Improving bycatch reduction strategies and escape vents in Queensland crab fisheries

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Cover photos: Top left: 120 x 50 mm large rectangular escape in heavy duty crab pot (photo credit DAF), where heavy duty pot is defined as ≥10 mm steel rings, ≥27 mm ply mesh); Top right: 75 x 60 mm escape vent in heavy duty crab pot (photo credit DAF); Bottom left: example of marine turtle entanglement in crab pot float-line (StrandNet record Z6566158, November 2022); Bottom right: example of marine turtle entrapment inside a 'lightweight' pot with a large entry funnel (StrandNet record Z6566418 February 2023), where lightweight pot is defined as <10 mm steel rings.

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The current project benefited from data sharing of crab morphometric measurements with FRDC Project Number 2019-062, Knowledge to improve the assessment and management of Giant Mud Crabs (*Scylla serrata*) in Queensland. We thank the staff and students from CQUniversity who assisted with Project Number 2019-062, including Dr Nicole Flint, William Charles and Mohamad Amzad Hossain.

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Abbreviations

CW	Carapace Width (legal size measurement in Queensland) is the distance between the tips of the largest opercular spines on each side of the dorsal carapace.
CH	Carapace Height is the distance between the dorsal carapace and the ventral cephalothorax.
CL	Carapace Length (legal size measurement in NSW) is the distance from the base of the notch between the frontal medial spines to the posterior dorsal margin of the dorsal carapace.
$C_{law}H$	Crusher Claw Height is the width at the widest point of the crusher claw i.e., the claw with 'molar'-like teeth as opposed to the cutter claw which has 'incisor'-like teeth.
FQ	Fisheries Queensland
GLMM	Generalised Linear Mixed Model
NW	Notch Width (standard measure in Queensland) is the distance between the notches anterior to the last opercular spines of the dorsal carapace.
NSW	New South Wales
NT	Northern Territory
SOCI	Species of Conservation Interest
TEPS	Threatened, Endangered and Protected Species
TL	Total Length is the distance from the tip of the longest frontal median spine (whichever side is longest) to the posterior edge of the midpoint of the abdominal flap.

Executive summary

The Queensland Crab Fishery is an iconic fishery, which encompasses the harvest of mud crabs (*Scylla serrata*, the Giant Mud Crab, and *Scylla olivacea*, the Orange Mud Crab) and Blue Swimmer Crabs (*Portunus armatus* and *Portunus pelagicus*), predominately using baited crab pots of various designs. The Fishery has a limited entry commercial sector that requires a C1 symbol to catch these species of crabs, plus possession of appropriate quota to catch mud crabs on the Queensland East Coast (EC1), Queensland Gulf of Carpentaria (GC1) or Blue Swimmer Crabs anywhere in Queensland (BC1). The Fishery also has a significant recreational sector, that uses similar apparatus and does not require a licence, but does have in possession limits.

The current research investigated the performance of escape vents in crab pots targeting Giant Mud Crabs to determine if current Queensland fisheries regulations should be revised to provide better commercial outcomes (i.e., retention of legal mud crabs – male and 150 mm carapace width or greater), whilst minimising the bycatch of non-legal crabs, finfish and other bycatch species, such as water rats. The research focussed on the Giant Mud Crab as it comprises greater than 99% of the commercial harvest of mud crabs in Queensland

The ongoing issue of marine turtle interactions with crabbing apparatus, including a recent increase of stranding reports, led to the research also collating available information about these interactions to support a risk mitigation strategy for the fishery's interaction with protected marine turtle species.

Results are to be considered by management, Fisheries Queensland and the Crab Working Group as part of the Harvest Strategy arrangements for the Queensland Crab Fishery.

Background

Escape vents in commercial pots targeting mud crabs became compulsory on the 1st September 2021. The current research was undertaken in response to industry concerns that regulated escape vents had not adequately considered regional variation in mud crab populations. Industry perceived that vents were allowing legal male Giant Mud Crabs to escape in some regions. The current research sought to understand how regional populations of Giant Mud Crabs differed in morphometrics and to quantify the performance of currently regulated escape vents. Results were to provide advice to management (Fisheries Queensland and the Crab Working Group) about refinements that could be made to Queensland escape vent regulations.

Marine turtle interactions with crabbing apparatus have been an ongoing bycatch issue in Queensland for many years. Marine turtles can be incidentally entrapped in crab pots, and result in the death of the turtle due to drowning. Marine turtles can also be entangled in the float-lines (i.e., ropes) attached to the crab pots as the animal swims past. These interactions are often highly visible to the public, resulting in social media publication, associated comments and reducing the social licence of crabbing as a sustainable fishing method. A risk mitigation strategy for marine turtle bycatch is one condition of the Commonwealth's assessment of the mud crab component of the Queensland Crab Fishery for the purposes of Part 13 of the *Environment Protection and Biodiversity Conservation Act* 1999*,* and would be essential if the fishery were to be re-considered export certification (i.e., Part 13B).

Aims and objectives

The current research focused on the Queensland Crab Fishery to:

1. Benchmark bycatch reduction devices and strategies currently in use in the mud crab component of the Queensland Crab Fishery.
2. Trial alternate configurations and advise on potential changes to escape vent regulations in the mud crab component of the Queensland Crab Fishery to achieve better commercial and ecological outcomes.
3. (a) Collate information on marine turtle interactions with crab pots (including ghost pots), and (b) Consider pot configuration(s) that could contribute to a risk mitigation strategy for marine turtles in the Queensland Crab Fishery.
4. Develop options for adopting bycatch reduction devices and strategies in the recreational sector of the Queensland Crab Fishery.

Methods

Researchers from DAF Agri-Science Queensland surveyed active commercial fishers who were reporting quota in the EC1 (East Coast mud crab) or GC1 (Gulf of Carpentaria mud crab) fisheries to determine the bycatch reduction devices and strategies in use in these components of the Queensland Crab Fishery. The Blue Swimmer Crab component of the Queensland Crab Fishery has fewer operators and does not require escape vents in crab pots targeting Blue Swimmer Crabs. Thus, the Blue Swimmer Crab component of the fishery was not the focus of objectives (1) and (2). Researchers recorded bycatch reduction devices in use during fishery-dependent sampling and conducted fishery-independent sampling to measure escape vent performance for currently regulated escape vents (i.e., 120 x 50 mm rectangular, 105 mm round, and two 75 x 60 mm rectangular).

To address industry concerns about regional variation in mud crabs, researchers measured ~11,000 male and ~5,000 female Mud Cabs across the fishery-dependent and fishery-independent sampling. The majority were the Giant Mud Crab, with a small number of Orange Mud Crabs measured. Sampling was targeted at regions reporting significant harvest including Mapoon, Weipa, Karumba (GC1 regions) and Hinchinbrook, Townsville, Burdekin, Mackay, Stanage, Gladstone, Great Sandy Strait, and Moreton Bay (EC1 regions). Morphometric measurements included carapace width (CW, standard legal measure), notch width (NW), carapace height (CH), carapace length (CL), and total length (TL). Relationships between the morphometric dimensions were analysed to determine the degree of regional differences and to provide an anatomical basis for escape vent design and performance. The behaviour of Giant Mud Crabs in pots fitted with escape vents was documented through underwater video footage. Researchers then trialled alternate escape vent configurations during additional fishery-independent sampling, which included top placement of currently regulated escape vents (based on industry feedback) and alternate sizes (guided by analysis of Giant Mud Crab morphometrics and industry feedback).

Information on marine turtle interactions with crabbing apparatus was drawn from (i) the StrandNet database, (ii) the Threatened and Protected Species (TEPS) logbook, and (iii) various research projects associated with crabbing apparatus. All records of marine turtle interactions with fishing apparatus were downloaded from StrandNet and forensically examined (including photographic evidence where available) to collate evidence as to where, when and in what type of gear, marine turtles are interacting with crab fishery associated apparatus in Queensland.

Project staff engaged with pot manufacturers to identify options for adoption of escape vents and/or other bycatch reduction strategies in the recreational sector, as well as collated responsible recreational crabbing approaches in other jurisdictions.

Results

Escape vents

The current research endorses the inference of Grubert and Lee (2013) that the dorso-ventral height (carapace height, CH) and anterior-posterior length (carapace length, CL, as a proxy for total length, TL) are the critical dimensions that determine the performance of any given escape vent. Grubert and Lee (2013) reported considerable variation in the total length and carapace height of Giant Mud Crabs for a given carapace width (tip-to-tip). Our field observations and measurements indicate that much of this variation is a function of wear to the tips of their opercular. The current research suggests that notch width (NW), is a more consistent metric to measure the width of a Giant Mud Crab, as notch width does not change during an inter-moult period, whereas carapace width (CW), which is based on tip-to-tip measurement, does change, with early inter-moult crabs (i.e., newly moulted) having slightly longer spines than late inter-moult crabs.

Analyses found statistically significant regional variation in morphometric relationships between notch width and carapace height. However, this variation was not biologically meaningful, with a generally very small (i.e., <1 mm) regional difference in carapace height for near-legal male Giant Mud Crabs (i.e., 148 to 151 mm CW). Carapace height represents the dorso-ventral height of Giant Mud crabs and is relevant to the performance of the 120 x 50 mm rectangular escape vent. Results from the current research indicate that almost all near-legal male Giant Mud Crabs (i.e., >99%) are greater than 50 mm in carapace height, consistent with the results of Grubert and Lee (2013). Thus, almost all near-legal Giant Mud Crabs would be unable to exit a crab pot via the 120 x 50 mm escape vent that is in good working order.

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Based on morphometric analysis, the 75 x 60 mm escape vent prevents male Giant Mud Crabs of 115 mm CW or greater exiting, as crabs of this size have a mean carapace length of 76 mm or greater. Of the male Giant Mud Crabs measured during the current study, ~5% were less than 115 mm in CW and would be able to exit a 75 x 60 mm escape vent. Results indicate that the 75 x 60 mm escape vent is of limited benefit in allowing Giant Mud Crabs of less than 150 CW to escape. It should be noted that experienced commercial crabbers often target habitats where legal crabs are more abundant and thus may not encounter many small crabs. Since the start of the project in mid-2022, there has been a general move by industry away from the 75 x 60 mm escape vents to slightly larger sizes (i.e., 80 x 80 mm etc.).

Giant Mud Crabs partially exiting escape vents (particularly the 120 x 50 mm) were observed on several occasions and the project team were sent multiple images from commercial crabbers. It was difficult to confirm or deny industry perceptions of an increase in the frequency of legal males with a claw missing (i.e., wingers). The increased frequency of wingers is attributed to crabs being stuck in escape vents and throwing claws or having their claws predated upon while stuck, both of which are possibilities.

Marine turtle interactions

All species of marine turtle that occur in Queensland waters are listed as Vulnerable or Endangered under Commonwealth and Queensland legislation. StrandNet data were collated to better inform where and how marine turtles are interacting with crabbing apparatus, with a view to identifying ways that the number of interactions with negative outcomes could be reduced. The annual numbers of marine turtles reported entangled in crabbing apparatus (pot or float-line) has fluctuated over the past decade, but in 2021 and 2022 amongst the highest annual number of entanglements were reported, at 53 and 50 respectively. Of the 240 records of marine turtles in StrandNet (2011 to 2023) attributed to crab pot entrapment, 89% were reported dead, and 11% were alive. Of the 295 records of marine turtles in StrandNet (2011 to 2023) attributed to float-line entanglement, 56% were reported dead, 39% were alive and 5% had an uncertain fate.

The majority of reported marine turtle interactions with crabbing apparatus (pot or float-line) were from southeast Queensland (i.e., Moreton Bay (82%), Great Sandy Strait, Hervey Bay, Fraser Island (6%)), reflecting human population density (for both sightings and crabbing effort) and marine turtle density. There was a slight seasonal trend in reported strandings for the greater Moreton Bay region, potentially reflecting the seasonality in crabbing effort, which increases between October to March.

Records from StrandNet over the past five years were examined for photographic evidence to better quantify the type of gear involved in crab pot entrapment and float-line entanglement. The results do not account for 'pot-type use bias' i.e., the absolute frequency of use by pot or float-line types by commercial and recreational crab fishers in Queensland waters[1].

Photos attached to StrandNet records (2018 to 2023, n = 107) indicated that collapsible rectangular mesh pots and collapsible round mesh pots with rings of less than 10 mm steel were more commonly associated with marine turtle entrapment (i.e., 2/3^rds^ of reported interactions) than collapsible mesh pots with rings equal to or greater than 10 mm steel (i.e., 1/3^rd^ of reported interactions). The former pot types are more commonly associated with the recreational sector than the commercial sector. This suggests that, on average, marine turtle entrapment in crab pots is more common in pots associated with the recreational crabbing sector than the commercial crabbing sector.

There are several ways the risk of marine turtle interaction with crabbing apparatus could be mitigated. The use of 'turtle strings' on entrance funnels could be made compulsory, although the efficacy of these is undetermined. Sink rope could be made compulsory, although the efficacy of this is also undetermined. Size differences between Giant Mud Crabs and marine turtles could be used to reduce the likelihood of marine turtle entry into crab pots by restricting entry funnel inner dimensions or with hard restrictors. Reducing the loss (accidental or deliberate non-collection) of 'lightweight' crab pots that become 'ghost' pots would also reduce the risk of marine turtle interactions with crabbing apparatus. Float-line entanglement is problematic, as there will always be an ongoing risk where high crabbing effort and high marine turtle densities overlap. Temporal restriction on crabbing effort is unlikely to be effective at reducing entanglement, but spatial restriction or improved standard of crabbing apparatus in areas of high marine turtle density may reduce the risk.

Adoption of bycatch reduction devices and strategies in the recreational sector of the Queensland Crab Fishery

Escape vents in crab pots are commonplace in other pot fisheries, within Australia and overseas, and provide the benefits of allowing sub-legal-size crabs and fish bycatch to escape, whilst having minimal impact on legal-size males. Escape vents in recreational crab pots targeting Giant Mud Crabs should be a long-term aim of Queensland fisheries management and the manufacturers of recreational crabbing equipment. This requires a legislative change, leadership from the recreational gear manufacturing sector and behavioural change by recreational crabbers. The project offered free escape vents (120 mm x 50 mm) to persons reporting Giant Mud Crabs that were tagged in FRDC 2019-062. Approximately half of the recreational crabbers that were offered free escape vents took up the option to trial them. This

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[1] Order of magnitude estimates of the number of crab pots deployed per calendar year in Queensland waters indicate approximately 1,000,000 commercial pot days on the Queensland east coast (EC1), approximately 100,000 commercial pot days in the Gulf of Carpentaria (GC1), and approximately 400,000 pot days in the recreational mud crab sector (likely an underestimate due to non-legal potting activities e.g., sunk pots).

suggests that there is an interest by recreational fishers to reduce incidental bycatch in their crab pots. The current project developed instructions on how to easily retrofit escape vents to existing pots.

Implications

The crab fishery is an important commercial and popular recreational fishery in Queensland. Its sustainability could be improved by regulating mud crab pots to contain appropriately sized escape vents that retain legal male Giant Mud Crabs, whilst reducing the bycatch of sub-legal-size crabs, finfish and other protected species such as water rats. Sustainability could also be improved by more detailed definitions of crabbing apparatus (pot and float-line) in the Queensland *Fisheries (General) Regulation 2019*, with the aim of reducing the risk of marine turtle entrapment – which has been a long-standing issue for this fishery.

Recommendations

Regarding escape vents, we recommend that:

(i) No change to the dimensions of the 120 x 50 mm rectangular escape vent, as collected data indicates that most legal male Giant Mud Crabs of 150 mm carapace width are not able to exit, unless their carapace has deformed or the carapace has not yet hardened (i.e., C-grade crab).
(ii) The minimum diameter of the round escape vent be reduced from 105 mm to either 100 or 95 mm, so that most legal male Giant Mud Crabs of 150 mm carapace width are retained, noting that smaller escape vents reduce the ability of finfish bycatch to escape.
(iii) The two 75 x 60 mm escape vent be removed as it is of marginal benefit to bycatch reduction.
(iv) Escape vents be constructed out of material that is not able to be distorted out of shape, such that the escape vent no longer performs as intended.
(v) Escape vents are permitted to be installed within 30 to 50 mm of the bottom of the apparatus, with a literal interpretation of 'on the bottom edge' being unnecessary pedantics.

Regarding marine turtle entanglement in crabbing apparatus, we recommend that legal crab pot definitions in Queensland be more prescriptive in terms of:

(i) entry funnel definitions - with the aim of reducing the marine turtle entry into crab pots, based on size differences between Giant Mud Crabs and marine turtles.
(ii) design - to bring Queensland crab pot regulations in line with that of other Australian jurisdictions. The aim being to reduce the number of crab pots that (accidentally or deliberately by non-collection) become 'ghost' pots, potentially by increasing the weight of pots so they do not drift or roll, such as by requiring the diameter of the rings in circular collapsible mesh pots to be ≥ 10 mm.

The recreational crabbing sector in Queensland is significant, both in terms of number of participants and spatial extent of activity. Its participants are diverse and have a range of approaches – in terms of gear quality as well as ethical standards. Without government regulation or significant leadership, we expect little change in fishing practices will occur in the recreational sector, and hence our recommendations. Regarding escape vents in the recreational sector, we strongly recommend that escape vents be regulated into this sector – as there are substantial benefits including the reduction in the capture of non-harvested mud crabs and reduced damage to harvestable legal-size males from sub-legal-size crabs that can occur during pot retrieval. One argument against escape vents in crab pots is the current escape vent sizes allow Blue Swimmer Crabs to escape. However, Blue Swimmer Crabs are not always targeted and locations where Giant Mud Crabs are targeted, noting that escape vents can easily be modified to allow retention of the smaller and thinner Blue Swimmer Crabs by the simple addition of string or cable ties.

Keywords

Giant Mud Crab, *Scylla serrata*, escape vents, crab pots, morphometrics, bycatch, marine turtles, *Chelonia mydas*, *Caretta caretta*, StrandNet

Introduction

Setting pots (also known as traps in some jurisdictions) for portunid crabs is a commercial and popular recreational activity in areas of Australia where mud crabs (*Scylla* spp.) and Blue Swimmer Crabs (*Portunus* spp.) occur. The regulated definition of permitted apparatus to catch mud crabs varies between states and territories (Table 1). Queensland has the least prescriptive definition of permitted apparatus, despite crabbing being a major commercial and popular recreational activity in the state.

In recent years, annual commercial effort targeted at Giant Mud Crabs was estimated to be over one million pot days along the Queensland east coast (EC1) and over 100,00 pot days in the Gulf of Carpentaria (GC1), based on logbook data (days fished and assuming 35 pots per C1 symbol). Annual recreational effort targeting at Giant Mud Crabs was estimated to be over 400,000 pot days across Queensland, based on State-wide Recreational Survey data. These estimates plus on water observations, suggest that most Queensland estuaries near population centres have very high densities of crab pots in the water for many months of the year. Peaks in crabbing effort occur during holidays, especially during summer and early autumn, particularly Christmas to New year. The implication of these estimates is that crab pots are a significant occurrence in Queensland waterways, and whilst impacting via harvest on the target species (regulated by gender and size), also have the potential to significantly impact on non-target individuals (sub-legal, female, fish bycatch), as well as protected species that interact with the gear, such as marine turtles.

Table 1. Definition of crabbing apparatus and legal-size limits of mud crabs in various Australian jurisdictions.

Jurisdiction	Definition
Queensland[1]	*Fisheries (General) Regulation 2019*, Part 4 Other fishing apparatus, 1 Crab pot: A *crab pot* is fishing apparatus consisting of a cage with a round opening in the top, or an elongated opening (parallel to the base) in the side, for trapping crabs. The pot must be attached by a rope to either (a) solid, light-coloured float at least 15cm in all its dimensions or (b) a fixed object above high water (e.g. a jetty or tree). Commercial pots targeting mud crab must be fitted with a regulated escape vent. Legal harvest: ≥ 150 mm Carapace Width (CW), male only
New South Wales[2,3]	Not exceeding 1.2 metres in length, 1 metre in width and 0.5 metre in depth (or has a diameter not exceeding 1.6 metres at the top or bottom); consisting of mesh not less than 50 mm; having not more than 4 entrance funnels none of which are on the top of the trap (excluding any access doors for removing crabs from the trap or baiting the trap). Recreational: Maximum dimensions: 1.2 metres (length) x 1 metre (width) x 0.5 metre (depth) or has a diameter not exceeding 1.6 metres at the top or bottom. Minimum mesh size: 50mm. Maximum of 2 traps to be used (or in possession) by any person at one time. Legal harvest: ≥ 85 mm Carapace Length (CL), male and female
Northern Territory[4]	**Complying marine pot** means an enclosed pot that: is designed to take mud crabs; and, has a volume of 0.5 m^3 or less; and does not exceed 1 m in length, width, height or diameter; for a pot made from polyethylene mesh used for amateur fishing – has a minimum mesh size of 50 mm when stretched; and has not more than four openings (excluding any opening for emptying mud crabs from the pot or placing bait in the pot); and does not have inside or attached to it material that is likely to entangle fish or aquatic life. Additionally, commercial pots (*Mud Crab Management Plan 2006)*: A licensee must not use a pot made of wire, steel or other rigid material unless the pot has one or

Jurisdiction	Definition
	more escape vents as follows: if the pot has one escape vent – the vent is not less than 46 mm in height and 240 mm in width; if the pot has 2 or more escape vents – each vent is not less than 46 mm in height and 120 mm in width. **A dilly pot** means a pot that: is made of flexible net that - is stretched over one or more metal hoops that do not exceed 1 m in diameter; and has a mesh size of not less than 15 mm; and does not exceed 1 m in length; and is constructed so that, when set, the sides collapse and the net lies flat on the ground and is not capable of entangling fish or aquatic life; and does not have attached to it material that is likely to entangle fish or aquatic life. Legal harvest: ≥ 140 mm CW males, ≥ 150 mm CW females, commercial sector ≥ 130 mm CW males, ≥ 140 mm CW females, recreational sector
Western Australia[5]	A person fishing in the Fishery under the authority of a licence must not fish by any means other than by crab trap. A person (*i.e., commercial fisher*) must not use a crab trap to fish for crabs in the Fishery unless that crab trap is – (a) a rectangular trap that – (i) when measured externally does not exceed 1000 mm in length, 600 mm in width and 300 mm in height; (0.18m^3) and (ii) is constructed with rigid mesh of not less than 50 mm by 75 mm in mesh size; and (iii) has no more than 2 openings for crabs to enter the trap; or (b) a round trap that – (i) when measured externally does not exceed 500 mm in height and 1200 mm in diameter; and (ii) is constructed with flexible nylon mesh of not less than 75 mm in mesh size; and (iii) has no more than 4 openings for crabs to enter the trap; or (c) a round trap that – (i) when measured externally does not exceed 500 mm in height and 1200 mm in diameter; and (ii) is constructed with flexible nylon mesh of not less than 50 mm in mesh size; and (iii) has a minimum of 2 escape gaps of not less than 90 mm in diameter if of a circular design, or not less than 40 mm in height and 120 mm in width if of a rectangular design; and (iv) has no more than 4 openings for crabs to enter the trap. (3) A person must not use a crab trap to fish for crabs in the Fishery unless that crab trap is attached to – (a) a surface float that is branded or stamped in legible characters with the licensed fishing boat number of the authorised boat that is being used to fish in the Fishery; or (b) another crab trap, and a surface float as specified in paragraph (a) is attached at each end of the line of traps. (4) A person fishing in the Fishery under the authority of a licence must pull and empty every crab trap at least once in any 48-hour period. (5) Subject to subclause (6), the master of an authorised boat must not permit the number of crab traps being carried on that boat to be more than the current entitlement of the licence under which fishing is to be carried out. Noting that recreational fishers are not permitted to use 'crab traps' as defined above, being able to legally catch crabs by hand, blunt hand-held wire hooks, drop nets or scoop nets. See http://rules.fish.wa.gov.au/Species/Index/46 Legal harvest: ≥ 150 mm CW male and female, *Scylla serrata* ≥ 120 mm CW male and female, *Scylla olivacea*

[1] https://www.legislation.qld.gov.au/view/whole/html/inforce/current/sl-2019-0179
[2] Fisheries Management (Estuary General Share Management Plan) Regulation 2006 - NSW Legislation
[3] https://www.dpi.nsw.gov.au/fishing/recreational/fishing-rules-and-regs/perm-prohib-saltwater#:~:text=in%20all%20dimensions.-,Crab%20trap,at%20the%20top%20or%20bottom.
[4] https://nt.gov.au/marine/recreational-fishing/rules/pots-dillies-and-nets
[5] https://www.wa.gov.au/system/files/2021-08/Kimberley%20Crab.pdf

Escape vents

Escape vents are commonly required in trap and pot fisheries around the world (Eldridge *et al*. 1979; Havens *et al*. 2009). Previous work by Grubert and Lee (2013) trialled escape vents in rigid rectangular steel mesh pots and polyethylene trawl mesh pots in the Northern Territory and Queensland, which have different size and sex rules for harvesting legal crabs (Table 1). Based on escape vents that were 120 mm by 46 mm, the authors estimated a ~40% reduction in the catch rates of Giant Mud Crabs <150 mm carapace width (number per pot lift) and the potential for up to a 30% increase in catch rates of legal-size crabs.

NSW Department of Primary Industries and Regional Development have also conducted numerous studies into bycatch reduction in crab pot/trap fisheries using escape vents and larger mesh covering the surface of collapsible polyethylene mesh crab pots (Rotherham *et al*. 2013; Broadhurst *et al*. 2014; Barnes *et al*. 2022; Broadhurst *et al.* 2018; Broadhurst *et al.* 2020). Despite the promising research results, there has been mixed voluntary uptake of escape vents in commercial and recreational pot fisheries targeting mud crab in northern Australia.

Escape vents became mandatory in the NT commercial mud crab fishery on the 25th July 2018, and in the commercial mud crab component of the Queensland Crab Fishery on the 1st September 2021 (http://classic.austlii.edu.au/au/legis/qld/consol_reg/ffr2019372/sch7.html, see Insert 1). Escape vents are still under consideration for mandated use in other jurisdictions.

Queensland *Fisheries (General) Regulation 2019* specifies the number, size and dimensions of permissible escape vents (Figure 1), noting that the vents must be positioned on the bottom edge of the apparatus. Prior to regulation, escape vents were voluntarily used by some commercial crabbers to address issues in their region (e.g. water rats) or from past experience with escape vents trials. The Fisheries Queensland (FQ) Observer Program reported the following bycatch reduction strategies in use in the crab fishery in 2011-2012: 100 mm round steel escape vents installed in the top of the pot, 'rat' escape holes (75 x 60 mm), as well as rubber drawstrings (to ensure tight closure of pot opening).

Insert 1. Escape Vents as defined by the *Queensland Fisheries (General) Regulation 2019, 168 Amendment of sch 7, pt 1* https://www.legislation.qld.gov.au/view/html/inforce/current/sl-2019-0179

An item of crab apparatus used to take mud crabs must have positioned on the bottom edge of the apparatus – (a) 1 large rectangular escape vent, or (b) 2 small rectangular escape vents or (c) 1 round escape vent, where a large rectangular escape vent means a rectangular opening of at least 120 mm long and 50 mm wide, round escape vent means a round opening that has a diameter of at least 105 mm, and small rectangular escape vent means a rectangular opening that is at least 75 mm long and 60 mm wide.

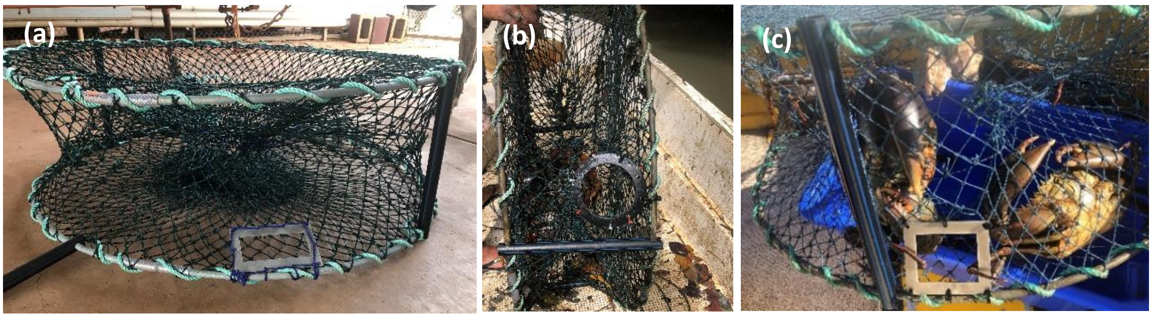

Figure 1. Escape vents in commercial crab pots: (a) large rectangular 120 x 50 mm; (b) round 105 mm diameter (internal); and (c) two small rectangular of a least 75 x 60 mm.

At the time the current research was proposed (December 2021), industry concerns were that legal crab in some regions was escaping through the large rectangular 120 x 50 mm escape vents, that the requirement for the vent to be positioned on the bottom edge of the apparatus was causing excessive wear to the pot, and that alternate positioning of the escape vent should be considered. Despite escape vents being distributed to regional commercial crabbers as part of FRDC 2010-042, via FQ Observers, no data on regional performance was recorded. Thus, there was no empirical evidence to confirm that legal crabs in different regions had different morphometrics that thus would allow them to escape from the regulated escape vents.

In May 2022, FQ clarified that the primary intent of regulating escape vents in commercial crabbing apparatus was to allow bycatch (i.e., small crabs, fish and protected species such as water rats) to escape the pot, with a secondary intent of allowing some of the animals caught in ghost pots to escape the baiting cycle (agenda paper of the FQ Crab Working Group, DAF unpublished). This clarification guided the recommendations of the current research, in terms of reporting the performance of current and alternate escape vents with a view to verifying and/or recommending amendments to escape vent regulation as part of regulatory reform.

Thus, the objectives of the current research specifically related to providing advice to the managing agency on escape vent regulations to maximise commercial outcomes (i.e., retention of legal Giant Mud Crabs, which are male and greater than or equal to 150 mm carapace width) and also ecological outcomes (i.e., exclusion of non-legal crabs and finfish bycatch).

Marine turtle interactions with crabbing apparatus

Marine turtles can become incidentally entrapped in crab pots when they get stuck in the pot, either fully inside or partially stuck in the entry funnel. They often drown when entrapped in the pot, as they are restrained by the gear and cannot surface to breathe. Marine turtles (and other threatened species) can also become entangled in the float-lines (i.e., ropes) that attached to the submerged pots as the animal swims past. This interaction is visually confronting (Figure 2), but relatively uncommon, given there is an estimated 1.5 million pot days fished per annum across Queensland (J Robins unpublished data). Reported interactions between marine turtles and crabbing apparatus are more prevalent in southeast Queensland, due to an overlap in marine turtle abundance and crab pot density, as well as the frequency of people using waterways and associated beaches. In 2021, 41 marine turtles were reported entrapped or entangled in crab pots, with social media promotion by various groups to change management arrangements to reduce the incidence of these events.

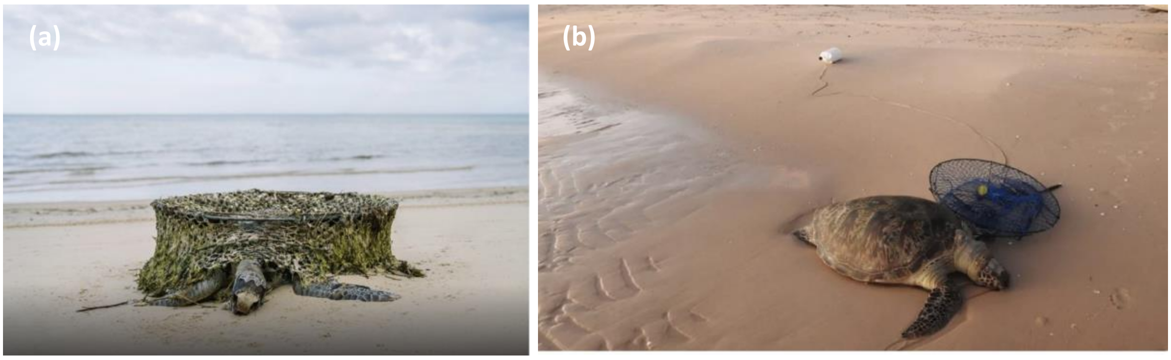

Figure 2. Examples of marine turtle interactions with crabbing apparatus: (a) Sea Shepherd social media post September 2020; (b) Queensland Parks social media post 4th September 2022, Fraser Island beach.

Assessment of the mud crab component of the Queensland Crab Fishery for the purposes of Part 13 of the Commonwealth's *Environment Protection and Biodiversity Conservation Act* 1999, included the condition to "develop and implement risk mitigation strategies for marine turtles by January 2022 in parallel with the development of a harvest strategy for the fishery"[2]. However, a risk mitigation strategy requires more details about these interactions (frequency, location, causes of entrapment or entanglement). The most recent publicly available StrandNet report (Meager and Limpus 2012) identifies crab pots and float-lines as the major cause of accidental mortalities from fishing or fishing-related activities. Available species of conservation interest (SOCI) logbook data[3] has a limited number of reported interactions, with a maximum of five reported interactions for any given year.

As an extension to research on bycatch issues in the Queensland Crab Fishery, the current research collated available information on marine turtle interactions with crabbing apparatus, to better quantify the frequency, location, and type of interaction (i.e., crab pot entrapment, float-line entanglement), and provide information upon which a risk mitigation strategy could be developed.

[2] https://www.awe.gov.au/sites/default/files/env/pages/8457b21d-547c-4302-883d-0778ac3ef27b/files/qld-mud-crab-assessment-2021.pdf
[3] https://www.data.qld.gov.au/dataset/quarterly-reports-species-of-conservation-interest-soci-interactions-from-2006/resource/7ec15655-5c2c-48f5-88ac-50a9501317a0

Objectives

1. Benchmark bycatch reduction devices and strategies currently in use in the commercial mud crab component of the Queensland Crab Fishery.

2. Trial alternate configurations and advise on potential changes to escape vent regulations to achieve better commercial and ecological outcomes.

3. (a) Collate information on marine turtle interactions with crab pots (including ghost pots) and (b) Consider pot configuration(s) that could contribute to a risk mitigation strategy for marine turtles in the Queensland Crab Fishery.

4. Develop options for adopting bycatch reduction devices and strategies in the recreational sector of the Queensland Crab Fishery.

Chapter 1. Giant Mud Crab morphometrics in Queensland, with implications for escape vents

Mud crabs predominately move sideways via walking, so the critical dimensions to be considered for efficiency of escape vents is their total length (TL) and carapace height (CH) (Grubert and Lee, 2013). Total length is the distance from the tip of the longest frontal median spine (whichever side is longest) to the posterior edge of the midpoint of the abdominal flap. Carapace height is the maximum dorso-ventral distance.

Grubert and Lee (2013) based prototype escape vents on the 'upper boundary line for the carapace width by total length relationship' and the 'lower boundary line for the carapace width by carapace height relationship' because "*This combination allows the longest of the undersized crabs to escape but limits the passage (i.e., exit) of all but the shallowest of legal-sized crabs".* Rectangular escape vents with a width at least twice the height were chosen by Grubert and Lee (2013) to reflect the dorso-ventral flattening of Giant Mud Crabs and their preferred movement in a sideways direction. Prototype escape vents were tested via hand passing of legal-size or larger crabs through the vent on the presumption that passage by hand is also the smallest opening a crustacean can pass through unaided.

Based on analysis of Giant Mud Crab morphometrics (n = 205) from the Adelaide and Roper Rivers (Arnhem-west and Western Gulf of Carpentaria Northern Territory Management Units respectively, Kirke *et al.* 2023), a 150 mm CW male Giant Mud Crab (minimum legal-size in Queensland) was estimated to have a minimum carapace height of 52 mm (but ranging up to 60 mm[4]) and a maximum total length of 118 mm (but ranging down to 106 mm[5]). Thus, a rectangular escape opening of 120 mm x 50 mm was recommended as suitable for retaining male Giant Mud Crabs of 150 mm CW or greater.

We sought to document the morphometrics of the Giant Mud Crab in various regions of Queensland to determine:

(i) If the inferences of Grubert and Lee (2013) were consistent and/or accurate for Queensland Giant Mud Crab populations.
(ii) If Giant Mud Crab morphometrics (Carapace Width to Carapace Height to Carapace Length dimensions) varied significantly between regions within Queensland.
(iii) If differences were sufficiently large to warrant a recommended change to the regulated escape vent dimensions.

Methods

Morphometric definitions and field measurements

The following metrics were defined and measured during field sampling as indicated:

- Notch width (NW, standard measure) - the distance (to the nearest mm) between the notches anterior to the last opercular spines of the dorsal carapace.
- Carapace width (CW, secondary measure, used for legal-size in Queensland) - the distance (to the nearest mm) between the tips of the largest opercular spines on each side of the dorsal carapace.
- Carapace length (CL, standard measure, legal-size measure NSW) - the distance (to the nearest mm) from the base of the notch between the frontal medial spines to the posterior dorsal margin of the dorsal carapace.

[4] Mean CH = 0.393*CW - 3.067 (r^2 =0.922, n = 205), Lowest CH -4mm, Largest CH + 4mm, Grubert and Lee (2013)
[5] Mean TL = 0.811*CW - 9.348 (r^2 = 0.887, n = 205), Lowest CH -6 mm, Largest TL + 6mm, Grubert and Lee (2013)

- Total length (TL, secondary measure) - the distance from the longest frontal median 'spine' (often underneath the eye) to the posterior edge of the tucked abdominal flap) and is the true 'length' of the crab.
- Carapace height (CH, standard measure) - the distance (to the nearest mm) between the dorsal carapace to the ventral cephalothorax, measured anteriorly (i.e., callipers placed between the claws and eyes).
- Crusher claw height ($C_{law}H$, standard measure) - the distance (to the nearest mm) of the crusher claw (i.e., the claw with 'molar'-like teeth as opposed to the cutter claw which has 'incisor'-like teeth) at its widest dimension.
- Crusher claw side - left or right.
- Gender -
    - male, distinguished by a narrow V-shaped abdomen, with functional maturity indicated by the presence or absence of mating scars (Knuckey 1996). Mating scars are caused by bacterial lesions infecting the male exoskeleton where it has abraded from coupling with female crabs during mating and appear as oval marks on the first pair of walking legs and/or as a 'Maltese cross' on the cephalothorax.
    - female, distinguished by abdominal shape, with mature individuals having a U-shaped abdomen (Figure 4).

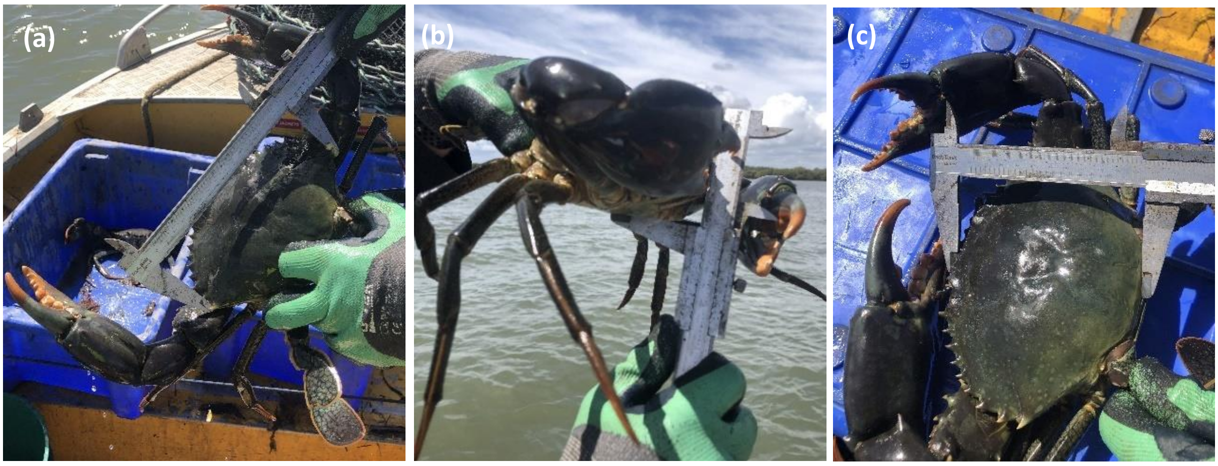

Figure 3. Morphometric measurement of Giant Mud Crabs: (a) notch width (NW), (b) carapace height (CH) and (c) carapace length (CL).

Figure 4. Gender and maturity indicators on Giant Mud Crabs: (a) male abdominal V-shape and mating scars (red circles) on the cephalothorax and/or first walking legs, (b) female abdominal shape, indicating juvenile (V-shape uncoloured), intermediate (U-ish shape but uncoloured), and mature (U-shape and dark/mottled).

The opercular spines on the dorsal carapace of Giant Mud Crabs change in length over time, being longest in a newly moulted crabs, and shorter in 'older' inter-moult crabs due to wearing or chipping. As such, CW (as measured at the longest opercular spines) is somewhat an inconsistent metric upon which to base morphometric analysis, as for any given individual, this metric will change over time. Therefore, for a more consistent morphometric measurement and speed in field work measurements, NW was adopted as the standard size measurement for all mud crabs sampled - as per Jebreen *et al*. (2008) and Flint *et al*. (2017). A sub-set of mud crabs in every region (as catches permitted) were also measured for CW (tip-to-tip) to permit conversion of NW to CW, thus allowing comparison to the Queensland minimum legal size of 150 mm CW (male only harvest) and relevance to escape vent performance.

Analysis

The current research focused on the performance of escape vents on harvestable crabs. As such, analyses focused on male crabs, especially in the vicinity of legal size i.e., 150 mm CW (range 148 to 152 mm CW). Analyses on females is included for completeness. Linear regressions were fitted using the "stats" package in R (v 4.2.2) to enable conversion from NW to CW so results can be compared to legal-size. Retention of regression terms was assessed using a backwards stepwise approach, informed by the Akaike information criterion (AIC).

Results

Morphometric analyses drew on fishery-independent and fishery-dependent sampling (see Chapter 2). Between November 2021 and October 2023, 10,906 male and 5,140 female Giant Mud Crabs were handled and measured by project staff. Some of these measurements were taken as a part of FRDC 2019-062, with regional morphometric analysis enhanced by data sharing between the projects. Time-constraints during field sampling, especially fishery-dependent, did not always permit all measurements to be taken for all crabs. From the large number of measurements, only complete pairwise observations were retained for each respective analysis.

Notch width to carapace width by sex

CW_{male} = 1.030106*NW + 2.971876 (n = 1,136)
CW_{female} = 1.030106*NW + 4.016038 (n = 429)

Based on this analysis, male Giant Mud Crabs with a NW of 142 mm or greater were considered as 'legal', and male Giant Mud Crabs with a NW less than 142 mm were considered as 'sub-legal' (Figure 5). This is a conservative allocation, as the estimated mean size for a 150 mm CW legal male Giant Mud Crab is 142.7 mm NW (n = 32, range 140 to 148 mm, median 143 mm, s.e. = 0.25 mm).

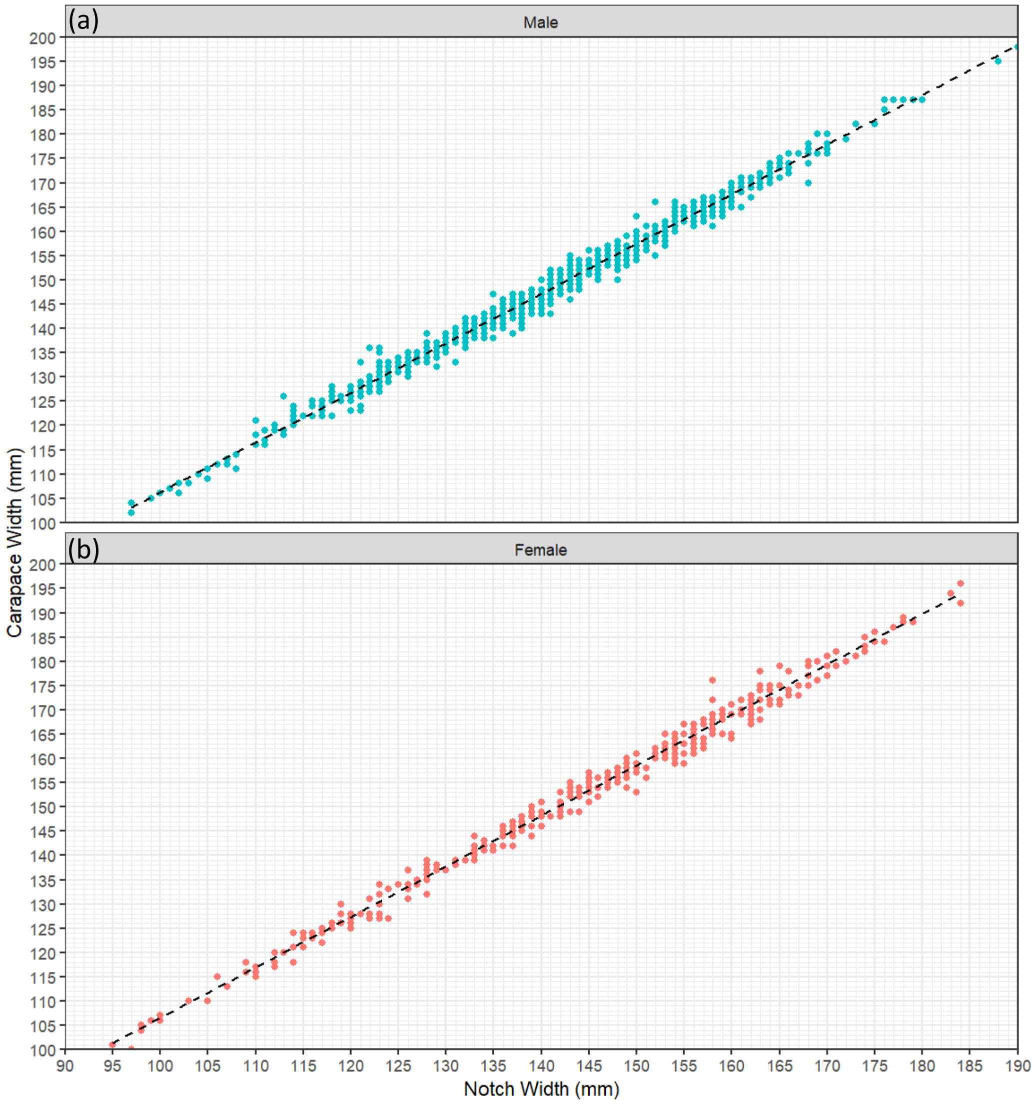

Figure 5. Queensland Giant Mud Crab notch width (NW) to carapace width (CW) relationships, observed (dots) and fitted (dotted line) for: (a) male (n = 1,136) and (b) females (n = 429).

Notch width to carapace height by region

A total of 6,737 Giant Mud Crabs were measured for NW and CH. Given the significant sex effect identified in the previous section, analyses were considered separately for males (n = 4,755) and females (n = 1,983). Only regions for which 200 or more Giant Mud Crabs were sampled for NW and CH were analysed, and only crabs with CH between 30 and 71 mm were analysed to maximise the overlap in the size ranges of CH measured amongst the different regions, and thus the power of the analysis to detect regional differences – a specific focus of the current research.

Males: Backward stepwise regression with region as the main effect was fitted, with the interaction between CH and region retained based on ΔAIC (n = 4,453, adjusted R^2 = 0.9195). The regression was re-fitted with outliers removed (n = 204 removed, residuals greater than two standard deviations from the mean, as these are considered field measurement errors).

The final fitted regression for CH as a function of NW (n = 4,249, adjusted $R^2 = 0.9524$) indicated a significant region effect ($p < 0.001$) and a significant NW by region interaction effect ($p < 0.001$). Thus, the slope and the intercept of the fitted regressions were different between regions (Figure 6). Based on parameter estimates from the regression, the following region-specific relationships between NW and CH for male Giant Mud Crabs were calculated:

$CH_{Mapoon} = 0.37821324*NW + 1.971322$
$CH_{Weipa} = 0.3730154*NW + 2.464091$
$CH_{Karumba} = 0.3351362*NW + 4.492633$
$CH_{Hinchinbrook} = 0.3919884*NW - 0.457859$
$CH_{Townsville/Burdekin} = 0.3351362*NW + 7.493324$
$CH_{CentralQld} = 0.3786949*NW + 1.269422$
$CH_{SouthEastQld} = 0.3915763*NW - 0.166348$

Although statistically significant, the regional differences in the NW to CH proportions of male Giant Mud Crabs were small. For near-legal male Giant Mud Crabs (i.e., CW 148 to 152 mm CW), the difference in CH between regions was approximately 1 mm. The significant NW by region interaction indicates that Giant Mud Crabs grow in slightly different dimensions with moult increment.

Carapace height is less than total height, as Giant Mud Crabs have a slight rise in the dorsal carapace lateral to the mid-line and approximately behind the eyestalks. Legal male Giant Mud Crabs with a CW of 150 mm (≅ 142 to 143 mm NW) had a median CH of 56 mm (observed range 51 to 59 mm, s.e. = 0.51 mm). This suggests that just legal male Giant Mud Crabs (i.e., 150 to 152 mm CW) are larger in total height than 50 mm, and thus are unable to fit through a 120 x 50 mm rectangular escape vent. This concurs with field observations on numerous occasions where 150 mm CW male Giant Mud Crabs were unable to be hand-passed through the 120 x 50 mm rectangular escape vent. However, the dimensions of a Giant Mud Crab, whilst relatively consistent, can differ for rare individuals when their carapace is soft (i.e., C-grade), or potentially because of an event or factor during hardening that alters the standard dimensions of their carapace.

Females: Backward stepwise regression with region as the main effect was fitted (n = 1,737, adjusted $R^2 = 0.8980$), with the interaction between CH and region removed based on ΔAIC. The regression was re-fitted with outliers removed (n = 77, residuals greater than two standard deviations from the mean, as these are considered field measurement errors). The final fitted regression (n = 1,660, adj $R^2 = 0.9422$) resulted in the following region-specific relationships between NW and CH height for female Giant Mud Crabs:

$CH_{Mapoon} = 0.366282*NW + 2.436261$
$CH_{Hinchinbrook} = 0.366282*NW + 2.435055$
$CH_{Townsville/Burdekin} = 0.366282*NW + 1.712458$
$CH_{CentralQld} = 0.366282*NW + 1.939645$
$CH_{SouthEastQld} = 0.366282*NW + 2.532458$

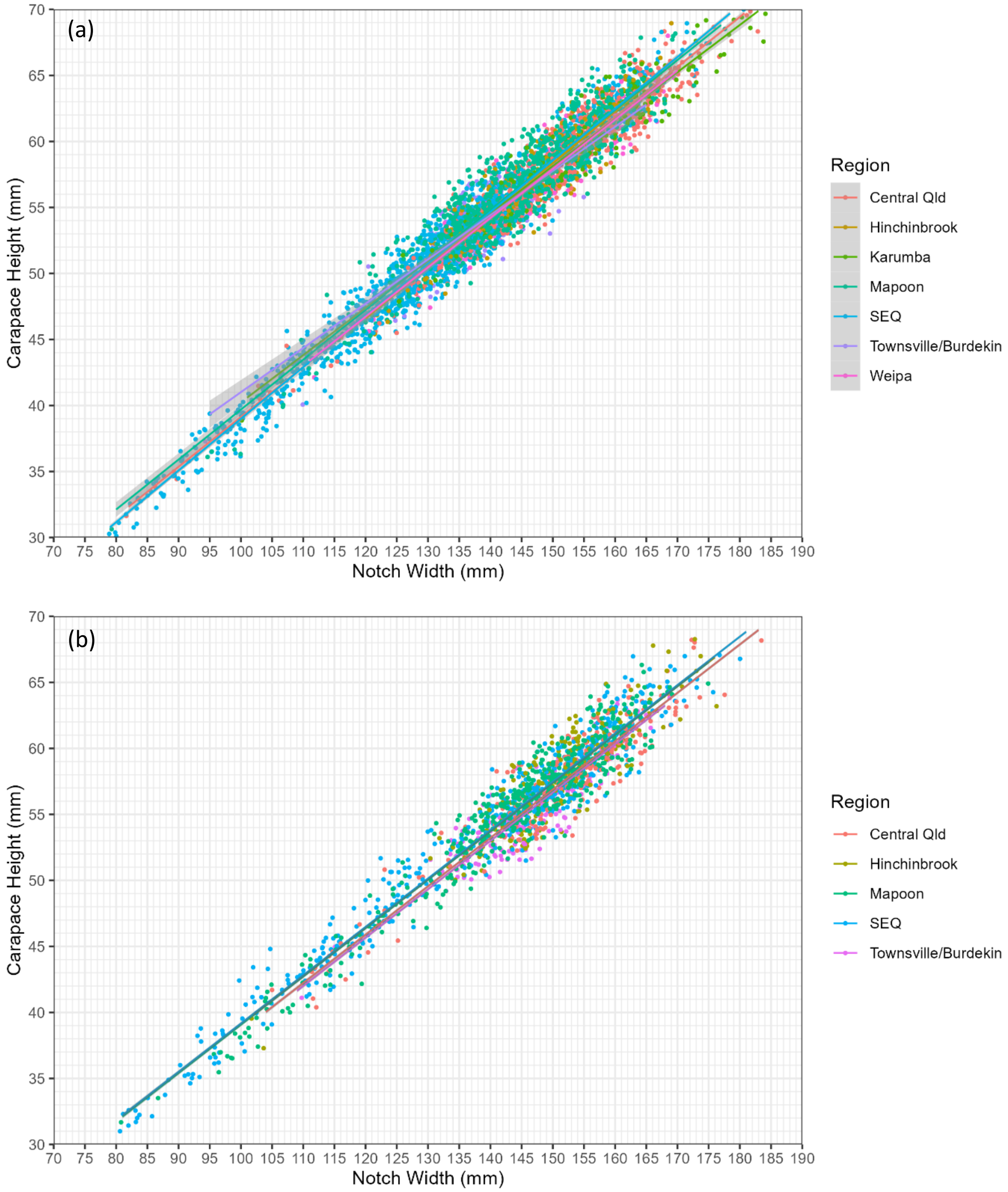

Figure 6. Queensland regional Giant Mud Crab notch width to carapace height relationships, observed (dots) and fitted (solid lines) for: (a) male (n = 4,235) and (b) female (n = 1,660).

Notch width to carapace length by region

Approximately 5,500 Giant Mud Crabs were measured for both NW and CL. Analyses were considered separately for males (n = 3,881) and females (n = 1,531). The data were further screened to retain only regions for which at least 200 Giant Mud Crabs had measured NW and CL. Only crabs with CH between 50 and 125 mm were analysed to maximise overlap in the size ranges of CL measured amongst the different regions.

Males: Backward stepwise regression with region as the main effect was fitted (n = 3,591, adjusted R^2 = 0.9685), with the ΔAIC indicating that the interaction between CL and region should be retained. The regression was re-fitted with outliers removed (n = 183, residuals greater than two standard deviations from the mean, as these are considered field measurement errors). The final fitted regression for CL as a function of NW (n = 3,408, adjusted R^2 = 0.980) indicated a significant region effect ($p < 0.001$) and a significant NW by region interaction effect ($p < 0.001$). Thus, the slope and the intercept of the fitted regressions were different between regions (Figure 7). Based on parameter estimates from the regression, the following region-specific relationships between NW and CL for male Giant Mud Crabs were calculated:

$CL_{Mapoon} = 0.677164*NW + 2.55548$
$CL_{Weipa} = 0.673518*NW + 2.46857$
$CL_{Karumba} = 0.669589*NW + 3.82401$
$CL_{Hinchinbrook} = 0.687772*NW + 1.07136$
$CL_{Townsville/Burdekin} = 0.656357*NW + 5.81501$
$CL_{CentralQld} = 0.66346*NW + 4.34113$
$CL_{SouthEastQld} = 0.695842*NW - 0.39555$

Although statistically significant, the regional differences in the NW to CL proportions of male Giant Mud Crabs are small. For near-legal male Giant Mud Crabs (i.e., CW 148 to 152 mm CW), the difference in CH between regions is approximately 1 mm. The significant NW by region interaction indicates that Giant Mud Crabs grow in slightly different dimensions with moult increment. Giant Mud Crabs from Weipa had the smallest CL for near-legal CW, with Townsville/Burdekin Giant Mud Crabs having the longest CL for near legal CW.

Carapace length is less than total length (TL) in male Giant Mud Crabs by 3 to 5 mm (n = 229), where TL measures to the posterior edge of the abdominal flap. A legal Giant Mud Crab with a CW of 150 mm (≅ 142 to 143 mm NW), has a CL of ~99 mm, and a TL of approximately 102 to 104 mm, depending on how tightly the abdominal flap is held against the cephalothorax. This suggests there is potential for near legal (i.e., 148 to 152 mm CW) male Giant Mud Crabs to be slightly smaller in TL than 105 mm. This concurs with field observations, where 150 mm CW male Giant Mud Crabs were able to be hand-passed through the 105 mm round escape vent.

Females: Backward stepwise regression with region as the main effect was fitted (n = 608, adjusted R2 =0.8101) and the ΔAIC indicating that the CH and region interaction should be removed. The regression was re-fitted with outliers removed (n = 36, where residuals greater than two standard deviations from the mean, as these are considered field measurement errors). The final fitted regression (n = 575, adj R^2 = 0.884) resulted in the following region-specific relationships between NW and CL for female Giant Mud Crabs:

$CL_{Hinchinbrook} = 0.645194*NW + 8.404174$
$CL_{SouthEastQld} = 0.645194*NW + 7.424219$

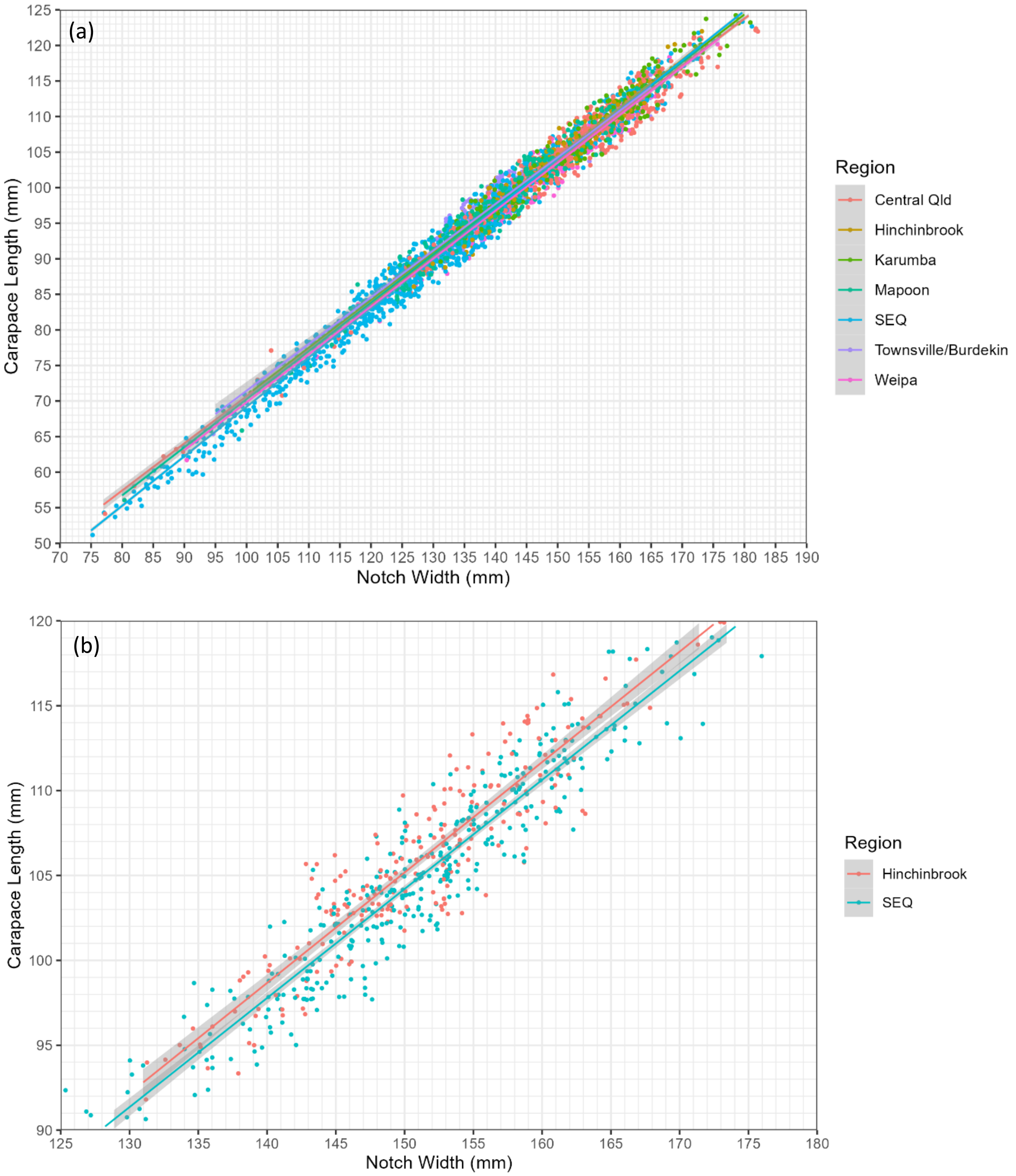

Figure 7. Queensland regional Giant Mud Crab notch width to carapace length relationships, observed (dots) and fitted (solid lines) for: (a) male (n = 3,408) and (b) female (n = 575).

Discussion

The commercial mud crab component of the Queensland Crab Fishery is spatially extensive with harvest in the 2022/2023 quota year reported at 564 tonnes for the Queensland east coast (EC1) and 100 tonnes for the Gulf of Carpentaria (GC1). At an assumed average weight of one kilogram per crab, then over 600,000 male mud crabs were harvested in Queensland, with commercial crabbing occurring in the majority of estuaries throughout state. Representative sampling of such a fishery is challenging, but with the resources available for mud crab research in Queensland, measurement of 10,906 male and 5,140 female Giant Mud Crabs was achieved, with sampling targeted at those regions reporting substantial harvest.

The current research endorses the inference of Grubert and Lee (2013) that the dorso-ventral height (carapace height, CH) and anterior-posterior length (carapace length, CL, as a proxy for total length, TL) are the critical dimensions that determine the performance of any given escape vent i.e., that on average, what size mud crab can (voluntarily) escape from the crab pot using the specified vent. Grubert and Lee (2013) reported considerable variation in the total length and carapace height of Giant Mud Crabs for a given carapace width (tip-to-tip). Our field observations and measurements indicate that much of this variation is a function of wear to the tips of the opercular spines. The current research suggests that notch width (NW), is a more consistent metric to measure the width of a Giant Mud Crab. Notch width does not change during an inter-moult period. Carapace width (CW) does change during an inter-moult period, with early inter-moult crabs (i.e., newly moulted) having longer spines than late inter-moult crabs.

Analyses found significant, but small (i.e., <1 mm) regional variation in Giant Mud Crab morphometric relationships between notch width and carapace height. The dorso-ventral height is relevant to the performance of the 120 x 50 mm rectangular escape vent. Results from the current research indicate that very few near-legal male Giant Mud Crabs are less than 50 mm in carapace height, consistent with the results of Grubert and Lee (2013). On a morphometric basis, no change to the 120 x 50 mm escape vent is recommended. However, we do recommend that escape vents be constructed out of material that is not able to be distorted out of shape, such that the escape vent no longer performs as intended (see Chapter 2).

Analyses also found significant, but small (i.e., <1mm) regional variation in Giant Mud Crab morphometric relationships between notch width and carapace length. The anterior-posterior length is relevant to the performance of the 105 mm round escape vent. Results indicate that a proportion of near-legal male Giant Mud Crabs would be able to exit the 105 mm round escape vent. On a morphometric basis, consideration should be given to revising the regulated diameter of the round escape vent. Results from the current research indicates that for near-legal Giant Mud Crabs (i.e., 148 to 151 mm CW):

100 mm round – estimated to prevent greater than 90.5% exiting via the escape vent
95 mm round – estimated to prevent greater than 99.5% exiting via the escape vent
90 mm round – estimated to prevent greater than 99.9% exiting via the escape vent

It should be noted that reducing the diameter of the round escape vent will also reduce its effectiveness at allowing fish bycatch to escape. These alternate sizes were tested during fishery independent trials (see Chapter 2) to gain a better understanding of performance in terms of catch rates and retention of legal and sub-legal Giant Mud Crabs.

Based on morphometrics, it is inferred that no legal male Giant Mud Crabs are able to escape from the 75 x 60 mm escape vent. Crabs can only exit using this size escape vent if their carapace length is less than 75 mm. This translates to a Giant Mud Crab of approximately 115 mm CW, which would generally be a juvenile. Of the male Giant Mud Crabs measured during the current study, approximately 5% were less than 115 mm in CW. The 75 x 60 mm escape vent thus offers limited benefit in reducing the bycatch of sub-legal crabs and should be removed as a management option and an alternative escape vent used.

Chapter 2. Benchmarking current bycatch reduction devices and strategies in the commercial mud crab component of the Queensland Crab Fishery, and trialling alternate gears

Benchmarking bycatch reduction devices and strategies currently in use in mud crab component of the Queensland Crab Fishery was approached by:

(i) surveying active commercial fishers who were reporting EC1 (East Coast mud crab) or GC1 (Gulf mud crab) quota.
(ii) recording bycatch reduction devices in use during fishery-dependent sampling.
(iii) recording Giant Mud Crab catch rates during fishery-independent sampling where pot type, bait, soak time, pot placement and vent type could be controlled in a replicated manner.

Alternate escape vent configurations were trailed during additional fishery-independent sampling and included top placement of currently regulated escape vents (based on industry feedback) and alternate sizes (guided by analysis of crab morphometrics (Chapter 1) and industry feedback)).

Methods

Survey of escape vents in use by commercial crab fishers

The aim of the survey was to document the gear currently in use by active commercial crabbers, including pot specifications, escape vents in use, concerns with current regulations, ideas about alternate bycatch reduction strategies and escape vent sizes, the degree of pot loss/theft (in terms of ghost pots), and willingness to assist with current research (see Appendix 3 for survey questions). It was intended that all active commercial crabbers (i.e., C1 symbol holders landing Queensland mud crab quota EC1 or GC1) would be contacted (by phone or in person) to be consulted as part of the current research on escape vents. The contact details of active C1 symbol holders were requested from Fisheries Queensland. However, legislative privacy conditions prevented Fisheries Queensland from providing these details directly to project staff. As a compromise, Fisheries Queensland emailed and sent hard copy letters to all active C1 symbol holders asking permission/interest to share their contact details with project staff. Of the estimated ~250 active C1's contacted by Fisheries Queensland, 12 provided their contact details. This low response rate was (and still is) indicative of industry sentiment towards Fisheries Queensland and the Queensland Government since the introduction of quota, escape vents in the crab fishery (September 2021), and other issues in Queensland fisheries management (e.g., east coast Spanish Mackerel total allowable catch). Project staff surveyed interested fishers as well as fishers who interacted with project staff to expand participants in the survey.

Fishery-dependent sampling

Active C1 symbol holders were approached to allow project staff onboard during commercial operations to document bycatch reduction devices and strategies in use, especially escape vents (shape, size, number and placement), and to document the performance of the bycatch reduction devices in terms of Giant Mud Crabs entrapped in the crab pot at the time of retrieval. Regions across the state were targeted to provide diversity in the scale and area of operation as well as regional representation of Giant Mud Crab populations. Target regions included Moreton Bay/southeast Queensland, Great Sandy Strait, Mackay and Sarina, Gladstone and Rockhampton, Stanage and Broadsound, Townsville and the Burdekin, Hinchinbrook, Karumba, Weipa and Mapoon. Fishery-dependent sampling relied upon the willingness of commercial operators to have DAF staff onboard, safety considerations (i.e., certificate of operation) and logistical constraints in getting staff to regional areas at times suitable for commercial operators.

Field measurements (see Morphometric definitions and field measurements, Chapter 1) during fishery-dependent sampling included the gear used (i.e., pot type, escape vent type and size), crab measurements (i.e., notch width, sex and maturity), and, depending on the number of crabs and distance between pot checks, carapace height, crusher claw height, carapace length, carapace width, and total length.

Fishery-independent sampling

Fishery-independent sampling was undertaken to control for variation both within and between different commercial crabbing operations. These were: design of pot, type of bait, soak time, simultaneous replication of all versions of escape vents and the inclusion of control pots (i.e., non-vented). Field measurements (see Morphometric definitions and field measurements, Chapter 1) during fishery-independent sampling included the gear used (i.e., pot type, escape vent type, size, and position), crab measurements (i.e., notch width, sex, maturity, carapace height, crusher claw height, carapace length), and as time and tidal constraints permitted carapace width (tip-to-tip) and total length. Apparatus were set under General Fisheries Permit 210183 and DAF Animal Ethics permit SA 2022/05/833.

Regulated escape vent trials

The sampling design included 10 crab pots for each of the escape vents as currently regulated (i.e., 120 x 50 mm rectangular, 105 mm round, two 75 mm by 60 mm, all 'positioned on the bottom edge of the apparatus'), 10 crab pots with no escape vents (i.e., controls), and three crab pots for each of the currently regulated escape vents but with the vents positioned on the top edge of the apparatus (i.e., top ring) to reflect industry preference for possible top ring placement of escape vents. Logistic constraints (tide, access, WHS issues) limited the number of pots set and checked to about 50 per day per trial. Details of the fishery-independent trials are given in Table 2.

Crab pots (common in use by Queensland commercial crabbers) used to test bottom-edge placement of escape vents were 'CrabNGear' 900 mm (diameter) collapsible circular pots, with a 12 mm bottom and 10 mm top rings constructed of galvanised steel, each with 6 mm chaff rope, covered in 30 ply 55 mm orange mesh, four entry funnels (230 mm stretched width at tensioning strings, 50 mm high mid centre at tensioning strings, 280 mm in depth (ring to end of funnel)), with four posts 320 mm in length by 3 mm thick wall, which when set resulted in 275 mm between the top and bottom rings. Crab pots (also commonly in use by Queensland commercial crabbers) used to test top-edge placement of escape vents were 'CrabNGear' 800 mm (diameter) collapsible circular pots, with a 12 mm bottom and 10 mm top rings constructed of galvanised steel, each with 6 mm chaff rope, covered in 30 ply 55 mm black mesh, three-entry funnels (270 mm stretched width at tensioning strings, 50 mm high mid-centre at tensioning strings, 310 mm in depth (ring to end of funnel)), with four posts 320 mm in length by 3 mm thick wall, which when set resulted in 275 mm between the top and bottom rings.

Alternate escape vent trials

Escape vent sizes selected for trialling as alternatives to current regulation were based on industry consultation and preliminary analyses of the morphometric data collected during fishery-dependent sampling (see Chapter 1). Notably, industry had a desire to consider placement of the escape vent in the upper part of the crab pot, as mesh pots were and still are 'wearing' on the bottom panel where Giant Mud Crabs attempt to exit the pot via the escape vent. In doing so, their walking legs and dorsal carapace rub on the mesh on the bottom of the pot. Therefore, as part of the escape vent fishery-independent trials, we included the currently regulated escape vents, but 'positioned on the top edge of the apparatus'. There was also a desire by industry to consider a round escape vent of a smaller dimension than that regulated (i.e., less than 105 mm internal diameter). Therefore, we considered round escape vents of 100, 95 and 90 mm internal diameter.

Fishery-independent trials of the currently regulated escape vents were repeated in southeast Queensland and central Queensland. On average, these two regions account for 21% and 35% of reported mud crab catch on the Queensland east coast respectively. Additionally, sample locations within each region (Table 2) contain marine protected areas, thereby increasing the likely capture of legal males to enhance the ability to detect differences in the performance of pots with various escape vents for a cost-effective sampling effort. Trials conducted in southeast Queensland occurred in areas open to commercial and recreational crabbing (allocated to 'SEQ fished' for analysis), as well as in the marine protected area adjacent to the Logan River (Figure 8). Further regional fishery-independent trials were considered, based on previous fishery-independent sampling by Fisheries Queensland (Jebreen *et al.* 2008). However, regional fishery-independent trials were not pursued because of: (i) high crabbing effort already occurring in most regional areas of Queensland, whereby commercial crab pots dominate the locations most suitable for catching legal male crabs (i.e., it would be difficult to find suitable and industry-credible locations to set 50 pots for five days on appropriate tides); and (ii) the logistical challenge of transporting and setting 50 pots in regional Queensland without sufficient local knowledge to support effective pot placement. Resources were instead directed to fishery-dependent sampling in regional areas to measure escape vent performance.

Fish and non-Giant Mud Crab bycatch in fishery-independent trials were recorded to species level where possible. Bycatch was returned to the water as quickly as possible following Animal Ethics Permit conditions (DAF AEC permit number SA 2022/05/83).

Table 2. Sampling details of fishery-independent escape vent trials.

Date and location	**Escape vent type, attachment location in pot, number of pots**			
Regulated escape vent trials	No vent	120 x 50 mm	105 mm round	2 x 75 x 60 mm
10th to 12th May 2022 southeast Queensland, (Logan River)*	n = 10	bottom n = 10 top n = 3	bottom n = 10 top n = 4	bottom n = 10 top n = 3
23rd to 26th May 2022 central Queensland (Eurimbula Creek)	n = 10	bottom n = 10 top n = 3	bottom n = 10 top n = 4	bottom n = 10 top n = 3
22nd to 25th November 2022 southeast Queensland (Logan River and southern Moreton Bay)	n = 9	bottom n = 10 top n = 3	bottom n = 11 top n =4	bottom n = 10 top n = 3
Alternate escape vent trials	No vent	100 mm round	95 mm round	90 mm round
21st to 24th March 2023 southeast Queensland (Logan River and southern Moreton Bay)	n = 11	bottom n=10 top n=3	bottom n = 10 top n = 3	bottom n = 10 top n = 3
17th to 20th April 2023 central Queensland (Eurimbula Creek)	n = 10	bottom n = 10 top n = 3	bottom n = 10 top n = 4	bottom n = 10 top n = 3

*Terminated due to major flooding after torrential rainfall over several days resulting in low Giant Mud Crab catchability.

Figure 8. Spatial placement of crab pots fitted with escape vents in: (a) southeast Queensland (Logan River and southern Moreton Bay), November 2022 and March 2023; and (b) central Queensland (Eurimbula Creek) in May 2022 and April 2023.

Analysis

Generalised Linear Mixed Models (GLMM) were implemented in RStudio (build 353) using the *lmer* package to estimate the effect of vent type per pot lift, after controlling for the effect of 'location' on the number of legal males captured (Poisson distribution), number of sub-legal males captured (Poisson distribution), median size of legal males captured (Gaussian distribution), and median size of all males captured

(Gaussian distribution). Unique fishing days were included as a random effect to account for variation in weather and tidal conditions that may affect crab catchability. Fewer replicate pot-lifts were carried out for escape vents positioned on the top edge of the apparatus than for the standard escape vents positioned on the bottom edge of the apparatus. As a result, interpretation of the statistical results regarding escape vents positioned on the top edge should be interpreted with some caution. The term 'location' was used as a covariate in comparative analyses of escape vent performance to account for multiple sources of spatial variation between central Queensland (Eurimbula Creek mud crab sanctuary) and southeast Queensland (MNP28 and SEQ fished), temporal variation between sampling dates (central Queensland sampled in May and southeast Queensland sampled in November), and 'fishing pressure' between areas closed to commercial and recreational crabbing (Eurimbula Creek and MNP28) and areas open to commercial and recreational crabbing (SEQ fished).

Results

Survey of escape vents in use by commercial crab fishers

Overall, forty-three active commercial crabbers and two pot manufacturers were surveyed by phone, Teams video meeting or in person. This included surveys conducted during fishery-dependent sampling. The following information has been collated to benchmark bycatch reduction devices and strategies currently used in the Queensland Crab Fishery:

Type of pots:

- The majority of commercial pots in use are collapsible round mesh pots 800, 900 or 1000 mm in diameter, with 10 or 12 mm steel rings (often galvanised), and two, three, or four entry funnels, and are a mix of self-made or purchased from major suppliers (e.g., CrabNGear™, Ultimate Pro Pots™, or smaller regional suppliers).
- A minority of other styles are used in some areas or by individuals, including rectangular wire pots (aka Northern Territory style), and custom-made wire and mesh circular pots.
- There is limited to no use of collapsible round mesh pots with steel rings less than 10 mm in diameter (i.e., 'lightweight' pots, see Chapter 3) by the commercial sector, predominately because these pots are not sufficiently robust for long-term commercial use. This is relevant to Chapter 3 which collates information on marine turtle interactions with crabbing apparatus.

Escape vents:

- There are regional and personal preferences on the type of escape vents deployed in commercial mud crab pots.
- The most common escape vent in use is a single 120 x 50 mm rectangular escape vent made from either: (i) aluminium plate or plastic with a 15 to 20 mm border or (ii) made from 3 or 4 mm wire or rolled stainless rod. All versions are able to be supplied in commercially manufactured pots.
- In some regions, especially north Queensland, the two 75 x 60 mm escape vent arrangement was commonly used and was a preferred escape vent type at the start of the project (September 2022). This vent type was often used in locations where just-legal crabs (i.e., 150 to 152 mm CW) are more commonly caught and are perceived to be able to escape out of the other regulated vents.
- Few fishers use the 105 mm round escape vent, although we did encounter fishers using 107 mm round escape vents. Round escape vents were used predominately where larger crabs (>155 mm CW) are targeted, because of the ease of self-manufacture from available materials or because of a personal preference to have a 'clean' catch of large male crabs requiring little sorting.
- Between September 2021 (when escape vents were first mandated in the commercial mud crab component of the Queensland Crab Fishery) to the present, there has been a general move away from using the two 75 x 60 mm escape vents to slightly larger versions i.e., 75 x 80 mm, 75 x 85 mm, 80 x 80 mm, or 94 x 71 mm.
- There has been a tendency to install more than the minimum number of escape vents in commercial crab pots, sometimes as a quick 'fix' to a hole in the mesh. For example, some commercial crab pots had two 75 x 60 mm escape vents plus two or more 90, 96, or 98 mm round escape vents.

- Regional preferences appear self-perpetuating.
- Two of the main manufacturers of crab pots that supply the commercial mud crab component of the Queensland Crab Fishery now install the single 120 x 50 mm rectangular escape vent in 3 mm or 4 mm rolled wire as standard. Aluminium plate and plastic moulded versions of the 120 x 50 mm rectangular escape vent are available (noting these have 15 or 20 mm solid frame) at a cost of ~$3.50 and $1.50 respectively.
- Prior to regulation of escape vents, many fishers voluntarily used escape vents of a various sizes (i.e., 80, 90, 95, 100 mm round; 115 x 50 rectangular) to allow fish (bream), small crab and water rats to escape. The size used often reflected fishers' opinion on what was optimal for crabs in their region. Positioning prior to regulation varied between fishers but included bottom, mid-side panel and top placement. Mid and top placement reflected fishers' opinions that these locations were more effective as smaller crabs tends to move higher in the pot to get away from larger (aggressive) crabs that may dominate the bottom of the pot.

Perceptions

- Mixed opinions remain as to the need and benefit of escape vents.
- Most commercial fishers would like to see escape vents compulsory in recreational crab pots to mirror the requirements of the commercial sector.
- Many commercial fishers see the benefit of escape vents at reducing the damage to marketable crab by non-legal crabs, as even slight damage can downgrade an A-grade Giant Mud Crab resulting is lesser economic return.
- There is ongoing perception of an increase in one-clawed crabs (referred to as 'wingers') due to crabs attempting to exit the pot via the escape vent, claw first (Figure 9). Claw loss occurs by the crab being predated upon externally or the crab dropping the claw because the claw and/or the crab gets stuck.
- Underwater video collected by DAF during the current research project indicated that Giant Mud Crabs attempt to 'walk' out of escape vents with their claw tucked against their body rather that with their claw extended, at least in the short-term (i.e., up to 30 mins). However, this does position part of the claw 'outside' of the pot, potentially making the claw vulnerable to predation by large estuarine fish (e.g., toadfish).
- Concern that the 120 x 50 mm rectangular escape vent in rolled stainless rod can over time distort out of shape due to crabs pushing against it and thus allowing a just legal (150 mm CW) B-grade crab to escape or incur damage to the carapace and thus become non-saleable.
- Wear to the bottom mesh of the collapsible mesh pots adjacent to the escape vents where crabs have attempted to exit the pot and their dorsal carapace and walking legs have abraded the mesh. Some fishers preferred a mid to top placement of escape vents, whilst others are content with bottom placement with a preference for a few meshes from the bottom ring.
- The exclusion of crabs below 150 mm CW results in fishers having a lesser understanding of the distribution and abundance of sub-legal male Giant Mud Crabs, which previously gave them insight into future (one to three month) likely catch locations, which then informed future pot placement within their 'patch'.

Figure 9. Giant Mud Crabs attempting to exit 120 x 50 mm escape vents.

The above information is consistent with that reported by the FQ observer program. Between February 2011 and August 2012, 93 'surveys' were conducted by FQ observers on 38 Primary Commercial Fishing Licences (i.e., Boat Marks) using a C1 symbol (i.e., crabbing). Most crabbing operations used collapsible trawl mesh pots (800, 900, 950, 1000, 1100 or 1300 mm in diameter), with a minority using rigid pots. Modifications to the commercial pots in use included 100 mm steel rings sewn into the pot to help fish escape, rubber drawstrings (to ensure closure of openings such that it is difficult for Threatened, Endangered and Protected Species (TEPS) to enter via the "drawstring" opening), and escape holes for water rats.

Bycatch reduction strategies

- Many fishers noted 'tuning' of their pots so as to 'tighten' the entry funnels, which is considered beneficial in retaining Giant Mud Crabs and keeping other bycatch out.
- Although strings across the entry funnels were commented upon by a few fishers, none were observed during fishery-dependent sampling; noting that most commercial crab fishers rarely (if ever) reported interactions between their crabbing apparatus and marine turtles.
- Several fishers used pots constructed of wire or large plastic mesh. Wire pots used in the Northern Territory typically have relatively small entry funnels restricting the entry of bycatch, such as marine turtles. Large square mesh (of wire or plastic) allows some fish bycatch to exit via the square meshes.

Fishery-dependent sampling

Sampling achieved

Project staff achieved broadscale coverage of commercial crabbing operations across Queensland because of the voluntary cooperation of commercial fishers, who allowed staff onboard and accommodated the handling and measuring of legal and non-legal crabs, often under tidally-driven time constraints and varying weather conditions.

Table 3. Fishery-dependent sampling achieved.

Region	Locations	Days Observed	Pot lifts	Crabs measured
Gulf of Carpentaria north	Mapoon	17	1600	1885
	Weipa	3	115	364
Gulf of Carpentaria south	Karumba	13	650	663
East Coast north	Hinchinbrook	18	1000	1871
East Coast north central	Townsville Burdekin Mackay	4	225	533
East Coast central	Stanage/Broadsound Gladstone	9	750	465
East Coast southeast	Great Sandy Strait Moreton Bay	5	300	355

Escape vents

As noted in the Survey results, a single 120 x 50 mm rectangular escape vent made from either (i) aluminium plate or plastic with a 15 to 20 mm border or (ii) made from 3 mm or 4 mm wire or rolled stainless rod; was the most common design encountered during fishery-dependent sampling. Two 75 x 60 mm escape vents were common in north Queensland. Few fishers use the 105 mm round escape vent.

The 105 mm round escape vents are used predominately where larger crab (>155 mm CW) is targeted, or because of the ease of self-manufacture from available materials or because of a personal preference to have a 'clean' catch of large male crabs requiring little sorting.

There has been a general move away from using the two 75 x 60 mm escape vents to slightly larger versions i.e., 75 x 80 mm, 75 x 85 mm, 80 x 80 mm, 94 x 71 mm. The reason for this change is uncertain, but potentially is linked to changing perceptions around escape vents. Two of the main crab pots manufacturers that supply the commercial mud crab component of the Queensland Crab Fishery, now install the single 120 x 50 mm rectangular escape vent in 3 mm or 4 mm rolled wire as standard. Aluminium plate and plastic moulded versions of the 120 x 50 mm rectangular escape vent are available (noting these have 15 mm solid frame) at a cost of ~$3.50 and $1.50 respectively.

Data collected during fishery-dependent sampling was used predominately in morphometric analysis (Chapter 1. Giant Mud Crab morphometrics in Queensland, with implications for escape vents) to determine if there were significant differences in crab morphometric relationships between regions.

Catch data collected during fishery-dependent sampling represents size and sex composition of Giant Mud Crabs per pot lift from individual fishing operations. Potting is a passive fishing method, with most commercial operations setting gear over a relatively small spatial proportion of the area that a regional Giant Mu Crab population utilises. Giant Mud Crab catch on any given day varies between pots, between operators and varies from other days for many reasons including seasonality, water quality (e.g., recent rainfall/flooding), previous recent harvest, time since last check etc. (Jebreen *et al*. 2008).

Quantitative information on catch rates from fishery-dependent sampling is not presented because (i) potential compromises in the confidentiality[6] of the catch data from the commercial fishing operations who voluntarily assisted the project; and (ii) uncertainty in the inferences on the performance of escape vents, given the lack of control over conditions the catch rates represent.

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[6] DAF has a confidentially rule whereby catch and effort data for fewer than five 'boats' is not publicly available. This project adheres to this precedent for catch rate data from fishery-dependent sampling.

Fishery-independent sampling

Escape vents as currently regulated

The first trial of escape vents as currently regulated (i.e., 10th to 12th May 2022) was terminated on day three of sampling due to torrential rainfall and imminent major flooding of the Logan River. The lowered salinity affected Giant Mud Crab catch rates during the trial. Data from this trial was excluded from further analysis.

The most notable difference between the trials repeated in southeast Queensland (Logan River and Moreton Bay) and in central Queensland (Eurimbula Creek) is that despite similar effort (i.e., number of pot lifts), there is a large difference in the catch rates (Table 1, Table 4) and size distribution (Figure 10).

Table 4. Summary results fishery-independent trials - escape vents as currently regulated (i.e., bottom placement). Catch rate = number per pot lift.

Southeast Queensland	**No vent**	**120 x 50 mm**	**105 mm round**	**Two 75 x 60 mm**
Total crabs (551)	182	118	109	149
Total pot lifts (155)	36	40	39	40
Legal males (n)	18	28	21	15
Legal males mean catch rate	**0.50**	**0.70**	**0.51**	**0.39**
Legal males mean CW (mm)	164.2	160.2	160.7	162.1
Sub-legal males (n)	93	49	25	105
Sub-legal mean catch rate	**2.58**	**1.26**	**0.61**	**2.60**
Sub-legal males mean size	129.6	130.8	122.7	132.9
Females ≥150 mm CW	57	31	49	20
mean CW (mm)	161.2	162.6	161.0	164.6
Females <150 mm CW	13	9	9	9
mean CW (mm)	130.6	128.2	133.9	146.2
Central Queensland	**No vent**	**120 x 50 mm**	**105 mm round**	**Two 75 x 60 mm**
Total crabs (547)	146	116	137	148
Total pot lifts (159)	41	38	40	40
Legal males (n)	110	89	121	105
Legal males mean catch rate	**2.75**	**2.54**	**3.18**	**2.69**
Legal males mean CW (mm)	165.2	165.6	164.3	163.1
Sub-legal males (n)	25	17	12	27
Sub-legal mean catch rate	**0.61**	**0.46**	**0.31**	**0.68**
Sub-legal males mean size	130.3	140.9	130.4	137.9
Females ≥150 mm CW	8	7	4	13
mean CW (mm)	164.8	160.3	160.3	161.9
Females <150 mm CW	3	2	3	1
mean CW (mm)	114.9	105.0	133.5	

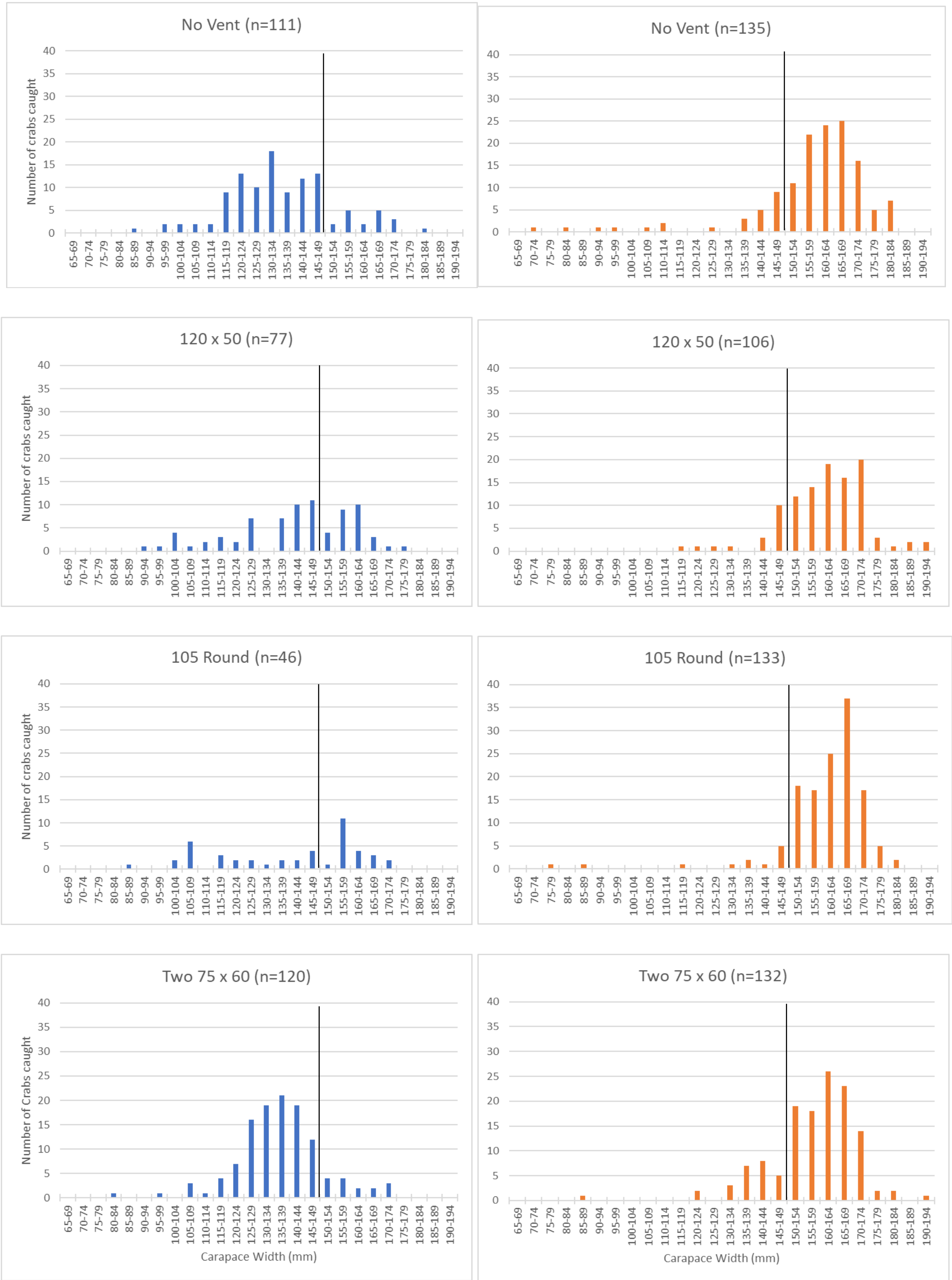

Figure 10. Size distribution of male Giant Mud Crabs caught in fishery-independent trials of escape vents as currently regulated in southeast Queensland (left column, blue bars) and central Queensland (right column, orange bars). Legal size (150 mm CW) indicated by black line. See Table 4 for further information.

Catch rate of legal males

The GLMM indicated that the number of legal males caught, modelled as a function of escape vent type and location with unique trip (date of capture) as a random factor, had a significant effect of location ($p < 0.001$) but that there was no significant effect of escape vent type ($p = 0.33$).

Table 5. Parameter estimates from the GLMM of legal male Giant Mud Crab catch rate (number per pot lift) during fishery-independent trials of escape vents as currently regulated (i.e., bottom placement unless otherwise indicated). Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	**0.995**	**0.089**	**11.21**	**<0.001**	***
120 x 50 mm rectangular	-0.027	0.126	-0.211	0.833	
105 mm round	0.120	0.120	0.993	0.321	
two 75 x 60 mm	-0.069	0.125	-0.547	0.584	
120 x 50 mm rectangular top	-0.318	0.208	-1.526	0.127	
105 mm round top	-0.184	0.184	-0.999	0.318	
two 75 x 60 mm top	0.069	0.181	0.383	0.701	
Location MNP28	**-1.106**	**0.135**	**-8.217**	**<0.001**	***
Location SEQ Fished	**-1.946**	**0.159**	**-12.257**	**<0.001**	***

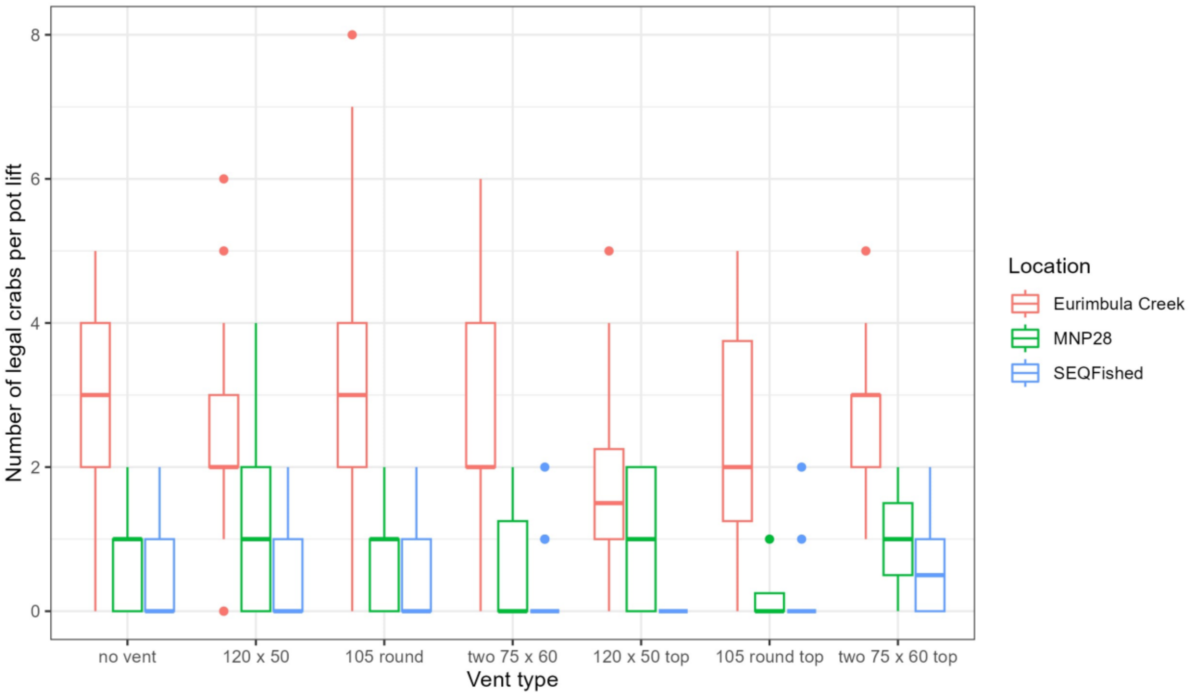

Figure 11. Catch rate (number per pot lift) of legal male Giant Mud Crabs by location and escape vent type as currently regulated i.e., bottom placement unless otherwise indicated), Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Catch rate of sub-legal males

The GLMM indicated that the number of sub-legal males caught, modelled as a function of escape vent type and location with unique trip (date of capture) as a random factor, was significantly influenced by location ($p < 0.001$) and escape vent type ($p < 0.001$). The number of sub-legal males was consistently highest at SEQ Fished sites and lowest at the central Queensland site. Relative to unvented control pots, the mean catch rate of sub-legal crabs (number per pot lift) was:

- 0.7 fewer sub-legal male crabs were caught in the 120 x 50 mm rectangular.
- 1.2 fewer sub-legal crabs were caught in the 105 mm round.
- No difference in the number of sub-legal crabs caught in the two 75 x 60 mm.
- 1.1 fewer sub-legal crabs were caught in the 120 x 50 mm rectangular top mounted.
- 0.8 fewer sub-legal crabs were caught in the 105 mm round top mounted.
- No difference in the number of sub-legal crabs caught in the two 75 x 60 mm top mounted.

Table 6. Parameter estimates from the GLMM of sub-legal male Giant Mud Crab catch rate (number per pot lift) during fishery-independent trials of escape vents as currently regulated (i.e., bottom placement unless otherwise indicated). Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to central Queensland region (i.e. Eurimbula Creek).

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	**-0.425**	**0.132**	**-3.221**	**0.001**	**
120 x 50 mm rectangular	**-0.659**	**0.157**	**-4.194**	**0.000**	***
105 mm round	**-1.237**	**0.196**	**-6.327**	**0.000**	***
two 75 x 60 mm	0.005	0.129	0.036	0.971	
120 x 50 mm rectangular top	**-1.087**	**0.330**	**-3.295**	**0.001**	***
105 mm round top	**-0.776**	**0.233**	**-3.326**	**0.001**	***
two 75 x 60 mm top	-0.124	0.206	-0.602	0.547	
Location MNP28	**1.208**	**0.145**	**8.333**	**0.000**	***
Location SEQ Fished	**1.424**	**0.128**	**11.128**	**0.000**	***

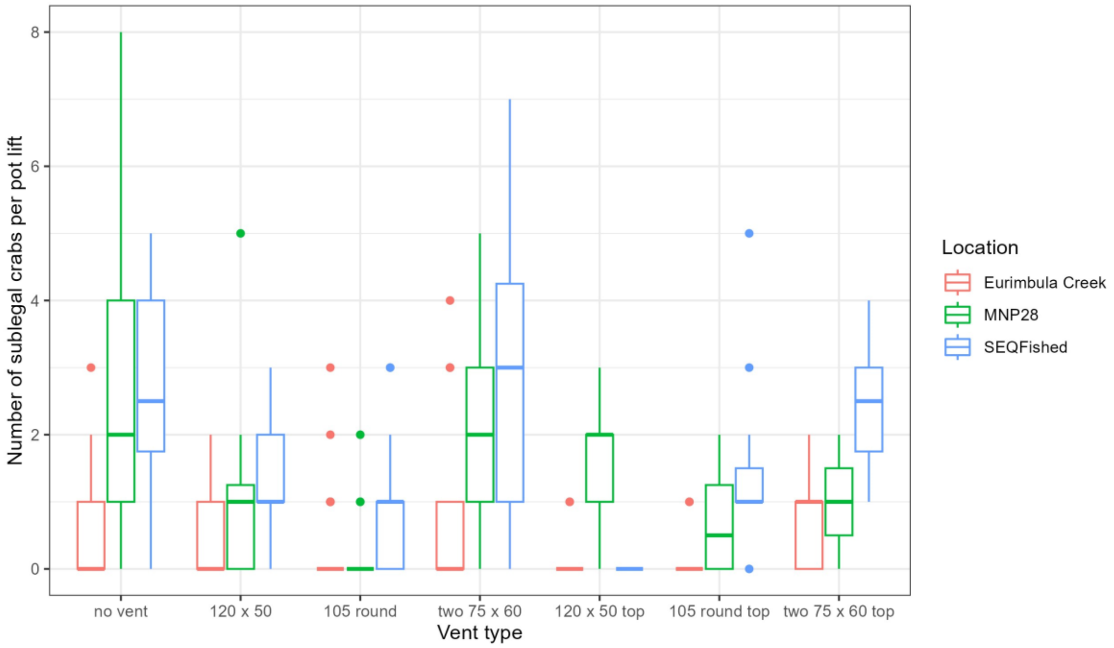

Figure 12. Catch rate (number per pot lift) of sub-legal male Giant Mud Crabs by location and escape vent type as currently regulated (i.e., bottom placement unless otherwise indicated), Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Median size (notch width) of legal males

The GLMM indicated that the median size of legal male Giant Mud Crabs per pot lift, modelled as a function of escape vent type and location with unique trip (date of capture) as a random factor, was significantly influenced by location ($p < 0.001$) but that there was no significant effect of escape vent type ($p = 0.20$). The median size of legal male Giant Mud Crabs was consistently larger at the central Location (i.e., Eurimbula Creek, which is a mud crab sanctuary) and smallest at the southeast Queensland sites open to commercial and recreational fishing.

Table 7. Parameter estimates from the GLMM of median size of legal male Giant Mud Crabs per pot lift during fishery-independent trials of escape vents as currently regulated (i.e., bottom placement unless otherwise indicated). Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e. Eurimbula Creek).

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**157.792**	**0.866**	**252**	**182.175**	**0.000**	***
120 x 50 mm rectangular	-1.192	1.187	252	-1.004	0.316	
105 mm round	-0.978	1.186	252	-0.825	0.410	
two 75 x 60 mm	**-2.414**	**1.203**	**252**	**-2.007**	**0.046**	*
120 x 50 mm rectangular top	-3.644	1.858	252	-1.962	0.051	.
105 round top	-0.337	1.759	252	-0.192	0.848	
two 75 x 60 top	-3.359	1.722	252	-1.950	0.052	.
Location MNP28	**-2.187**	**1.108**	**252**	**-1.974**	**0.050**	*
Location SEQ Fished	**-4.791**	**1.148**	**252**	**-4.172**	**0.000**	***

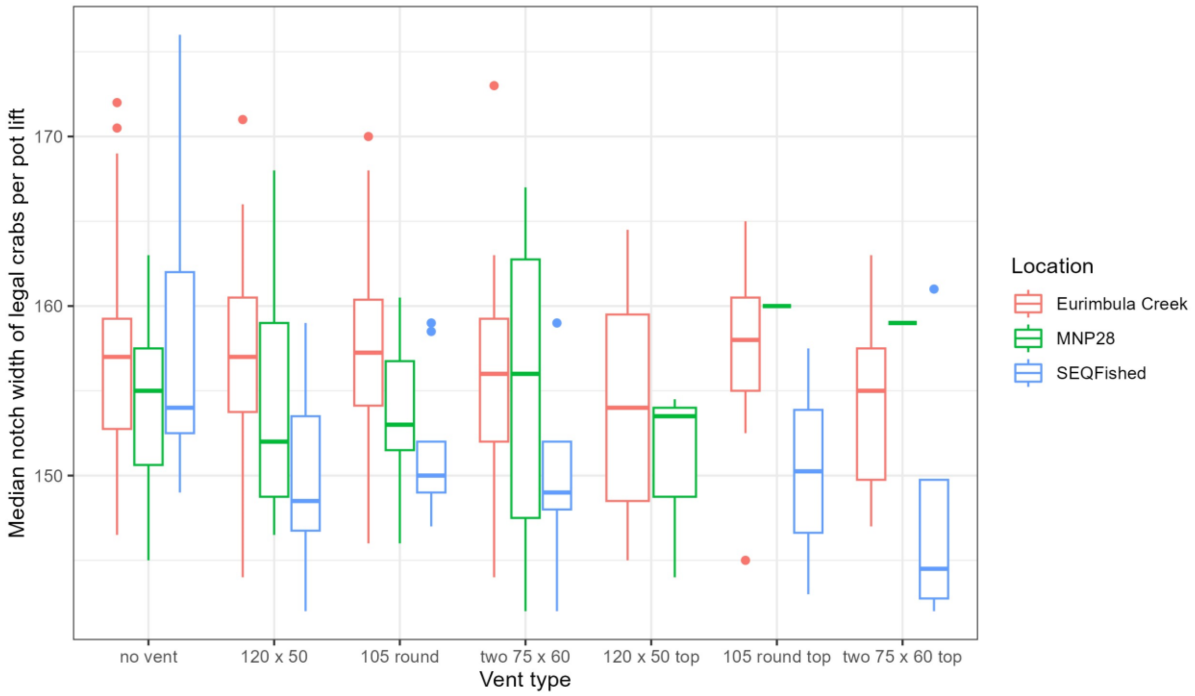

Figure 13. Median notch width (mm) of legal male Giant Mud Crabs by location and escape vent type as currently regulated (i.e., bottom placement unless otherwise indicated), Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Median size (notch width) of all males

The GLMM indicated that the median size of all male crabs caught, modelled as a function of escape vent type and location with unique trip (date of capture) as a random factor, was significantly influenced by location ($p < 0.001$) but that there was no detectable effect of escape vent type ($p = 0.62$). The median size of male Giant Mud Crabs caught was consistently larger at the central Queensland location (i.e., Eurimbula Creek, which is a mud crab sanctuary) and smallest at the southeast Queensland sites open to commercial and recreational fishing.

Table 8. Parameter estimates from the GLMM of median size of male Giant Mud Crabs per pot lift during fishery-independent trials of escape vents as currently regulated (i.e., bottom placement unless otherwise indicated). Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**151.667**	**1.535**	**347**	**98.835**	**0.000**	***
120 x 50 mm rectangular	3.032	2.020	347	1.501	0.134	
105 mm round	2.691	2.053	347	1.310	0.191	
two 75 x 60 mm	0.019	1.962	347	0.010	0.992	
120 x 50 mm rectangular top	0.373	3.285	347	0.114	0.910	
105 mm round top	0.945	2.774	347	0.341	0.733	
two 75 x 60 mm top	2.652	2.953	347	0.898	0.370	
Location MNP28	**-15.034**	**1.777**	**347**	**-8.462**	**0.000**	***
Location SEQ Fished	**-25.931**	**1.507**	**347**	**-17.210**	**0.000**	***

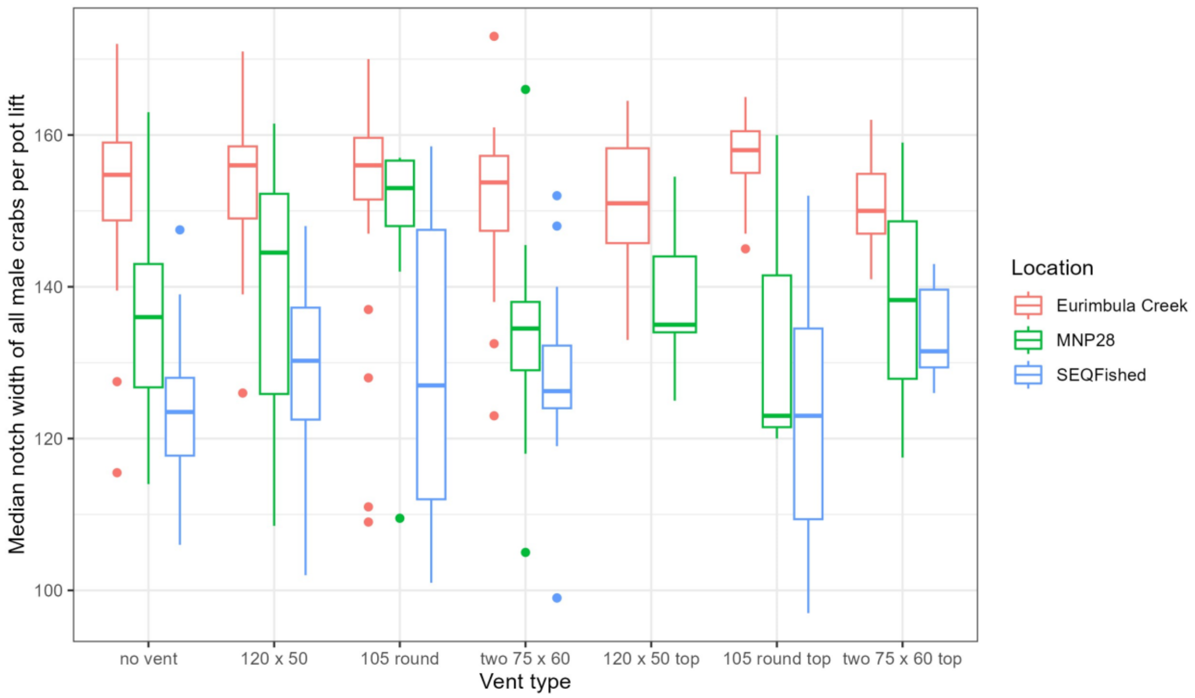

Figure 14. Median notch width (mm) of all male Giant Mud Crabs by location and escape vent type as currently regulated (i.e., bottom placement unless otherwise indicated), Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland. Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Catch rate of females

The GLMM indicated that the number of females caught, modelled as a function of escape vent type and location with unique trip (date of capture) as a random factor, was significantly influenced by location ($p < 0.001$) but that there was no significant effect of escape vent type ($p = 0.19$). The catch rate of female Giant Mud Crabs was significantly higher at SEQ Fished sites than at Eurimbula Creek and MNP28. This result likely reflects the complex distribution of the population of male and female Giant Mud Crabs throughout estuarine habitats, although we could not discount speculation of an effect on entry by females into the pots from aggression or competition from large males.

Table 9. Parameter estimates from the GLMM of female Giant Mud Crab catch rate (number per pot lift) during fishery-independent trials of escape vents as currently regulated (i.e., bottom placement unless otherwise indicated). Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.311	0.170	1.831	0.067	
120 x 50 mm rectangular	-0.075	0.184	-0.407	0.684	
105 mm round	-0.168	0.167	-0.987	0.324	
two 75 x 60 mm	-0.364	0.187	-1.94	0.052	
120 x 50 mm rectangular top	0.156	0.234	0.668	0.504	
105 mm round top	-0.427	0.256	-1.667	0.096	
two 75 x 60 mm top	-0.544	0.194	1.364	0.173	
Location MNP28	0.265	0.194	1.361	0.173	
Location SEQ Fished	**0.929**	**0.162**	**5.719**	**0.000**	***

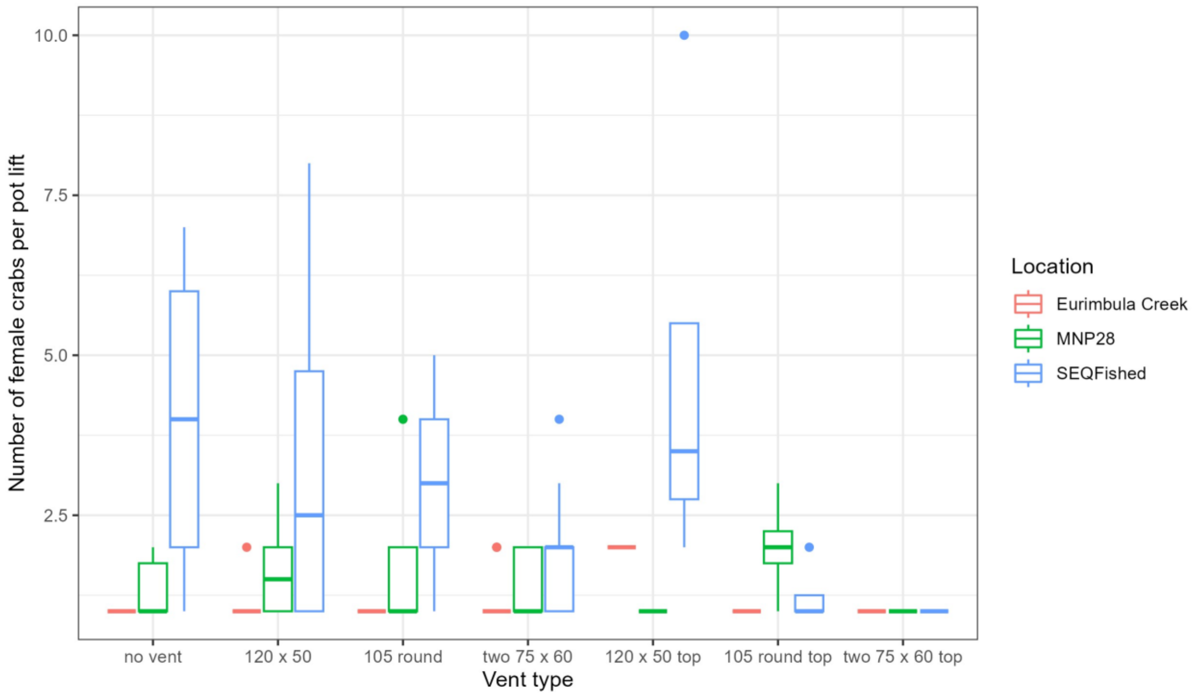

Figure 15. Catch rates of female Giant Mud Crabs by location and escape vent type as currently regulated (i.e., bottom placement unless otherwise indicated), Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Median size of females

The GLMM indicated that the median size of all females caught, modelled as a function of escape vent type and location with unique trip (date of capture) as a random factor, was not significantly influenced by location (p = 0.51) nor escape vent type (p = 0.49).

Table 10. Parameter estimates from the GLMM of median size of female Giant Mud Crabs per pot lift during fishery-independent trials of escape vents as currently regulated (i.e., bottom placement unless otherwise indicated). Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**145.620**	**3.773**	**135**	**38.595**	**0.000**	***
120 x 50 mm rectangular	-5.375	4.760	135	-1.126	0.261	
105 mm round	2.072	4.575	135	0.453	0.651	
two 75 x 60 mm	-0.820	4.469	135	-0.184	0.855	
120 x 50 mm rectangular top	6.832	6.988	135	0.978	0.330	
105 mm round top	1.751	5.652	135	0.310	0.757	
two 75 x 60 mm top	-8.845	7.448	135	-1.188	0.237	
Location MNP28	2.918	3.940	135	0.741	0.460	
Location SEQ Fished	-1.342	3.588	135	-0.374	0.709	

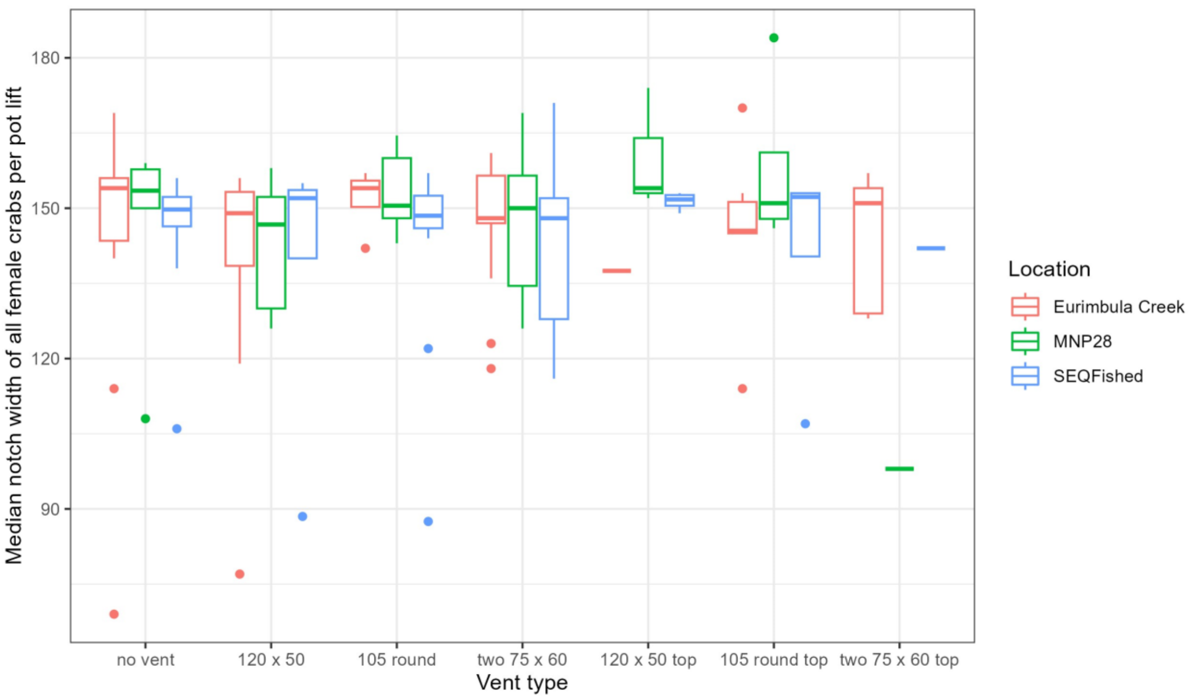

Figure 16. Median notch width (mm) of female Giant Mud Crabs by location and escape vent type as currently regulated (i.e., bottom placement unless otherwise indicated), Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Other results – bycatch

Fish bycatch in pots was infrequent, with low species diversity and numbers caught. This is consistent with previous findings (Jebreen *et al*. 2008; Garland 2012). Bycatch species included Yellowfin Bream (*Acanthopagrus australis*), Blackspotted Rockcod (*Epinephelus malabaricus*), Goldspotted Rockcod (*Epinephelus coioides*), Blue Catfish (*Neoarius graeffei*), and Moses Snapper (*Lutjanus russelli*). A single juvenile King Threadfin (*Polydactylus macrochir,* 220 mm TL) meshed externally in a pot in the Logan River during May 2022, at the start of a flood event. Blue Swimmer Crab was also a bycatch species in pots targeting Giant Mud Crabs, though they were variable in occurrence and abundance.

The finfish bycatch rates were 0.20 individuals per pot lift during fishery-independent trials. This is above the average reported from past programs (i.e., 0.08 per pot lift, Garland 2012) and may be biased by the locations of the trials (i.e., southern Moreton Bay). Bycatch survival rates were high, with greater than >97% of finfish released alive. Yellowfin Bream was the main fish bycatch in southeast Queensland. Goldspotted Rockcod was the main fish bycatch in central Queensland.

Escape vents alternate sizing

The trials testing alternate sizes of escape vents were repeated in southeast Queensland (Logan River and southern Moreton Bay) and in central Queensland (Eurimbula Creek) in March and April 2023 respectively. There was less discrepancy in the abundance and size distribution of Giant Mud Crabs caught between the two locations than during the trials of the regulated escape vents (Table 11).

Table 11. Summary results of fishery-independent trials - escape vents alternate sizing with bottom placement.

Southeast Queensland	**No vent**	**100 mm round**	**95 mm round**	**90 mm round**
Total crabs (792)	164	83	90	126
Total pot lifts (153)	36	39	39	39
Legal males (n)	36	60	45	41
Legal males mean catch rate	**1.2**	**1.6**	**1.5**	**1.4**
Legal males mean CW (mm)	158.9	161.7	160.9	160.6
Sub-legal males (n)	128	23	45	85
Sub-legal mean catch rate	**3.5**	**0.6**	**1.2**	**2.2**
Sub-legal males mean size	134.4	137.4	141.4	139.2
Females ≥150 mm CW	70	75	59	76
mean CW (mm)	165.3	166.9	165.6	166.4
Females <150 mm CW	25	8	7	9
mean CW (mm)	126.4	123.6	136.9	132.3
Central Queensland	**No vent**	**100 mm round**	**95 mm round**	**90 mm round**
Total crabs (452)	148	80	105	119
Total pot lifts (148)	40	34	37	37
Legal males (n)	52	55	59	80
Legal males mean catch rate	**1.3**	**1.8**	**1.6**	**2.2**
Legal males mean CW (mm)	162.3	165.6	164.1	163.5
Sub-legal males (n)	43	1	7	21
Sub-legal mean catch rate	**1.1**		**0.2**	**0.6**
Sub-legal males mean size	135.0		145.9	142.4
Females ≥150 mm CW	37	24	36	13
mean CW (mm)	165.3	165.1	163.9	164
Females <150 mm CW	16	0	3	5
mean CW (mm)	128.2		139.2	

Catch rate of legal males

Results of the GLMM (Table 12), found that location had a significant effect on the catch rate of legal males ($p < 0.001$), as did escape vent type ($p = 0.03$). The catch of legal males was generally highest at MNP28 (green zone in southern Moreton Bay) and lowest at SEQ Fished sites. Pots with escape vents had slightly higher catch rates of legal male crabs than unvented control pots, with the 100 mm and 90 mm round escape vents top placement catching (on average) about 0.50 more crabs per pot lift (respectively) than unvented pots.

Table 12. Parameter estimates from the GLMM of legal male Giant Mud Crab catch rate (mean number per pot lift) during fishery-independent trials of escape vents alternate sizing with bottom placement unless otherwise indicated. Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	**0.313**	**0.110**	**2.838**	**0.005**	**
100 mm round	**0.360**	**0.139**	**2.598**	**0.009**	**
95 mm round	0.201	0.141	1.424	0.154	
90 mm round	**0.337**	**0.137**	**2.459**	**0.014**	*
100 mm round top	**0.545**	**0.178**	**3.054**	**0.002**	**
95 mm round top	0.252	0.191	1.320	0.187	
90 mm round top	**0.453**	**0.194**	**2.334**	**0.020**	*
Location MNP28	0.112	0.113	0.989	0.323	
Location SEQ Fished	**-0.501**	**0.104**	**-4.843**	**0.000**	***

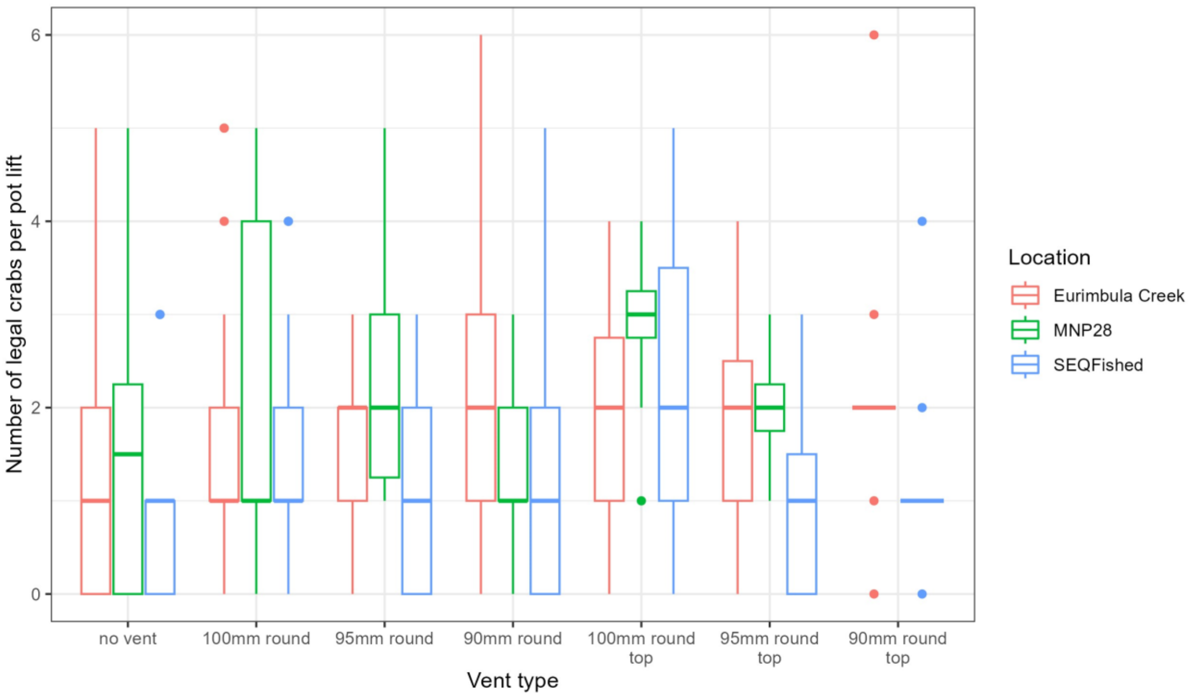

Figure 17. Catch rates of legal male Giant Mud Crabs by location and escape vent type alternate sizing with bottom placement unless otherwise indicated, Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Catch rate of sub-legal males

Results of the GLMM (Table 13) found that location had a significant effect on the catch rate of sub-legal males ($p < 0.001$), as did escape vent type ($p < 0.001$). The number of sub-legal males was consistently highest at SEQ Fished sites and lowest at the central Queensland location (i.e., Eurimbula Creek). Relative to unvented control pots, there were significantly fewer sub-legal males caught in pots with escape vents. The greatest reduction in the catch of sub-legal males was in pots fitted with the 100 mm round escape vent, regardless of its placement (bottom or top).

Table 13. Parameter estimates from the GLMM of sub-legal male Giant Mud Crab catch rate during fishery-independent trials of escape vents alternate sizing with bottom placement unless otherwise indicated. Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.109	0.140	-0.779	0.436	
100 mm round	**-2.119**	**0.237**	**-8.950**	**0.000**	***
95 mm round	**-1.353**	**0.167**	**-8.117**	**0.000**	***
90 mm round	**-0.570**	**0.126**	**-4.507**	**0.000**	***
100 mm round top	**-3.765**	**1.003**	**-3.753**	**0.000**	***
95 mm round top	**-1.247**	**0.242**	**-5.143**	**0.000**	***
90 mm round top	**-0.914**	**0.228**	**-3.991**	**0.000**	***
Location MNP28	**1.122**	**0.189**	**5.948**	**0.000**	***
Location SEQ Fished	**1.504**	**0.155**	**9.694**	**0.000**	***

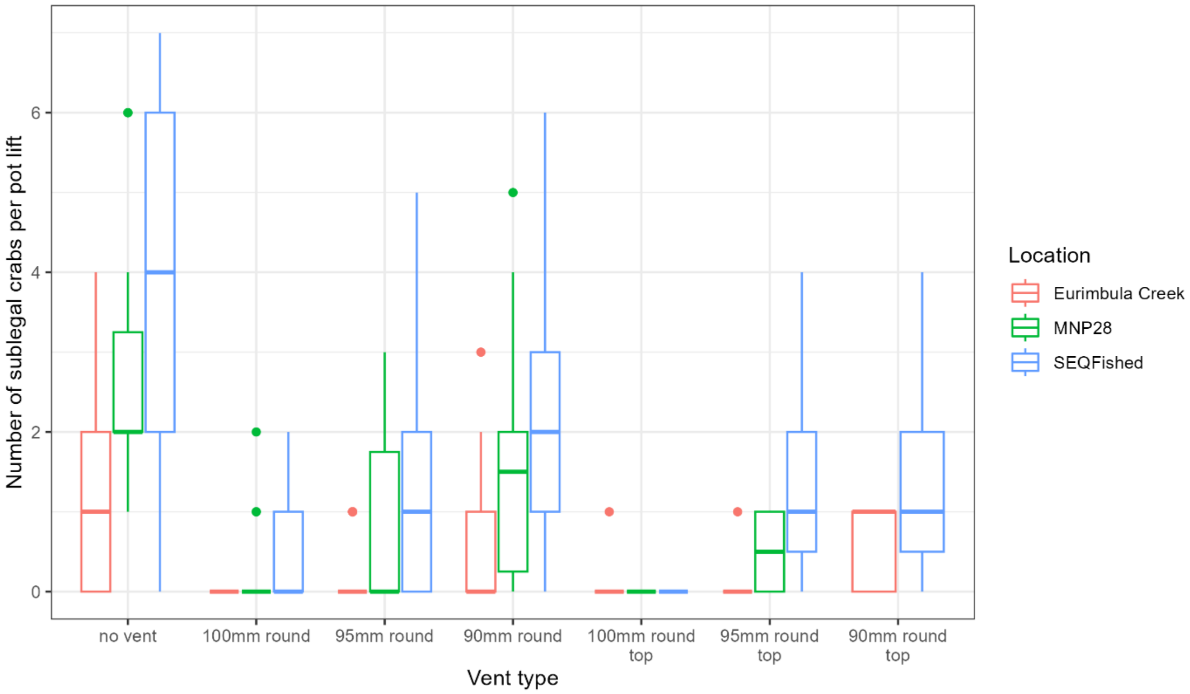

Figure 18. Catch rates of sub-legal male Giant Mud Crabs by location and escape vent type, Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Median size (notch width) of legal males

Results of the GLMM (Table 14) found that location had a significant effect ($p < 0.001$) on the median size of legal males caught, as did escape vent type ($p < 0.03$). The median size of legal male Giant Mud Crabs was consistently larger at the central Queensland location (i.e., Eurimbula Creek, a mud crab sanctuary) and smallest at the southeast Queensland sites open to commercial and recreational fishing. Relative to the unvented control pot, the median notch width of legal male crabs (per pot lift) was 4.3 mm larger in pots with the 100 mm round escape vent, and 2.5 mm larger in pots with the 95mm round vent.

Table 14. Parameter estimates from the GLMM of median size of legal male Giant Mud Crabs per pot lift during fishery-independent trials of escape vents alternate sizing with bottom placement unless indicated otherwise. Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**153.431**	**0.953**	**279**	**160.958**	**0.000**	***
100 mm round	**4.291**	**1.224**	**279**	**3.507**	**0.001**	***
95 mm round	**2.515**	**1.228**	**279**	**2.048**	**0.041**	*
90 mm round	1.473	1.218	279	1.209	0.228	
100 mm round top	1.960	1.742	279	1.125	0.261	
95 mm round top	1.212	1.659	279	0.730	0.466	
90 mm round top	1.563	1.702	279	0.918	0.359	
Location MNP28	**-3.095**	**1.075**	**279**	**-2.880**	**0.004**	**
Location SEQ Fished	**-4.088**	**0.870**	**279**	**-4.702**	**0.000**	***

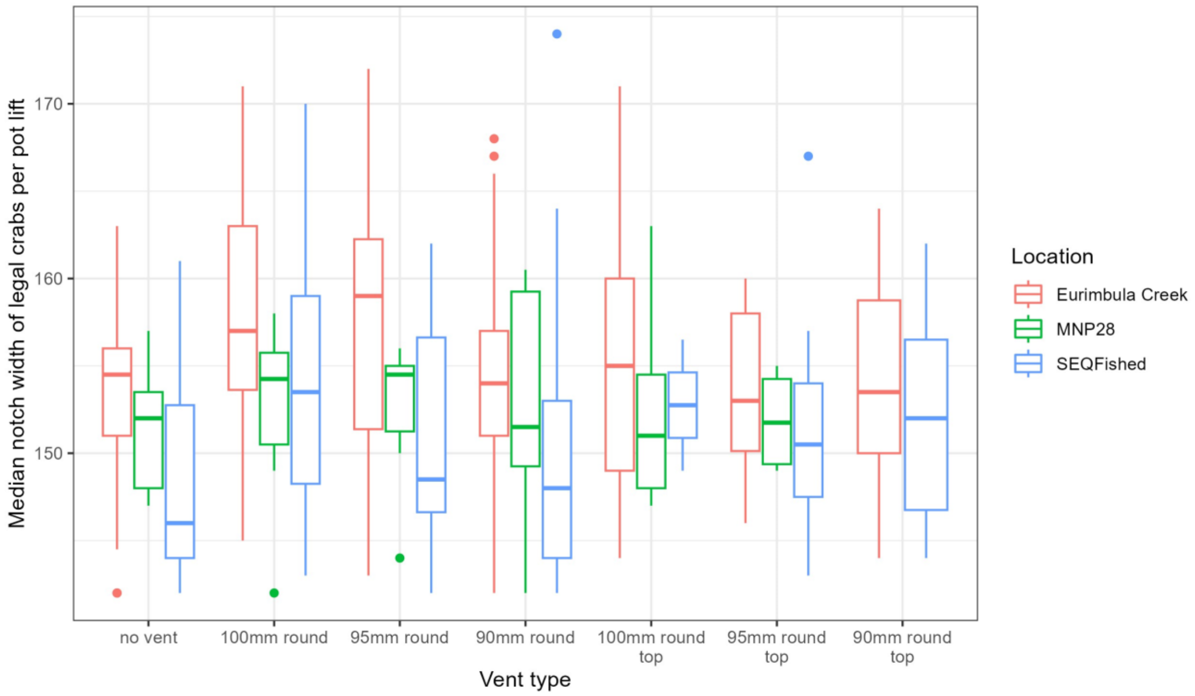

Figure 19. Median notch width (mm) of legal male Giant Mud Crabs by location and escape vent type, Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Median size (notch width) of all males

Results of the GLMM (Table 15) found that location had a significant effect ($p < 0.001$) on the median size of all male Giant Mud Crabs per pot lift, as did escape vent type ($p < 0.001$). The median size of all male crabs was consistently larger at the central Queensland location (i.e., Eurimbula Creek, a mud crab sanctuary) and smallest at the southeast Queensland sites open to commercial and recreational fishing (SEQ Fished). Relative to the unvented control pots, the median notch width of male crabs was 14 mm larger in pots with the 100 mm round escape vents, 11 mm larger in the pots with the 95 mm round escape vent and 7 mm larger in pots with the 90 mm round escape vent (Table 15).

Table 15. Parameter estimates from the GLMM of median size of all male Giant Mud Crabs per pot lift during fishery-independent trials of escape vents alternate sizing with bottom placement unless indicated otherwise. Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**142.976**	**1.250**	**43.6**	**114.404**	**0.000**	***
100 mm round	**14.112**	**1.630**	**334**	**8.660**	**0.000**	***
95 mm round	**11.130**	**1.598**	**334**	**6.963**	**0.000**	***
90 mm round	**7.045**	**1.578**	**334**	**4.466**	**0.000**	***
100 mm round top	**12.684**	**2.434**	**334**	**5.212**	**0.000**	***
95 mm round top	**10.973**	**2.213**	**334**	**4.959**	**0.000**	***
90 mm round top	**10.67**	**2.334**	**334**	**4.571**	**0.000**	***
Location MNP28	**-6.687**	**1.518**	**24**	**-4.405**	**0.000**	***
Location SEQ Fished	**-12.136**	**1.169**	**8**	**-10.384**	**0.000**	***

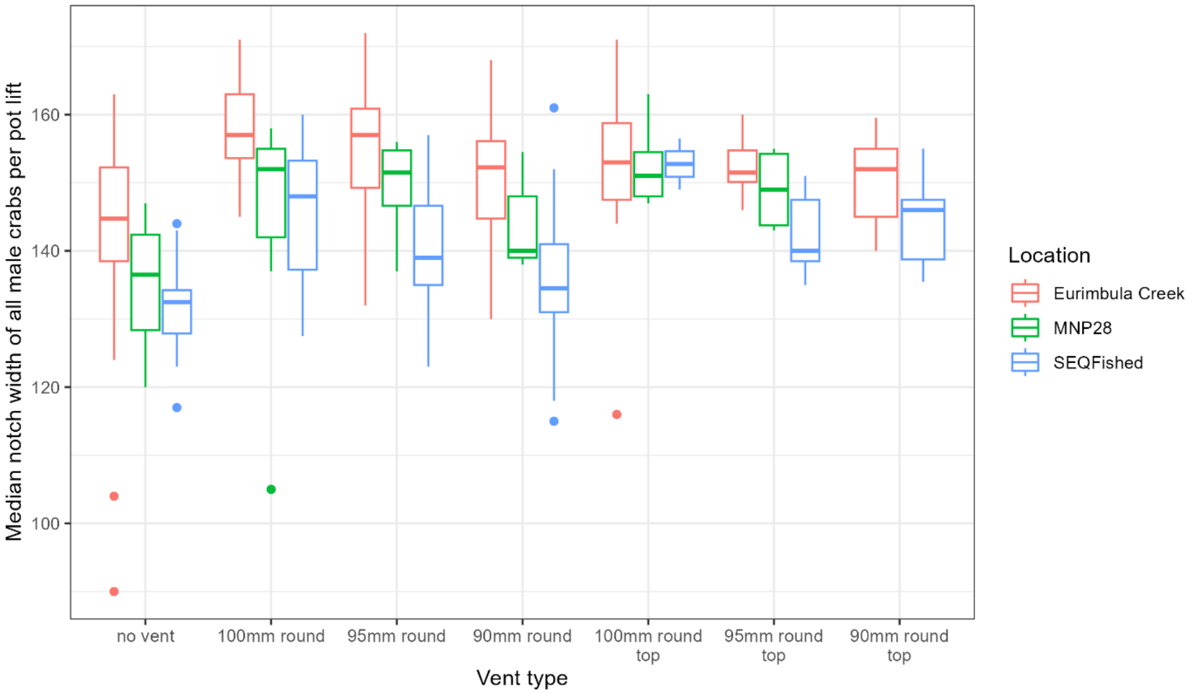

Figure 20. Median notch width (mm) of all male Giant Mud Crabs by location and escape vent type, Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland. Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Catch rate of females

Results of the GLMM, found that location had a significant effect ($p < 0.001$) on the catch rate of females, but that there was no significant effect of escape vent type ($p = 0.50$). The catch rate of female Giant Mud Crabs was significantly higher at MNP28 and SEQ Fished sites than at the central Queensland location (i.e., Eurimbula Creek, Table 16).

Table 16. Parameter estimates from the GLMM of female Giant Mud Crab catch rate during fishery-independent trials of escape vents alternate sizing with bottom placement unless otherwise indicated. Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	**0.609**	**0.103**	**5.941**	**0.000**	***
100 mm round	-0.064	0.128	-0.502	0.615	
95 mm round	-0.170	0.128	-1.327	0.185	
90 mm round	-0.156	0.129	-1.212	0.225	
100 mm round top	-0.225	0.256	-0.877	0.381	
95 mm round top	-0.384	0.203	-1.887	0.059	
90 mm round top	-0.215	0.186	-1.152	0.249	
Location MNP28	**0.533**	**0.127**	**4.201**	**0.000**	***
Location SEQ Fished	**0.543**	**0.101**	**5.388**	**0.000**	***

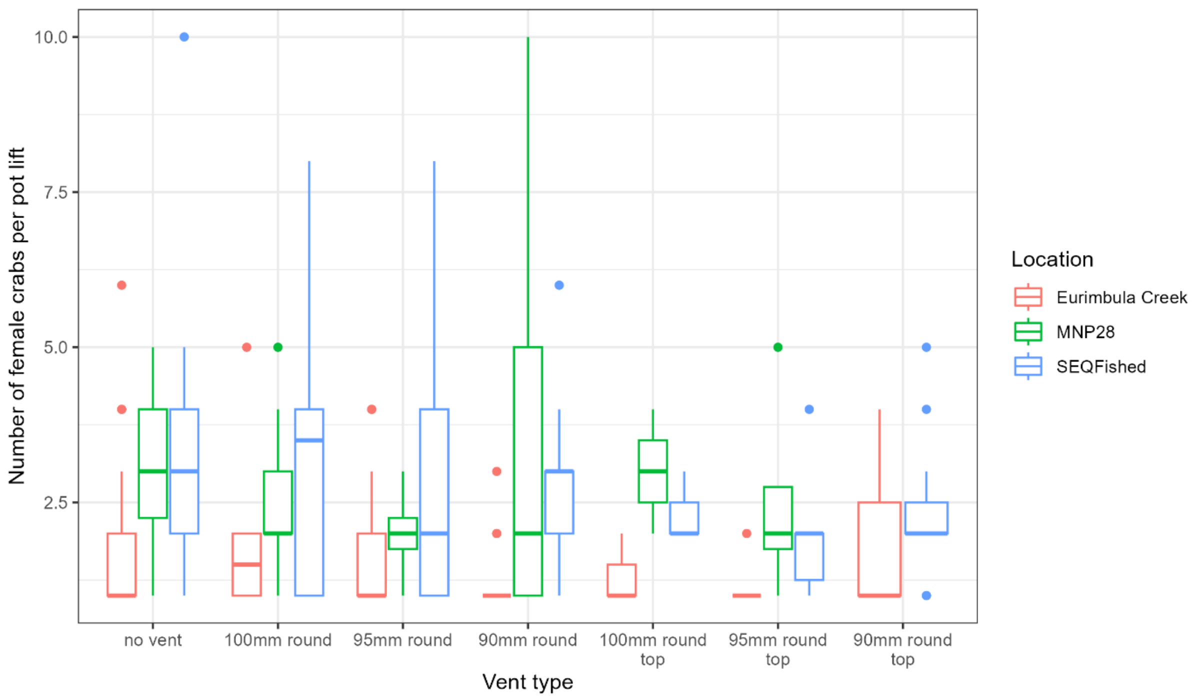

Figure 21. Catch rates of female Giant Mud Crabs by location and escape vent type, Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland). Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Median size (notch width) of females

Results of the GLMM (Table 17) found no significant overall effect of location (p = 0.058) or escape vent type (p = 0.31) on the median size of female Giant Mud Crabs caught per pot lift. However, further investigation of the factor levels in the GLMM indicated a borderline statistically significant effect for the 100 mm round escape vent and the MNP28 location. Relative to the unvented control pots, the median notch width of female crabs was 5.19 mm larger in the in the pots with the 100 mm round escape vent. the median notch width of female crabs was 5.25 mm larger at the MNP28 location (southeast Queensland), relative to the central Queensland locations (Eurimbula Creek, a mud crab sanctuary).

Table 17. Parameter estimates from the GLMM of median size of female Giant Mud Crabs per pot lift during fishery-independent trials of escape vents alternate sizing with bottom placement unless indicated otherwise. Significant effects bolded. Estimated effects of vent type are relative to unvented control pots; estimated effects of location are relative to the central Queensland location (i.e., Eurimbula Creek).

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	**147.37**	**1.891**	**41**	**77.918**	**0.000**	***
100 mm round	**5.190**	**2.599**	**223**	**1.997**	**0.047**	*
95 mm round	4.738	2.485	223	1.907	0.058	
90 mm round	3.789	2.567	223	1.476	1.141	
100 mm round top	5.597	4.828	225	1.159	0.248	
95 mm round top	6.010	3.615	223	1.662	0.098	
90 mm round top	6.254	3.568	222	1.753	0.081	
Location MNP28	**5.249**	**2.490**	**32**	**2.108**	**0.042**	*
Location SEQ Fished	-0.385	1.866	10	-1.206	0.840	

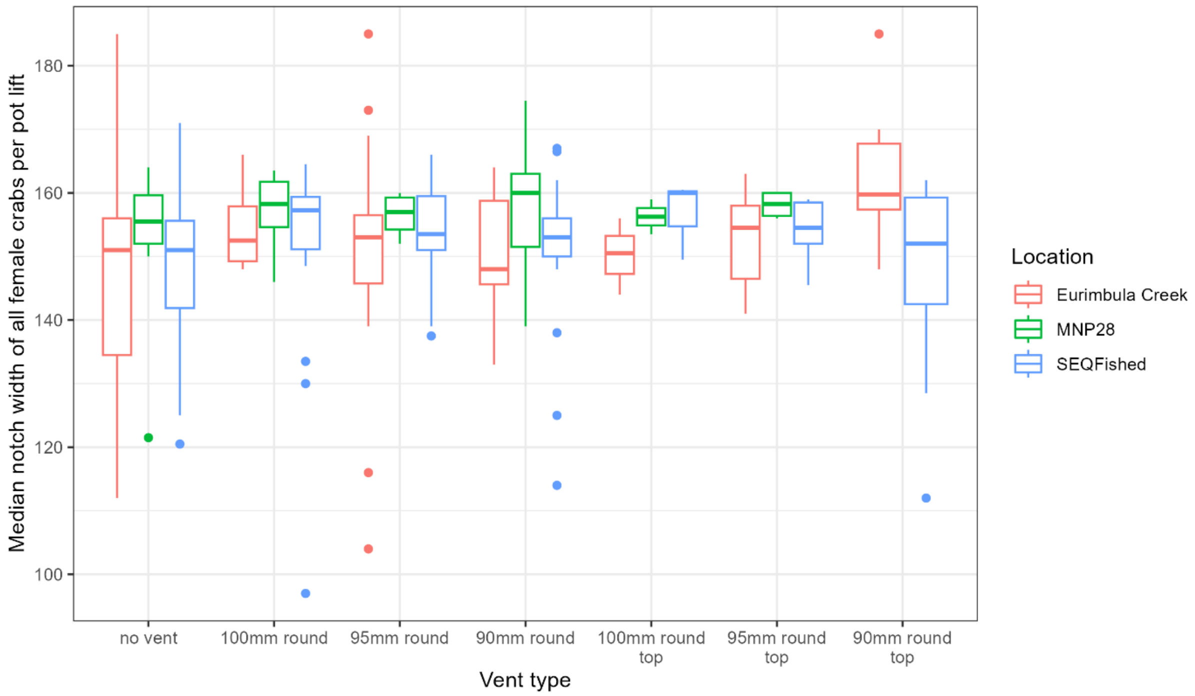

Figure 22. Median notch width (mm) of female Giant Mud Crabs by location and escape vent type, Eurimbula Creek (central Queensland, mud crab sanctuary), MNP28 (green zone Moreton Bay, southeast Queensland), SEQ Fished (blue zone Moreton Bay, southeast Queensland. Boxes indicate the range of the central 50% of the data, the central horizontal line indicates the median value, whiskers extend to 1.5 times the interquartile range, points indicate outliers.

Discussion and recommendations

There has been a shift in attitude towards escape vents by operators in the commercial mud crab component of the Queensland Crab Fishery over the life of this project. Attitudes changed from initial scepticism or disagreement with regulated escape vent dimensions, to a general acceptance of escape vents in commercial pots targeting Giant Mud Crabs.

Results from the fishery-independent trials indicated that although there are differences in the abundance and size of Giant Mud Crabs between different locations, the 120 x 50 mm escape vent did not have a significant effect on catch rates of legal male Giant Mud crabs, or on the median size of legal crabs. This is consistent with results from the morphometric analysis (Chapter 1), which indicated that legal male Giant Mud Crabs are unable to exit using the 120 x 50 mm escape vent because their carapace height is larger 50 mm. During fishery-dependent sampling, project staff noticed that some 120 x 50 mm escape vents, particularly those made from wire, distorted over time such that their dimensions changed. Distortion from a rectangular escape vent of 120 x 50 mm to an oval shape <120 mm and >50 mm will permit near-legal Giant Mud Crabs to escape. The 120 x 50 mm escape vent allows finfish that are laterally compressed to escape. An example of a common crab pot bycatch species is Yellowfin Bream, which is laterally compressed i.e., a small width to body height ratio. Whilst not explicitly measured, based on equations in Broadhurst *et al.* (2006)[7], we expect Yellowfin Bream up to approximately 320 mm total length should be able to exit a crab pot fitted with a 120 x 50 mm escape vent because it has an estimated body height of110 mm and a body width 41 mm. thus in both dimensions, it would be smaller than the dimensions of the 120 x 50 mm escape vent – presuming the Bream is able to side on its side. Given the retention of near-legal male Giant Mud Crabs, the ability for sub-legal crabs and laterally compressed finfish bycatch to exit, we recommend no change to the specification of the 120 x 50 mm escape vent, other than ensuring the escape vent does not distort from its original dimension over time.

Results from the fishery-independent trials indicated that the 105 mm round escape vent did not have a significant effect on catch rates of legal male Giant Mud Crabs, or on the median size of legal crabs. This is inconsistent with morphometric analyses (Chapter 1), which indicated that a near-legal male Giant Mud crab (148 mm to 152 mm CW, 102 to 104 mm TL) may be able to exit a 105 mm round escape vent. Results from the fishery-independent trials indicated that the 105 mm round escape vent did have an effect on the catch rate of sub-legal male Giant Mud Crabs, with significantly fewer caught, consistent with morphometric analyses. Results from the fishery-independent trials of alternate vent sizes indicated a significant although slight increase in catch rates of legal male crabs (0.34 to 0.36 mean number of crabs per pot lift) and a reduction in the catch rate of sub-legal males (0.57 to 2.12 mean number of crabs per pot lift), possibly a result of pot saturation effects (reference). Catch rates from more pot lifts fitted with alternate size vents would be required to determine the consistency of this result over time and space to ascertain the extent of this potential commercial benefit.

Whilst not explicitly measured, based on equations Broadhurst *et al.* (2006)[8], we expect Yellowfin Bream up to approximately 303 mm total length should be able to exit a crab pot fitted with a 105 mm round escape vent because it has an estimated body height of 104 mm and a body width of 389 mm. Thus, in both dimensions, it would be smaller than the dimensions of the 105 mm round escape vent. We recommend consideration should be given to revising the regulated internal diameter of the round escape vent to either 100 mm round or 95 mm round to improve retention of near-legal male Giant Mud Crabs, while maintaining the potential exclusion of finfish and other bycatch. We would expect Yellowfin Bream of up to approximately 286 mm and 273 cm total length to be able to exit a crab pot fitted with a 100 and 95 mm round escape vent respectively, as at these total lengths, the Bream have estimated body heights of 99 and 94 mm respectively.

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[7] Yellowfin Bream TL (mm) = 2.994*maximum body height – 4.0305; TL (mm) = 7.9888*maximum body width – 6.355; Broadhurst *et al*. (2006).

Results from the fishery-independent trials indicated that the two 75 x 60 mm escape vents did not have a significant effect on catch rates of legal male Giant Mud Crabs or on the median size of legal males, but also did not significantly reduce the number of sub-legal males caught. This result is consistent with morphometric analyses (Chapter 1), which indicated that only Giant Mud Crabs smaller than 115 mm CW are able to exit using this size escape vent. Regulations specify that two 75 x 60 mm escape vents are required. Some fishers install two separate 75 x 60 mm escape vents on opposite sides of the crab pot, providing alternate places of escapement. Other fishers have combined the two 75 x 60 mm escape vents into a single unit, which does not confer this advantage. The 75 x 60 mm escape vent would permit the exit of small fish (i.e., juvenile Yellowfin Bream up to approximately 210 mm total length, based on Broadhurst *et al.* 2006) as well as water rats, but not larger finfish, such as the estuary cods. There would be a benefit to sub-legal crabs and finfish bycatch if this escape vent configuration was removed from regulation.

Most fishery-dependent pot lifts only caught Giant Mud Crabs, with bycatch being day and location specific. This is consistent with findings reported by the FQ Fisheries Observer program (2000 to 2009), which from 1,452 pot lifts, reported that bycatch was 98% comprised of Giant Mud Crabs being 49% females, 39% undersize males, 10% soft males. The remaining 2% was comprised of assorted finfish and other crustacean species.

Placement

Positioning of escape vents in crustacean traps has been previously studied by Eldridge *et al.* (1979) and Havens *et al*. (2009) for Blue Crabs (*Callinectes sapidus*), and by Jirapunpipat *et al.* (2008) for Orange Mud Crabs (*Scylla olivacea*). These studies recommended at least two escape vents per pot, with one being placed at the bottom edge of the pot and the others being placed in the top.

Giant Mud Crab behaviour observed via underwater video footage during the current research indicates that escape vents perform best when placed near the bottom of the apparatus. Queensland *Fisheries (General) Regulation 2019* specifies that escape vents must be positioned 'on the bottom edge of the apparatus'. This has been interpreted by some (including enforcement staff) that the vent must be touching or almost touching the bottom ring/structure of the pot. However, the natural sideways movement of mud crabs and the articulation of their walking legs, suggests that placement of the escape vent in the lower 1/3rd of the pot side wall is likely to provide the simplest 'opportunity' for a mud crab smaller than the size of the escape vent to exit.

Escape vents made of plastic or aluminium with a 15 to 20 mm border (often drilled with holes to allow installation) results in an escape opening that is near to, but about 20 mm off the bottom edge of the pot. Underwater video footage suggests that the vents may perform better when the escape opening is slightly elevated off the bottom edge as this better suits the natural behaviour of Giant Mud Crabs (Figure 23, Figure 24). Escape vents with a 'border' that are attached to the bottom edge of the pot are most suited to the natural sideways movement of crabs. Escape vents made of rolled wire or PVC pipe (or similar) result in an escape opening that is hard against the bottom of the pot, and often the substrate, and which crabs need to "hunker down" to utilise.

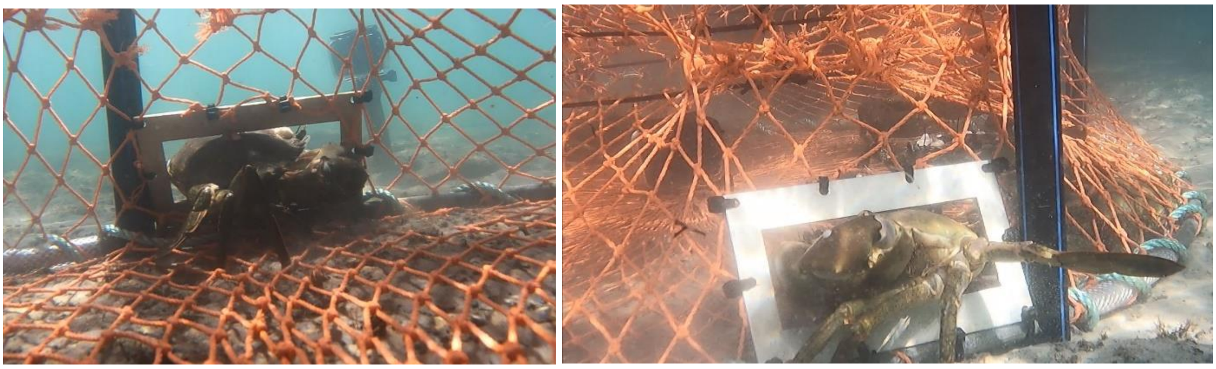

Figure 23. Underwater image of a male Giant Mud Crab exiting via a 120 x 50 mm escape vent that has a 20 mm border.

Figure 24. Underwater image of a male Giant Mud Crab exiting via a 105 mm round escape vent that has a 20 mm border.

Chapter 3. Marine turtle interactions with apparatus of the Queensland Crab Fishery: collation of extent and potential means of mitigation

Introduction

Marine turtle interactions with crabbing apparatus have been an ongoing bycatch issue for many years (Text Box 1, Sumpton *et al*. 2000; Meager and Limpus 2012). Marine turtles can be incidentally entrapped partially or fully inside crab pots, which may result in death due to drowning. Marine turtles can also be entangled in the float-lines (i.e., ropes) attached to the crab pots as the animal swims past. The number of reported marine turtle interactions with crabbing apparatus reported to the Queensland Government via StrandNet varies annually (Table 18). Interactions are often highly visible to the public, causing comment in social media. Marine turtle interactions with crabbing apparatus occur most frequently where high densities of marine turtle overlap with areas of high crabbing effort adjacent to populated foreshores.

Table 18. Fishing activity associated with reported marine turtle strandings in StrandNet, annually 2000 to 2011, reproduced from Walton and Jacobsen (2019).

Year	Fishing activity associated with reported marine turtle stranding				
	Boat Strike	Crab pot/float-line	Ghost nets	Netting	Fishing line or rope
2000	78	14	0	0	10
2001	83	18	0	0	11
2002	65	19	0	0	23
2003	60	18	3	3	4
2004	75	25	21	5	7
2005	63	22	53	15	6
2006	67	26	6	4	11
2007	70	31	12	2	13
2008	92	47	22	4	16
2009	68	55	1	1	11
2010	93	44	15	0	14
2011	126	37	5	32	24

Marine turtle entrapment in crabbing apparatus was explicitly considered in the Level 1 (whole-of-fishery) Ecological Risk Assessment (ERA) for the Queensland Crab Fishery (Walton and Jacobsen 2019). The Queensland Crab Fishery was assessed as having a high level of risk to this species group. The ERA identified that key information is needed to refine the risk profile, including details on species compositions, interaction rates, and fate post-release in both the recreational and commercial crabbing sectors. The entrapment of marine turtles in crab pots was inferred to pose a greater risk of mortality (due to drowning) than entanglement. Walton and Jacobsen (2019) also noted the uncertainty around whether the interaction was predominately with 'active' crab pots (i.e., pots that are baited and being checked on a regular basis) or 'ghost' crab pots (i.e., pots that are lost, submerged, discarded and may or may not be self-baited through the entrapment of animals in the ghost pot).

The level 2 ERA for the Queensland Crab Fishery ranked green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles at high risk from the Fishery, with hawksbills (*Eretmochelys imbricata*), flatbacks (*Natator depressor*) and leatherbacks (*Dermochelys coriacea*) ranked at medium risk and olive Ridley's (*Lepidochelys olivacea*) at low risk (Walton and Jacobsen 2020).

Text Box 1 Turtle bycatch in the Blue Swimmer Crab fishery (quoted from Sumpton et al. 2000, p 24).

> There has been considerable recent concern about the deaths of threatened sea turtles caused by fishing operations. It is believed that many sea turtles become entangled in the ropes of buoy lines from crabbing operations or are caught up in the trap itself whilst trying to access the crabs and bait. The most common way that a turtle becomes entangled is passive entanglement of the front swimming flipper as a turtle swims past a rope. There are also instances where turtles will tear out the tops or bottoms of crab pots to attack the bait or crabs. Turtles are also known to put their heads into the funnels of crab pots to access the crabs and bait. At times they may get caught by their throats when trying to remove their heads from the pots.
>
> One of the advantages of the trawl mesh pots is their greater resistance to interference and damage caused by sea turtles trying to eat the bait and trapped crabs. It is possible that these designs may lower the mortality of turtles caused by their becoming entangled in the funnels and mesh of wire pots.
>
> Fishers often lose pots due to boat strikes, trawlers and poaching, and it is also likely that a proportion of pots are lost when turtles become entangled in the lines and drag them from their set positions. Fishermen have commented on turtles becoming entangled in their ropes as a relatively infrequent occurrence, but it is possible that turtles that become entangled and drag pots away from their positions are not detected. Nevertheless, in over 200 observer days on (Blue Swimmer) crabbing vessels, only one entangled sea turtle was encountered. That turtle was caught by its front right flipper and was subsequently freed by the fisher and released unharmed.
>
> Interviews with commercial crab trap fishermen in Moreton Bay indicated that the detectable rate of entanglement of sea turtles in crabbing apparatus was between one and two per fishing year although this varied considerably from area to area. Fishermen working closer to the banks at the northern and eastern side of Moreton Bay reported a higher incidence of turtle interactions than those working in the western areas of Moreton Bay.

Overview of marine turtle population status in northern Australia

Six of the seven species of marine turtles occur in Queensland (and Australian) waters. All are listed as Vulnerable or Endangered under Commonwealth and Queensland legislation (Table 19). The listed conservation status reflects the observed or suspected reductions in marine turtle stock size within three generations. Under Queensland legislation (*Nature Conservation Act 1992*), threatened species conservation classes are based on observed or suspected reductions in population size and degree of risk of extinction. Endangered species have a 20% or greater probability of extinction in the near future. Vulnerable species have a 10% or greater probability of extinction in the near future (https://www.qld.gov.au/environment/plants-animals/conservation/threatened-species/classes/conservation-classes).

The life history of marine turtles is relevant to the population-level risk of their interactions with crabbing apparatus. Marine turtles hatch out of eggs at nesting beaches, then swim offshore and have a juvenile ‘oceanic’ phase, (except for flatbacks which remain on the Australian continental shelf) of up to several decades, then settle in feeding grounds where they mature before migrating back to natal beaches/regions to breed. This means that marine turtle interactions with crabbing apparatus on feeding grounds, such as embayments like Moreton Bay and Hervey Bay, may be impacting on genetic stocks that breed (and are monitored) some distance away. There are 10 genetic stocks of the six species of marine turtles that occur in Queensland waters (Figure 25).

Table 19. Conservation status of marine turtles.

Species	Australia[1]	Qld[2]	Stock	Stock condition[3]	Stock trend[3]
Green	VU	VU	southern Great Barrier Reef	Depleted	Moderate recovery
			northern Great Barrier Reef	Severely depleted	Significant decline
			Coral Sea	Unknown	Unknown
			Gulf of Carpentaria	Unknown	Unknown
Loggerhead	EN	EN	southwest Pacific	Severely depleted	Moderate recovery (declining)
Hawksbill	VU	EN	north Queensland	Severely depleted	Significant decline
Olive Ridley	EN	EN	western Cape York	Severely depleted	Significant decline
Flatback	VU	VU	eastern Queensland	Depleted	Moderate decline
			Arafura Sea	Severely depleted	Stable/possibly increasing
Leatherback	EN	EN	Undefined, no known nesting since 1996	Severely depleted	Significant decline

VU = vulnerable, EN = endangered, CR = critically endangered. DD = data deficient, nl = not listed.
*WCU criteria – Critically endangered as an 80% decline, Endangered as 50% decline and Vulnerable as a 20% decline.
[1] Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*; [2] Queensland *Nature Conservation (Wildlife) Regulations 1994*; [3]Queensland Marine Turtle Conservation Strategy 2021 – 2031.

The *Queensland Marine Turtle Conservation Strategy 2021 – 2031* recognises there are multiple threats to marine turtle stocks, including climate change and climate variability, marine debris, chemical and terrestrial discharge, international take, terrestrial predation, fisheries bycatch, light pollution, habitat modification, indigenous take, vessel disturbance, noise interference, recreational activities, and disease and pathogens. From a risk assessment process, domestic fisheries bycatch was rated as very high for leatherbacks, high for the olive Ridley north west Cape York stock, flatback Arafura Sea stock and green Gulf of Carpentaria stock, moderate for the green southern Great Barrier Reef stock, green northern Great Barrier Reef stock, green Coral Sea stock, and flatback eastern Queensland stock, and low for the loggerhead south west Pacific stock (Table 20).

The *Queensland Marine Turtle Conservation Strategy 2021 – 2031* has an interim objective (Target 3.3) that “marine turtle bycatch mortality in commercial fisheries and the Queensland shark control program is reduced to negligible (i.e., no impact on the stock)”. Noting that a key action (with a very high priority) in the plan is to “support QDAF to implement strong auditing and compliance processes and improved technologies for crab fisheries to substantially reduce turtle bycatch”.

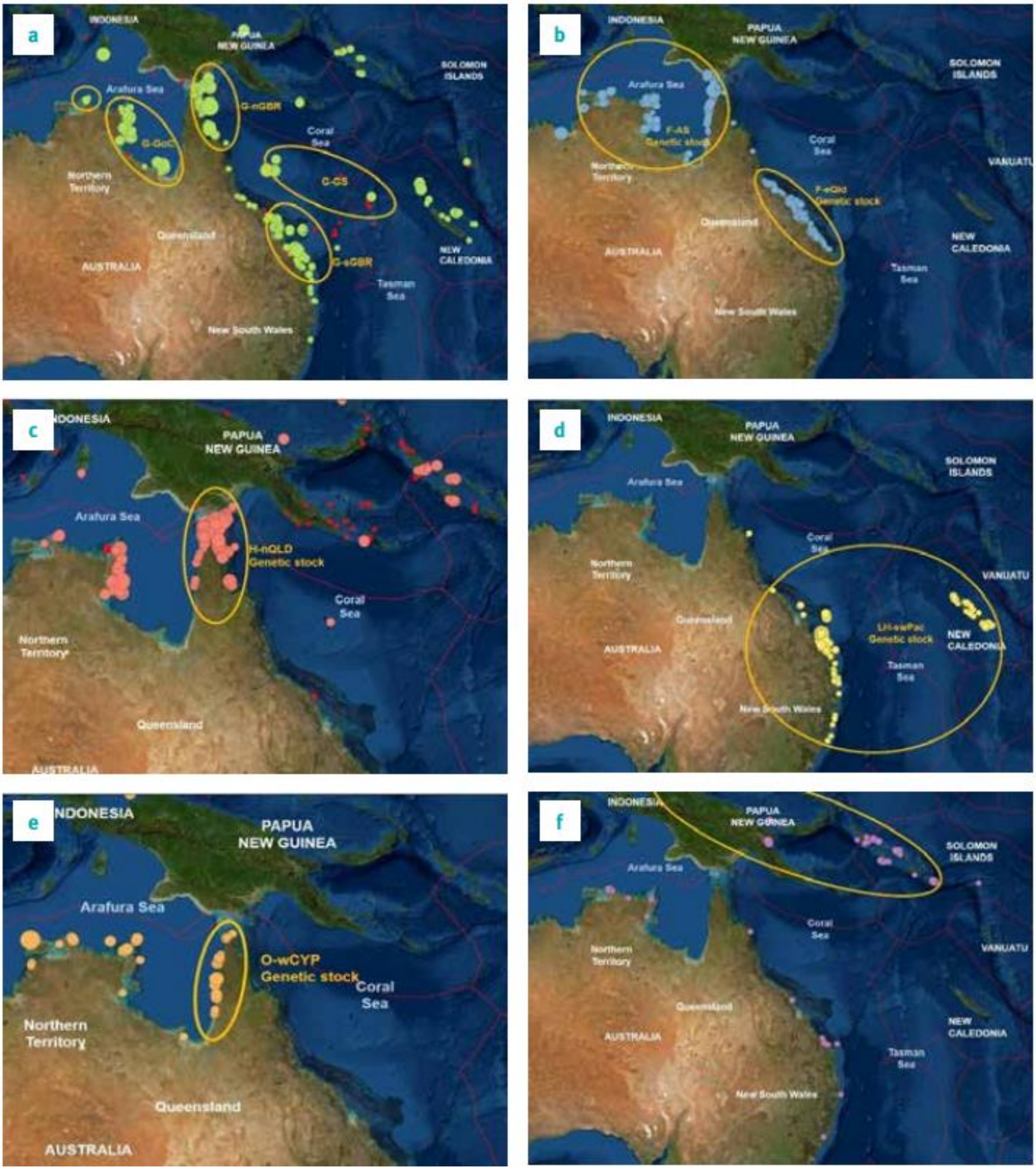

Figure 25. Breeding distribution of the 10 genetic stocks of the marine turtles in Queensland (reproduced from Figure 1 of the Queensland Marine Turtle Conservation Strategy 2021 - 2031).

a	Green turtle southern Great Barrier Reef (G-sGBR), northern Great Barrier Reef (G-nGBR), Coral Sea (G-CS) and Gulf of Carpentaria (G-GoC).
b	Flatback turtle eastern Queensland (F-eQld) and Arafura Sea (F-AS).
c	Hawksbill turtle north Queensland (H-nQld).
d	Loggerhead turtle southwest Pacific (LH-swPAC), shared with New Caledonia.
e	Olive Ridley north-western Cape York (O-nwCYP).
f	Leatherback turtle genetic stock (LB). As there has been no reported nesting in Queensland since 1996, leatherback turtles are considered as part of a single regional stock that is possibly extinct for breeding n Queensland.

Table 20. Summary of the threat risk assessment process for each Queensland marine turtle stock (reproduced from the Queensland Marine Turtle Conservation Strategy 2021 - 2031, Table 3).

	SPECIES									
THREAT	G-sGBR	G-nGBR	G-CS	G-GoC	F-eQld	F-AS	H-nQld	LH-swPac	O-nwCY	LB
A. Climate change and variability	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high
B. Marine debris–entanglement	Moderate	High	U	Very high	Moderate	Very high	Very high	High	Very high	Moderate
B. Marine debris–ingestion	High	High	High	High	High	U	High	High	U	High
C. Chemical and terrestrial discharge–acute	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Low
C. Chemical and terrestrial discharge–chronic	High	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Low	Moderate	U
D. *International take*–outside Australia's jurisdiction	Moderate	Moderate	Moderate	Moderate	Low	Low	Very high	Moderate	Low	Very high
D. *International take*–within Australia's jurisdiction	Low	Moderate	Low	Moderate	Low	Low	Moderate	Low	Low	Low
E. Terrestrial predation	Low	Very high	Low	Moderate	Moderate	Very high	High	Moderate	Very high	U
F. *Fisheries bycatch*–international	Moderate	Low	Moderate	Moderate	U	High	Moderate	Very high	Very high	Very high
F. *Fisheries bycatch*–domestic	Moderate	Moderate	Moderate	High	Moderate	High	Moderate	Low	High	Very high
G. Light pollution	Moderate	Low	Low	Low	Very high	High	Low	High	Very high	Low
H. Habitat modification–infrastructure/coastal development	Moderate	High	Low	Moderate	Moderate	High	Low	Moderate	Very high	Moderate
H. Habitat modification–dredging/trawling	Moderate	Moderate	Low	Moderate	Moderate	Low	Low	Moderate	Low	Low
I. *Indigenous* take (requires further assessment)										
J. Vessel disturbance	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Low	Very high	Moderate	High
K. Noise interference–acute	Low	Low	Low	Moderate	U	Moderate	U	Low	Low	U
K. Noise interference–chronic	U	Low	Low	U	U	Low	U	U	U	U
L. Recreational activities	Low	Low	Moderate	Low	Low	Low	Low	Low	Low	Low
M. Diseases and pathogens	U		U	U	U	U	U	Low	U	U

Risk rating: Very high | High | Moderate | Low | U = unknown

Key information about each stock, taken from the *Queensland Marine Turtle Conservation Strategy 2021 – 2031,* is summarised below (unless otherwise indicated), to give context to marine turtle interactions with crabbing apparatus in Queensland waters.

Green turtle - southern Great Barrier Reef stock

- Severely depleted by commercial harvest for turtle soup (1860 to 1950). Recovering well. Nesting populations have doubled over the last 40 years.
- Nesting grounds include Capricorn Bunker Islands and mainland beaches Bustard Head to Sunshine coast.
- Feeding grounds include Capricorn Bunker reefs and sheltered embayments e.g., Moreton Bay, Great Sandy Straight, Hervey Bay, Shoalwater Bay, Repulse Bay, Cleveland Bay.

Green turtle - northern Great Barrier Reef stock

- Severely depleted.
- Evidence of low hatchling production at Raine Island (primary rookery), feminisation of the stock (due to increasing sand temperatures, which determine sexual development of embryos).
- Nesting grounds between Princess Charlotte Bay and Torres Strait, but 90% occurs on Raine Island and Moulter Cay.
- Feeding grounds include Torres Strait and southern Gulf of Carpentaria.

Green turtle – Gulf of Carpentaria stock
- Unknown stock condition.
- Nesting grounds Sir Edward Pellew and Wellesley Islands, Groote Eylandt Archipelago and Arnhem land mainland beaches.
- Feeding grounds predominately the Gulf of Carpentaria.

Green turtle – Coral Sea stock
- Unknown stock condition.
- Nesting grounds Coral Sea sand cays (Coringa-Herald, Lihou Reef cays).
- Feeding grounds New Caledonia, Capricorn Bunkers reefs, and sheltered embayments e.g., Moreton Bay, Shoalwater Bay, Hervey Bay.

Loggerhead turtle – southwest Pacific stock
- Severely depleted.
- Nesting grounds mainland beaches Bundaberg to Wreck Rock, Fraser Island, Sunshine Coast, Capricorn Bunker Islands, (and New Caledonia).
- Feeding grounds sheltered embayments e.g., Moreton Bay, Shoalwater Bay, Hervey Bay and Capricorn Bunker reefs (and New Caledonia).

Hawksbill turtle – north Queensland stock
- Severely depleted, noting commercial harvest for tortoiseshell from 1800 to 1968.
- Nesting grounds Islands Torres Strait, Cape York beaches, noting breeding population estimated at 4,000 nesting females).
- Feeding grounds northern GBR, Torres Strait, northern Gulf of Carpentaria.

Olive Ridley turtle – western Cape York Peninsula stock
- Severely depleted, small population.
- Nesting grounds eastern Gulf of Carpentaria mainland beaches, main concentration between Aurukun to Pormpuraaw.
- Feeding grounds sub-tidal waters of the Gulf of Carpentaria and Arafura Sea in Australian and Indonesian waters.

Flatback turtle – eastern Queensland stock
- Depleted.
- Nesting grounds inshore continental islands of the Great Barrier Reef (including Peak, Wild Duck, Avoid and Curtis Islands) and mainland beaches between Mackay and Bundaberg.
- Breeding population estimated at 1,500 nesting females or less.
- Feeding grounds sub-tidal and non-reef habitats, distributed between Bundaberg and Torres Strait.
- Increasing population abundance since the early to mid-2000's, based on index nesting beaches (Limpus *et al*. 2020).

Flatback turtle – Arafura Sea stock
- Severely depleted.
- Nesting grounds western Torres Strait (Deliverance Island), Gulf of Carpentaria (including Crab Island), northeast Arnhem Land, Cobourg Peninsula, western NT.
- Feeding grounds sub-tidal and non-reef habitats across the continental shelf.

Leatherback turtle – Australian nesting
- Severely depleted.
- Nesting grounds not recorded nesting on the east coast of Australia since 1996, but could be part of the north-west Pacific stock that breeds in northern Papua and the Solomon Islands.
- Feeding grounds pelagic deep water, although seen in the southern Gulf of Carpentaria and Moreton Bay. This species undergoes vast migrations.

The aims of the current chapter were to:

(i) Collate information on marine turtle interactions with crab apparatus.
(ii) Consider pot configuration(s)/modifications that could contribute to a risk mitigation strategy for marine turtles in the Queensland crab fishery.

Methods

StrandNet

StrandNet is an online Oracle database that was developed to record sightings of sick, injured, dying or dead marine wildlife in Queensland (for details see Meager and Limpus (2014) and Marsh *et al*. (2019)). Sightings reported via a telephone hotline by the public, environmental organisations, community groups, Government officers are entered into the database by authorised users, with verification occurring where possible (sighting, species, etc. confirmed). Various lines of evidence (photos, necropsies by veterinarians, carcass examination by trained staff e.g., Rangers) are used to indicate a probable cause of death, otherwise the probable cause of death is recorded as 'unknown'. Species recorded include marine cetaceans (whales and dolphins), pinnipeds (seals and sea lions), dugong and marine turtles. The database is currently curated by the Queensland Government Department of Environment and Science.

Being based on sightings, the records in the database are spatially biased towards areas that are densely populated, where humans move along waterways, including beaches and foreshores, and in areas patrolled by marine park rangers (Marsh *et al*. 2019). Thus, most records are from south-east Queensland to Port Douglas, with some records from the far north and the Gulf of Carpentaria.

Previous publications of StrandNet data summarise reported strandings only, and provide limited insight into the type of apparatus, or likely sector (commercial/recreational, Blue Swimmer Crab, Giant Mud Crab or Spanner Crab fishery), with the last detailed report on marine turtle strandings published over a decade ago (Meager and Limpus 2012). The aim of the current research was to collate StrandNet data and examine in detail the reported interactions between marine turtles and crabbing apparatus to elucidate (as much as possible) where, when, how and what types of gear were involved.

Full access to the StrandNet database was granted by the Department of Environment and Science to the Principal Investigator (J. Robins). All records relating to Taxon = "marine turtles" were exported from the database for all years (i.e., 5th November 1962 to the 4th of April 2023 inclusive). All fields were exported. The database has evolved over time, has been entered by numerous persons, and despite guidelines, data entry into various fields is somewhat inconsistent. Therefore, the following fields were added and evaluated for each record to provide consistency and assist in summarising the StrandNet data for marine turtles (Table 21).

Table 21. Fields added to the StrandNet data extracted for reported marine turtles to assist with data consistency and summary.

Field name	**Details**
Species	*Chelonia mydas, Caretta caretta, Natator depressus, Lepidochelys olivacea, Dermochelys coriacea, Eretmochelys imbricata, unidentified*
Sex	Male, Female, Not determined
Year	Calendar
Month	1 to 12
Record type	Certain - photo, QG/expert report Semi-certain - sufficient detail to give partial confidence Uncertain, Unvalidated - insufficient detail, no photos, non-expert report Duplicate
Fate	Alive, Dead, Uncertain, Unspecified
Flagged	Record flagged if any field in the record contained the any of the following words - Boat Strike, Crab Pot, Drowned, Entanglement, Fishing, Float, Hook, Net, Predation, Prop Strike, Rope, Shark Control Program (SCP), Synthetic Material, Uncertain, Unspecified
Entanglement type	Based on information in the record allocated to one of the following - Anchor Rope, Crab Pot, Fishing Line, Fishing Hook, Float-line, Ghost Net, Gill Net, Net, Other, Rope, Synthetic Material, Trawl Netting, Uncertain
Photo	Yes or No. For records flagged, and considered as Fishing or Entanglement and included Crab Pot or Float-line, reported April 2023 to November 2018 (due to time constraints). Photos downloaded and assessed for additional information.
Sector	Commercial or Recreational on the basis of markings (e.g., symbols), float type, or photographic evidence of pot style, otherwise allocated to Uncertain
Pot Style	Rectangular Lightweight (i.e., <10 mm steel ring, no chafe rope, <27 ply mesh) Heavy duty (i.e., ≥10 mm steel ring, chafe rope present, ≥27 ply mesh)
Comments	Additional information garnered from the report including associated photos e.g., pot good to fair condition and likely an 'active' pot, pot dilapidated/broken and likely a 'ghost' pot, mesh type (ply and colour), identifying marks on the gear (e.g., commercial symbols or residential address), reported by QG staff, duplicate record, float line type (Telstra rope, heavy duty rope, sink rope etc.) float type (polystyrene float, household item e.g. milk bottle)
Cause of Death	Boat strike, Disease, Fishing, Natural causes, Natural mortality shark, Predation crocodile, Propellor Strike, Unknown
Location*	Bundaberg Coast, Burdekin, Cairns/Wet Tropics, Cooloola Coast, Gladstone, Gold Coast, Great Sandy Strait, Gulf of Carpentaria, Hervey Bay/Fraser Island, Mackay, Moreton Bay, Townsville, Yeppoon

*Record type = contains non-blank information

Threatened, endangered and protected species (TEPS) logbook

The threatened, endangered and protected species (TEPS) logbook replaced the species of conservation (SOCI) logbook that was/is part of Queensland commercial fishing license requirements (https://www.business.qld.gov.au/industries/farms-fishing-forestry/fisheries/commercial/report/logbook/tep). Under Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act 1999*), commercial fishers, including those operating in the C1 fishery, must report all interactions with protected species via a TEPS paper logbook or the Queensland eFisher app. Reporting these interactions is part of Commonwealth Wildlife Trade Operation (WTO) approval, that may permit export (part 13B) and protects commercial fishers against prosecution for unintentional interactions with protected species (part 13). Walton and Jacobsen (2019) reported that 34% of report TEPS interactions from the C1 Fishery (2002 to 2017) involved marine turtles, with a species composition mix of 34% hawksbills, 24% greens, 21% loggerheads and 9% unspecified. The vast majority (97%) were reported to be released alive. To update the data from Walton and Jacobsen (2019) and compare it with that in StrandNet, the current project downloaded the reported interactions between commercial fisheries and species of conservation interest from the Queensland Government Open Data portal https://www.data.qld.gov.au/dataset/quarterly-reports-species-of-conservation-interest-soci-interactions-from-2006/resource/7ec15655-5c2c-48f5-88ac-50a9501317a0.

Marine turtle morphometrics

During project execution, it became apparent there was potential to exclude some marine turtles from becoming entrapped in crab pots based on the size (and behaviour) differences between crabs and marine turtles. Curved carapace length (CCL) is the standard measure for marine turtles in Australia and is the anterior-posterior curved length of the carapace (i.e., shell). Relevant to the issue of marine turtle entrapment in crab pots are: (i) Straight carapace width (SCW), measured at the widest part of the carapace of the sea turtle (measured perpendicularly to the midline axis of the carapace), and (ii) Carapace height (CH = body depth), measured as the vertical distance between the plastron (= belly) and the highest point of the carapace. (Figure 26).

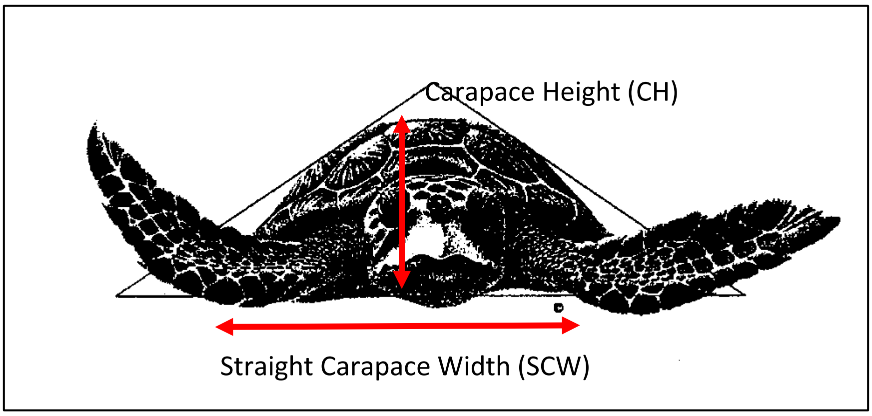

Figure 26. Dimensions of marine turtles relevant to crabbing apparatus (image modified from Epperly and Teas 2002).

Morphometric dimensions of marine turtles previously collated by DAF and DES (Robins *et al.* 2003, unpublished; Queensland Turtle Research Group, Table 22) were used to estimate the SCW and CH of marine turtles reported in StrandNet that included size information and compared to the morphometric dimensions of Giant Mud crabs collected as part of the current project and FRDC 2019-062. The aim was to determine if based on size (and behaviour) gear modification could possibly maintain the entry funnel selectivity of crab pots for Giant Mud Crabs whilst reducing the likelihood of marine turtle entry.

Table 22. Regression equations between morphometric dimension of marine turtles.

Species	Regression Equation	R^2	Source
Green turtles	SCW = 0.6972*CCL + 4.5188	0.98	Limpus 2003
	CH = 0.239*CCL + 1.7712	0.67	Limpus 2003
Loggerhead turtles	SCW = 0.7281*CCL + 3.3040	0.97	Limpus 2003
	CH = 0.3616*CCL – 1.1195	0.81	Robbins 2001
Flatback turtles	SCW = 0.7024*CCL + 7.5781	0.97	Limpus 2003
	CH = 0.2774*CCL + 1.725	0.80	Robbins 2001
Hawksbills	SCW = 0.7362*CCL – 1.0503	0.94	Limpus 2003

Results

StrandNet

Overall, 23,541 verified records of marine turtles were extracted from StrandNet, representing reports between 5th November 1962 and 4th April 2023. Most records were for green turtles (66%), and species unidentified (18%). All other marine turtle species known to occur in Australian waters were recorded in the database, but at lower frequency: loggerheads (8%), hawksbills (5%), olive Ridleys (1%), flatbacks (1%) and leatherbacks (<0.5%). The number of marine turtles reported stranded per year varied, with the most strandings reported in 2011 and 2012 (Figure 27). The number of marine turtles stranded per region also varied, with the greatest number of stranding reported in the greater Moreton Bay region, accounting for about 40% of StrandNet records (Figure 28). Most marine turtles reported in StrandNet were dead (78%), with 19% alive, and the remainder being in uncertain condition.

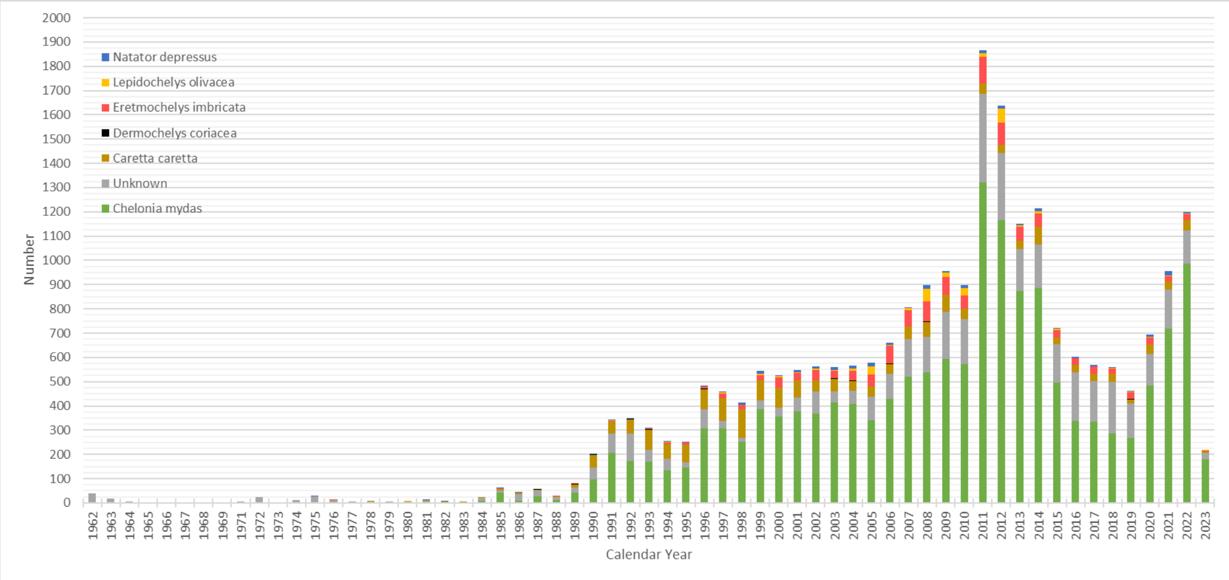

Figure 27. Annual (verified) reports of stranded marine turtles in StrandNet (all regions pooled), 1962 to April 2023.

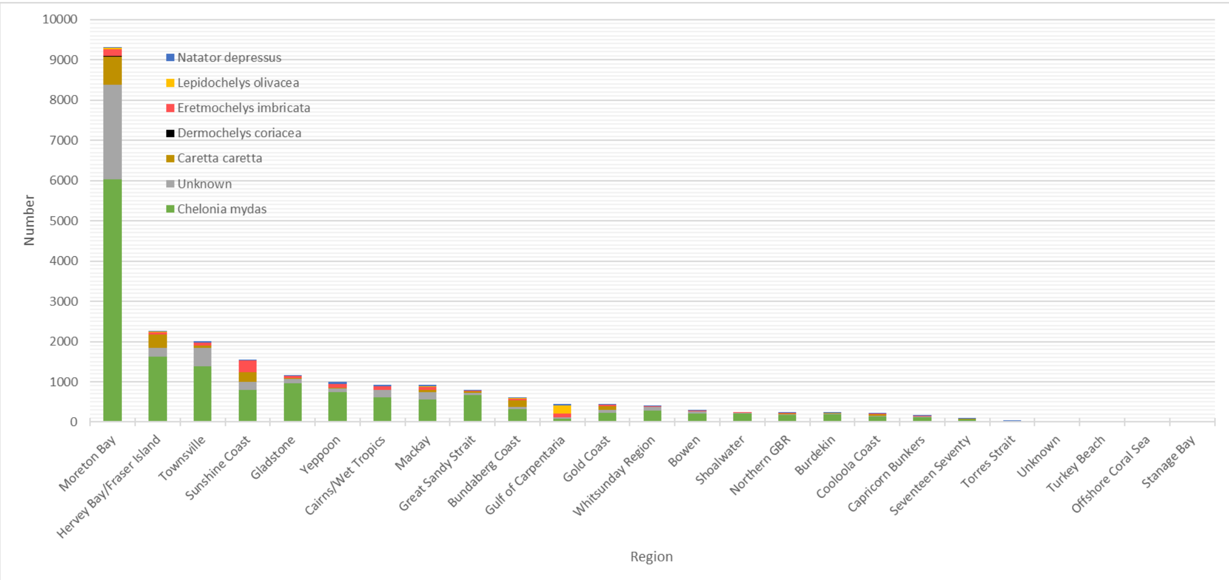

Figure 28. Regional location of (verified) reported marine turtles in StrandNet (all years pooled), 1962 to April 2023.

Associated with crabbing apparatus

All fields in the data extract were searched for the following terms - fishing, tangled, crab, pot, net, line, hook, float, rope; with 1,252 records being flagged as 'fishing' related (all years). Noting that this explicitly did not include records reported as an interaction with the Shark Control Program (SCP, n = 320), nor those attributed to propellor or boat strike (n = 589). Of the 1,252 records flagged as being 'fishing' related, 71% were dead, 27% were alive, and 1% had an uncertain fate (often due to no verification of the record by Queensland Government staff or further information reported).

Attribution to entanglement type of 'fishing' related reported standings is presented in Table 23 for recent years (2011 to 2023), and includes reports attributed to propellor or boat strike. The annual number of marine turtle interactions with crabbing apparatus (of all sectors and target species) is about 50 per year, consistent with previous reports. Of the 240 records in StrandNet (2011 to 2023) attributed to crab pot entrapment, 89% were reported dead, and 11% were alive. Of the 295 records in StrandNet (2011 to 2023) attributed to float-line entanglement, 56% were reported dead, 39% were alive and 5% had an uncertain fate.

Table 23. Marine turtle standings reported to StrandNet and attributed cause of interaction between 2011 to 2023 calendar years (ordered from most recent), noting 2023 is only to 4th April.

Year	Crab Pot	Float-Line	Fishing Line or Hook	Ghost net	Netting	Other & uncertain	Propellor or Boat Strike
2023#	15	6	4	1		0	19
2022	19	33	22	1	1	1	46
2021	26	27	25		10	1	54
2020	12	27	19	1	1	0	44
2019	14	19	17	1		0	36
2018	16	27	11	1		3	33
2017	20	33	14		2	1	26
2016	20	25	22		2	4	25
2015	15	14	25	1	2	2	21
2014	21	22	18	10	8	5	30
2013	25	17	23	2	1	5	55
2012	19	28	23	87	7	2	54
2011	18	17	27	32	6	13	57

Often, but not always, there were more reported marine turtle entanglements in the float-lines associated with crabbing apparatus than marine turtle entrapment in crab pots. Over the past five years, StrandNet records increasingly have photographic evidence associated with the reports (examples provided in Figure 29). This evidence, along with written commentary in the StrandNet records, highlighted that crab pots rectangular in shape (with wide entry funnel inner openings) or pots classed as 'lightweight' (i.e., with rings of less than 10 mm steel and <27 mm mesh ply) accounted for two-thirds of marine turtle entrapment in crab pots. The remaining one-third of marine turtle entrapments were associated with crab pots classed as 'heavy duty' (i.e., rings equal to or greater than 10 mm steel and mesh equal to or greater than 27 mm ply). During fishery-dependent trials of the current research project (Chapter 2), pots used by commercial operators were of heavy-duty style – mostly for longevity of the pot. Therefore, by inference, rectangular and 'lightweight' pots are predominately, if not exclusively, used by the recreational crabbing sector. A small proportion of the recreational sector do use heavy-duty style pots.

Of the 62 reported strandings reviewed that included images of crab pot entrapment, 50% were considered by project staff to be 'ghost' pots (i.e., pots that were not freshly baited, and were dilapidated or broken). The other 50% were in fair to good condition. Implications of this result is considered in the Discussion section of this chapter.

Of the 44 reported strandings reviewed that included images of entanglement in float-lines, 86% were non-sink rope – with the most common ropes estimated to be 8 mm green rope, 'Telstra' rope and 4 mm silver.

Figure 29. Examples of marine turtle interactions with crabbing apparatus taken from StrandNet database: (a) rectangular pots (Z235406Oct 2019, Z6566418 Feb 2023, Z1598089 Sep 2020), (b) 'lightweight' pots (<10mm steel rings, 27 mm ply mesh – Z6566217 Nov 2022, Z656888 Sept 2022, Z1599263 Nov 2021, (c) heavy duty pots (≥10mm steel rings, ≥27 mm ply mesh – Z1598381 Feb 2021; Z6566413 Feb 2023, and (d) float-lines (Z6566158 Nov 2022, Z6566225 Dec 2022).

Green turtles were the most common species to interact with crabbing apparatus, with fewer interactions by loggerhead turtles (Table 24). Other marine turtle species were rarely reported as interacting with crabbing apparatus. There were a number of marine turtle interactions in crabbing apparatus that were not identified to species (i.e., unidentified), which are likely to be green or loggerhead turtles.

Table 24. Species composition of marine turtles reported to StrandNet where the attributed cause was crabbing apparatus (crab pot entrapment or float-line entanglement) between 01/01/2011 to 04/04/2023.

Year	Green	Loggerhead	Hawksbill	Leatherback	Olive Ridley	Unidentified	Grand Total
2023#	15	1				5	21
2022	39	2	1			10	52
2021	38	1		1	1	12	53
2020	21	2				16	39
2019	16	1				16	33
2018	24					19	43
2017	38	1				14	53
2016	24	6	2			13	45
2015	20	2				7	29
2014	30	2				11	43
2013	26	4				12	42
2012	34	3				10	47
2011	22	1	1			11	35

#data to 04/04/2023, year incomplete

For green turtles, the relative levels of crab pot entrapment and float-line entanglement varied between years, whereas loggerhead turtles were predominately reported entangled in float-lines (Table 25). Of the limited number of reported hawksbill turtle interactions, three of the four since 2011 were entrapped in the pot. The single olive Ridley (Table 24) was entrapped in the pot, while the leatherback turtle was entangled in the float-line. Noteworthy is that no flatback turtles were reported interacting with crabbing apparatus, with only one record in StrandNet of a flatback turtle entangled in a float-line at Trinity Beach, Cairns in 2009.

Table 25. Entanglement type for green, loggerhead and unidentified species of marine turtle reported to StrandNet where the attributed cause was crabbing apparatus between 2011 to 2023.

Year	Green		Loggerhead		Unknown	
	Crab Pot	Float-line	Crab Pot	Float-line	Crab Pot	Float-line
2023#	13	2		1	2	3
2022	15	23		2	3	7
2021	20	18		1	5	7
2020	4	17	1	1	7	9
2019	11	5		1	3	13
2018	13	11			3	16
2017	17	21		1	3	11
2016	12	12	3	3	4	9
2015	13	7		2	2	5
2014	14	16	1	1	6	5
2013	16	10	2	2	7	5
2012	16	18		3	3	7
2011	11	11		1	6	5

#data to 04/04/2023, year incomplete.

The majority of reported marine turtle interactions with crabbing apparatus (crab pot or float-line) were from southeast Queensland (Figure 30): greater Moreton Bay region (82%), Great Sandy Strait and Hervey Bay/Fraser Island (both 6%). This likely reflects the overlap in human population density (for sightings and crabbing effort) and marine turtle density. This spatial pattern did not change significantly when only more recent years of data were considered.

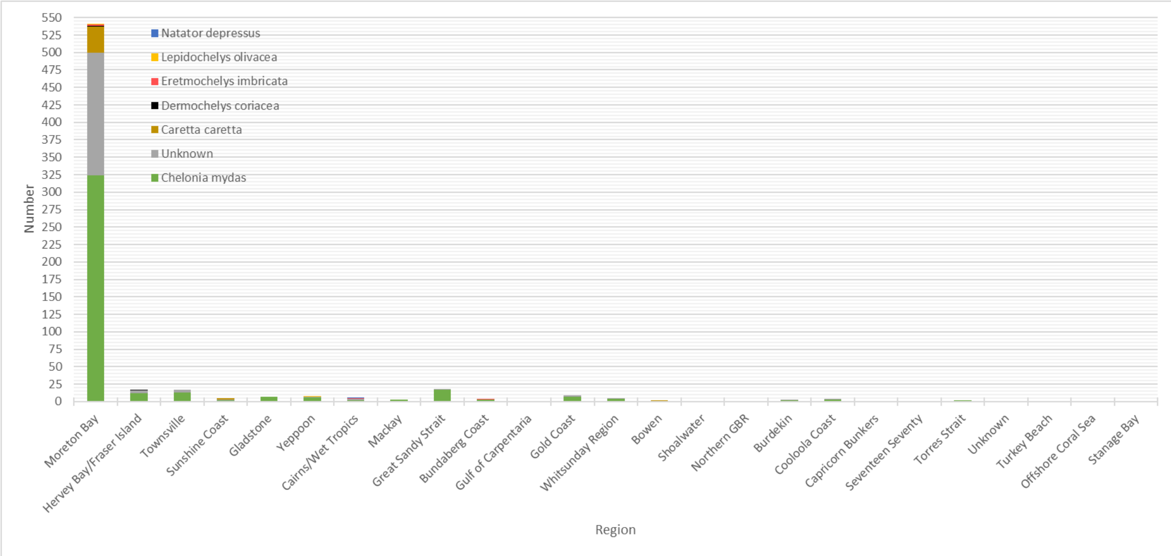

Figure 30. Number of (verified) reported marine turtles in StrandNet by region where the entanglement type was attributed to crabbing apparatus either pot entrapment or float-line entanglement, (all years pooled - 1962 to April 2023).

There was a clear seasonal trend in reported marine turtle strandings for the greater Moreton Bay region, (Figure 31). Strandings were three to four times greater in summer months than winter months, potentially reflecting the seasonality in crabbing effort and human activity on the water and adjacent foreshores.

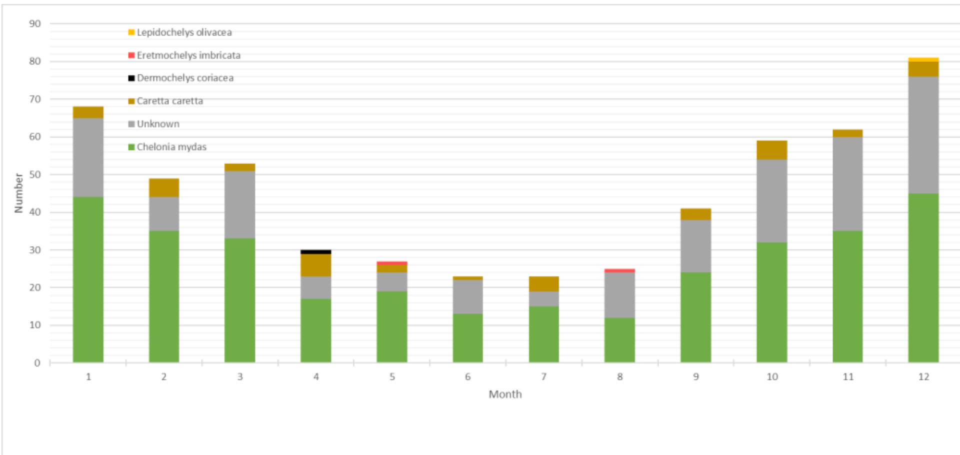

Figure 31. Monthly number of (verified) reported marine turtles for the greater Moreton Bay region (26.8°S to 28.35°S) in StrandNet where the entanglement type was attributed to crabbing apparatus either pot entrapment or float-line entanglement, (all years pooled - 1962 to April 2023).

Marine turtle morphometrics

StrandNet data were further investigated for the size of marine turtles interacting with crabbing apparatus. Two hundred and fifty-four stranding reports included size information. Green turtles had the most reports that included size information (n = 223). For green turtles (Figure 32), there was a distinct peak in the size of animals entrapped in crab pots (i.e., 40 to 50 cm CCL, range 30 to 65 cm). The peak size of green turtles entangled in float-lines was between 95 and 110 cm CCL, ranging from 40 to 120 cm CCL (Figure 32). At 30 cm CCL, green turtles are (on average) 25 cm SCW and 10 cm CH, based on the equations in Table 22.

There were few reports of size information for other marine turtle species entrapped in crab pots. Based on the equations in Table 22, at 30 cm CCL, the other marine turtle species were similar in SCW and CH to that of green turtles, noting that flatbacks were slightly wider but about the same height (~29 cm SCW, 10.0 cm CH) and hawksbills slightly smaller (~21.0 cm SCW, no estimate of CH). The implications of these morphometrics are considered further in the Discussion.

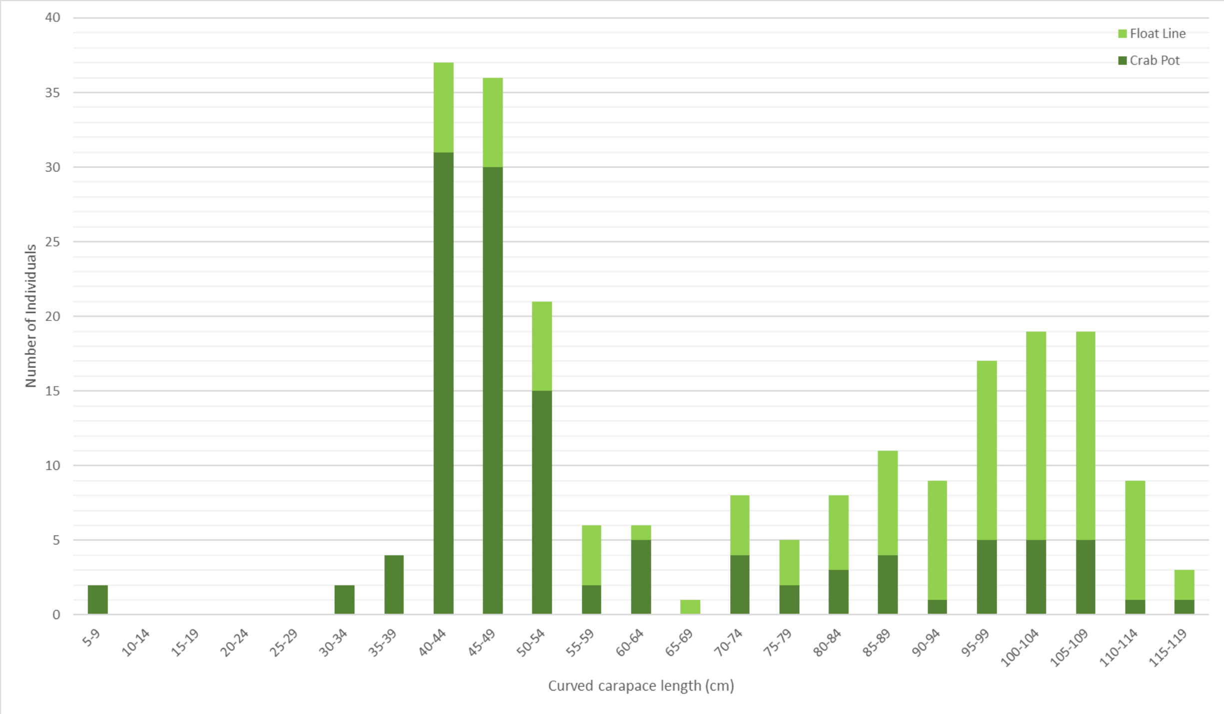

Figure 32. Size distribution of (verified) reported green turtles in StrandNet between 1962 to April 2023, where the entanglement type was attributed to crabbing apparatus either pot entanglement (dark green) or float-line entanglement (light green).

Threatened, endangered and protected species (TEPS) logbook

Between 2006 and September 2023, 18 marine turtles were reported interacting with the commercial C1 fishery. Green turtles were the most commonly reported species (55%), then loggerhead turtles (17%), with few reported interactions with leatherback and hawksbill turtles. Three-quarters of the reported interactions released the marine turtle alive, with the remainder released dead. The species mix in the TEPS logbook was more consistent with the StrandNet data than that reported in the Level 1 ERA (Walton and Jacobsen 2019) – i.e., green turtles are the species most likely to interact with crabbing apparatus followed by loggerhead turtles. This is likely the consequence of the overlap in high commercial crabbing effort in areas of high abundance for green and loggerhead turtles (i.e., marine embayments). Hawksbill turtles are more associated with rocky and coral reef habitats, which are not favoured habitats of Giant Mud Crabs and associated crabbing effort. Leatherback turtles are more oceanic, which is a location not favoured for Giant Mud Crabs, but at certain times and in certain places is associated with some Blue Swimmer Crab commercial operations.

Table 26. Threatened, endangered and protected species logbook reported interactions with marine turtle for fishing method = potting (crab), species = marine turtle.

Year	Green	Loggerhead	Hawksbill	Leatherback	Saltwater unspecified	Grand Total
2006					2	2
2009		2				2
2010	1					1
2012			1			1
2013	1					1
2017	1					1
2018		1				1
2020	1					1
2021	1			1		2
2022	4			1		5
2023	1					1

Discussion

The review of marine turtle interactions with crabbing apparatus reported to StrandNet provided evidence that:

- Interaction rates are low, given an estimated order of magnitude of one million commercial pot days on the Queensland east coast, 100,000 commercial pot days in the Gulf of Carpentaria, and over 400,000 pot days in the recreational sector[8].
- The key species affected are green and loggerhead turtles.
- Crab pot entrapment has very high mortality (89%).
- Float-line entanglement has high mortality (56%).
- Rectangular and lightweight pots account for two-thirds of interactions.
- Reported entrapment numbers were similar in crab pots of fair to good condition (working pots) and 'ghost' pots.

Crabbing effort is not spatially or temporally uniform. Interactions were more common in areas where crabbing effort and marine turtle densities are high, such as embayments - particularly Moreton Bay and Hervey Bay.

There is limited information upon which to speculate about the relative abundance of 'working' pots compared to 'ghost' pots. It is likely that there are relatively fewer 'ghost' pots in Queensland waters than active 'working' pots, but this may vary spatially and temporally, with any estimate of their relative abundance being highly speculative.

Regardless of their actual relative abundance, 'working' pots are usually checked on a regular basis, and there is the potential for a marine turtle interaction to be dealt with before it becomes a mortality. Ghost pots are not checked on a regular basis, and therefore pose a greater mortality risk to marine turtles. Thus, all efforts to eliminate or reduce the abundance of ghost pots – either through pot clean ups (e.g. https://www.abc.net.au/news/rural/2023-06-16/illegal-crab-pots-clean-up-pumicestone-passage-fishing/102482952) or regulating to reduce the number of pots that are 'lost' and thus become 'ghost' pots should be a priority for management, gear manufacturers and operators of crab pots regardless of sector, as this could have a major impact on reducing marine turtle mortalities. Potential means of mitigating marine turtle interactions with crab pots are discussed further below.

StrandNet reports of marine turtle interactions in crabbing apparatus was dominated by occurrences in the greater Moreton Bay region. Green turtles from this feeding ground are predominately (~90%) from the southern GBR stock (FitzSimmons and Limpus 2014), with a small proportion from the Coral Sea stock and northern GBR stock. The southern GBR green turtle stock, while depleted, has been on an increasing trajectory based on feeding ground monitoring of adults and juveniles (trend = moderate recovery, *Queensland Marine Turtle Conservation Strategy 2021 – 2031*). The mortality on this stock from interactions with crabbing apparatus reported in StrandNet is in the tens of individuals per annum. However, this level of mortality occurs in most years, such that cumulative effects over a decade are an order of magnitude higher (i.e., ~100).

Loggerhead turtles feeding in Moreton Bay are from the southwest Pacific stock, which is severely depleted and has a 'poor' stock outlook (*Queensland Marine Turtle Conservation Strategy 2021 – 2031*). The mortality on this stock from interactions with crabbing apparatus is fewer than five individuals per annum. However, this level of mortality occurs in most years, such that cumulative effects over a decade are an order of magnitude higher (i.e., ~50).

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[8] based on logbook days effort by primary commercial licences reporting mud crab harvest, assuming 35 pots per C1 symbol (likely an underestimate) and State-wide Recreational Surveys for the recreational sector (likely an underestimate due to non-legal behaviour e.g., sunk pots).

Hawksbills, olive Ridleys, leatherbacks and flatbacks were rarely reported as interacting with crabbing apparatus, although these species could be in the unidentified species records. The above information could be considered as a refinement to the Level 2 ERA for the Crab Fishery, particularly the level of impact (i.e., mortality) from bycatch interactions for each of the 10 genetic stocks of marine turtles in Queensland.

Reducing and/or mitigating marine turtle interactions in crabbing apparatus in the greater Moreton Bay region (and more broadly southeast Queensland i.e., Hervey/Bay to the Queensland New South Wales border) would address a large proportion of the interactions. Any appropriate mitigation measures (options discussed below) should be considered in other areas where interaction occurs.

Mitigation options

Without change, it is unlikely that the numbers of marine turtles interacting with crabbing apparatus (see Table 24) and experiencing mortality will decline, unless recreational and/or commercial crabbing effort significantly declines. Therefore, mitigation options are limited to: (i) modifying either the fishing apparatus (pot and float-line) through design alteration or (ii) reducing effort, either spatially or temporally.

Gear modification

Crab pots

The risk of marine turtle entrapment in crab pots could be reduced by improving the 'quality' of crab pots used in Queensland but requires improved apparatus definitions in the *Fisheries (General) Regulation 2019.* More specific apparatus definition would align Queensland regulations with those of other Australian jurisdictions (see Table 1). The aim of improved apparatus definition could be to:

(i) require entry funnel inner openings to be of a size such that crabs can enter but marine turtles, especially juveniles, cannot.
(ii) reduce the risk of pots becoming lost and thus contribute to ghost potting.

A review of the StrandNet data provided strong evidence that rectangular and 'lightweight[9]' crab pots (see Figure 29 (a) and (b)), were involved in about two-thirds of marine turtle entrapment in pots. These pot designs often have wide entry funnel inner openings (i.e., entrance dimensions). For example, rectangular pots (880 mm long by 550 mm wide by 200 mm high) have two 'open V shaped entry funnels that are 550 mm wide by 28 mm high (Leland *et al*. 2013). There are multiple styles of 'lightweight' pots, but those indicated more frequently in marine turtle entrapment (Figure 29 (b)), popular in use and still readily available in tackle stores, have four entry funnels. Examples of wide entry funnel inner dimensions measured by project staff are 450 x 120 mm, and 270 mm by 65mm. Such dimensions readily allow marine turtles, especially juvenile turtles, to enter the pot.

One modification that aims to reduce turtle entrapment is 'turtle strings', which are twine placed vertically at the mid-point of entry funnels to reduce the entrance size and reduce the risk of wildlife such as marine turtles entering the pot (Figure 33). OceanWatch Australia recommends the addition of a heavy ply twine at the centre of each entry funnel (i.e., 'turtle strings'), as well as two extra steel rings to reduce the ability of marine turtles to tear holes in the meshes of the crab pots and to give the pot extra weight to reduce accidental movement and loss of the pot (i.e., ghost pots). While the concept is valid, there is limited evidence of the efficacy of the strings at discouraging marine turtles from entering the pot. Thirty-nine records in StrandNet for marine turtles interacting with crabbing apparatus noted the lack of turtle exclusion modifications, with a single record (of float-line entanglement) noting the pot had turtle exclusion modifications. At present, such modifications are voluntary. However, some operators in the C1 fishery, in the northern Moreton Bay region have 'turtle strings' installed in the entry funnels of their pots, reducing the unobstructed entry width to 180 mm (Figure 33).

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[9] rings of <10 mm steel, and < 27 mm mesh ply.

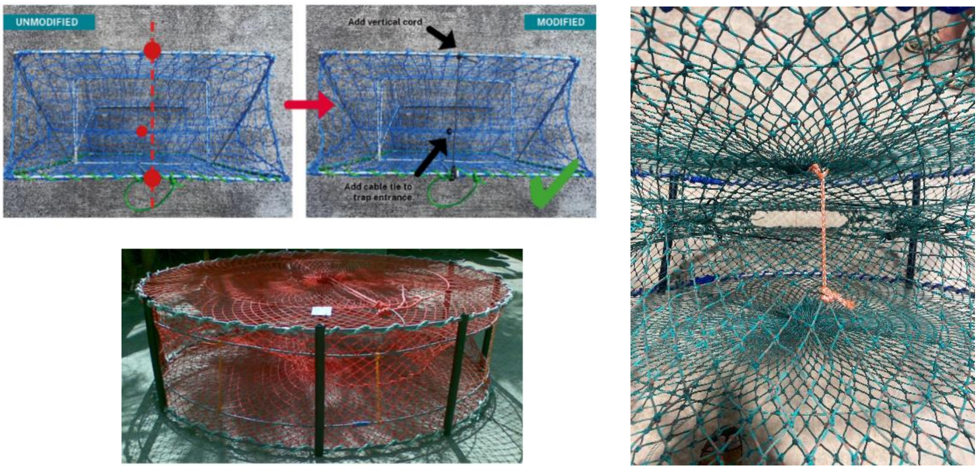


Figure 33. Examples of turtle strings: (a) reproduced from [https://www.dpi.nsw.gov.au/fishing/recreational/fishing-skills/responsible-fishing-guidelines/crab-traps-preventing-turtle-drownings,](https://www.dpi.nsw.gov.au/fishing/recreational/fishing-skills/responsible-fishing-guidelines/crab-traps-preventing-turtle-drownings) (b) Oceanwatch (reproduced from https://www.oceanwatch.org.au/wp-content/uploads/2016/07/Turtle-smart-crab-pot-1.pdf) and (c) installed the entry funnel of a 1000 mm diameter trawl mesh pot, three meshes in from the bottom ring (photo credit P. Hyland).

An alternative to 'turtle strings' would be to design entry funnel inner openings such that side-ways moving crabs can enter but that marine turtles are too large to enter. In principle, this would require maximum dimensions to be specified for entry funnel openings. In some states of the USA, crab pots for Blue Crabs (*Callinectes sapidus* equivalent to the Blue Swimmer Crab) are required to be installed with bycatch reduction devices (BRDs; Roosenburg and Green 2000; Butler and Heinrich 2007; Reinsel *et al*. 2023). These BRDs are constructed of plastic or wire, are oval or rectangular in shape, and are installed in each of the entry funnels to allow the entry of Blue Crabs but exclude Terrapin Turtles.

The project team has been trialling entry funnel 'shark' excluders, lent to the current project from the CSIRO-DECCEEW TEP mitigation research project on speartooth sharks (https://www.dcceew.gov.au/environment/marine/marine-species/reducing-bycatch-threatened-migratory-species). These excluders are stainless steel rectangular BRDs (240 mm x 65 mm) designed to exclude juvenile speartooth sharks from entering crab pots in the northern Gulf of Carpentaria (Figure 34). A similar BRD could be designed to exclude marine turtles from entering crab pots in southeast Queensland. Based on morphometric differences between Giant Mud Crabs and marine turtles, an entry funnel excluder 150 mm wide by 100 mm high should be suitable to allow the entry of all legal Giant Mud Crabs but prevent the entry of marine turtles. The largest male Giant Mud Crab measured for carapace length (a 2 kg crab of 195 mm CW) had a carapace length of 130 mm and a carapace height of 76 mm, which would be able to walk side-ways into an entry funnel fitted with a shark excluder that was larger than 150 mm wide but less than 250 mm wide.

Figure 34. Shark excluders (240 x 65 mm stainless steel rod rectangle) fitted mid-way along funnel entrance of a commercial grade 'heavy duty' crab pot being trialled in southern Moreton Bay. Noting that the placement aims to not change the natural angle of the entry funnel.

Limiting the maximum size of the entry funnel could also be achieved through the cut and design of mesh entry funnels. Their maximum internal opening dimension is function of the pot diameter (if round), whether there are two, three or four-entry funnels, whether the funnels are 'sewn in' or are the side-wall of the pot 'drawn inwards' and the degree of tightness of the inner tensioning funnel strings. During fishery-dependent sampling, project staff observed pots that had entry funnels that were in the order of 200 mm wide, usually being 'sewn-in' funnels of 20 to 25 meshes round. Commercial crabbers using wire NT-style pots had entry funnels constructed of plastic mesh (e.g. gutter guard style), with these entry funnels being ~180 mm in width.

There is significant scope for improving the design and specification of crab pots used in Queensland, such that legal crabs (Giant Mud Crabs or Blue Swimmer Crabs) can enter pots, while marine turtles are prevented. Whether bycatch reduction device modifications to crab pots (aka 'turtle friendly crab pots') are required in areas where interaction is greatest (e.g., greater Moreton Bay) or are required state-wide is a matter that requires further consideration.

Campbell and Sumpton (2009) reported a perception that 'light weight pots' were a major contributor to ghost pots. An ongoing point of discussion at most meetings of the Fisheries Queensland Crab Working Group has been to improve fisheries regulations such that 'lightweight' and rectangular pots will not be permitted apparatus in Queensland. A review of the StrandNet data indicated that active 'working' crab pots and 'ghost' pots were equally represented in the reports of marine turtle entrapment and that 'ghost pots' involved with entrapment were equally lightweight or heavy duty. It is likely that working crab pots are more abundant than ghost pots in the marine environment, although any estimate of would be speculative. However, the evidence suggests a disproportionate contribution of ghost pots to marine turtle entrapment and associated mortality and population impacts.

We support changes to the definition of crabbing apparatus in the Queensland *Fisheries (General) Regulations 2019* that would lead to fewer working pots becoming 'ghost' pots. We also support the removal of 'ghost' pots from the environment, via regular clean-up programs.

Float-lines

More challenging is finding a means to reduce the risk of marine turtle entanglement in the float-lines (independent of pot type) as all rope (non-sink, weighted, sink, lead core) is an entanglement risk. However, the less rope in the water, the less risk of entanglement. There have been calls to require float-lines attached to crab pots be made from sinking rope or lead core rope. New South Wales have addressed the issue of float-lines by specifying that for commercial crab traps that they must be "moored in such a way that no rope is floating on the surface of the water" (Fisheries Management (Estuary General Share Management Plan) Regulation 2006 - NSW Legislation), and for recreational crab traps "there must also be a 50 gram weight attached to the float/buoy line so that no line is floating on the surface of the water" (Permitted and prohibited saltwater fishing methods (nsw.gov.au)).

Reducing the amount of rope associated with crab pots in Queensland waters may require a different means in different sectors (commercial versus recreational), different locations or pots targeting different crab species (i.e., Giant Mud Crabs compared to Blue Swimmer Crabs). Advances are being made in 'ropeless' fishing (Stevens 2021) and may become a cost-effective solution in areas or seasons where there is high interaction.

Chapter 4. Options for improving bycatch reduction in the recreational sector of the Queensland crab fishery

Mud crabbing is a popular recreational fishing activity in Queensland, with Giant Mud Crabs being one of the most harvested crustaceans (Teixeira *et al*. 2021) and being the most commonly targeted species in boat ramp surveys by Fisheries Queensland (all regions pooled).

Recent statewide estimates of recreational fishing for the 2019/2020 year indicate that across Queensland, about 797,658 mud crabs are caught, of which 160,087 (~20%) are retained for harvest. The remainder (637,571 mud crabs ~80%) are released/discarded for a number of reasons, including regulations on minimum legal size and sex (Dashboard | Department of Agriculture and Fisheries, Queensland (daf.qld.gov.au). These results are reinforced by boat ramp survey data, which indicate similar levels of harvest and discard (https://www.daf.qld.gov.au/business-priorities/fisheries/monitoring-research/monitoring-reporting/boat-ramp-survey-program/dashboard).

The use of escape vents in recreational crab pots could improve bycatch reduction and reduce the number of Giant Mud Crabs that need to be manually released/discarded. As noted in Chapter 2, about half of recreational fishers reporting tagged Giant Mud Crabs accepted the offer to trial free escape vents (120 x 50 mm). This suggests that there is somewhat a desire in the recreational sector to have improved selectivity in recreational crab pots for legal male crabs.

A common reason for the lack of use of escape vents in recreational crab pots is the dual targeting of Blue Swimmer Crabs and Giant Mud Crabs in some areas (e.g., parts of Moreton Bay). While these species do co-occur at certain times and certain places (Broadhurst *et al.* 2020), in many instances recreational fishers are targeting one species more than the other. Arguments against escape vent requirement in recreational pots targeting Giant Mud Crabs is that escape vents would preclude the capture of Blue Swimmer Crabs. Broadhurst *et al*. (2020) identified a means of overcoming this problem by temporarily attaching an escape vent designed for Blue Swimmer Crabs (internal escape opening of 120 mm x 36 mm) to a permanently fitted escape vent designed for Giant Mud Crabs (Figure 35).

During the current project, discussions were held with manufacturers of recreational crab pots who were supportive of the concept of escape vents in recreational pots and who were considering regional market trials.

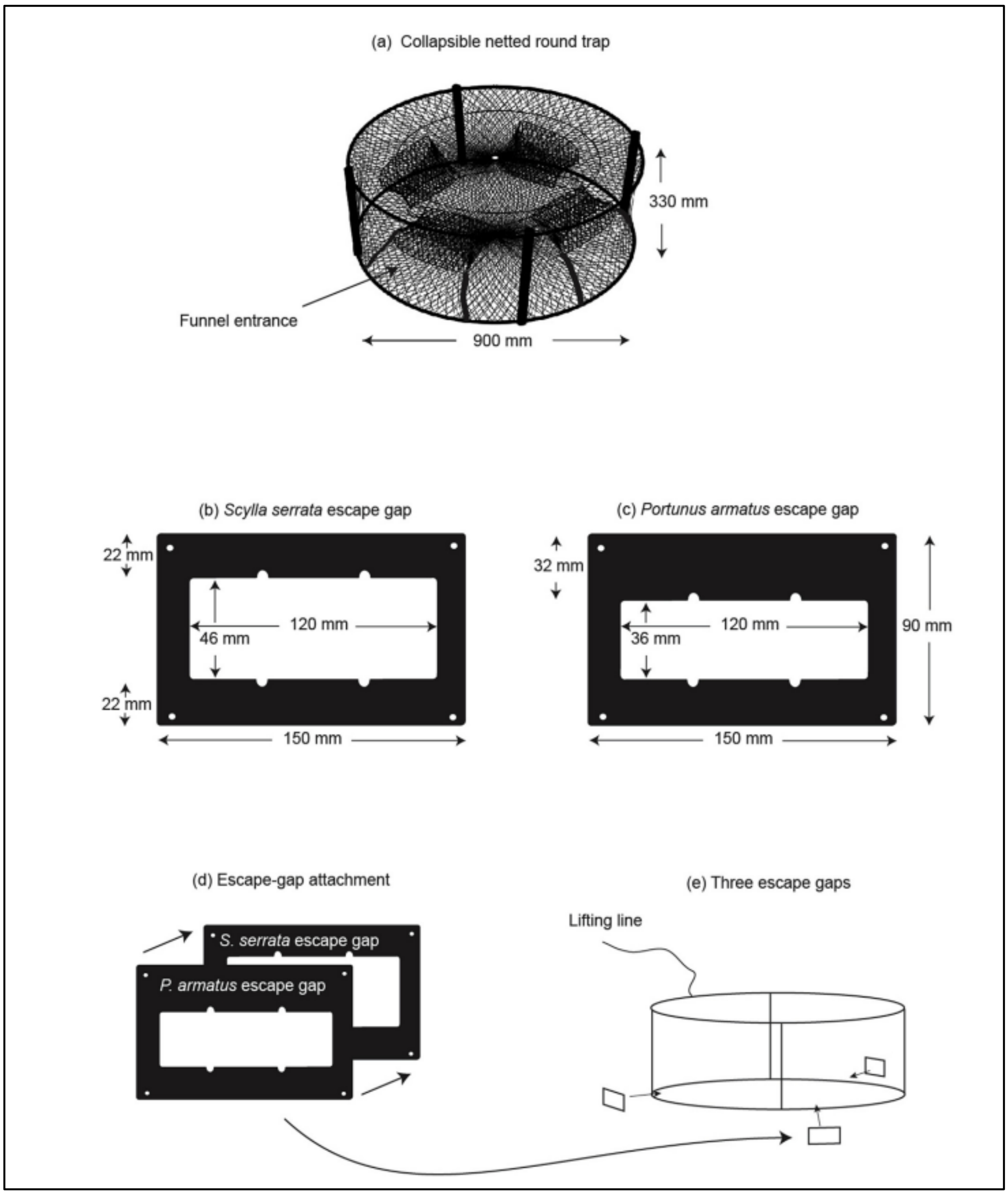


Figure 35. Escape vents fitted to collapsible polyethylene mesh pots: (a) conventional collapsible, polyethylene mesh round crab pot with four entry funnels; with escape vents suitable for (b) Giant Mud Crabs - NSW legal size, (c) Blue Swimmer Crabs, (d) the temporary overlay attachment configuration, and (e) bottom edge placement of multiple vents. Reproduced from Broadhurst et al. (2020).

Recommendations:

- Escape vents to be required in recreational pots targeting Giant Mud Crabs in Queensland, including a definitive date for compulsory use so that a phase in approach can be adopted by gear manufacturers, importers and fishers.

- Crab pots have more prescriptive definition in the Queensland *Fisheries (General) Regulation 20*19 to ensure apparatus are of a similar standard to that required in other states and territories (see Table 1).

- To support the recreational sector using crabbing apparatus that is less likely to have wildlife interactions, especially in regions where marine turtle interactions are frequent (i.e., Moreton Bay, Hervey Bay, Great Sandy Strait), consider a 'gear-exchange' program (https://www.marine.nsw.gov.au/knowledge-centre/newsroom/news/helping-crab-fishers-embrace-more-environmentally-friendly-options2?follow_link=true), where rectangular traps and/or lightweight pots are exchanged for preferred responsible-fisher crab pots (i.e., 800 mm, 10 mm steel rings, fitted with escape vents, turtle strings and sink rope).

Chapter 5. Conclusions, implications, recommendations

Conclusions

The current research gathered empirical data on two bycatch related issues in the Queensland Crab Fishery: (i) the performance of currently regulated and alternate escape vents in crab pots targeting Giant Mud Crabs, and (ii) marine turtle interactions with crabbing apparatus. This quantitative information can inform discussion on the issues and relevant management decisions to improve the sustainability of the Queensland Crab Fishery.

Escape vents used in pots targeting Giant Mud Crabs in the Queensland Crab Fishery should support commercial outcomes (i.e., retention of legal male crabs) whilst minimising the bycatch of non-legal crabs, finfish and other bycatch species such as water rats. Measurement of ~11,000 males and ~5,000 females across Queensland found statistically significant regional variation in Giant Mud Crab morphometrics (i.e., the relationship between notch width to carapace height to carapace length. However, this variation was not biologically meaningful, with generally very small (i.e., <1 mm) regional morphometric differences, especially for near-legal male Giant Mud Crabs (i.e., 148 to 151 mm CW). Results indicated that provided the escape vents are in good working order (i.e., not distorted), the 120 x 50 mm escape vent retains legal Giant Mud Crabs whilst allowing many crabs less than 150 mm CW and fish to escape. The 105 round vent allows Giant Mud Crabs up to 152 mm CW to escape, thus including some just legal Giant Mud Crabs. The 75 x 60 mm escape vent retains Giant Mud Crabs of 115 mm CW or greater, offering limited escape opportunities for sub-legal crabs and fish.

The review of StrandNet data indicated that green and loggerhead turtles are the main marine turtle species interacting with crabbing apparatus in Queensland. Mortality occurred for greater than >50% of reported marine turtle interactions with crabbing apparatus. Rectangular and lightweight pots accounted for two-thirds of reported interactions. Reports of marine turtle entrapment were similar in crab pots of good to fair condition (i.e., 'working pots) and 'ghost' pots. Interactions were more common in areas where crabbing effort and marine turtle densities are high such as Moreton Bay and Hervey Bay. On average, about 50 interactions between marine turtles and crabbing apparatus were reported to StrandNet each year, suggesting that overall interaction rates are low in the Queensland Crab Fishery given the intensity and popularity of crabbing throughout the state (i.e., estimated more than 1.5 million pot days per year, all sectors, areas and target species combined). Mortality of endangered loggerhead and vulnerable green turtles could be partially mitigated by changes in fishing practices (i.e., gear modification). Improved definitions of crabbing apparatus (pot and float-line) in the Queensland *Fisheries (General) Regulation* 2019 to reduce the risk of marine turtle entrapment should be an aim of crab fisheries management in Queensland.

Mud crabbing is a popular recreational fishing activity in Queensland. Escape vents in crab pots are commonplace in other pot fisheries, within Australia and overseas. Mandatory escape vents in recreational crab pots targeting Giant Mud Crabs would have the same benefits as currently occurs in the commercial sector i.e., no loss in the catch of legal male Giant Mud Crabs, but reduced capture, injury and mortality of crabs less than 150 mm CW, finfish and protected species such as water rate. We recommend escape vents in recreational crab pots targeting Giant Mud Crabs should be a long-term aim of management in Queensland.

Implications

Crabbing is an important commercial and popular recreational fishing activity in Queensland. Its sustainability could be improved by regulating appropriately sized escape vents in crab pots targeting Giant Mud Crabs, so that legal crabs are retained whilst the bycatch of crabs less than 150 mm CW, finfish and other protected species such as water rats is reduced. The sustainability of the Queensland Crab Fishery could also be improved by more specific definitions of crabbing apparatus (pot and float-line) with the aim of reducing the risk of marine turtle interactions, which has been a long-standing issue for this fishery.

Recommendations

Regarding escape vents, we recommend:

(i) No changes to the dimensions of the 120 x 50 mm rectangular escape vent, as the data indicates that most legal male Giant Mud Crabs of 150 mm carapace width are not able to exit, unless their carapace has deformed or the carapace has not yet hardened (i.e., C-grade crab).
(ii) Consideration be given to reducing the minimum diameter of the round escape vent from 105 mm to either 100 or 95 mm, so that most legal male Giant Mud Crabs of 150 mm carapace width are not able to exit, noting that smaller escape vents reduce the ability of finfish bycatch to escape.
(iii) Consideration be given to removing the two 75 x 60 mm escape vent option from regulation as they provide marginal benefit.
(iv) Escape vents be constructed out of material that is not able to be distorted out of shape, such that the escape vent no longer performs as intended.
(v) Escape vents are installed near the bottom of the pot i.e., within 30 to 50 mm of the bottom of the apparatus, not literally 'on the bottom edge' as has been interpreted by some enforcement officers.

Regarding marine turtle entanglement in crabbing apparatus, we recommend:

(i) Crab pots and associated float-lines have improved design, potentially via more prescriptive definitions in the Queensland fisheries regulations, such that marine turtles have less risk of entry or entanglement in gear that is being actively worked.
(ii) Working apparatus has less possibility of being lost or abandoned, such that a working pot and float-line becomes a ghost pot and would include the removal of 'lightweight' pots being a legal option in Queensland waters.
(iii) Ghost pots and float-lines are removed from the environment of a regular basis to minimize the time they pose a risk to wildlife, including threatened and endangered marine turtles.

To achieve the above recommendations legal crab pot definitions in Queensland could be more prescriptive in terms of:

(i) Entry funnel dimensions, with the aim of reducing the marine turtle entry into crab pots, based on size differences between Giant Mud Crabs and marine turtles.
(ii) Design, to bring Queensland crab pot regulations in line with that of other Australian jurisdictions, with the aim of reducing the number of crab pots that become 'ghost' pots, potentially by requiring the diameter of the rings in circular collapsible mesh pots to be ≥ 10 mm, thus increasing the weight of these pots.

The recreational crabbing sector in Queensland is significant, both in terms of number of participants and spatial extent of activity. Its participants are diverse and have a range of approaches, in gear quality and behaviour. Without government regulation or significant leadership, we expect little change will occur in this sector, and hence our recommendations for regulatory change. Regarding escape vents in the recreational sector, we strongly recommend that escape vents be regulated into this sector, as the catch of legal male Giant Mud Crabs can be unaffected whilst permitting sub-legal crabs and fish to escape. One argument against escape vents in crab pots is the current escape vent sizes allow Blue Swimmer Crabs to escape. However, Blue Swimmer Crabs are not targeted at all times and locations where Giant Mud Crabs are targeted. Escape vents can be readily modified to allow retention of the smaller and thinner Blue Swimmer Crabs by the simple addition of string, cable ties or temporary overlay attachments (Figure 35).

Currently, crab pots are defined in the Queensland *Fisheries (General) Regulation 2019* as 'fishing apparatus consisting of a cage with a round opening in the top or an elongated opening (parallel to the based) in the side for trapping crabs". We recommend that crab pots have a more prescriptive description to improve the selectivity of the gear, reduce marine turtle interactions, reduce the risk of 'working pots' becoming lost or abandoned, and thus becoming 'ghost' pots, and to align crab pot definitions in Queensland with that of other Australian jurisdictions (see Table 1).

Further development

The current project noted the size differential between Giant Mud Crabs and marine turtles. There is potential further development in the design (including size) of crab pot entry funnels so that crabs can enter pots and marine turtles are excluded. Turtle 'strings' are advocated as one solution to this problem, although we found little evidence for or against the efficacy of turtle strings at discouraging turtles from entering crab pots. However, we concur with the principle of creating an impediment to the forward movement of marine turtles into the entry funnels of crab pots.

Chapter 6. Extension and adoption

In June 2022, Fisheries Queensland emailed and sent hard copy letters to all active C1 symbol holders advising of the project and seeking permission to share their contact details with project staff so commercial fishers could contribute to (i) the survey of current use of bycatch reduction devices and strategies in the fishery, and (ii) determine their interest in engaging with observers to quantify escape vent performance in regional commercial crabbing operations.

Social media post 3 March 2023 by Agriculture Queensland, reposted 23 March 2023 by Fisheries Queensland (DAF) – Social media post about reporting tagged Giant Mud Crabs (2019-062) with the offer of a free escape vent (2021-119). FRDC was consulted on the draft of the post, which had over 15 million views across social media.

An associated media release was published on a number of sites:
https://bnbfishing.com.au/free-crab-escape-vents-offered/
https://www.sail-world.com/news/259528/Find-a-yellow-tagged-crab-to-get-free-escape-vent

FRDC News article June 2023 Research in Queensland is focused on maximising the commercial and ecological health of one of northern Australia's iconic species, the Giant Mud Crab.

Preliminary results for the project were presented to the Fisheries Queensland Crab Working Group in March 2023.

Final results for the project were presented to the Fisheries Queensland Crab Working Group in March 2024.

Presentation to FRDC's Queensland Research Advisory Committee meeting March 2024

Results from the current project were used to inform a discussion paper on management reforms regarding the prohibition of lightweight crab pots in Queensland March 2024 (https://daf.engagementhub.com.au/recreational-fishing).

Results from the current project were used to inform a discussion paper on management reforms regarding changes to regulated escape vent sizes in commercial pots targeting Giant Mud Crabs in Queensland (March 2024) (https://daf.engagementhub.com.au/crab-consultation).https://daf.engagementhub.com.au/crab-consultation)

Draft results collating marine turtle interactions with crabbing apparatus were shared (in-confidence) with Dr Colin Limpus (Chief scientific officer, Wildlife and Threatened Species Operations, Department of Environment and Science, Queensland).

Subsequent to the submission of the draft final report, meetings were held with gear manufacturers who are major suppliers to the recreational and commercial fishery, to extend results regarding size differences between Giant Mud Crabs and marine turtles, with the aim of engaging manufacturers to adopt possible changes to entry funnel sizes and thus reduce the risk of marine turtle entrapment in crab pots.

Results were also discussed (23rd May 2023) with the Queensland National Park and Wildlife Service (Moreton Bay base at Manly), who oversee many of the marine turtle strandings and the StrandNet database, to extend results and obtain their feedback on the interactions between marine turtles and crabbing apparatus.

Project materials developed - Escape vent installation flyer

Department of Agriculture and Fisheries

Mud Crab Fishery Escape Vents

Escape Vents in crab pots enable the release of sublegal size crab and fish bycatch before retrival. Less undersize crabs in pots makes it easier to sort your catch and reduces the risk of crabs damaging each other when pots are crowded.

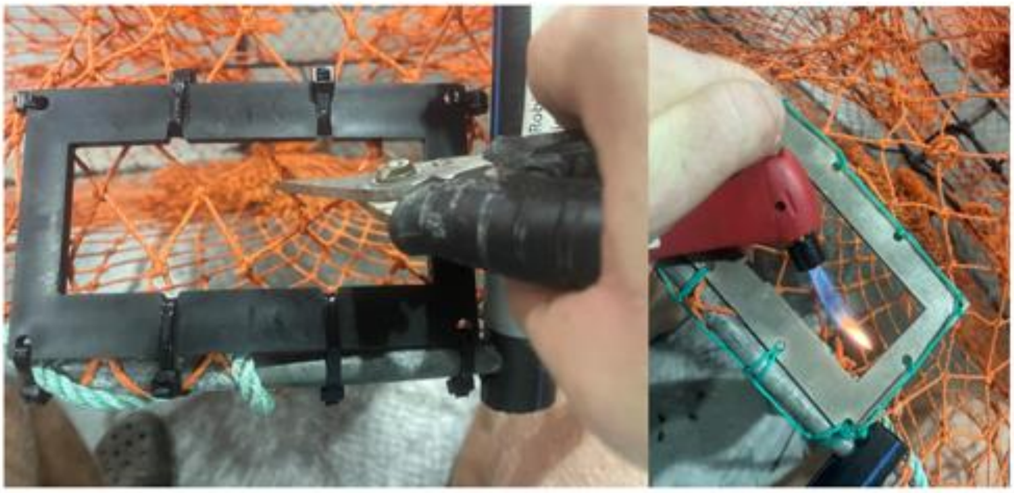
120mm x 50mm Escape Vent Installation

1. Vents can be cable tied or bound with twine into pots. The 120 x 50 mm aluminium vents are predrilled with 10 attachment holes which will take a ziptie up to 3.2mm (width). The plastic vents come with 4 holes and 4 slots for attachment.
2. Select a location to install. We find that in 900 mm, 4 funnel pots the bottom or top ring adjacent to an upright is good choice as the vent will sit flat and installation won't effect the tightness of the funnels. Make sure your pot it set up (all 4 legs) before installing.
3. Dryfit the escape vent in the selected location to ensure sits nicely (meshes maitin their natural shape). Fitting is easiest if you start attaching on the ring of the crabpot, then work around the meshes ensuring a tight fit.

FRDC

Queensland Government

4. Once firmly bound or cable tied into place, trim the tag ends and cut out meshes behind the vent making sure to heat treat (singe) the cut ends to prevent the mesh unravelling. If you have one, a heatknife is handy for this part of the process.



Congratulations! Your vents have been installed. One vent per pot is good but two vents per pot is great.

FAQs

What size crabs will these 120mm x 50mm vents let out?

- In rectangular vents, height is the variable which controls the size of crab which can escape. Of roughly 8000 crabs measured across QLD, no legal male mud crab has a body height or claw height that would allow it to exit through this size vent. Most sub-legal mud crabs with a carapace width of 135mm and below will be able to exit pots via this size escape vent.

Will these vents exclude all of undersize crabs from my pots?

- Undersize crab will still enter your pots however in research trials to date have less small mud crab in pots fittted with escape vents. By attaching your float line on the bottom ring directly opposite the vent location, small crabs remaining in the pot at time of retrevail often fall out while pulling them in.

I use my pots for mud crabbing and sand crabbing, will sandcrabs get out of this size vent?

- Yes, if you want to chase sandcrab in pots with vents installed simply put a ziptie or two across the center of the vent.

Will attaching a aluminium vent to the galvanised ring of my crabpot cause issues?

- If you have concerns about electrolosis attach vent in a location where it will not be in constant contact with a galvanised ring.

Appendix 1. Project staff

Department of Agriculture and Fisheries, Queensland (in alphabetical order)

Dr Susannah Leahy, Senior Fisheries Scientist, Fisheries & Aquaculture, Agri-Science Queensland

Dr Julie Robins, Principal Fisheries Scientist, Fisheries & Aquaculture, Agri-Science Queensland

Mr Samuel Seghers, Fisheries Technician, Fisheries & Aquaculture, Agri-Science Queensland

Mr Nicholas Stratford, Fisheries Technician, Fisheries & Aquaculture, Agri-Science Queensland

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Appendix 3. Questionnaire for escape vents and bycatch reduction strategies in the mud crab component of the Queensland Crab Fishery

QDAF are doing some work on escape vents in crab pots, as they have been regulated into the mud crab component of the Queensland Crab Fishery. If your happy to have a chat, can I ask you a few questions about the type of vent you've gone with?

Fisher Name:

Main area fished and how long have they been involved in the crab fishery?

What sort of pots do you run? (Collapsible, diameter, bought/home-made, gauge of steel ring).

On average how many pots do you run?

What escape vents are in your pots? And how are they positioned in relation to funnel entrances and struts?

- **One large rectangular escape vent (120 mm x 50 mm)**
- **Two small rectangular escape vents (75 mm x 60 mm)**
- **One round escape vent (diameter of at least 105 mm).**

What do you think of escape vents in crab pots?

What's good? Is there anything you would like to change?

Prior to escape vents being regulated, what sort of bycatch did you get in your pots?

If we were to run some research trials on escape vents, what changes would you be interested in seeing tested – with potential for improvements in escape vent specification in the regulations?

Over a crabbing season, how many pots would you lose? And What do you think is the major cause of pot loss: weather / tidal run / theft / turtles / other.

Has pot loss increased / decreased / or remained the same over the years (circle).

Have you ever had a sea turtle caught in your gear? Entangle in rope or entangle in the pot itself. What happened to the turtle?

Is there anything else you'd like to make comment on in regard to escape vents?

Thank for their time, and ask if they would be interested in us keeping in touch with them? Did they know we are doing other work on Giant Mud Crabs? Have they ever seen an egg-bearing female muddy? Is so, can they remember when and where. If they encounter an egg-bearing female, could they pls send us a pic with date and position.

Appendix 4. OceanWatch Turtle Smart Crab Pot

Reproduced from

https://www.oceanwatch.org.au/wp-content/uploads/2016/07/Turtle-smart-crab-pot-1.pdf

OceanWatch Australia works with the seafood industry and the community to ensure Australia's marine environment is healthy, productive, valued and used in a responsible way.

OCEANWATCH AUSTRALIA

Turtle smart crab pot –Modifications to existing conventional (2 or 4 entry funnel) round mesh crab pots:

(a) Two extra steel rings (6-mm) ~1.0m diameter (each)
*Potential benefits- Inserting two extra steel rings at strategic locations will have two potential benefits:

1. Reduce sea turtles ability to tear holes in the crab pot meshes (at areas which have been noted as having the most frequent interaction). This will reduce the chance of turtles being entangled in the pot meshes, and reduce loss of crab catches through these areas.
2. The two extra rings increase the weight of the trap (from 5 to 7.5kg) and reduce movement and loss of pot in rougher environmental (sea) conditions.

(b) Reducing the circumference of the crab pot entry point (funnels) through insertion of a heavy ply twine at the centre of each funnel.
*Potential benefits- This aims to prevent sea turtles from entering the crab pot (and subsequent drowning) in their attempt to remove the bait-bag or trapped crabs.

(c) Heavier ply mesh (36 ply)
*Potential benefits- There are two potential benefits to increasing mesh ply thickness.

1. Reduce the ability of turtles tearing holes in the crab-pot meshes (increasing twine thickness from 24 to 36 ply). This will reduce the chance of turtles and finfish bycatch species from being entangled in the pot meshes.
2. Turtles are a learned animal that may associate crab pots with a free feed. Increasing ply thickness may minimise sea turtle interactions.

- (d) Lead core polyethylene rope/ or sink rope (no lead). The length of rope used is dependent on area, conditions and depth deployed.

*Potential benefits- Lead core rope/ sink rope, hangs vertical in the water column (negatively buoyant) which alleviates two potential problems:

1. Reduce turtles chance of being entangled in the crab pot float rope (lead core rope/ sink rope are rigid and less susceptible to entangling animals that contact it).
2. Vertical orientation of lead core/ sink rope should reduce the number of propeller cut-offs by alleviating the amount of excess rope floating on the water surface (this will reduce the number of pots lost whilst fishing, i.e. reduce crab pot ghost fishing).