harvest. Unlike gill nets, which indiscriminately entangle juveniles, berried females, and non-target organisms, serial collapsible crab traps capture crabs alive and allow the easy release of undersized and berried individuals, thereby supporting stock sustainability. The passive operation of these traps minimizes seabed disturbance and reduces post-capture mortality, resulting in better product quality. Additionally, the collapsible design enhances ease of handling, storage, and transport, while lower fuel consumption and reduced ghost-fishing risk make SCCT a more environmentally responsible and fisher-friendly alternative to gill nets in crab fisheries.

SCCT achieve higher CPUE than gill nets due to their active bait-based attraction, which continuously lures crabs into the trap over the soaking period, and their ability to retain crabs alive, minimizing escape and predation losses. The serial deployment of multiple trap units increases spatial coverage and fishing efficiency. SCCTs selective retention of marketable crabs, along with the release of undersized or berried individuals, ensures that fishing effort is efficiently converted into harvestable catch. These operational advantages make SCCTs a more consistent, sustainable, and high-yielding gear compared to traditional gill nets.

CONCLUSION

The study underscores the higher efficiency and sustainability of collapsible crab traps over gill nets for *Portunus pelagicus* fishing in Palk Bay and the Gulf of Mannar. The results advocate for a gear transition policy that emphasizes trap-based fishing, supported by science-driven regulations, to ensure the long-term viability of crab fisheries in India. Region-specific conservation measures, such as restricting gill net usage in biodiversity hotspots and promoting trap-based selective fishing, could enhance both yield and biodiversity conservation.

DECLARATIONS

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IRB approval

For this study, approval was given by the Advisory Committee Members of Tamil Nadu Dr.J.Jayalalithaa Fisheries University, Thoothukudi–628 008, Tamil Nadu, India.

Generative AI and AI-assisted technology statement

The authors declare that no generative artificial intelligence (AI) tools or AI-assisted technologies were used in the design of the study, data collection, analysis, interpretation of results, or preparation of the manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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