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Dietary overlap of carcharhinid sharks in the Gulf of Papua

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ABSTRACT

Assessing the feeding patterns of sharks provides insight into ecological interactions. Three coastal sharks are common by-catch in the Gulf of Papua prawn fishery in Papua New Guinea. The diets of *Carcharhinus coatesi* (*n* = 122), *Rhizoprionodon acutus* (*n* = 83) and *Rhizoprionodon taylori* (*n* = 177) were assessed using stomach content analysis. Teleosts, crustaceans and molluscs were the main prey. Percentage frequency of occurrence (%FO) and percentage frequency by number (%N) were computed to describe dietary compositions. Non-metric multidimensional scaling and Morisita Index determined the level of feeding overlap. *Rhizoprionodon taylori* was a generalist feeder having the broadest diet, *R. acutus* was the most selective feeder, preying predominantly on teleosts and *C. coatesi* consumed the greatest proportion of crustaceans that increased with size. The pairwise ANOSIM tests showed significant difference in dietary compositions of *R. acutus* and *R. taylori* (*P* = 0.1%, *R* = 0.318) and *R. acutus* and *C. coatesi* (*P* = 0.1%, *R* = 0.589), which indicate potential resource partitioning. Further work should aim to adequately characterise diets, improve prey identification and investigate spatial and temporal resource use patterns. Understanding ecological processes informs ecosystem approaches fisheries management.

Keywords: carcharhinid sharks, *Carcharhinus coatesi*, coastal shark diet, fisheries management, Gulf of Papua Prawn Fishery, GoPPF, *Rhizoprionodon acutus*, *Rhizoprionodon taylori*, shark by-catch.

Introduction

Fisheries are a major contributor to the decline of shark populations (Dulvy *et al.* 2014) that function mainly as top and middle order predators in marine ecosystems (Heupel *et al.* 2014). Concern for the survival of these populations has also highlighted that the flow on effects of low predator abundance on the ecosystem remain largely unknown, partly due to the paucity of ecological information for specific regions (Ferretti *et al.* 2010). Therefore, establishing an understanding of the ecology of species, and their contributions to ecosystem processes (Bornatowski *et al.* 2014*a*), is a crucial element in predicting the outcomes of population declines and potential species loss. Assessing the ecosystem impacts of fisheries in order to set appropriate management and conservation guidelines requires information from both target and non-target (by-catch) species (Pikitch *et al.* 2004).

Characterising the dietary traits of sharks from stomach content analysis provides empirical evidence of the trophic linkages in the food chain (Cortes 1999). Such information can be incorporated into ecosystem models to support fisheries management (Rogers *et al.* 2012). In addition, knowledge of feeding patterns may reveal diet specialisation, which highlights the vulnerability of predators and the impacts on the ecosystem from their decline. Specialised feeders have a narrow range of prey and may be more vulnerable to perturbations that may directly affect food availability whereas generalist feeders are more resilient to environmental changes (Simpfendorfer *et al.* 2001; Munroe *et al.* 2014). The level of diet overlap among similar sympatric species is an indirect measure of competition when food resources are limited (Wetherbee *et al.* 2012). Diet studies show that elasmobranchs reduce competition through partitioning of food resources by consuming different proportions of available prey (Platell *et al.* 1998; White *et al.* 2004), specialisation on a specific set of prey (Sommerville *et al.* 2011; Bornatowski *et al.* 2014*b*) and differential spatial distribution of species (Papastamatiou *et al.* 2006). Dietary investigations, therefore, provide some insight into complex and dynamic ecological interactions.

Small-bodied coastal sharks are generally considered to be meso-predators that connect the lower and top trophic levels of the food chain (Heupel *et al.* 2014) and are also common in coastal fisheries by-catch (Stobutzki *et al.* 2002). The Australian blackspot shark (*Carcharhinus coatesi*), the milk shark (*Rhizoprionodon acutus*) and the Australian sharpnose shark (*Rhizoprionodon taylori*) are all small-bodied coastal sharks that are commonly caught as by-catch in the Gulf of Papua Prawn Fishery (GoPPF) in Papua New Guinea, making up 9, 7 and 29% respectively of the total elasmobranch by-catch sampled by number (White *et al.* 2019). The life histories of *C. coatesi* and *R. taylori* indicate that the populations of each species may be affected differently by the fishery based on growth and biological productivity (Baje *et al.* 2018; Baje *et al.* 2019). However, the ecology of these sympatric sharks has not been investigated in the Gulf of Papua, and their ecological roles are not well understood. Using samples collected from the by-catch of this fishery, this study aimed to characterise the diets of *C. coatesi*, *R. acutus* and *R. taylori* and estimate the level of dietary overlap to assess if competition and partitioning of food resources occurs among these species in the Gulf of Papua. We hypothesise that *R. taylori* will have the broadest diet range to support rapid growth in early life stages, whereas *R. acutus,* attaining a larger size and greater depth range, will have the most distinct diet and potentially partition food resources.

Methods

Study site

The Gulf of Papua, situated on the south coast of Papua New Guinea (PNG) (Fig. 1), is a region composed of extensive mangrove and estuarine areas with high riverine input. Waterways from high-altitude areas of PNG drain into the Gulf forming several major river systems, the largest of which is the Fly River in the West. North Eastward of the Fly River are the Kikori and Purari rivers along with several other systems. These areas provide major nursery grounds for penaeid prawn species that eventually recruit into the Gulf of Papua prawn trawl fishery that mainly targets banana prawns (*Penaeus merguiensis*) (Evans *et al.* 1997). The region experiences two main seasons: the north-west monsoon from November to March each year and the south-east monsoon winds that occur from April to October (Moore and MacFarlane 1984). The GoPPF is only open to domestic based vessels offering 15 licenses annually. However, only 6–9 twin- or quad-rigged trawlers are active at any one time due to the old age of vessels that constantly face operational problems (Kompas and Kuk 2008). Fishing operations have remained relatively unchanged over the

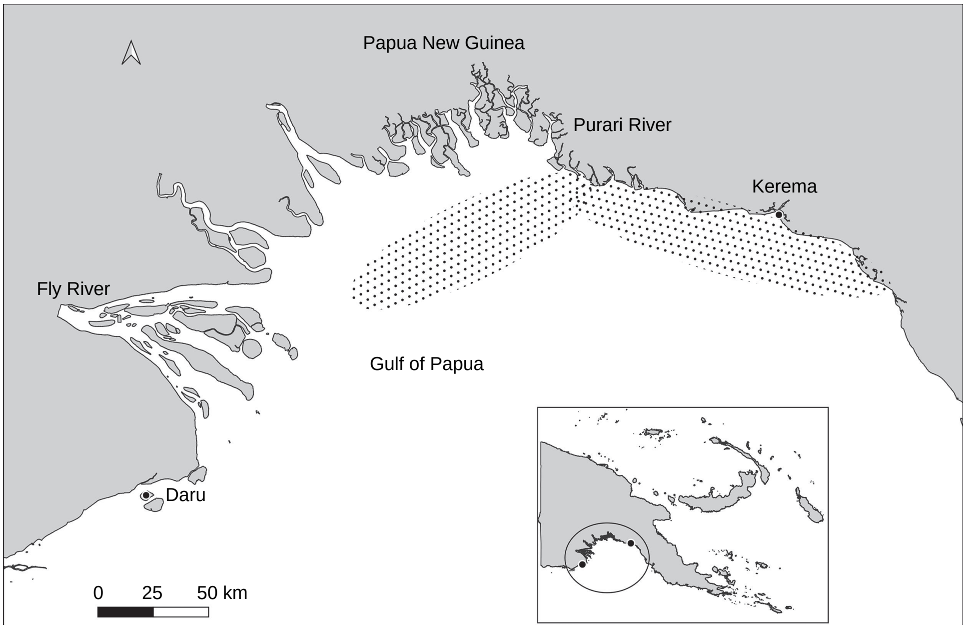

Fig. 1. The Gulf of Papua situated in the south of Papua New Guinea. The dotted areas representing the fishing zone.

past 20 years where trawling typically occurs over soft muddy continental shelf areas. The fishery is open throughout the year although sections of the fishing zone in the east of the Gulf of Papua are closed off to allow for recruitment from December to March each year (National Fisheries Authority 2008).

Sampling and sample preservation

Fishery observers were deployed on seven prawn trawl fishing trips between June 2014 and August 2015 to collect shark by-catch samples. No shark was intentionally harmed for the study, all samples collected had suffered mortality during the fishing activity due to the length of trawls that last on average for 4–5 h. Samples were kept whole and frozen on board. In a laboratory, sharks were thawed, total length (TL) measured to the nearest ±1 cm, sex recorded, and stomachs excised. Contents from each stomach were removed, fixed in 10% formalin and transferred to 70% ethanol for preservation. Each set of stomach contents were weighed and examined to identify the number and type(s) of prey to the lowest possible taxa. In order to detect if the sample size was sufficient to adequately describe diets, a cumulative prey curve was produced using the specaccum function of the 'vegan' package (ver. 2.4.3, J. Oksanen, F. G. Blanchet, R. Kindt, P. Legendre, P. R. Minchin, R. O'Hara, G. L. Simpson, P. Solymos, M. H. H. Stevens, and H. Wagner, see https://cran.r-project.org/web/packages/vegan/index.html) in R (ver. 3.2.2, R Foundation for Statistical Computing, Vienna, Austria, see https://www.R-project.org/).

Fisheries observers of the National Fisheries Authority (NFA) collected sharks that were caught as by-catch and discarded on prawn trawl vessels. All sampling procedures were allowed by the NFA and in line with James Cook University, Animal Ethics approval A2310 that was obtained before the commencement of the study. Sampling did not involve endangered or protected species. No further permits were required by authorities in PNG.

Dietary indices

To assess the importance of each prey item in the diet of the three shark species the percentage frequency of occurrence (%FO) and the percentage by number (%N) were calculated. The former is the number of times a prey category is present in one or more stomachs expressed as a percentage of the total number of stomachs containing food, whereas the latter is the number of each prey category found in each stomach expressed as a proportion of the total number of prey for all stomachs of a particular species (Hyslop 1980). The advanced state of digestion and mastication in most of the samples meant that prey items could not be adequately identified and separated, therefore, volumetric and gravimetric methods were not carried out.

Dietary overlap

Dietary overlap, which is a measure of the level of similarity in the diets between shark species, was measured using the simplified Morisita index (Krebs 1989):

$$\mathrm{CH} = \frac{2\Sigma_i^n p_{ij}\, p_{ik}}{\Sigma_i^n p_{ij}^2 + \Sigma_i^n p_{ik}^2}$$

where CH is the Simplified Morisita index of overlap between two species with values ranging from 0 (no overlap) to 1 (complete overlap); p_{ij} is the proportion prey in species i that is of the total prey categories used by species j; p_{ik} is the proportion prey i is of the total prey categories used by species k; and n is the total number of prey categories.

To avoid confounding results all teleost both identified and unidentified were grouped and unidentified prey that could not be allocated to a specific prey category were omitted from the analysis.

Multivariate analysis

Samples were randomised and pooled according to species, sex, season and size (10-cm size classes) to minimise the large number of zeros and improve the effectiveness of the analyses (Sommerville *et al.* 2011). The resulting new samples for each factor comprised stomach contents from four to five individuals randomly pooled together. Grouping of prey items for the analyses was the same as for the diet overlap above. The percentage by number (%N) was calculated for each prey item in each sample and entered into Primer-E (ver. 7.0.13, Plymouth Routines in Multivariate Ecological Research, Quest Research Limited, Auckland, New Zealand). Prior to further analysis the data were subject to square-root transformation followed by creation of a Bray–Curtis resemblance matrix. To test for differences in dietary composition a one-way Analysis of Similarities (ANOSIM) was conducted, in this context the *R* statistic computed does not infer multifactorial tests and interactions that are also available in Primer. Similarities of Percentages (SIMPER) was used to identify the components that typified the diets of each shark species. Non-metric Multidimensional Scaling (nMDS) ordination was used to produce plots to visualise the similarities in the diets. To test for the multivariate variability in the diet of each species Multivariate Dispersion (MVDISP) was conducted. To support the nMDS plot for size classes a column graph was constructed to assess if the diets of the three shark species undergo changes with respect to growth.

Results

Size ranges and sample size

Total lengths recorded were similar among species and ranged from 31 to 76 cm TL for *R. taylori*; 31–84 cm TL for *R. acutus*; and 35–79 cm TL for *C. coatesi* (Fig. 2). A total

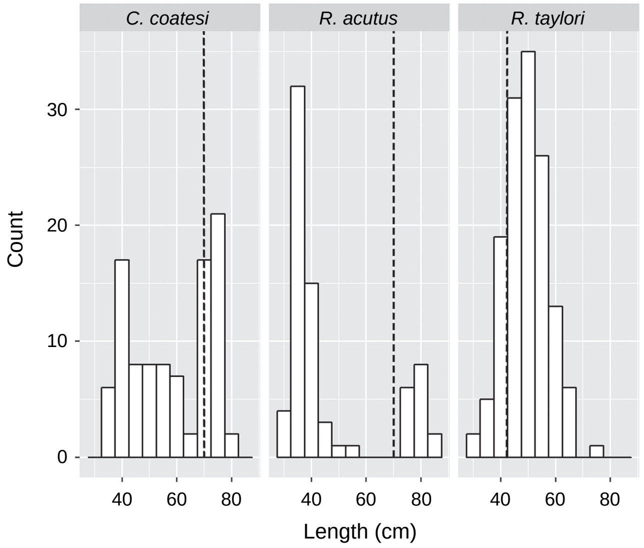

Fig. 2. Length–frequency of *Carcharhinus coatesi*, *Rhizoprionodon acutus* and *Rhizoprionodon taylori* caught in the Gulf of Papua prawn trawl fishery and used for stomach content analysis. The length at maturity for each species is indicated by the dashed lines.

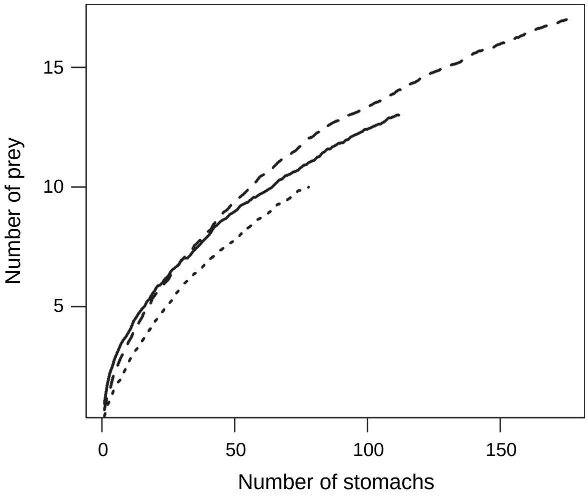

Fig. 3. Cumulative prey curves for *Carcharhinus coatesi* (solid) *Rhizoprionodon acutus* (dotted) and *Rhizoprionodon taylori* (dashed) from the Gulf of Papua.

of 177 stomachs were sampled of *R. taylori*, 83 of *R. acutus*, and 122 of *C. coatesi*. The cumulative prey curve for all three species did not appear to reach asymptote, indicating a larger sample size would be required to fully characterise the diets (Fig. 3). The number of stomachs containing prey was high with few empty stomachs encountered for each species (Table 1).

Main prey types and proportions in diet

Teleosts, crustaceans and molluscs were observed as the main prey groups, with sixteen teleost families, three crustacean families and two families of molluscs identified. The proportion of individual %FO and %N of each teleost family was low, not exceeding 5% owing to mastication and the process of digestion that resulted in only a small number of individual fishes being identified. Of the 16 families of teleosts observed only 3 families: Haemulidae, Engraulidae and Trichiuridae appeared in the diet of all 3 shark species. Other families were only shared between two of the species, for example Leiognathidae was only present in the stomach contents of *R. acutus* and *C. coatesi*. However, distinctively the families Pegasidae, Fistulariidae and the eel families Muraenesocidae and Ophichthidae, were only present in the diet of *C. coatesi*. The proportion of unidentified teleosts was high for all species (Table 1).

The presence of crustaceans in the diet, %FO and %N of Penaeidae was high for all species, but particularly prevalent in the diet of *C. coatesi* (54.5%FO). Stomatopoda were also more common in the diet of *C. coatesi* (23.14%FO and 7.51%N) compared to *R. taylori* (11.61%FO and 5.36%N) but were absent in the diet of *R. acutus*. Similarly, with respect to crabs there was a higher %FO and %N in the diet of *C. coatesi* (7.44%FO and 2.15%N) compared to *R. taylori* (1.29%FO and 0.59%N) and *R. acutus* (1.33%FO and 0.5%N). Molluscs played a lesser role in the diet of the all three species; *R. acutus* (2.67%FO and 0.99%N) consumed fewer cephalopods than *R. taylori* (7.74%FO and 5.06%N) and *C. coatesi* (5.78%FO and 6.22%N), whereas Gastropoda were only found in the stomach contents of *R. taylori* (Table 1).

Diet overlap

The Morisita Index of Similarity calculated for each pair of species showed high overlap for all species. The highest overlap was between *R. taylori* and *C. coatesi* ($C_H = 0.99$) with less overlap between the diets of *R. taylori* and *R. acutus* ($C_H = 0.85$) and *R. acutus* and *C. coatesi* ($C_H = 0.82$). Langton (1982) prescribes a ranking of the similarity index as 0–0.29 as low overlap, 0.30–0.59 as medium and >0.6 as high.

Multivariate analyses

Intraspecific dietary comparison

Dietary data for males and females were pooled for subsequent analysis as there was no significant difference between sexes ($P = 0.4$, $R = 0.039$). A one-way ANOSIM indicated a significant difference among the diets of *R. taylori*, *R. acutus* and *C. coatesi* ($P = 0.1\%$, $R = 0.259$). The pairwise tests between species showed a significant difference in dietary compositions of *R. acutus* and *R. taylori* ($P = 0.1\%$, $R = 0.318$) and *R. actus* and *C. coatesi* ($P = 0.1\%$, $R = 0.589$). However, there was no significant difference in dietary compositions between *R. taylori* and *C. coatesi* ($P > 0.1\%$, $R = 0.05$). The multivariate dispersion

Table 1. Percentage frequency of occurrence (%FO) and percentage by number (%N) of prey categories found in the stomachs of *Rhizoprionodon taylori*, *Rhizoprionodon acutus* and *Carcharhinus coatesi* in the Gulf of Papua.

Prey categories	***R. taylori***		***R. acutus***		***C. coatesi***	
	%FO	**%N**	**%FO**	**%N**	**%FO**	**%N**
Teleostei						
Sciaenidae	3.1	0.6	2.7	2.0	–	–
Labridae	1.6	0.3	–	–	–	–
Mullidae	1.6	0.3	–	–	–	–
Haemulidae	3.1	0.89	1.3	2.0	1.65	0.43
Engraulidae	1.55	0.3	2.67	0.99	0.83	0.215
Nemipteridae	1.29	0.6	–	–	–	–
Gobiidae	1.94	0.89	–	–	0.83	0.22
Synodontidae	1.29	0.6	1.33	0.5	–	–
Terapontidae	1.29	1.2	2.67	1.0	–	–
Trichiuridae	0.65	0.3	2.67	0.5	0.83	0.22
Carangidae	0.65	0.3	–	–	–	0.22
Leiognathidae	–	–	4.00	1.99	4.13	1.07
Pegasidae	–	–	–	–	0.83	0.22
Fistulariidae	–	–	–	–	0.83	0.22
Muraenesocidae	–	–	–	–	1.65	0.43
Ophichthidae	–	–	–	–	0.83	0.22
Unidentified eel	–	–	–	–	0.83	0.24
Unidentified teleost	56.77	45.24	77.33	77.11	54.5	44.42
Crustacea						
Penaeidae	36.77	27.68	25.33	10.95	51.24	33.05
Stomatopoda	11.61	5.36	–	–	23.14	7.51
Crab	1.29	0.59	1.33	0.5	7.44	2.15
Unidentified crustacean	6.45	3.57	1.33	0.5	–	–
Mollusca						
Cephalopoda	7.74	5.06	2.67	0.99	5.78	6.22
Gastropoda	1.29	0.89	–	–	–	–
Other unidentified	20.15	4.17	1.33	0.5	7.44	2.15
Number of stomachs analysed	177		83		128	
Number of stomachs with food	155		75		121	
Number of empty stomachs	22		8		7	

(MVDISP) analysis showed that *R. taylori* had the highest dispersion of 1.13, followed by *C. coatesi* with 0.89 and *R. actus* with 0.67. Similarities of percentages (SIMPERs) showed that the main groups that typified the diets of *R. taylori* and *C. coatesi* were teleosts and penaeid prawns, whereas teleosts typified the diet of *R. acutus*. Between pairs of species teleosts (41.8%), followed by penaeids (20.5%) and stomatopods (15.5%) contributed most to the dissimilarity in prey consumption of *R. taylori* and *R. acutus*. Between *R. taylori* and *C. coatesi*, the dissimilarity resulted from penaeids (22.7%), teleosts (20.31%), stomatopods (17.37%) and cephalopods (15.27%). Although the dissimilarity between *R. acutus* and *C. coatesi* was characterised by teleosts (31.3%), penaeids (24%) and stomatopods (18.2%).

The nMDS ordination plot of the dietary compositions of the three shark species showed that *R. taylori* has a broad diet that overlaps with *C. coatesi* and *R. acutus*. Samples of

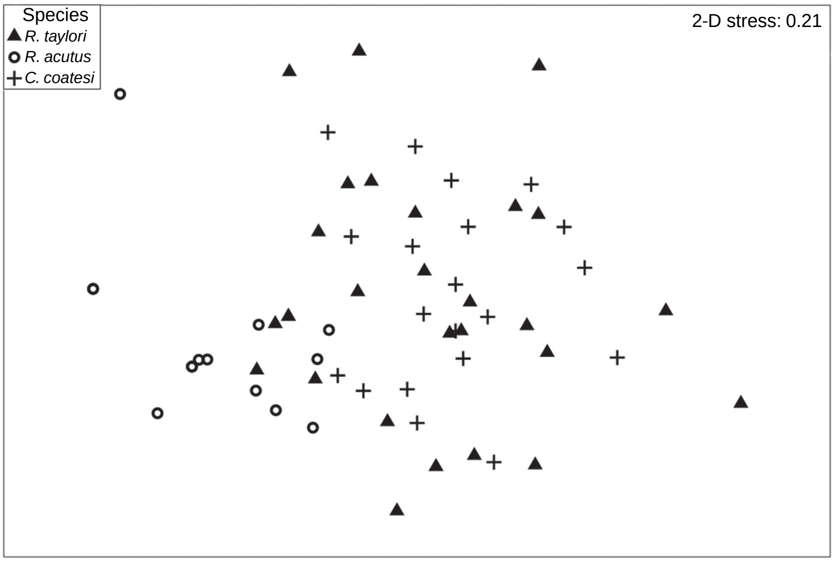

Fig. 4. Non-metric multidimensional scaling ordination of dietary composition by number (%N) of *Rhizoprionodon taylori*, *Rhizoprionodon acutus* and *Carcharhinus coatesi* in the Gulf of Papua.

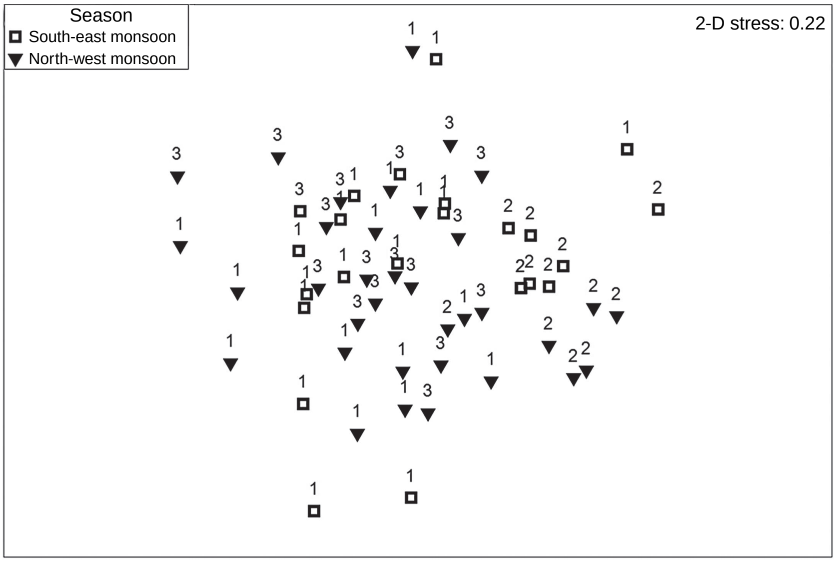

Fig. 5. Non-metric multidimensional scaling ordination of dietary composition by number (%N) according to north-west monsoon and south-east monsoon periods that occur in the Gulf of Papua. Numbers 1, 2 and 3 represent *Rhizoprionodon taylori*, *Rhizoprionodon acutus* and *Carcharhinus coatesi* respectively.

R. acutus appeared in the bottom left of the plot and did not overlap with *C. coatesi* (Fig. 4).

Dietary comparison by season

A one-way ANOSIM testing between north-west monsoon and south-east monsoon periods did not detect a significant result ($P > 0.1\%$, $R = 0.017$) indicating there was no difference in the diets of all three species between seasons. The nMDS ordination of diets sampled in different seasons showed that most south-east monsoon samples overlapped with north-west monsoon indicating similarity (Fig. 5).

Dietary composition among size classes

Comparison of diet composition among size classes for each species showed that *R. taylori* has a relatively consistent diet with respect to proportions of different dietary components. Cephalopods were not consumed by the smallest size class and there may be a reduction in the consumption of penaeid prawns in the largest sizes class with a possible increase in the consumption of teleosts. *Rhizoprionodon acutus* consumes large proportions of teleosts in all size classes and may consume less crustaceans and cephalopods with increasing size. *Carcharhinus coatesi* had a marked decrease in teleost consumption with increasing size accompanied by an increase in the consumption of crustaceans particularly penaeid prawns (Fig. 6).

The nMDS ordination plot of size classes showed both similarities and differences particularly in the smallest and largest size classes (Fig. 7). Among the *R. taylori* samples there is a general similarity across all size classes except for the largest size class 61–70 cm, samples in this size class were the furthest right on the plot of all *R. taylori* samples. Similarly, diets of mainly larger size *C. coatesi* in the 71–80-cm category were clustered together towards the

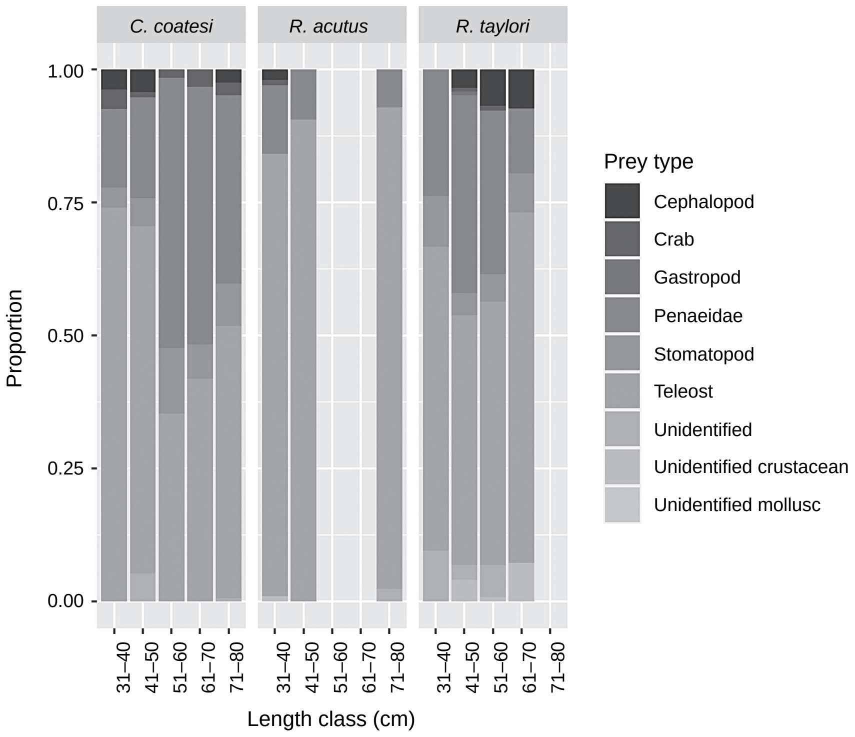

Fig. 6. Composition of the diets of *Carcharhinus coatesi*, *Rhizoprionodon acutus* and *Rhizoprionodon taylori* according to different size classes.

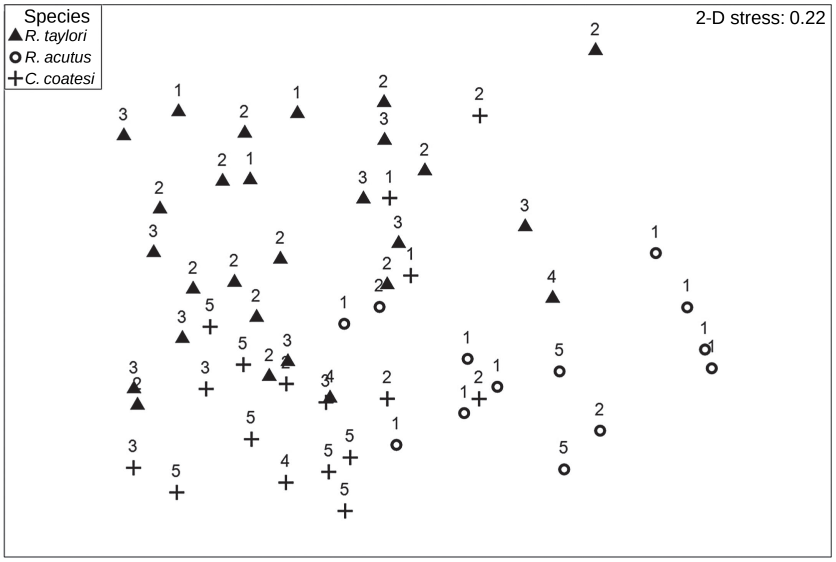

Fig. 7. Non-metric multidimensional scaling ordination of dietary composition by number (%N) of size classes of *Rhizoprionodon taylori*, *Rhizoprionodon acutus* and *Carcharhinus coatesi* in the Gulf of Papua. The numbers represent the size classes: 1, 31–40 cm; 2, 41–50 cm; 3, 51–60 cm; 4, 61–70 cm; 5, 71–80 cm.

lower section of the plot whereas some of the smallest *R. acutus*, 31–40 cm also showed a larger dissimilarity to other size classes of this species.

Discussion

Many shark species are considered to be generalist feeders (Munroe *et al.* 2014) and have been observed to feed in a density-dependent manner (Salini *et al.* 1992). The small-bodied carcharhinids studied here feed at similar trophic levels (Cortes 1999), therefore where they co-occur competition for food resources can arise if prey are limited. This study shows that teleosts, crustaceans and molluscs make up most of the prey of *C. coatesi*, *R. acutus* and *R. taylori*. Teleosts and greater proportions of crustaceans were found in the diet of *R. taylori* and *C. coatesi* whereas the diet of *R. actus* consisted predominantly of teleost with other prey categories being much less important. Stevens and McLoughlin (1991) found similar predominant prey types for all three species in northern Australia, however the relative amounts of prey differed from this study. The findings of this study align with the classification of *R. taylori* as dietary generalist due to its broad diet breath (Munroe *et al.* 2015) and additionally a predominance of teleosts in the diet of *R. acutus* (White *et al.* 2004; Ba *et al.* 2013).

The level of diet similarity as an indicator of competition for food resources was high between species, however, differences in individual diets exist and may facilitate co-occurrence. Significant dietary differences and the lower level of similarity in the diet of *R. acutus* indicate this species may partition food resources by feeding predominantly on teleosts and consuming the lowest levels of crustaceans, molluscs and other prey groups among all three species. *Rhizoprionodon acutus* occupies a broader depth range (White *et al.* 2017), therefore, characterisation of diets alone is insufficient to detect temporal and spatial partitioning that may also be occurring (Bornatowski *et al.* 2014*b*; Lear *et al.* 2021). Future work should incorporate datasets from all resource use axes (White *et al.* 2004) to draw a clearer picture of the food web and ecosystem use.

High similarity in diets of sympatric species may indicate that prey is not limited (Heithaus *et al.* 2013) although prey availability may fluctuate with temporal seasonality (Nunn *et al.* 2020). Despite the high diet similarity between *R. taylori* and *C. coatesi* a few differences were observed. Some prey found in the diet of *C. coatesi* were not detected in the *R. taylori* diet. *Carcharhinius coatesi* also fed on more crustaceans overall increasing its intake with size. Intraspecific dietary change with growth is widely detected in elasmobranchs (Sommerville *et al.* 2011; Barbini and Lucifora 2012). Morphological traits such as dentition and gape size develop with growth and enable capture of larger prey (Powter *et al.* 2010), in this instance a preference for crustaceans in older *C. coatesi* could potentially be a means to avoid competition. In particular, *C. coatesi* consumed a greater amount of crab compared to *R. taylori.* One criticism of stomach content analysis is the predominance of hard parts such as cephalopod beaks and crustacean exoskeleton, which may overestimate the presence of these groups (Kim *et al.* 2012). Since the cumulative prey curves show that the sample size was not sufficient to fully describe diets further sampling and proper identification of prey will be required to adequately characterise diets and investigate the extent of these preliminary observed differences. Both *R. taylori* and *C. coatesi* are morphologically similar but appear to be reproductively different, *R. taylori* breeds annually and has a rapid growth rate reaching maturity in less than 1 year (Baje *et al.* 2018) compared to aseasonal reproduction in *C. coatesi*, which reaches maturity at 5 years of age (Baje *et al.* 2019) these factors may also influence feeding behaviour at various life stages such as the broad diet of *R. taylori* is needed to support rapid growth in the first year of life to reach maturity.

Volumetric and gravimetric (bulk) descriptions of diets have been consistently included with other measures to produce compound indices and have been the preferred measure on which to conduct multivariate analysis. However, practically assessing stomach contents to achieve bulk measures of diets is associated with the difficulty of sorting through masticated and partially digested prey items that are separated into many pieces or loose tissue, which makes it impossible to know which prey item they belong to or if they are part of a separate prey item altogether. Thus, the inclusion of bulk dietary measures introduces inherent errors linked to the difficulty in identifying and quantifying prey items (Baker *et al.* 2014). The absence of a bulk measure of the diet meant that a compound index (e.g. percentage index of relative importance) was not calculated for this study. Compound indices have been recommended as a standard practice (Hyslop 1980; Cortés 1997; Brown *et al.* 2012), however, they have been found to have little significance, as opposed to considering separate dietary measures individually (Baker *et al.* 2014), particularly for demersal species (Macdonald and Green 1983).

This study is the first attempt to investigage the diets of inshore meso-predator sharks frequently caught as by-catch in the GoPPF that focuses on a component of the ecological system that fishing activities constantly interact with. The results are in agreement with the stated hypotheses, however, this work is limited in the use of methodology to identify prey. Future studies should incorporate molecular techniques and stable isotope analysis to improve prey identification (Matley *et al.* 2018). Stable isotope analysis is non-lethal and can also detect longer-term habitat use and diet preferences (Kinney *et al.* 2011; Shiffman *et al.* 2012). Defining the ecological niche of a species is a multivariate exercise requiring empirical evidence from multiple sources (Munroe *et al.* 2014), therefore, future research should complement dietary information with fishery independent surveys, tag–recapture and acoustic tracking to investigate the ecology of species across time and space (Wiley and Simpfendorfer 2007; Donaldson *et al.* 2014) if possible. The Gulf of Papua is a hot spot for species diversity (Pernetta and Hill 1981) including a large proportion of elasmobranchs that are encountered in the GoPPF, some of which are endemic (White *et al.* 2017; Baje *et al.* 2021). Ecological data and information from this region are therefore important to support ecosystem approaches to fisheries management and conservation of vulnerable species.

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Data availability. The data that support this study are available in the article.

Conflicts of interest. Colin Simpfendorfer is an Associate Editor of *Marine and Freshwater Research* but did not at any stage have editor-level access to this manuscript while in peer review, as is the standard practice when handling manuscripts submitted by an editor to this journal. *Marine and Freshwater Research* encourages its editors to publish in the journal and they are kept totally separate from the decision-making processes for their manuscripts. The authors have no further conflicts of interest to declare.

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