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Distribution, habitat and biology of a rare and threatened eastern Australian endemic shark: Colclough's shark, *Brachaelurus colcloughi* Ogilby, 1908

Peter M. Kyne[A,E], *Leonard J. V. Compagno*[B], *Joanna Stead*[C], *Micha V. Jackson*[D] *and Michael B. Bennett*[C]

[A]Tropical Rivers and Coastal Knowledge, Charles Darwin University, Darwin, NT 0909, Australia.
[B]Shark Research Center, Iziko – South African Museum, P.O. Box 61, Cape Town 8000, South Africa.
[C]School of Biomedical Sciences, The University of Queensland, St Lucia, Qld 4072, Australia.
[D]North Australian Indigenous Land and Sea Management Alliance, Charles Darwin University, Darwin, NT 0909, Australia.
[E]Corresponding author. Email: peter.kyne@cdu.edu.au

Abstract. Despite increasing research effort and conservation focus on sharks, small species of little commercial value are often overlooked, although they make a considerable contribution to global diversity. The poorly known Colclough's shark, *Brachaelurus colcloughi*, is naturally rare to uncommon and is encountered only irregularly. Collating all known records ($n = 50$), we review the species' geographic and bathymetric distribution, habitat, reproductive biology and diet. All but four *B. colcloughi* records are from within a core distribution of $<2°$ latitude on the Australian east coast. Bathymetric distribution is from less than 4 to 217 m depth, with all but three records from less than 100 m depth. The species shelters on rocky reefs during the day and is thought to forage nocturnally around reefs and adjacent substrates. *B. colcloughi* is viviparous, with litter sizes of 6–7. Mature males and females have been observed from 61.0- and 54.5-cm total length, respectively. Gravid females have been collected in austral winter months. Dietary analysis indicates a predominantly piscivorous diet. Our results are placed in the context of existing threats and future research and management directions, demonstrating that shark species with low abundances and restricted ranges, such as *B. colcloughi*, require a suite of management arrangements to ensure long-term population viability.

Additional keywords: bycatch, diet, *Heteroscyllium*, IUCN Red List, reproductive biology.

Introduction

Although there has been a general increase in the conservation and management focus on sharks (and their relatives the batoids, collectively constituting the Elasmobranchii) (e.g. Camhi *et al*. 1998; Stevens *et al*. 2000; Dulvy *et al*. 2008; Simpfendorfer and Kyne 2009), small, poorly known species are often overlooked. These species, particularly if they are rare, inconspicuous and have no or little commercial or recreational value, are often of lower priority for research and conservation planning. Colclough's shark, *Brachaelurus colcloughi* Ogilby, 1908, also commonly referred to as the blue-grey carpetshark, is an example of such a species. It is also of interest in being one of the few elasmobranchs whose occurrence is centred primarily around a rapidly expanding urban area (south-east Queensland (SEQ), Australia, including the conurbations of the Gold Coast, Greater Brisbane and the Sunshine Coast) (Stimson and Taylor 1999). A large and increasing proportion of the world's human population is concentrated within coastal regions, and heavily populated coastal zones, such as SEQ, can focus industrial, commercial and recreational activities (Suchanek 1994; Small and Nicholls 2003). The cumulative effects of multiple stresses exerted by increased anthropogenic activity place heavy pressure on the coastal and marine environment, and elasmobranchs occurring within nearshore environments may be susceptible to these impacts (Jennings *et al*. 2008; Knip *et al*. 2010). In light of these concentrated impacts, it is valuable to understand the basics of elasmobranch distribution, habitat and ecology to assist with their conservation and management.

Brachaelurus colcloughi is a small benthic elasmobranch with a maximum recorded size of 85-cm total length (TL) (Queensland Museum record) (Fig. 1). It is sometimes placed within the genus *Heteroscyllium* (i.e. Compagno 2001), and is one of only two species within the carpet shark (Orectolobiformes) family Brachaeluridae (blind sharks) (Compagno 2001). Both *B. colcloughi* and the blind shark *Brachaelurus waddi* (Bloch & Schneider, 1801) are endemic to the east coast of Australia in the western Pacific. Although *B. waddi* is common across its range from southern Queensland to southern

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Fig. 1. *Brachaelurus colcloughi*. Immature male of 536 mm total length (© CSIRO Marine and Atmospheric Research).

New South Wales, *B. colcloughi* is a little-known species and is considered rare (Compagno *et al*. 2005); despite decades of survey work and ongoing fishing activities across and adjacent to, its known range, it is not encountered with any regularity. Prior to 2001, only ~20 records of this shark were known. Its apparent rarity and the occurrence of threatening processes across its limited geographic range prompted its listing as Vulnerable C2a(ii) on the *IUCN Red List of Threatened Species* (Compagno *et al*. 2005).

Despite the concern raised for the status of *B. colcloughi* by Compagno *et al*. (2005), there is in fact little supporting information to accurately evaluate its population status, trends, capture in fisheries or the effects of identified threatening processes on the species, and thus its management requirements. Uncertainty regarding the population status of *B. colcloughi* is related to a lack of systematic data collection on the species and its likely misidentification as the common and morphologically similar *B. waddi* or grey carpetshark *Chiloscyllium punctatum* Müller & Henle, 1838.

Over the last decade, further sampling of the shark fauna of SEQ (Taylor 2007; Kyne 2008; Stead 2010) has yielded additional records and specimens of *B. colcloughi*, which provide an opportunity to document additional information on the species. We review all museum collection data and literature records and combine these with data from specimens collected in the field during 2001–2007 to provide baseline information on the species' geographic and bathymetric occurrence, habitat requirements, reproductive biology and diet, and to identify knowledge gaps and information required for effective management and conservation.

Materials and methods

The present study reviewed museum collections and the literature for records of *B. colcloughi*, and examined material collected from bycatch of commercial fisheries in SEQ. Museum records were obtained from the Australian Museum, Sydney (AMS), the Australian National Fish Collection, Hobart (CSIRO) and the Queensland Museum, Brisbane (QM). Museum records ($n = 28$), as well as fisheries observer records provided to the QM (J. Johnson, pers. comm.) ($n = 2$) provided data on the geographic and bathymetric occurrence and habitat of the species. Additional information on these attributes, together with data on reproductive biology and diet, were obtained from bycatch specimens ($n = 19$) (three bycatch specimens were accessioned into museum collections and three were released alive at sea; therefore, not all data were available from all bycatch specimens). Literature searches provided a further site record (i.e. Parker 1999). Geographic records were plotted using ArcGIS and analysed by regions defined as northern New South Wales (NSW) (south of the NSW/Queensland (Qld) border; 28°10′S), Moreton Bay, SEQ (central point: 27°15′S, 153°15′E; the area bounded to the east by Moreton, North Stradbroke and South Stradbroke Islands), SEQ excluding Moreton Bay (north of 28°10′S and south of 24°42′S), and the Capricorn region, Central Qld (north of 24°42′S).

Bycatch specimens were collected by trawl ($n = 6$) in the Qld East Coast Trawl Fishery (ECTF) or by gill-net ($n = 11$) and tunnel net ($n = 2$) in the Qld East Coast Inshore Fin Fish Fishery (ECIFFF). Trawl specimens were collected in September and October 2001 by commercial otter-board trawlers fitted with three 2-seam Florida Flyer nets (net body mesh size 50.8 mm, codend mesh size 44.5 mm, headrope length 12.8 m). Gill-net specimens were collected between May 2005 and May 2006 by monofilament bottom-set gill-net (length 700–800 m, drop 2 m, mesh size 152, 178 or 203 mm). Tunnel net specimens were collected in June 2007; most gear specifications are unavailable with the exception of the mesh size of the 'tunnel', which was 38 mm.

For bycatch specimens, total length (TL, the distance from the tip of the snout to the distant margin of the caudal fin) was measured on the ventral surface to ±1 mm. Maturity stages (immature or mature; adolescent individuals were not observed for either sex) were assessed for males and females. Males were classed as immature if they possessed short, uncalcified claspers, and the testes and the remainder of the reproductive tract were undeveloped, or mature if they had calcified and elongated claspers, the testes were developed and lobular, and the epididymides highly coiled. Females were classed as immature if they possessed undeveloped ovaries, undifferentiated oviducal glands and thin uteri, or mature if they possessed developed ovaries with yellow vitellogenic follicles, and fully developed oviducal glands and uteri; embryos were also sometimes present in mature females. Reproductive systems were removed, with seminal vesicles examined macroscopically in mature males for the presence of sperm, and ovaries in females examined for the presence of follicles, with follicle diameter measured to ±1 mm to determine maximum follicle diameter (MFD), and the uteri inspected for ovulated ova or embryos. When possible, embryos were sexed by external examination for the presence or absence of claspers. The TL of embryos was measured to ±0.1 mm and mass was measured to ±0.1 g. If present, the diameter of external yolk sacs was measured to ±0.1 mm. The literature was reviewed for a comparison of reproductive parameters between *B. colcloughi* and other viviparous orectoloboid sharks.

Bycatch specimens were examined for dietary analyses ($n = 13$). For each specimen, the stomach was excised, opened and all stomach contents removed. Prey items were identified to the lowest possible taxonomic level and counted and weighed to ±0.1 g. Unidentified prey items were categorised as 'unknown' within their broad taxonomic grouping. The incidence of empty stomachs was recorded and expressed as a percentage of the total number of stomachs examined. To analyse dietary composition, the percentage frequency of occurrence (%F_o, percentage of stomachs containing a specific prey item or category), percentage numerical composition (%N_c, number of a specific prey item or category as a percentage of the total number of prey items found) and percentage mass composition (%M_c, mass of a specific prey item or category as a percentage of the total mass of prey ingested) were determined. These three indices were combined to calculate the index of relative importance (IRI), a standardised index of dietary composition (Pinkas *et al*. 1971). The IRI was calculated for the major prey categories as IRI = $(N_c + M_c)F_o$ and was expressed on a percentage basis (%IRI), allowing easier comparison of IRI values between prey categories (Cortés 1997). The average number of prey items per stomach containing prey was calculated.

Results

Distribution

Brachaelurus colcloughi is endemic to the east coast of Australia, with confirmed records from Julian Rocks, off Byron Bay, northern NSW (28°36.8′S, 153°37.6′E) to the Hard Line Reefs off the Capricorn Coast of Central Qld (20°41′S, 151°21′E) (Fig. 2). Of 50 available records, 56% (*n* = 28) are from Moreton Bay, SEQ, 24% (*n* = 12) are from northern NSW, 14% (*n* = 7) are from SEQ outside of Moreton Bay, and 6% (*n* = 3) are from the Capricorn region of Qld Records range across ~8° of latitude, however, all but four are south of ~27°48′S, highlighting a core distribution of <2° latitude within SEQ and northern NSW. There are further reports of *B. colcloughi* from off North Stradbroke Island and the Gold Coast, SEQ, in a dive magazine (Marsh 2003), which have not been included in our analysis.

Habitat

Brachaelurus colcloughi has a recorded bathymetric range of <4–217 m depth; however, all but three records for which depth information was available (*n* = 38) were collected in water of depths ≤98 m. The deeper-water records (one individual at 217 m and two at 130–160 m) were trawled at the northern extent of the species' occurrence on the southern Great Barrier Reef system. All gill-net and tunnel-net bycatch specimens (*n* = 13) were taken in shallow inshore waters <4 m deep and museum records from Moreton Bay for which there are depth data available (*n* = 4) are from ≤10 m deep. Queensland trawl bycatch specimens (*n* = 8) were taken on the continental shelf at 26–160 m depth, whereas museum records from NSW (*n* = 11) were trawled at depths of 54–71 m. Parker (1999) reported the species from depths of 10–22 m at Julian Rocks in northern NSW.

All gill-net bycatch specimens were collected on seagrass (eel grass *Zostera capricorni*) beds with a mud–sand–shell substrate, and nearly always where there was a ledge or drop-off nearby. All were collected during the night. Both tunnel net bycatch specimens were collected adjacent to coral reefs. Specific details of habitat are available for three QM records: (1) a 516-mm-TL female collected at night from coarse silty sand and shell substrate, ~40 m away from a submerged rocky reef with numerous overhangs and small caves; (2) a 700-mm-TL female collected during the day from under a coral ledge where it was sheltering at the back of a narrow cave under *Acropora* spp. coral with a coarse sand substrate; and (3) a 755-mm-TL female collected during the day from deep under a wreck where it was sheltering between the wreck hull and fine sand substrate (J. Johnson, pers. comm.).

Reproductive biology

Males at 475–555-mm TL were immature (*n* = 4) and males at 613–731-mm TL were mature (*n* = 5). Sperm was present in the seminal vesicles of all mature males; these individuals were collected in the austral winter months of June, July and August. Females at 398–474-mm TL were immature (*n* = 2) and at 545–685-mm TL were mature (*n* = 4). *Brachaelurus colcloughi* displays a lecithotrophic reproductive mode referred to as aplacental yolksac viviparity, where embryos rely on yolk from a single ovulated ovum for development. Two gravid females were recorded. One collected in early June (620-mm TL) was carrying seven embryos with a mean (±s.d.) size of 162.9 ± 6.7-mm TL (range 149.9–169.9-mm TL) and mass of 24.7 ± 2.8 g (see Accessory Publication). External yolk sacs were present, with a mean diameter of 18.9 ± 3.1 mm. Four embryos were in the right uterus (2♀, 2♂) and three in the left uterus (2♀, 1♂). The second gravid female collected in late August (653-mm TL) was carrying two embryos in the right uterus that were at sizes of 185.2-mm and 185.4-mm TL, and weighed 35.3 and 34.8 g, respectively (see Accessory Publication). External yolk sacs had been completely absorbed, suggesting that they were close to parturition. The right uterus was loose around the embryos, and the left uterus was expanded, suggesting that the female had recently given birth to additional pups (an alternative explanation is that additional pups were aborted upon capture). Two non-gravid adult females had large ovarian follicles of 36-mm diameter. One of these was collected in early June; a collection date is not available for the other.

Diet

Of 13 specimens examined for dietary analyses, six stomachs (46.2%) were empty. The limited dietary analysis of the remaining seven specimens indicated that sampled *B. colcloughi* were predominantly piscivorous, with teleost fishes comprising the majority (85.7% F_o; 93.6% N_c; 99.8% M_c; 99.4% IRI) of prey ingested (Table 1). Cephalopoda constituted the remaining prey (0.6% IRI). The average number of prey items per stomach was 2.3.

Discussion

Distribution, habitat and population status

Last and Stevens (2009) reported *B. colcloughi* from off the tip of Cape York Peninsula and in the area south of Princes Charlotte Bay in northern Qld However, there are no specimens to support the species occurring off northern Qld (Pogonoski *et al*. 2002), and these records may be erroneous (possibly based on misidentifications of the similar *C. punctatum*). These records are therefore not included in the description of distribution presented here, although future surveys in those areas should be mindful of the possible occurrence of the species. The distribution map presented in Compagno (2001) also indicates that the species is more wide-ranging across the entire east coast of Qld Again, there are no records to support such a range, and *B. colcloughi*, as presently known, should be considered to be restricted to the waters of central to southern Qld and northern NSW.

Details of habitat occupancy available for individual records and information accompanying bycatch specimens indicate that the species shelters on rocky reefs during the day and is thought to forage nocturnally around reefs and over adjacent seagrass beds and soft substrates. Carraro and Gladstone (2006) showed

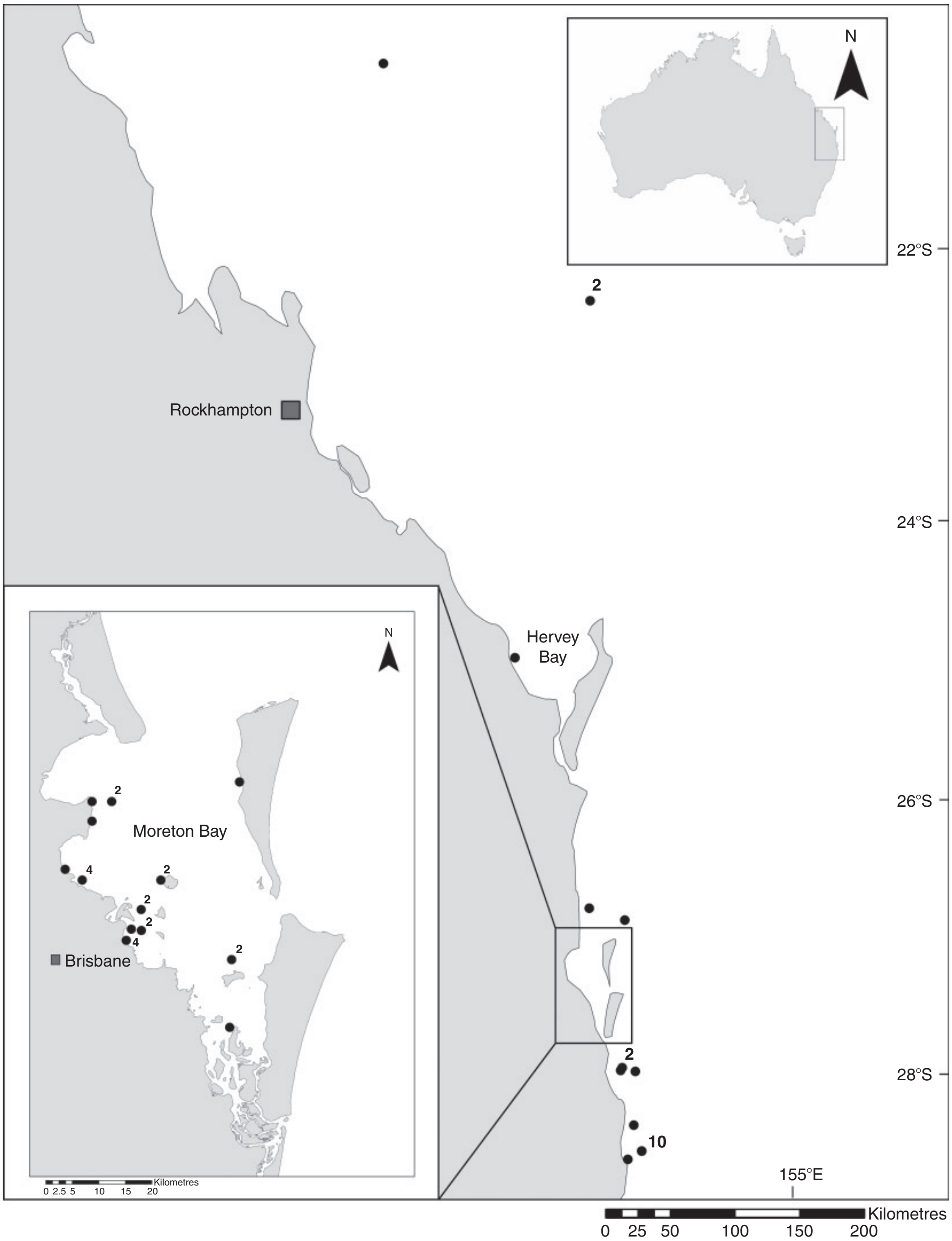

Fig. 2. Distribution of *Brachaelurus colcloughi* in the southern Queensland/northern New South Wales region of Australia, and within Moreton Bay, Queensland (inset). Distribution is a composite of all recorded museum, bycatch and literature records, with the exception of four museum records for which the collection locality is given only as 'Moreton Bay'. Each data point represents a single individual record, except where a number indicates the total number of individuals collected from the same locality.

that ornate wobbegong *Orectolobus ornatus* (De Vis, 1883) selected topographically complex daytime refugia that were characterised by a high volume of crevices, with individuals showing site fidelity to specific resting positions. It is unknown if *B. colcloughi* displays similar fidelity.

The threatened species listing of *B. colcloughi* by the IUCN is based partially on the species' suspected low population size (estimated to be $<$10 000 mature individuals based on the IUCN Red List Category and Criteria applied by Compagno *et al.* 2005). However, there are no robust population assessments to

Table 1. Dietary composition of *Brachaelurus colcloughi* from shallow inshore waters of Moreton Bay, Queensland ($n = 7$)
%F_o, percentage frequency of occurrence; %N_c, percentage numerical composition; %M_c, percentage mass composition; %IRI, index of relative importance

Prey group/item							
Major group	Order	Family	Species	%F_o	%N_c	%M_c	%IRI
Cephalopoda			Unknown	14.29	6.25	0.24	0.60
Teleostei	Clupeiformes (herrings and anchovies)	Clupeidae (herrings)	*Herklotsichthys castelnaui*	14.29	6.25	9.74	
	Perciformes (perch-like fishes)	Gerridae (silver biddies	*Gerres subfasciatus*	14.29	6.25	28.35	
		Gobiidae (gobies)	*Arenigobius* spp.	28.57	18.75	2.05	
		Mugilidae (mullets)	Unknown	14.29	6.25	2.12	
		Sillaginidae (whitings)	*Sillago* spp.	14.29	6.25	10.13	
	Scorpaeniformes (scorpion fishes and sculpins)	Platycephalidae (flatheads)	*Platycephalus* spp.	14.29	6.25	18.95	
	Siluriformes (catfishes)	Plotosidae (eel-tailed catfish)	*Plotosus lineatus*	14.29	6.25	8.93	
Unidentified Teleostei			Unknown	57.14	37.50	19.49	
Total Teleostei				85.71	93.75	99.76	99.40

test the validity of this assertion. The species has hitherto been considered very rare, with only ~20 records known before 2001 (Compagno *et al*. 2005). Records compiled here suggest that it may not be as rare as previously thought, but despite decades of survey work and ongoing fishing activities across its range, as well as areas adjacent to its known range, and across its entire depth range and beyond, it is not encountered with any regularity. The low number of specimens sampled during recent intensive survey work and fishery-dependent sampling, with a focus on Moreton Bay and SEQ, and including considerable coverage of available habitat (Taylor 2007; Kyne 2008; Stead 2010), support the rare status of this shark. In surveys of the bycatch of the Qld ECTF between 26°42′S and 27°59′S in depths of 19–86 m, *B. colcloughi* had a catch rate of $0.005 \pm 0.003\ \text{ha}^{-1}$ (the overall catch rate of chondrichthyan fishes was $0.958 \pm 0.175\ \text{ha}^{-1}$) (Kyne 2008). Anecdotal evidence from commercial fishers suggests that the species was trawled more regularly (albeit in small numbers) in the 1970s when a large fleet of small trawlers operated in Moreton Bay's inshore waters (the number of small trawlers operating in the area has since decreased substantially) (J. Johnson, pers. comm.). It is, however, impossible to determine actual historic catch rates.

Johnson (1999) reported *B. colcloughi* as being 'common' inside Moreton Bay, but 'rare' outside the Moreton Bay region. The 'common' status afforded the species is based on Johnson's (1999) relative abundance indicator of 10–100 records from Moreton Bay. The QM holds the most specimens of the species of any museum collection ($n = 16$), with the majority of these ($n = 14$) from within Moreton Bay. Parker (1999) reported the species as 'occasional' in a survey of Julian Rocks and adjacent waters in northern NSW (of four survey sites, the species was recorded only at Julian Rocks). There are no quantitative data of the species' occurrence in Parker (1999), although 'occasional' is defined as 'recorded at some habitats although uncommon at others'.

The records presented here do not represent all interactions that have occurred with the species, only those available in museum collections, recent bycatch sampling and the scientific literature. The overall extent to which the species is encountered by divers and fishers is unknown, although encounters are likely to be irregular. However, its documented geographic and bathymetric range is not explained by limited sampling; its known distribution, as well as areas to the north and south, is well-surveyed and consistently sampled.

Reproductive biology and diet

Previous suggestions of maturity in females at ~650-mm TL (i.e. Last and Stevens 2009) need to be readjusted, as mature females were observed from 545-mm TL in the present study. Compagno (2001) reports adolescent males at sizes to 516-mm TL, whereas we observed immature males to 555-mm TL, but with no mature males observed at <613-mm TL, a more accurate estimate of male size at maturity cannot be made. Although there are records in the literature of fecundity for *B. colcloughi* of 6–8 pups (Compagno *et al*. 2005; Last and Stevens 2009), there are only two previously examined gravid females, both held in the QM. These two gravid females were 658-mm and 755-mm TL, with litter sizes of 6 and 7 pups, respectively (also documented in Compagno 2001). Of the two gravid females examined from bycatch specimens, it is difficult to speculate on the litter size of one that possessed only two near-term embryos, and a uterine condition suggesting recent birthing (or possible abortion of pups). External yolk sacs were absent in these embryos (185-mm TL), which were observed in August, but were still attached to embryos (averaging 163-mm TL) recorded in June. Similarly, Compagno (2001) reported external yolk sacs attached to embryos at 164–168-mm TL, but not on embryos at 174–186-mm TL. Combining these observations, a size at birth of ~170–190-mm TL is likely. The observation of gravid females in austral winter months and near-term embryos in late August suggests a winter parturition period. However, the extent of the reproductive season and length of gestation remain unknown for *B. colcloughi*.

Of the order Orectolobiformes, the families Brachaeluridae (blind sharks), Orectolobidae (wobbegongs), Rhincodontidae (whale shark) and Ginglymostomatidae (nurse sharks) are viviparous; all of these show aplacental yolksac viviparity, although the tawny nurse shark, *Nebrius ferrugineus* (Lesson, 1831), is also reported to be viviparous with oophagous embryos (Compagno 2001). The remaining families in the order, Parascylliidae (collared carpetsharks), Hemiscylliidae (long-tailed carpetsharks) and Stegostomatidae (zebra shark), are oviparous (Compagno 2001). Table 2 provides a summary of reproductive parameters documented for viviparous orectoloboid sharks (except *N. ferrugineus*). Brachaelurids have some of the smallest documented litter sizes of viviparous species in the order, but as their reproductive periodicity is unknown, their annual reproductive output is also unknown. If they have an annual reproductive cycle, then their fecundity (up to eight pups per year) may be similar to that of some *Orectolobus* spp., which have larger litter sizes, but a triennial reproductive cycle (see Huveneers *et al*. 2007*b*). The large follicles (MFD 36 mm) observed in two non-gravid female *B. colcloughi* suggests a lengthy ovarian cycle. Smaller follicle sizes of <30 mm are associated with annual ovarian cycles, whereas sizes reaching >40 mm suggest biennial or triennial ovarian cycles (Huveneers *et al*. 2007*b*; Walker 2007). For *B. colcloughi*, observed follicle sizes may point to a biennial reproductive cycle for the species. Elucidating the reproductive cycle as either annual or biennial will have considerable consequences for our understanding of the species' productivity. Doing so, however, is difficult for such a rare and irregularly encountered species.

Compagno (2001) presumed that this shark fed on benthic invertebrates, but noted that the diet had not been recorded. Dietary analyses presented here, the first for the species, suggests a piscivorous diet, although the importance of invertebrate prey cannot be ruled out with the small sample size of stomachs examined. Most of the teleost fish genera and species identified in the stomach contents of *B. colcloughi* were benthic or benthopelagic, supporting a demersal feeding strategy for the species. Although not described quantitatively, the diet of *B. waddi* is reported to be a variety of invertebrates as well as small fishes (Whitley 1940; Compagno 2001). Of the limited number of quantitative dietary studies on carpetsharks, the small reef-associated epaulette shark *Hemiscyllium ocellatum* (Bonnaterre, 1788) has been shown to feed predominantly on benthic invertebrates (Heupel and Bennett 1998), *C. punctatum* is an opportunistic predator feeding on both benthic invertebrates and teleost fishes (Stead 2010), whereas wobbegongs *Orectolobus* spp. are largely piscivorous (Huveneers *et al*. 2007*a*). The nurse shark *Ginglymostoma cirratum* (Bonnaterre, 1788) is also primarily piscivorous (Castro 2000). Where several species of carpetsharks co-exist in the waters of eastern Australia (in particular northern NSW, where *B. waddi*, *Orectolobus* spp. and *C. punctatum* are common and *B. colcloughi* also occurs), resource partitioning may occur with different prey groups or prey sizes being selected by the different species, facilitating their co-existence on rocky reef environments.

Threats

The area of occupancy of *B. colcloughi* faces anthropogenic pressures in the form of fisheries, both commercial and recreational, and the alteration and loss of habitat – its rarity, limited reproductive capacity (as evidenced by its small litter size) and restricted distribution make it inherently vulnerable to population depletion (Compagno 2001). A considerable proportion of its range is subject to trawling effort by the Qld ECTF, both by beam-trawl vessels operating in shallow nearshore waters

Table 2. Comparison between reproductive parameters of aplacental yolksac viviparous sharks of the order Orectolobiformes

General data from Compagno (2001) and Last and Stevens (2009), more specific references are given for each species where relevant; maturity values represent smallest known mature individuals except *L_{50}, the size at which 50% of individuals have obtained sexual maturity, or where a range represents the sizes over which maturity occurs (maturity values for *R. typus* are estimates); TL, total length

Family	Species	Maximum size (cm TL)	Female size at maturity (cm TL)	Male size at maturity (cm TL)	Size at birth (cm TL)	Litter size (mean)	Gestation period (months)	Reprod. period (years)	Key references
Brachaeluridae	*Brachaelurus colcloughi*	85	55	61	17–19	6–7	?	?	The present study
	Brachaelurus waddi	122	66	60	15–18	7–8	?	?	Whitley (1940)
Orectolobidae	*Orectolobus halei*	206	159*	178*	25–30	12–47	10–11	3	Huveneers *et al*. (2007*b*)
	Orectolobus hutchinsi	149	112	112	22–26	18–29 (23)	9–11	2–3	Chidlow (2003)
	Orectolobus japonicus	107+	101	103	21–23	20–23	?	?	–
	Orectolobus leptolineatus	120	94	90	?	4	?	?	Last *et al*. (2010)
	Orectolobus maculatus	170	112*[1], 103[2]	128*[1], 114[2]	20–25	8–31 (21)	10–11	3	Huveneers *et al*. (2007*b*); Stead (2010)
	Orectolobus ornatus	110	73*[1], 57[2]	80*[1], 56[2]	20	4–18 (9.4)	10–11	3	Huveneers *et al*. (2007*b*); Stead (2010)
	Sutorectus tentaculatus	92	60–65	60–65	22	12	?	?	–
Ginglymostomatidae	*Ginglymostoma cirratum*	280	223–231	214–215	28–31	21–50	5–6	2	Castro (2000)
Rhincodontidae	*Rhincodon typus*	1200+	900+	800+	55–64	~300	?	?	Joung *et al*. (1996); Stevens (2007)

[1]New South Wales.
[2]South-east Queensland.

(rivers and estuaries) and by larger otter-trawl vessels operating in Moreton Bay and on the continental shelf (QDPI&F 2009). Inshore areas are also fished by the ECIFFF, and SEQ is a recreational fishing hotspot, with Moreton Bay alone accounting for one-third of the recreational fishing effort in Qld (Williams 2002). The species is also apparently exploited at low levels for the marine aquarium trade (Pogonoski *et al*. 2002; Compagno *et al*. 2005), but specific details are not available.

The compulsory use of turtle exclusion devices (TEDs) by otter-trawlers in the ECTF may reduce the bycatch of larger individuals, but may not be effective at excluding smaller sharks (Kyne 2008). However, a female *B. colcloughi* of 67-cm TL was captured in a trawl net fitted with a TED during a bycatch reduction survey, highlighting that even relatively large individuals may not be excluded (Kyne 2008). This is likely a result of the size of space between the bars of the TEDs; in Qld, bar spacing cannot be greater than 120 mm. However, to deal with periodical aggregations of jellyfish (*Catostylus mosaicus*), otter-trawl operators in Moreton Bay sometimes utilise a second grid with the standard bar spacing of 120 mm offset by bars spaced at 60 mm (A. Courtney, pers. comm.). The resultant 60-mm bar spacing is likely to be more effective at excluding smaller shark bycatch, although specific data are lacking. Beam-trawlers, which are restricted to rivers and estuaries, are not required to use TEDs, but will do so on occasion to exclude jellyfish and large debris, particularly after flooding (A. Courtney, pers. comm.).

Although inner coastal reefs have been identified as critical habitat for the species (Pogonoski *et al*. 2002), it would appear that inshore seagrass beds are also critical habitat for foraging, as suggested by the collection of net bycatch specimens in this habitat. The apparent behaviour of *B. colcloughi* of taking refuge in caves and under ledges on rocky reefs during the day, and emerging nocturnally to forage around reefs and over adjacent seagrass beds and soft substrates, exposes it to fishing activities that operate at night, including trawling. The continued loss or alteration of important inshore habitats will further threaten to reduce the already small area of occupancy of this shark (Pogonoski *et al*. 2002; Compagno *et al*. 2005). For example, current pressures on Moreton Bay, a core area of the species' distribution, include large-scale developments that impact on nearshore marine habitats (e.g. the Port of Brisbane and Brisbane Airport land 'reclamation' projects), runoff from terrestrial sources, and pollution from marine and terrestrial sources, as well as the aforementioned fishing activities. These impacts combine to threaten the species' main population, but at present there is insufficient information to determine the extent of impact from threatening processes.

Future research and management directions

The lack of basic ecological knowledge of rare, inconspicuous marine species can hinder effective fisheries management and conservation planning. Rare elasmobranchs with a restricted range and limited productivity may require precautionary management to counter the lack of detailed data. Marine Protected Areas, fisheries management, public awareness and education, and research effort all have a role to play in conserving these rare species. For *B. colcloughi*, an immediate research objective that could direct conservation planning towards adequate habitat protection is to accurately examine the species' habitat use (including site fidelity and home ranges) and movement patterns (both short and long-term). Essential to implementing management strategies is knowledge of how widely individuals forage at night away from critical daytime resting habitat, and how these movements may overlap with fishing activities. An investigation of the species' use of existing Marine Protected Areas (e.g. protected zones within the Moreton Bay Marine Park), to determine if these adequately protect critical habitat, is also warranted.

Limiting mortality from recreational and commercial fishing is an obvious beneficial conservation goal for rare marine species. In the specific case of *B. colcloughi*, it is recommended that the species be designated a 'no-take' species under Qld and NSW fisheries legislation. Additionally, the incorporation of *B. colcloughi* into commercial fishing logbooks would assist in obtaining information on occurrence and interactions with commercial fisheries, and educating fishers on correct identification and safe handling and release would assist in recording that information and potentially increase post-release survival. Together, these management measures could have considerable benefits for the long-term population viability of this rare species, and may serve as a case study to securing a rare, poorly known, threatened shark, that may in future be applied to other species.

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