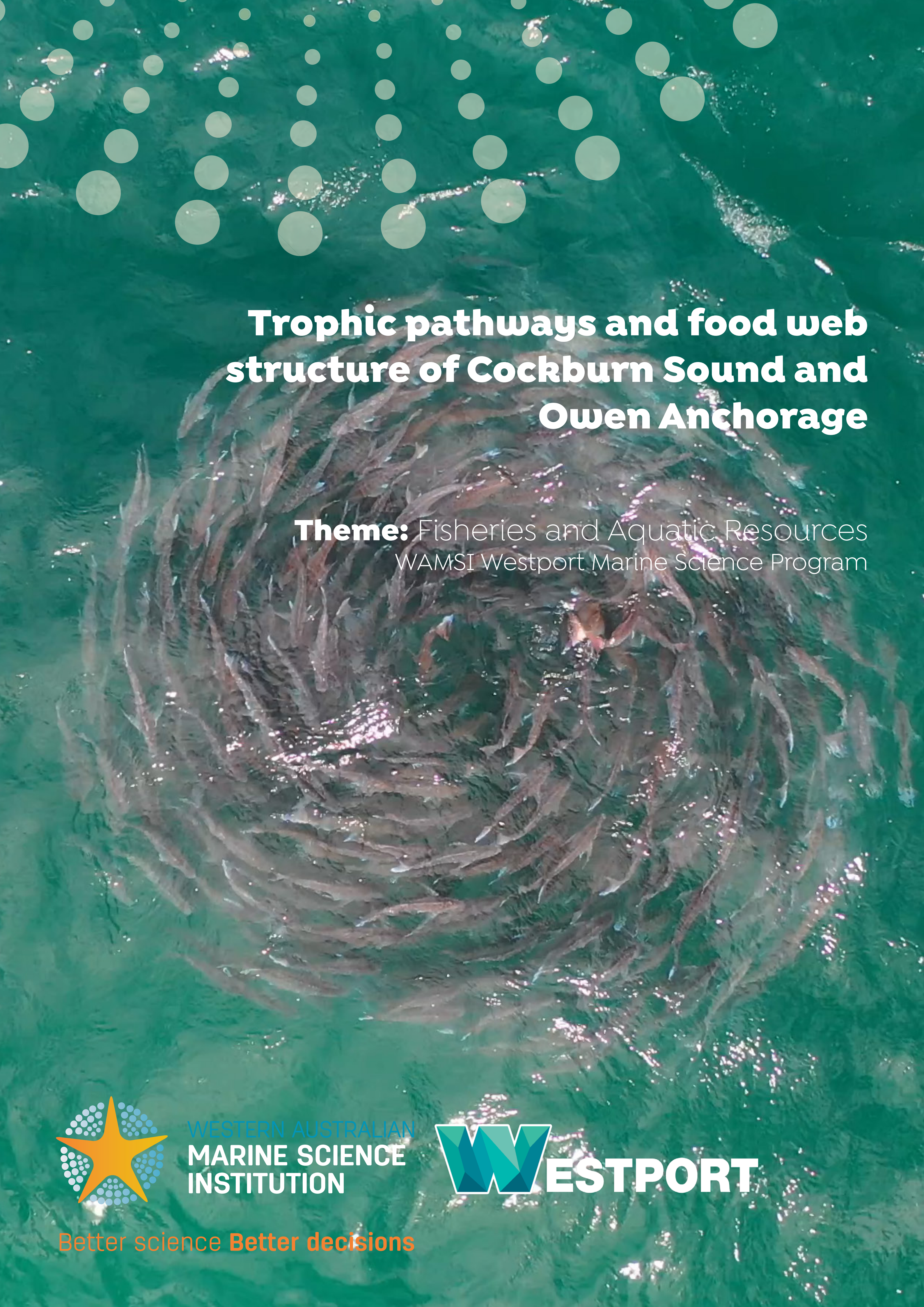

Trophic pathways and food web structure of Cockburn Sound and Owen Anchorage

Theme: Fisheries and Aquatic Resources

WAMSI Westport Marine Science Program

WESTERN AUSTRALIAN
MARINE SCIENCE
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WESTPORT

WAMSI WESTPORT MARINE SCIENCE PROGRAM

ABOUT THE MARINE SCIENCE PROGRAM

The WAMSI Westport Marine Science Program (WWMSP) is a $13.5 million body of marine research funded by the WA Government. The aims of the WWMSP are to increase knowledge of Cockburn Sound in areas that will inform the environmental impact assessment of the proposed Westport development and help to manage this important and heavily used marine area into the future. Westport is the State Government's program to move container trade from Fremantle to Kwinana, and includes a new container port and associated freight, road and rail, and logistics. The WWMSP comprises more than 30 research projects in the biological, physical and social sciences that are focused on the Cockburn Sound area. They are being delivered by more than 100 scientists from the WAMSI partnership and other organisations.

FUNDING SOURCES
The $13.5 million WAMSI Westport Marine Science Program was funded by the Western Australian Government, Department of Transport. WAMSI partners provided significant in-kind funding to the program to increase the value to >$22 million.

DATA
Finalised datasets will be released as open data, and data and/or metadata will be discoverable through Data WA and the Shared Land Information Platform (SLIP).

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FRONT COVER IMAGE
Theme: Fisheries and Aquatic Resources
Front cover image: A school of pink snapper in Cockburn Sound (DPIRD).

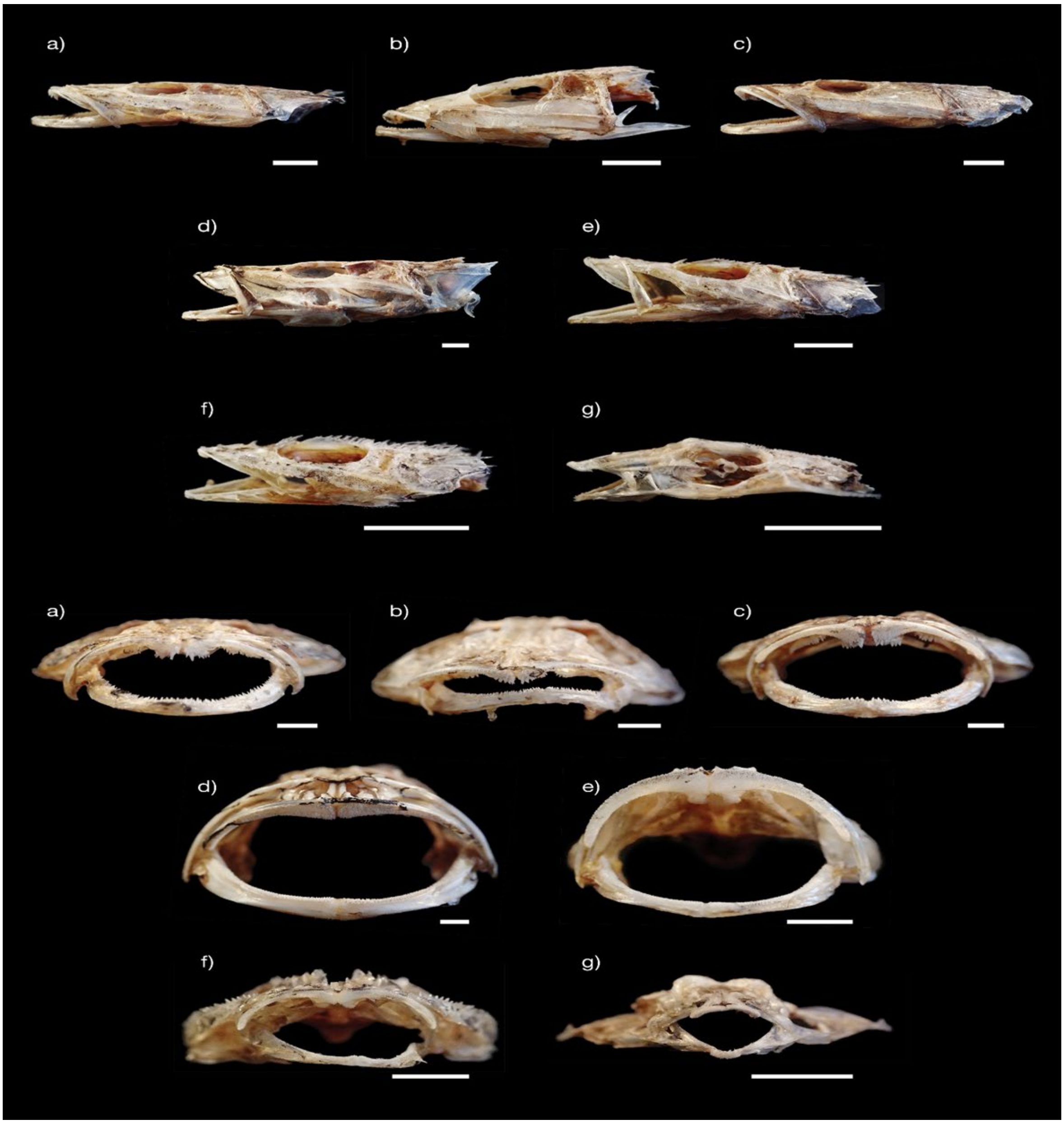

Image*. Photographs of the lateral view of the head and jaws of (a) southern bluespot flathead* Platycephalus speculator *(Total Length (TL) = 290 mm), (b) longspine flathead* Platycephalus grandispinis *(TL = 245 mm), (c) yellowtail flathead* Platycephalus westraliae *(TL = 329 mm), (d) longhead flathead* Leviprora inops *(TL = 390 mm), (e) rusty flathead* Inegocia japonica *(TL = 184 mm), (f) midget flathead* Onigocia spinosa *(TL = 105 mm) and (g) longspine dragonet* Pseudocalliurichthys goodladi *(TL = 125 mm). Skulls shown as similar sizes for photographs, White Scale bar =10 mm. Images taken and compiled by Mitchell Haywood and Daniel Cox.*

Contents

The WAMSI Westport Marine Science Program is a $13.5 million body of research that is designed to fill knowledge gaps relating to the Cockburn Sound region. It was developed with the objectives of improving the capacity to avoid, mitigate and offset environmental impacts of the proposed Westport container port development and increase the WA Government's ability to manage other pressures acting on Cockburn Sound into the future. Funding for the program has been provided by Westport (through the Department of Transport), and the science projects are being delivered by the Western Australian Marine Science Institution.

Trophic pathways and food web structure of Cockburn Sound and Owen Anchorage

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Project
Project 4.2.3 - Trophic pathways and food web structure of Cockburn Sound and Owen Anchorage

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This was a collaborative project involving a team from multiple agencies. Involvement included initial project conception, design and funding, scientific and experimental design, data collection, sample processing, data analyses, report writing/editing and/or project management. The final report authorship (below) recognises overall contribution to the project.

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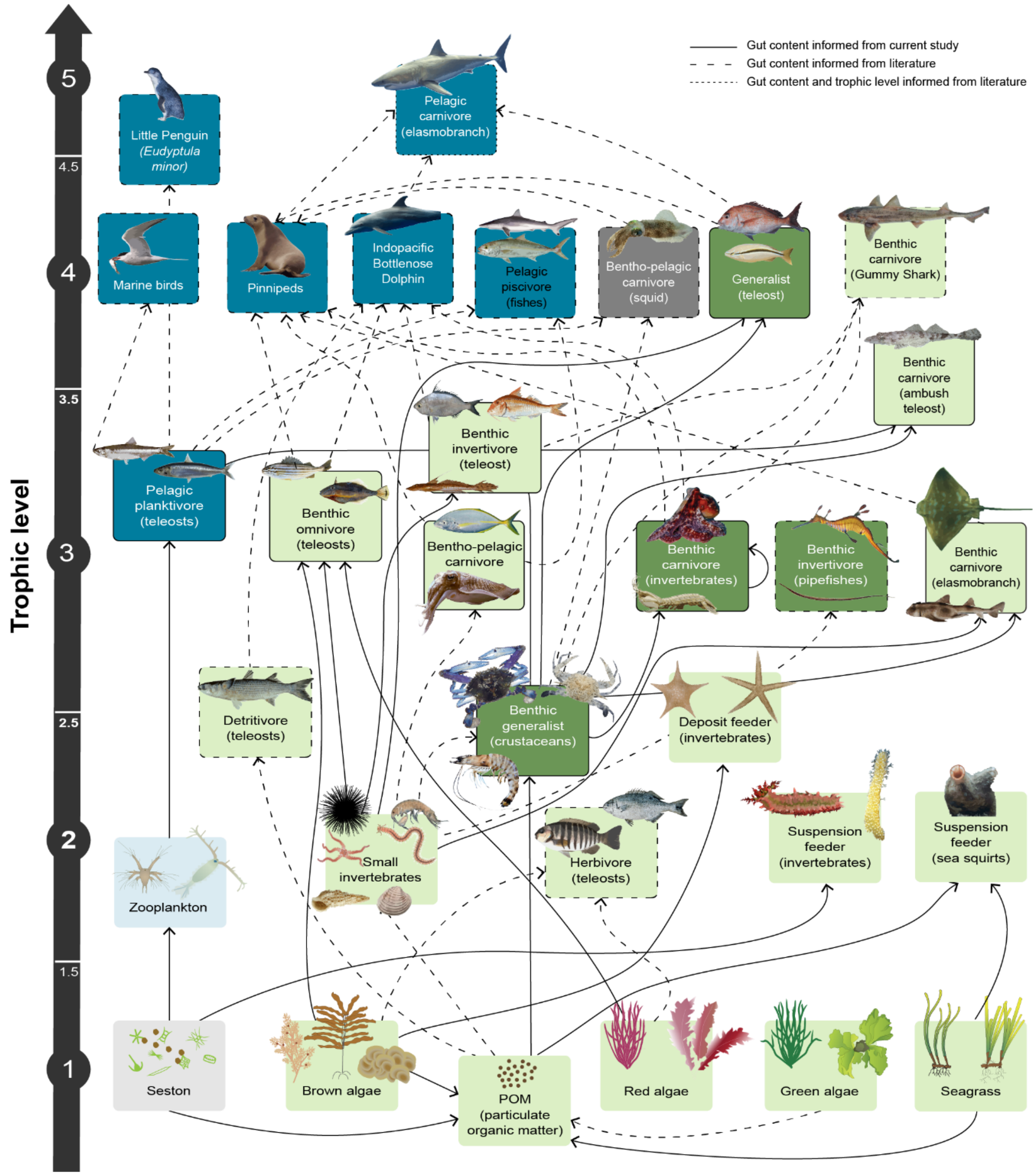
Executive summary

Sheltered coastal waters like Cockburn Sound support a diverse range of flora and fauna, many of which are of ecological, economic and cultural importance. These species and the biological communities they form are organised into food webs that respond to single and cumulative pressures acting simultaneously at multiple spatial and temporal scales. By understanding trophic linkages and the flow of nutrients, the effects of real and hypothesised environmental changes on both the structure of biological diversity and ecosystem functioning can be quantified and predicted. The overall aim of this study was to produce a conceptual model for the food web structure for Cockburn Sound and Owen Anchorage (see overleaf) that describes the flow of nutrients and energy from base sources of production to higher trophic levels (e.g. fish and apex predators) that will inform the potential impacts of the Westport or any future infrastructure development for EIA and climate change, and contribute to the prediction of the likely effects of the potential resilience building initiatives on productivity in Cockburn Sound. To achieve this, the current study utilised three main data sources: (i) gut contents of 2,117 fish and invertebrates from 18 species; (ii) $\delta^{13}C$ and $\delta^{15}N$ signatures for nine primary producers and 55 consumers ranging from detritivores to apex predators; and (iii) the scientific literature.

Gut content analysis provided high-resolution data on the last meal of an individual. It demonstrated that each species studied had a different diet, which was influenced by their mouth and body morphology. The small pelagic baitfish blue sprat and sandy sprat fed primarily on zooplankton, particularly planktonic crustaceans, while most other species consumed benthic or epibenthic prey. Blue swimmer crab and longspine dragonet consumed mainly bivalve and gastropod molluscs, while soldier, midget flathead and western rock octopus ingested predominantly crustaceans. Other species, such as skipjack trevally, western butterfish, snapper and western trumpeter whiting, had a broad diet consuming a range of taxa, including molluscs, polychaetes, crustaceans and echinoderms. Several of the larger flathead species consumed fish. The dietary composition of most species differed with increasing body size, noting that differences would have been larger if the full-size range of each species was able to be sampled. Typically, larger predators consumed larger and more mobile prey. Regional and seasonal differences in diet were also detected for most species, with the diets of individuals caught from Owen Anchorage typically being the most distinct. As most species were founds to be generalists and that the trends in the volume of prey consumed in the different regions mirror those in some of the benthic invertebrate fauna recorded in the WWMSP project “Benthic Communities in Soft-sediment and Natural Hard Habitats” it appears many species feed opportunistically. However, benthic invertebrates, particularly decapods (crabs and prawns), stomatopods (mantis shrimp) and bivalve molluscs, were consumed frequently and in large volumes, indicating they are an important food source for many fish species, especially more specialist feeders.

Stable isotope analyses revealed a high degree of variability in the stable isotope signatures for sources of production (primary producers), invertebrates, and fishes. Trophic levels varied up to almost 5 (where a value of 1 reflects the base level of primary producers and 5 reflects high-order carnivores), indicating a high diversity of trophic guilds in the system. The high variability in $\delta^{13}C$ across consumer guilds and species indicates a range of sources contribute to the food web. Mixing models, based on $\delta^{13}C$ and $\delta^{15}N$, suggested that a range of primary producers contributed to the sedimentary detritus in the system, including benthic macrophytes (kelp and seagrass) and seston (phytoplankton). Benthic invertebrates and fishes gain their nutrients predominantly from a range of benthic primary producers, through either direct consumption of detritus or indirectly via their prey. Even some suspension feeders, i.e. sea squirts, are likely to gain their nutrients from the resuspension of sedimentary particulate organic matter (POM). This formed a clear benthic food web within the system, driven by sedimentary POM. In comparison, seston appeared to form the major base source for the pelagic food web, with planktivorous fishes forming the first consumer level. In comparison, the slightly enriched $\delta^{13}C$ values of other consumers suggest that benthic sources also contribute to this food web. Thus, the resuspension of benthic POM or the movement of consumers through the water column provides some coupling of these two food webs.

The empirical information derived in this study, together with the collation and standardisation of data from the scientific literature, provide a comprehensive data set on the dietary composition and trophic level for over 200 of the fish species known to occur in Cockburn Sound that can be used in ecosystem models to help predict the impacts of the proposed or future infrastructure developments and climate change on trophic linkages and the flow of nutrients.



Conceptual food web for the Cockburn Sound region based on the results of the gut content analysis and stable isotope analysis from the current study and the scientific literature (Appendices 4 and 5). Blue shading for a functional group indicates that it feeds primarily in the pelagic environment and green primarily on or near the benthic environment. Darker boxes indicate groups containing species of commercial, recreational fishery and/or conservation significance.

Acknowledgments

This project would not have been made possible without the samples and data provided by other projects within the WAMSI Westport Marine Science Program (WWMSP) portfolio and highlights the value of collaborative, interdisciplinary research. We thank the staff and volunteers associated with those projects for their help, particularly those affiliated with other projects in the WWMSP, particularly "Benthic Communities in Soft-sediment and Hard Substrates" and "Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound", where most of the samples for gut content analysis and stable isotope analysis came from. Processing of those biological samples was aided greatly by staff from the Western Australian Museum and student volunteers from Murdoch University. Dylan Bennett (Murdoch University) is thanked for helping with the functional analysis of morphological traits.

A wide range of images were utilised in the compilation of this report, in particular figures 27, 29 and 100. These were obtained through (i) the Integration and Application Network/University of Maryland Center for Environmental Science symbol and Image Libraries (CC BY-SA 4.0; www.ian.umces.edu/media-library) or (ii) publicly available photographs (CC by Attribution-NonCommercial) obtained from iNaturalist, Wikimedia Commons, Fishbase and Flickr, that were edited to remove any background in Adobe Photoshop and vectorised using SVGConverter https://svgconverter.app/free and Adobe Express. Original photographs used to make the vectors © Alexander Semenov; Alexandra Hoschke; Alexis Lours; Arthur Anker; Australian National Fish Collection (CSIRO); Barry Hutchins (Western Australian Museum); Brian M. Hunt; Brian Gratwicke; David Harris; Elias Levy; Erik Schlogl; Callum Evans; Florida Museum of Natural History; Gary Cranitch; Glen Whisson; Graham Short; Gray (Biodiversity Heritage Library); H. Zell; Hans Hillewaert; Henrik Glenner (Universitetet i Bergen); Indra Bone; J. Martin Crossley; James St. John; JJ Harrison; John E. Randall; John Sear; Jonathan Sims; Julian Finn (Museums Victoria); Ken Graham; Michael Marmach; Museum National d'Histoire Naturelle; MyFWC Research; Nathaniel Evans; NCFishes; NOAA/NMFS (E. Hoffmayer, S. Iglésias and R. McAuley); P. Good; R. Tucker Abbott and S. Peter Dance; Rodolfho B. Reyes; Marine Global Earth Obersvatory; Sus barbatus; Tarsip / iNaturalist.org; and Wayne Martin.

Integration with other projects

This project had no fieldwork component and thus utilised samples from other projects in the WAMSI Westport Marine Science Program. Whole specimens and identifications of macroalgae, seagrass and benthic macroinvertebrates were provided from "Benthic Communities in Soft-sediment and Hard Substrates", and larger invertebrates and fish from "Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound". Seston (i.e. phytoplankton and suspended particulate matter) samples were provided by "Zooplankton in Cockburn Sound", and stable isotope values for Penguins and Dolphins by "Determining the Diet, Causes of Mortality, Foraging Habitat and Home Range of Little Penguins", "Australian Sea Lions in the Perth Metropolitan Area (abundance: movement, habitat use and diet", and "Spatio-temporal Distribution of Key Habitat-uses and Key Prey Species for Indopacific Bottlenose Dolphins in Owen Anchorage and Cockburn Sound". All sampling was carried out under the permits acquired by the investigators of those projects.

1. Introduction

Understanding trophic interactions is critical for assessing the ecological functioning and integrity of ecosystems, particularly through determining the main sources of production that drive secondary production and biodiversity, and the flow of nutrients and energy through the food web (Thompson et al. 2012, Calver et al. 2024). By using combined stable isotope and gut content approaches, this project has determined the dietary composition and key trophic pathways for secondary production and biodiversity in both benthic and pelagic components of Cockburn Sound.

The combined use of stable isotopes (SIA) of bulk tissue and gut contents (GCA) analyses has become a powerful tool to determine the trophic structure of marine ecosystems (e.g. Hyndes & Lavery 2005, Crawley et al. 2006, Crawley et al. 2009, Greenwell et al. 2019). Compared to gut content analyses, stable isotopes are based on the assimilation of material from food sources over periods of weeks to months (Vander Zanden et al. 2015), and therefore represent the uptake of material over far longer periods than the "snapshot" provided by GCA. Also, SIA has the capacity to determine the primary source(s) of production that drive the food web. Carbon ($^{13}C/^{12}C$ expressed as $\delta^{13}C$) and nitrogen ($^{15}N/^{14}N$ expressed as $\delta^{15}N$) are common isotopes used in food web studies. Because $\delta^{13}C$ is not considered to change markedly between trophic steps, it can be useful to distinguish between sources of production, e.g. seagrass and macroalgae. In comparison, $\delta^{15}N$ is often used to determine the number of trophic steps since it is considered to increase by approximately 3‰ at each trophic level. Sulfur ($^{34}S/^{32}S$ expressed as $\delta^{34}S$) has been shown to provide greater delineation between sources in a multiple isotope approach, particularly with sources derived from either oxygen-enriched or depleted environments (Connolly et al. 2004).

While there is considerable knowledge of food web dynamics in Owen Anchorage to the north of Cockburn Sound, based on the Shell Sand Dredging Environmental Management Programme or Cockburn Cement Limited (CCL) in the late 1990s, there is no such comprehensive knowledge of trophic interactions in Cockburn Sound (Smit et al. 1998, Platell & Hall 2006). Furthermore, knowledge of food web dynamics in Owen Anchorage is based on seagrass as a major benthic habitat (Kendrick & Hyndes 2005, MacArthur & Hyndes 2007), whereas seagrasses currently form <10% of the area of benthic habitats in Cockburn Sound (Kendrick et al. 2002). The few studies that have used stable isotopes to determine the main sources driving food webs in the Perth Metropolitan region have shown that seagrass provides only a minor contribution to the food webs in the shoreline areas in Cockburn Sound, Shoalwater Bay and the northern beaches of the Perth Metropolitan region (Crawley et al. 2009) and more offshore waters of Owen Anchorage (Smit et al. 2005, Smit et al. 2006), whereas macroalgae and, to a lesser extent, benthic microalgae make larger contributions (Hyndes & Lavery, 2005). While seagrass meadows only cover ~9% of the benthic habitat in Cockburn Sound, the export of seagrass leaves from these and other meadows in Owen Anchorage will contribute to the detrital pool in other regions of Cockburn Sound, e.g. shoreline areas and the deeper basin. Other sources of production, such as epiphytic macroalgae on seagrass, macroalgae on reef or rock walls (e.g. *Sargassum*) and phytoplankton, are also likely to contribute either directly through grazing or indirectly through the detrital pathway to the food web of Cockburn Sound. Furthermore, detrital kelp and other macroalgae from reefs outside of Cockburn Sound are likely to be imported into Cockburn Sound and contribute to its food web.

Gut content analysis is a well-established and utilised method of quantifying, to a fine taxonomic resolution, the last meal of fish and large invertebrates (e.g. crabs and octopus) species (Lek et al. 2011, Greenwell et al. 2018). This snapshot approach to determining the diet of a species is particularly valuable for species that are not permanent residents in Cockburn Sound. For example, snapper aggregate in Cockburn Sound to spawn (Wakefield et al. 2011), during which they have been known to heavily predate on shellfish on the mussel farm (Glenn Dibbin, Blue Lagoon Mussels, personal obs.). Determining the diet of this species during this critical time in their life cycle would be crucial to any ecological risk assessment. Moreover, species like Blue Swimmer Crabs undergo a migration to and from estuaries. Thus, while SIA would provide a dietary signature across both their estuarine and marine phases, GCA would allow discrimination of their diet during the time they are utilising Cockburn Sound (Campbell et al. 2021). Thus, while SIA and GCA aim to determine the dietary composition of a species, they do this in different ways that are complementary and vital to understanding the trophic structure of Cockburn Sound and Owen Anchorage.

This project is the first comprehensive study of the food web in Cockburn Sound. The main sources of production driving the food web in the embayment will be determined through mixing models of SIA data collected during the project. This will feed directly into the development of conceptual food web models to predict the potential impacts of the Westport development, either through the direct loss of sources of production from land reclamation and dredging, or indirectly from loss associated with sediment plumes and sedimentation. Combined with GCA from this project, key pathways for the flow of these driving sources will be determined for key fisheries species, including snapper *Chrysophrys auratus*, whiting species *Sillago burrus*, baitfish (e.g. blue sprat *Spratelloides robustus* and sandy sprat *Hyperlophus vittatus* [also referred to as whitebait], blue swimmer crab *Portunus armatus*, western rock octopus *Octopus djinda*, and ultimately to higher trophic levels including apex predators including the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), Australian sea lion (*Neophoca cinerea*) and little penguin (*Eudyptula minor*).

This project had the core objective to provide a conceptual model and data for the food web structure for Cockburn Sound and Owen Anchorage that describes the flow of nutrients and energy from base sources of production to higher trophic levels (e.g. fish and apex predators, such as little penguins and Indo-Pacific bottlenose dolphins) that will inform the potential impacts of the Westport or any future infrastructure development for EIA and climate change, and contribute to the prediction of the likely effects of the potential resilience building initiatives (e.g. restoration of seagrass and deployment of artificial reefs) on productivity in the Sound.

This will be achieved through:

- Determining the diet of key fisheries species through gut content analyses and investigating whether they differ through ontogeny and spatially and temporally.
- Determining the main sources of production that drive secondary production and the flow of nutrients and energy through the food web using stable isotope analyses.

2. Materials and methods

This study investigated food web structure through complementary approaches. Diet and trophic flows were determined using GCA on 16 species of fish, blue swimmer crabs and western rock octopus that reflect the food resources ingested in the past hours, and SIA on a broader suite of 55 consumers to provide information on the sources of production that contribute to the nutrients assimilated in the tissue over weeks. In addition to comparing differences in diet between species and for each species with body size, spatially within regions of Cockburn Sound and between two seasons, relationships between morphology and dietary composition were investigated. In addition, a meta-analysis was carried out to collate dietary information for a broader suite of species that occur in coastal waters in the Perth region but were not investigated empirically during the current study. These data sources were then used to construct a conceptual food web.

2.1. Sampling regime

Samples for GCA and SIA were collected by staff working on the WWMSP Project "Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound" using a combination of sampling methods in November 2021 (spring) and May 2022 (autumn). Fishes and megabenthic invertebrates (>1 cm in size, including blue swimmer crab [*P. armatus*]) were primarily obtained through sampling conducted with large otter trawls, small otter trawls, beach seines, benthic sled and rod and line fishing (Figure 1a). The large trawl had an 11 m wide headrope, 1 m opening height, and was constructed with 55 mm mesh in the wings and 45 mm mesh in the cod-end. The trawl was twin-rigged (two nets deployed in parallel) and was towed at a speed of ~3.3 knots for 5 minutes (swept area of ~3,750 m^2 per net). The small trawl had a 4.5 m headrope, 0.5 m opening height and was constructed with 51 mm mesh in the wings and 25 mm mesh in the cod end. The trawl was towed at a speed of ~2.7 knots for 9 minutes (swept area of ~2,260 m^2). Two sizes of beach seine were used. The smaller net was 21.5 m long, had a vertical drop of 1.5 m, two 10 m long wings (outer 6 m comprising 9 mm mesh and inner 4 m comprising 3 mm mesh), a 1.5 m long bunt (3 mm mesh) and swept an area of approximately 116 m^2. The larger seine net was 61.5 m long with a 2 m vertical drop. This net comprised 22 mm mesh outer wings, 8 mm mesh inner wings and bunt, and swept an area of ~592 m^2. To avoid damaging the seagrass beds, a benthic sled (i.e. a trawl net raised on skis) was used to collect fish from these habitats. The sled had a 0.75 wide and 0.45 m high mouth opening, a 4 m long, 26 mm mesh body and a 1 m long, 6 mm mesh cod-end. The sled was towed at a speed of ~2 knots for 5 minutes (swept area of ~231 m^2). Trawling and benthic sled samples were collected at night (>1 hour after sunset), whereas seine netting was conducted during daylight. After collection, samples were placed on ice or frozen and transported to Murdoch University for storage at -18 °C and subsequently defrosted and processed (see below).

When enough samples for a particular species were not obtained from sampling activities in November 2021 and May 2022, additional fish were sometimes able to be obtained using the same methods in other seasons. Only juvenile snapper (*C. auratus*) were collected in the large trawls (mean total length (TL) = 123 mm; range = 106-196 mm), yet the Cockburn Sound is also a spawning ground for larger individuals (Wakefield 2010), large fish (mean TL = 852 mm; range = 656-944 mm) were collected by DPIRD using a rod and line. Western rock octopus (*Octopus djinda*) were obtained by DPIRD from commercial octopus fishers operating in Cockburn Sound.

Infaunal invertebrates (>500 µm) and sediment were sampled as part of WWMSP Project "Benthic Communities in Soft-sediment and Hard Substrates" using a Van Veen grab (Figure 1b). The sediment grabs were further split into shallow (<10 m) and deep (>10 m depth), respectively. After collection, grab samples were gently sieved to remove excess fine sediment using a 500 µm mesh. Invertebrates were removed by hand from the retained sediment under a Nikon SMZ745T dissecting microscope and preserved in 100% ethanol. A range of primary producers were collected opportunistically throughout Cockburn Sound during summer and winter via collection from reefs and seagrass meadows.

All sampling was conducted under permits approved by Murdoch University's Animal Ethics Committee (permit number RW3369/21 and cadaver 903) and the Department of Primary Industries and Regional Development, Fisheries Division (exemption number 250929821).

To elucidate whether diet and trophic structure differed spatially across Cockburn Sound, the embayment, which for this study includes Owen Anchorage, was split into three regions, i.e. Owen Anchorage, North Cockburn Sound and South Cockburn Sound (Figure 1).

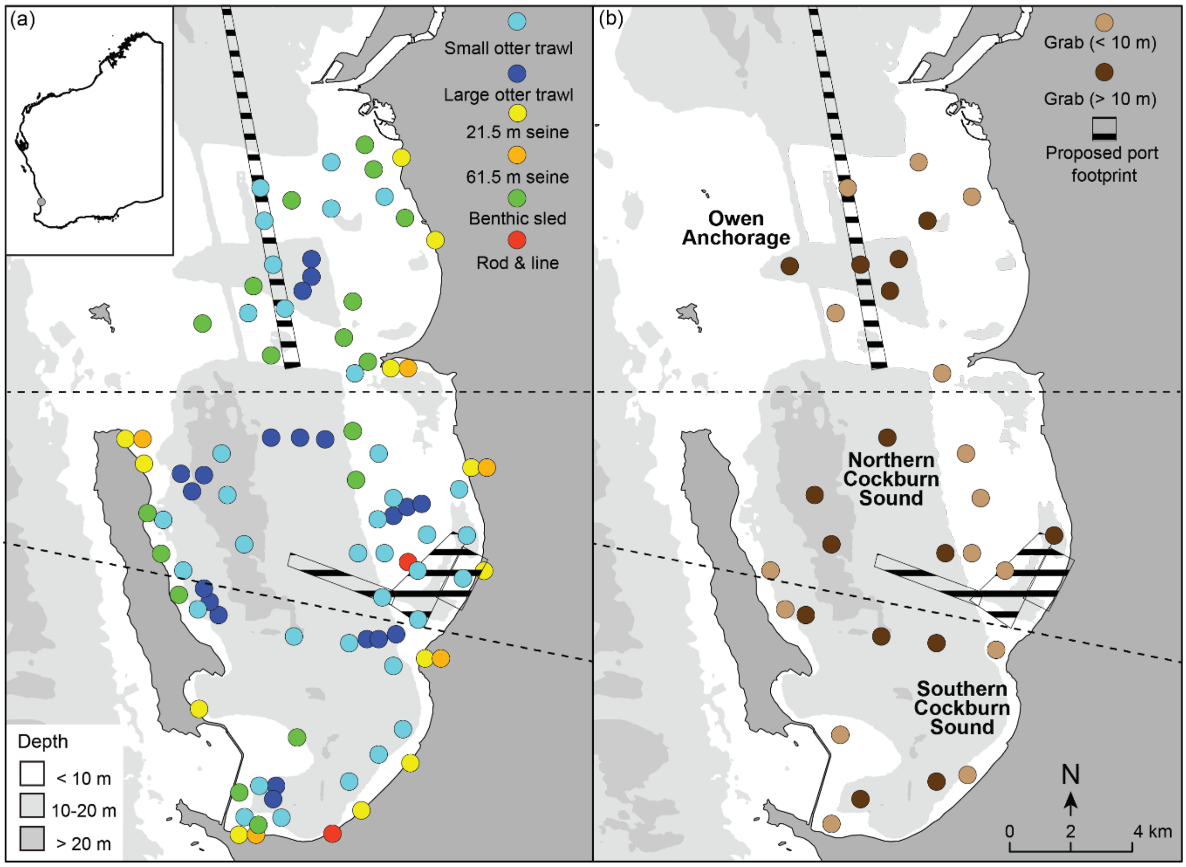


Figure 1. Map showing the location where samples of (a) fish and megabenthic invertebrates and (b) infaunal invertebrates and sediment were collected. Dashed lines denote the spatial boundaries of the three regions of Cockburn Sound. For context, an estimated outline of the proposed port footprint is provided.

2.2. Laboratory processing

Samples of finfish from WWMSP Project "Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound" were removed from the freezer and once lightly defrosted, individual fish were separated, identified to species level and a decision made as to whether to include them in the GCA (Subsection 3.2.1), SIA (Subsection 3.2.2) and morphometric (Subsection 3.2.3) analyses based on samples size and feeding functional group to which they belonged. GCA involved obtaining larger numbers of samples for a given species and focusing on those species that were abundant and/or of importance to recreational and/or commercial fishing. As the dietary composition of many fish changes with increasing body size (Sánchez-Hernández et al. 2019), the widest possible size range of each species was used in the GCA. A smaller number of individuals but a broader range of species were selected for SIA. Note, where the SIA sample of a particular individual was subjected to analyses so was the corresponding digestive tract. Finally, as wide a range of fish species as possible was selected for morphometric analysis. Samples of invertebrates where whole specimens were available, i.e. blue swimmer crabs and western rock octopus, were subjected to GCA and SIA. In contrast, those of other taxa, where only muscle tissue was available, e.g. spinner sharks, were only subjected to SIA.

2.2.1. Gut contents

The total length (TL) for each whole individual retained for GCA was measured to the nearest mm and weighed to the nearest 0.1 g wet weight. Body size for the southern eagle ray (*Myliobatis tenuicaudatus*) and blue swimmer crab was measured as disk width (mm) and carapace width (mm), respectively. Scissors were used to make an incision on the ventral surface, from the cloaca to the throat. For finfish, the digestive tract (stomach and intestines) was dissected, preserved in >70% ethanol and left for at least three days to ensure adequate preservation before the contents were identified. In the case of blue swimmer crabs, the proventriculus, which contains the cardiac and pyloric stomachs, was removed and preserved (Campbell et al. 2021). As a previous study on western rock octopus (albeit at the time known as *Octopus* aff. *O. tetricus*) found that a far greater taxonomic diversity and resolution of diet could be determined from crop than the stomach (Greenwell et al. 2019), only this portion of the carcass was utilized.

The fullness of each stomach was recorded on a scale of 0, i.e. empty, to 10, i.e. fully distended (Platell & Potter 2001). Each item in the stomach was examined under a Nikon SMZ745T dissecting microscope, sorted into dietary items, and the percentage contribution of each of those items to the total volume was estimated visually to the nearest 1% (Hynes 1950, Hyslop 1980). Each time a new dietary item was found, it was photographed using a Tucsen MIchrome 6 camera mounted on the microscope and lodged in a physical reference collection in 100% ethanol. All dietary items were identified to the lowest taxonomic level possible using a range of identification tools (Todd et al. 1996, Beesley et al. 2000, Rouse & Pleijel 2001, Jones & Morgan 2002, Poore 2004, Gomon et al. 2008, Huber 2010, 2015, Dowling et al. 2021, Robin 2021, Whisson & Hoschke 2021, Poore & Ahyong 2023). Only adult snapper were caught using line fishing. As the bait used to catch those fish had been cut into distinct segments and was undigested, it was easily distinguishable and excluded from subsequent dietary analyses (Platell et al. 2022).

Dietary information was obtained from a total of 2,117 individuals from 16 finfish species (15 teleosts and one elasmobranch (southern eagle ray) and two large invertebrates, i.e. blue swimmer crabs and western rock octopus (Table 1).

Table 1. Total number of guts of each species examined overall (#) the region, season in which they were collected, and method used to obtain them. For each species, the mean and range of both body size (total length for teleosts; disk width for batiods and carapace width for crustaceans) and weight are provided.

Common and species name		Region			Season				Method						Size (mm)		Weight (g)	
	#	OA	NC	SC	Sp	S*	A	W*	BT	ST	S	BS	LF	CF	Mean	Range	Mean	Range
Western smooth boxfish; *Anoplocarpus amygdaloides*	10	3	4	3	6	4			10						180	131-280	252.95	97.07-593.05
Snapper; *Chrysophrys auratus*	109	24	55	30	109				85				24		284	105-944	1,666.99	20.09-10,552.00
Solider; *Gymnapistes marmoratus*	93	24	28	41	20	4	69		35	48	1	9			75	38-152	9.57	0.20-71.88
Sandy sprat; *Hyperlophus vittatus*	58	19	19	20	14	14	30		45		13				84	45-109	5.01	0.48-9.04
Rusty flathead; *Inegocia japonica*	318	14	153	151	89		229		294	24					147	71-273	25.58	2.25-146.82
Longhead flathead; *Leviprora inops*	18	15		3	10		8		1	17					210	118-390	91.60	9.09-389.69
Southern eagle ray; *Myliobatis tenuicaudatus*	34	3	9	7	6	6	22		34						608	392-759	4,304.92	956.59-8,360.00
Western rock octopus; *Octopus djinda*	98							98						98				
Midget glathead; *Onigocia spinosa*	212	52	112	48	85		127		89	122	1				92	54-140	8.48	1.60-70.70
Western butterfish; *Pentapodus vitta*	146	49	48	49	91		55		146						149	73-216	47.17	4.39-129.71
Longspine flathead; *Platycephalus grandispinis*	50	6	32	12	21		29		45	5					211	108-273	67.79	6.42-157.80
Southern bluespot flathead; *Platycephalus speculator*	4	1	3		3		1		2	1	1				302	109-499	304.59	7.01-898.91
Yellowtail flathead; *Platycephalus westraliae*	5	3	2		2		3		5						259	127-330	155.52	91.53-238.62
Blue swimmer crab; *Portunus armatus*	219	53	76	90	113		106		194	10	15				106	38-163	109.45	2.74-399.93
Longspine dragonet; *Pseudocalliurichthys goodladi*	285	43	106	136	82		203		230	55					116	60-153	8.53	1.19-18.98
Skipjack trevally; *Pseudocaranx wrighti*	155	55	52	48	97		58		155						152	56-208	46.83	1.84-106.11
Western trumpeter whiting; *Sillago burrus*	174	52	55	67	105	7	62		167		7				171	59-245	46.81	1.67-117.61
Blue sprat; *Spratelloides robustus*	129	42	46	41		96	33			41	88				53	34-97	1.14	0.21-5.94
Total	2,117	458	800	746	853	131	1,035	98	1,537	323	126	9	24	98				

Region: OA; Owen Anchorage: NC; North Cockburn Sound: SC; South Cockburn Sound. Season: Sp; spring; S; Summer: A; Autumn: W; Winter. Method: BT; big trawl: ST; small trawl; S; seine net: BS; benthic sled: LF; line fishing: CF; commercial fishers. * Additional sampling to obtain sufficient numbers of individuals.

2.2.2. Stable isotopes

2.2.2.1. Potential sources and consumers

Where possible, fish and invertebrate muscle were collected and cleaned with deionised water from five replicate samples per species from each of the three regions and in both seasons (n = 30). Only southern school whiting (*Sillago bassensis*) had sufficient sample sizes for both juveniles and adults across all regions and seasons. Samples were dried at 60°C until constant weight and ground using a mill and ball grinder (Retsch MM-400). Given the low coverage of macrophytes across the Sound, five replicate samples of each macrophyte (macroalgae and seagrass) species were collected across Cockburn Sound and Owen Anchorage rather than within the three designated regions (Table 2). Macrophyte tissue was washed free of epiphytes, and then, similar to fish and invertebrate muscle, dried and ground. Ground material was then weighed into tin capsules (fish and invertebrates ~1 mg, macrophytes ~1.4 mg) and, due to cost and efficiency, analysed at The Stable Isotope Facility at University of California, Davis for $\delta^{15}N$ and $\delta^{13}C$ using isotopes using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 IRMS (Sercon Ltd., Cheshire, UK). Analytical precision was estimated via analysis of two proteinaceous internal reference materials, with analytical precision at ±0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$.

A subsample of species was chosen for $\delta^{34}S$ analysis. Replication was reduced to three for the chosen species due to the high costs associated with this analysis. Approximately 10 - 40 mg of each sample was sent to the University of Hawaii, Hilo Analytical Lab for $\delta^{34}S$ analysis using a Costech ECS 4010 interfaced with a Thermo Delta V IRMS. Again, samples were sent to Hilo due to the cost and efficiency of getting samples analysed. Sulfur isotope data were normalized to IAEA-S3 ($\delta^{34}S$ vs CDT = -32.49) & NBS-127 ($\delta^{34}S$ vs CDT = +21.17), accurate to 0.3‰.

Sediment samples were collected at the same time as benthic invertebrate samples using a benthic grab in WWMSP Project "Benthic Communities in Soft-sediment and Hard Substrates". These samples were dried at 60°C until constant weight. A subsample of ~10 g was removed and ground using a mill and ball grinder (Retsch MM-400) for SIA and loss on ignition. As carbonate skews $\delta^{13}C$ results, the sediment was treated using 1M hydrochloric acid (HCl) to remove any carbonates present. This treatment process influences the $\partial^{15}N$ analysis, so the sediment samples were triplicated: 1 treated sample for δ13C, 1 untreated sample for δ15N, and $\delta^{34}S$ analysis separately. All samples were sent to the University of Hawaii for analyses, but samples had insufficient amounts of Sulfur for $\delta^{34}S$ analyses. Consequently, only $\delta^{13}C$ and $\delta^{15}N$ values are available for sediment POM.

Seston (phytoplankton and suspended particulate matter) samples were collected within WWMSP Project "Zooplankton in Cockburn Sound" in December 2021 and May 2022. Briefly, 1 litre of water at 15 sites across Cockburn Sound and Owen Anchorage was filtered through a glass fibre filter (GFF) paper and stored frozen for laboratory processing (see below). Samples were dried at 60°C overnight and weighed. Each filter was then subsampled into halves; one half was acidified with 1M HCl and rinsed for $\partial^{13}C$ and one half for $\partial^{15}N$. Additional samples were processed for $\delta^{34}S$. The $\delta^{13}C$ and $\delta^{15}N$ samples were encapsulated in tin capsules and analysed on a SerCon 20-22 IRMS or Thermo Delta V IRMS with EA (precision $\delta^{13}C$ and $\delta^{15}N$ ±0.10 ‰) at The West Australian Biogeochemistry Centre (University of Western Australia).

Stable isotope data were also provided for Indo-Pacific bottlenose dolphin tissue biopsies and the estuary cobbler (*Cnidoglanis macrocephalus*) from WWMSP Project "Spatio-temporal Distribution of Key Habitat-uses and Key Prey Species for Indopacific Bottlenose Dolphins in Owen Anchorage and Cockburn Sound)", Australian sea lion whiskers from WWMSP Project "Australian Sea Lions in the Perth Metropolitan Area (Abundance; Movement, Habitat Use and Diet)", and little penguin feathers from WWMSP Project "Determining the Diet, Causes of Mortality, Foraging Habitat and Home Range of Little Penguins)". For the sea lion, the first 3 mm of whisker was used for the sample, as this was considered to reflect their recent ~1 month of activity in the study region. Dolphin and penguin samples were analysed at The West Australian Biochemistry Centre on a SerCon Elemental Analyser Coupled with a 20-22 Stable Isotope Ratio Mass Spectrometer (Sercon, Crewe/ UK), while Australian sea lion samples were analysed at ECU's stable isotope facilities using a Thermo Fisher Scientific IRMS.

A complete list of species (along with the total sample size in each region and season) of macrophytes is available in Table 2, and invertebrates, fish, penguins, sea lions, and dolphins in Table 3. Using published knowledge of the morphology and/or diet, fish and invertebrate species were grouped into 14 "feeding guilds". The guilds were kept broad to ensure all food source contributions would be captured (see Table 3 for guild names).

Table 2. Sources of primary productivity and number of samples collected and used for stable isotope analyses across the study region where sufficient replicate individuals were collected. Where sources are likely to form detrital material that is transported across regions, samples were collected "Across Sound". Where sources likely reflect regional variation, samples were collected in each region (North Cockburn; NC, South Cockburn; SC, Owen Anchorage; OW, or Across Sound).

Source group	**Species/source**	**Sample size**	
		Summer (NC, SC, OW)	**Winter (NC, SC, OW)**
Brown algae	*Ecklonia* sp.	Across Sound, 5	5
	Padina sp.	Across Sound, 5	5
	Sargassum sp.	Across Sound, 4	5
Green algae	*Hydroclathrus* sp.	-	10
Red algae	*Laurencia* sp.	Across Sound, 5	5
Seagrass	*Posidonia australis*	Across Sound, 3	5
	Posidonia sinuosa	Across Sound, 5	5
Seston	Seston	7, 4, 3	7, 5, 3
Sedimentary POM	Sediment POM	10, 9, 9	10, 8, 9

Table 3. Invertebrate and fish assigned feeding guilds based on a literature search focused on southern and western Australia. Regional collection indicates where (North Cockburn; NC, South Cockburn; SC, Owen Anchorage; OA, or Across Sound) sufficient replicate individuals were collected for SIA. Larger, transient species collected were applied across the Sound and not limited to within a region (Across Sound).

Group	Assigned Feeding Guild	Species	Common Name	Summer (NC, SC, OA)	Winter (NC, SC, OA)	Length range (mm)
Invertebrates	Zooplankton	Zooplankton		3, 1, 2	1, 2, 2	-
	Suspension (filter) feeder	*Cercodemas anceps*	Red box sea cucumber	5, 0, 0	-	-
		Colochirus quadrangularis	Spiny sea cucumber	-	5, 0, 5	-
		Herdmania sp.	Brown sea squirt	5, 0, 0	5, 5, 4	-
		Cavernularia sp1	Sea pen	5, 5, 5	5, 5, 0	10 - 281
	Benthic detritivore	*Archaster angulatus*	Sea star	0, 0, 5	-	179 - 228
		Stellaster inspinosus	Sea star	5, 5 , 0	5, 3, 5	-
	Benthic generalist	*Metapenaeopsis fusca*	Velvet prawn	-	5, 5, 5	-
		Metapenaeopsis lindae	Lindas velvet prawn	5, 3, 5	-	46 -77
		Portunus armatus	Blue swimmer crab	5, 5, 5	5, 5, 5	82 - 158
		Panaeus latisulcatus	Western king prawn	5, 5, 5	5, 5, 4	108 - 211
		Thalamita sima	Four-lobed swimmer crab	5, 5, 5	5, 5, 5	25 - 56
		Trionectes rugosus	Pink swimmer crab	5, 5	5, 5, 5	26 -44
	Benthic carnivore	*Belosquilla laevis*	Mantis shrimp	5, 5, 5	5, 5, 5	54 - 133
		Octopus djinda	Western rock octopus	-	5, 0, 5	-
	Benthopelagic carnivore	*Sepioteuthis australis*	Southern squid	5, 0, 0	5, 5, 4	50 - 113
		Ascarosepion novaehollandiae/ cultratum	Cuttlefish	7, 3, 3	5, 4, 5	38 - 257
Fish	Benthic detritivore	*Mugil cephalus*	Sea mullet	0, 5, 0	-	45 - 53
	Benthic omnivore	*Anoplocapros amygdaloides*	Western smooth boxfish	5, 5, 5	5, 5, 4	143 - 279
		Acanthaluteres spilomelanurus	Bridled leatherjacket	5, 5, 0	5, 5, 5	70 -89
		Hyporhamphus melanochir	Southern garfish	-	5, 5, 0	-
		Pelsartia humeralis	Sea trumpeter	0, 0, 4	5, 0, 5	115 - 210
		Helotes octolineatus	Western striped grunter	5, 5, 5	5, 5, 5	128 - 225
	Benthic invertivore	*Aldrichetta forsteri*	Yelloweye mullet	0, 5, 5	5, 5, 5	48 - 252
		Aptychotrema vincentiana	Western shovelnose ray	Across Sound, 4	5	137 - 828
		Chrysophrys auratus	Snapper	5, 5, 5	10, 0, 0	62 - 136
		Cnidoglanis macrocephalus	Estuary cobbler	5	5	-
		Ostorhinchus rueppellii	Western gobbleguts	5, 5, 5	5, 5, 5	59 - 85
		Pseudocalliurichthys goodladi	Longspine dragonet	5, 5	5, 5, 5	103 - 133
		Parequula melbournensis	Silverbelly	5, 3, 5	5, 4, 5	51 - 125
		Pentapodus vitta	Western butterfish	5, 5, 5	5, 5, 5	91 - 215

Group	Assigned Feeding Guild	Species	Common Name	Summer (NC, SC, OA)	Winter (NC, SC, OA)	Length range (mm)
		Pseudocaranx georgianus	Silver trevally	5, 4, 5	0, 0, 5	70 - 197
		Pseudocaranx wrighti	Skipjack trevally	5, 5, 5	5, 5, 5	122 - 194
		Sillago bassensis	Southern school whiting	Large: 5, 0, 3	4, 5, 5	84 - 234
				Small: 5, 3, 5	-	43 -91
		Sillago burrus	Western trumpeter whiting	5, 5, 5	5, 5, 5	150 - 229
		Sillago schomburgkii	Yellowfin whiting	0, 5, 0	2, 5, 0	124 - 244
		Upeneus australiae	Australian goatfish	5, 5, 5	4, 5, 5	100 - 172
	Benthic carnivore (ambush predator)	*Gymnapistes marmoratus*	Soldier	5, 5, 5	5, 5, 4	70 - 132
		Inegocia japonica	Rusty flathead	5, 5, 4	5, 5, 5	105 - 198
		Lesueurina platycephala	Flathead sandfish	5, 5, 5	3, 4, 0	48 - 96
		Onigocia spinosa	Midget flathead	5, 5, 5	5, 5, 5	2 - 115
		Platycephalus grandispinis	Longspine flathead	5, 5, 0	5, 3, 4	193 - 273
	Benthic carnivore (elasmobranch)	*Heterodontus portusjacksoni*	Port Jackson shark	5, 4, 0	5, 5, 0	64 - 355
		Mustelus antarcticus	Gummy shark	Across Sound, 5		347 - 1280
		Myliobatis tenuicaudatus	Southern eagle ray	Across Sound, 6	7	450 - 718
	Pelagic planktivore	*Atherinomorus vaigiensis*	Common hardyhead	0, 5, 5	5, 5, 5	105 -150
		Engraulis australis	Australian anchovy	5, 5 , 0	2, 0, 0	52 -120
		Hyperlophus vittatus	Sandy sprat	5, 5, 0	5, 5, 5	45 - 109
		Sardinella lemuru	Scaly mackerel	5, 0, 5	NA	189 - 210
		Spratelloides robustus	Blue sprat	5, 5, 5	5, 5, 5	37 - 66
		Sardinops sagax	Australian sardine	5, 0, 5	-	60 - 182
		Trachurus novaezelandiae	Yellowtail scad	5, 0, 5	2, 0, 6	71 - 180
	Pelagic piscivore	*Carcharhinus brevipinna*	Spinner shark	4, 4, 4	NA	-
		Sphyraena obtusata	Striped barracuda	Across Sound, 2	8	135 - 172
Mammals and Birds	Pelagic carnivore	*Tursiops aduncus*	Indo-Pacific bottlenose dolphin	Across Sound, 13	14	-
		Neophoca cinerea	Australian sea lion	Across Sound, 7	-	-
		Eudyptula minor	Little penguin	Across Sound, 11	-	-

2.2.3. Morphometrics

The dietary composition of a species is a function of its morphology. For example, the position and size of a fish's eye help to locate prey, the shape and extent of protraction of an oral gape enable the capture and processing of larger prey, and the fish's swimming ability allows the potential to obtain more mobile prey (Haywood 2023). Due to this and the fact that this project investigates the diet of a wide range of fish species with different morphologies, a range of morphometric measurements were recorded. A random selection of up to 10 individuals of each available fish species (many of which were also used for GCA and SIA) were selected for morphometric analysis. These individuals covered as wide a size range as possible for each species; for example, for snapper the total length ranged from 54 to 904 mm TL. The rationale for undertaking this additional component of the study was that while it was not possible to conduct dietary analysis on all species caught in substantial numbers during sampling for WWMSP Project "Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound", determining the fish species that have similar morphologies could help inform ecosystem modeling. This is because species with similar traits are likely to occur in the same part of the water column, frequent similar habitats, and target, capture, and consume similar types of prey.

The total length of each fish specimen was measured to the nearest 1 mm and weighed to the nearest 0.01 g blotted wet weight. Values for six morphometric measurements (Figure 2) were then recorded to the nearest 0.01 mm using 150 mm digital vernier calipers (Kincrome, Melbourne, Australia). The specimen was then laid on a metal tray containing solid wax and its fins splayed out and pinned in a natural position, i.e. without hyper-extension. A ruler was placed adjacent to the specimen to provide a scale. The specimen was then photographed using a Nikon D7000 digital camera (16.9-million-pixel resolution) with a wide-angle macro lens mounted on a tripod. A total of 452 specimens representing 67 fish species were photographed. Images of each specimen were loaded into ImageJ (Ferreira & Rasband 2012), calibrated using the rule to convert pixels to mm and 14 morphometric characteristics (Figure 2) were measured in pixels and converted to the nearest 0.01 mm. These 20 morphometric measurements were used to calculate 17 morpho-anatomical traits (Table 4) that describe the relative size, shape, and/or position of the body parts involved in each step of the food acquisition process from detection to capture and digestion (see Villéger et al. 2010, 2017). Seven of the morpho-anatomical traits relate to the function of food acquisition, including the size of the eye, and the extent of protrusion and shape of the mouth. The remaining 10 are associated with aspects of locomotion e.g., body shape and hydrodynamics and potential for pectoral and caudal fins to provide propulsion (Table 4). Although this standard protocol was designed to cover a broad range of fish morphologies, species of pipefish and sea horses in the genera *Stigmatopora* and *Hippocampus* have no caudal fin (Blake 1976, Browne & Smith 2007). For such specimens, values for the (i) caudal peduncle throttling, (ii) caudal fin aspect ratio, and (iii) fins surface ratio were fixed to 0 following Leitão et al. (2016). Similarly, substantially dorsoventrally flattened species, e.g. flatfishes, were considered without functionally pectoral fins, so (i) pectoral fin position and (ii) aspect ratio of the pectoral fin were fixed to 0. All morpho-anatomical traits are a unitless ratio between comparable body parts, they typically incorporate the potentially confounding effect of body size on the dimensions of the trait (Villéger et al. 2017).

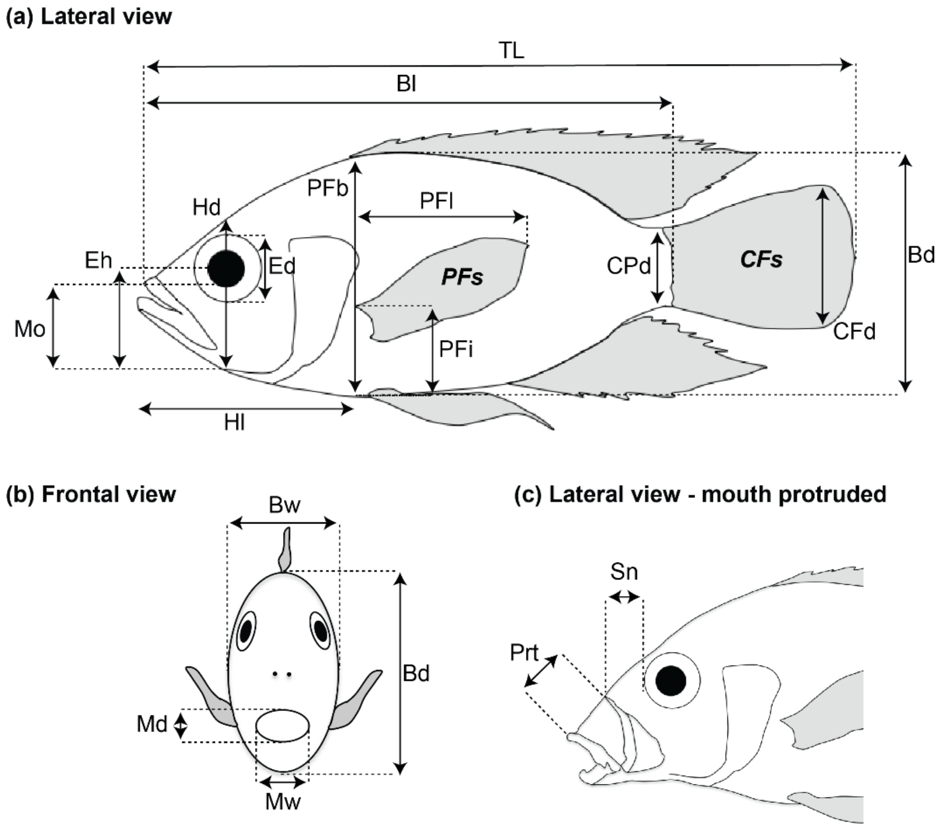


Figure 2. Diagram showing the 20 morphological measurements recorded for each fish using (a) photographs and ImageJ and (b, c) a digital vernier caliper. TL = total length; Bd = body depth; CPd = caudal-peduncle minimal depth; CFd = caudal-fin depth; CFs = caudal-fin surface; PFi = distance between the insertion of the pectoral fin to the bottom of the body; PFb = body depth at the level of the pectoral-fin insertion; PFl = pectoral-fin length; PFs = pectoral-fin surface; Hd = head depth along the vertical axis of the eye; Ed = eye diameter; Eh = distance between the centre of the eye to the bottom of the head; Mo = distance from the top of the mouth to the bottom of the head along the head depth axis; Bw = body width; Md = mouth depth; Mw = mouth width; Sn = snout length; Prt = protrusion length; Bl = body standard length. Image adapted from Leitão et al. (2016).

Table 4. Morpho-anatomical traits and the equations used to calculate them for the major trait categories of Food acquisition (7) and Locomotion (10). Codes for morpho-anatomical measures are given in Figure 2.

	Trait	Equation	Description
Food acquisition	Oral gape size (surface)	$\frac{\mathrm{Mw} \times \mathrm{Md}}{\mathrm{Bw} \times \mathrm{Bd}}$	Nature and size of food items able to be captured using mouth area calculations. Larger gape would allow larger prey to be eaten (Karpouzi & Stergiou 2003)
	Oral gape shape	$\frac{\mathrm{Md}}{\mathrm{Mw}}$	Method to capture food items. The oral shape would limit the size and type of prey that would fit into the mouth (Karpouzi & Stergiou 2003)
	Oral gape position	$\frac{\mathrm{Mo}}{\mathrm{Bd}}$	Feeding method in the water column. A low mouth would indicate a benthic feeder, high mouth position would indicate a surface feeder (Sibbing & Nagelkerke 2000)
	Head protuberosity	$\frac{\mathrm{Hl}}{\mathrm{Bl}}$	Method of prey capture. Length of the skull relative to body size (Motta 1988)
	Mouth protrusion length	$\frac{\mathrm{Prt}}{\mathrm{Sn}}$	Nature of food items captured and feeding method, higher values indicate suction feeding (Gatz 1979)
	Eye size	$\frac{\mathrm{Ed}}{\mathrm{Hd}}$	Prey detection and indicates visual feeder (Villéger et al. 2017)
	Gill raker length	$\frac{\mathrm{GRI}}{\mathrm{Hd}}$	Filtering ability or gill protection (Sibbing & Nagelkerke 2000)
Locomotion	Eye position	$\frac{\mathrm{Eh}}{\mathrm{Bd}}$	Vertical position in the water column. Indicates if the species is a benthic or water column feeder (Gatz 1979), and prey detection (Villéger et al. 2017)
	Body elongation	$\frac{\mathrm{Bd}}{\mathrm{Bl}}$	Hydrodynamics indicates vertical position in the water column and locomotive ability (Villéger et al. 2017)
	Body transversal shape	$\frac{\mathrm{Bd}}{\mathrm{Bw}}$	Vertical position in the water column and hydrodynamism. Lower values indicate species has a swimming lifestyle (Sibbing & Nagelkerke 2000)
	Body transversal surface	$\frac{\ln\left(\left(\frac{\pi}{4} \times \mathrm{Bw} \times \mathrm{Bd}\right) + 1\right)}{(\ln \mathrm{Mass} + 1)}$	Mass distribution along the body for hydrodynamism. Indicates locomotive ability (Villéger et al. 2010)
	Pectoral fin aspect ratio	$\frac{\mathrm{PFi} \times 2}{\mathrm{PFs}}$	Pectoral fin use for propulsion. Indicates efficiency of transmission of momentum (Fulton et al. 2001, Villéger et al. 2010)
	Pectoral fin position	$\frac{\mathrm{PFi}}{\mathrm{PFb}}$	Pectoral fin use for manoeuvrability. Indicates efficiency in direction change (Dumay et al. 2004)
	Caudal peduncle throttling	$\frac{\mathrm{CFd}}{\mathrm{CPd}}$	Caudal propulsion efficiency through reduction of drag. Indicates the rate of propulsion (Webb 1984)
	Caudal fin aspect ratio	$\frac{\mathrm{CFd} \times 2}{\mathrm{CFs}}$	Caudal fin use for propulsion and/or direction – indicates swimming performance (Webb 1984)
	Fins surface ratio	$\frac{2 \times \mathrm{PFs}}{\mathrm{CFs}}$	Main type of propulsion between caudal and pectoral fins, indicates propulsion efficiency (Villéger et al. 2010)
	Fins surface to body size ratio	$\frac{(2 \times \mathrm{PFs}) + \mathrm{CFs}}{\pi \div 4 \times \mathrm{Bw} \times \mathrm{Bd}}$	Acceleration and/or manoeuvrability efficiency – indicates propulsion efficiency (Villéger et al. 2010)

2.3. Data analyses

2.3.1. Gut contents

2.3.1.1. Dietary description

The stomachs of 2,117 fish and invertebrates were examined, and the resultant prey was grouped into 979 different types of prey (referred to as *dietary items*). These were reliably identified to the lowest possible level, varying from unidentifiable material (for very heavily masticated and digested prey), through phylum to species. Each item was initially assigned to a "*major taxa*" (*n* = 16), which for taxa in the Kingdom Animalia was phylum-level but also included the subphylum Foraminifera, macrophytes (i.e. algae and seagrass), and several groups where taxonomic identification was impossible (e.g. unidentifiable egg) and/or irrelevant (e.g. inorganic material, synthetic material). Note that unidentifiable calcareous material was separated from inorganic material, as this prey contributed between 15 to 47% of the volume of the stomach of blue swimmer crabs from the Swan-Canning and Peel-Harvey Estuary and Cockburn Sound and is important for replenishing calcium carbonate in the exoskeleton of decapods after moulting (de Lestang et al. 2000, Campbell et al. 2021).

Dietary items were also assigned a "*broad dietary category*" (*n* = 43) based on a combination of taxonomy, functional features and the level of identification (see Platell et al. 2024). A complete list is available in Table 5. Examples include separating larvae from adults of the same taxa if they have a pelagic larval phase and benthic adult phase and categories based on habitat and body size as the diet of many fish changes with position in the water column (pelagic vs benthic) and ontogeny. Thus, dietary items were classified into the following broad categories.

- *Errant polychaetes*, i.e. free-living species in the families Eunicida, Glyceridae, Goniadidae, Lumbrineridae, Nereididae, Onuphidae, and Polynoidae.
- *Sedentary polychaetes*, i.e. burrowing or tube-dwelling species in the families Cirratulidae, Sabellidae, Serpulidae, and Terebellida.
- *Polychaete larvae* in the trochophore, metatrochophore, and nectochaete stages.
- *Small* (≤ 5 mm width; e.g. cerithiids and retusids) and *large gastropods* (> 5 mm width; e.g. nassarids, and philinid).
- *Small* (≤ 5 mm width; e.g. venerids and tellinids) and *large bivalves* (> 5 mm width; e.g. pectinids, and mytilids).
- *Pelagic crustaceans* included pelagic copepods, cladocerans, and a range of larvae (i.e. zoea, nauplii and the cyprid larvae of barnacles) and typically have a maximum size of <2 mm.
- *Small crustaceans* included amphipods, isopods, ostracods, harpacticoid copepods, tanaids, and cumaceans.
- *Small brachyurans* included hymenosomatids (false spider crabs), leucosiids (pebble crabs), and other taxa of a similar size. Note that larger brachyurans, e.g. blue swimmer crabs, *Thalamita sima*, and *Trionectes rugosus,* are all portunids and so were included in the category Portunidae.
- *Unidentified large crustaceans* were those items typically larger than *small crustaceans* but were too degraded to be reliably identified to a lower taxonomic level than crustaceans. These likely included Pleocyemata, Dendrobranchiata, Squillidae, Brachyura, and other similar-sized decapod crustaceans.

Visual and quantitative descriptions of the overall diet of each species studied were compiled irrespective of seasonal, regional, and ontogenetic differences (i.e. pooling all available data). Each description discusses the relative volumetric contribution (%V) and frequency of occurrence (%F; i.e. the proportion of stomachs that contained that type of prey) contributions of prey at the major taxa level, with particular broad dietary categories and dietary items mentioned when they made large contributions. Photographs of important prey items are also provided.

A stacked bar graph was constructed to compare the volumetric contributions of the major taxa ingested by individuals of each of the 18 species visually. Note that for simplicity, only identifiable animal prey were included in this plot. Thus, macrophytes, inorganic and synthetic material, and unidentifiable organic material were removed.

The feeding strategy and importance of particular prey to the diet of the 18 species were assessed visually using modified Costello plots (Costello 1990) with the modification proposed by Amundsen et al. (1996). Each plot compares, for each prey type, the prey-specific abundance (%PSV; *y*-axis), which is defined as the average percent volumetric contribution of the prey type to the overall identifiable content in only those stomachs where this prey was present ($(\sum S_i \ / \ \sum S_t) \ \times 100$, and the frequency of occurrence (F%; *x*-axis). This analysis was conducted using dietary data at the broad dietary category level, with the following modifications designed to increase the relevance of the categories to prey selection or to reduce clutter (increase clarity) on the plots. (i) Small, large, and unidentified bivalves were combined into Bivavia. (ii) Similarly, Octopoda and unidentified Cephalopoda were combined into Cephalopoda. (iii) Pleocyemata (shrimp), Dendrobranchiata (prawns), Squillidae (mantis shrimp), and unidentified large crustaceans were combined into Decapoda and Stomatopoda to incorporate large, non-brachyuran decapods. (iv) Bryozoa, unidentified molluscs, mollusc larvae and polychaete larvae all represented <1 V% of %F to the diets of any species and were not plotted to prevent clutter in the plots. (v) Finally, unidentified organic material, synthetic material, inorganic material, and unidentifiable eggs were removed as they do not provide insight into prey selection. Species with < 10 examined stomachs were not included, i.e. southern bluespot flathead and yellowtail flathead.

2.3.1.2. Interspecific composition and relationship to morphology

All analyses described in subsections 2.3.1.2 and 2.3.1.3 were conducted using the routines in the PRIMER v7 multivariate statistics package (Clarke & Gorley 2015) and the PERMANOVA+ add-on module (Anderson et al. 2008). Data used in the interspecific comparisons were analysed at the broad dietary category level to avoid potentially over-inflating differences between predator species.

The volumetric contribution of prey belonging to each of the 43 broad dietary categories for each individual of the 16 species that had sample sizes ≥10 individuals (i.e. all except southern bluespot flathead and yellowtail flathead where n < 10) was calculated. Contributions made by non-food and completely unidentifiable items, such as synthetic material, inorganic material, and unidentified organic material were removed from the data set, and the data was re-standardised to 100%. As the stomach contents of individual fish may contain only a small number of broad dietary categories, two individuals of the same species collected at the same time from the same location may differ markedly in their dietary composition, which can mask subtle but "real" trends in diet. To reduce this potential effect, individuals for each species were randomly sorted into groups of between two and nine, depending on the total number of individuals of that species, and averaged (Greenwell et al. 2021, Platell et al. 2024). This grouping helped to balance the number of samples among species and pool across the potentially confounding effects of body size, region and season. The averaged data were square-root transformed to avoid the tendency for any of the broad dietary categories to be excessively dominant and used to produce a Bray-Curtis resemblance matrix.

This matrix was used in a one-way Analysis of Similarities (ANOSIM; Clarke et al. 2014a) test to determine whether the dietary composition of the 16 species (excluding species with n<10) differed ($P < 0.05$) and the magnitude of that difference (Global *R* and pairwise *R* statistics). Trends in dietary composition were visualised using non-metric Multidimensional Scaling (nMDS) ordination and centroid nMDS ordination. A shade plot (Clarke et al. 2014b) was constructed using transformed and averaged data for each species. The order of the species (*x*-axis) and broad dietary categories (*y*-axis) were determined by seriation using an Index of Association resemblance matrices. Interpretation of these plots and the species responsible for any spatial and temporal shifts in composition was aided by Similarity Percentages (SIMPER; Clarke et al. 2014a).

The data matrix containing the values of the 17 morpho-anatomical traits for each of the 460 individual fish belonging to the 72 species was compiled. These data were then averaged to provide a single value for each trait for each species. As the traits were measured in slightly different scales (Table 4), the data were normalised, i.e. each value was subtracted by the mean for that variable and divided by the standard deviation of that variable to place them all on a comparable scale (Tweedley et al. 2015). These data were then used to create a draftsman plot. Visual analysis of the pairwise plots showed that none of the variables were highly correlated (i.e. Pearson's correlation $R > 0.9$) or skewed. The normalised data were then used to construct a Euclidian distance matrix and subjected to hierarchical agglomerative clustering with group-average linking (CLUSTER) and an associated similarity profile (SIMPROF) test (Clarke et al. 2008). A SIMPROF test was performed at each node of the dendrogram to determine whether the group of species being subdivided contains significant internal structure ($p < 0.05$). This analysis provided an objective way of grouping species with statistically similar morpho-anatomical traits. The allocation of species into groups was also visualised using an nMDS ordination of all 72 species and a centroid nMDS plot of each of the 25 cluster groups. To aid interpretation and identify the morpho-anatomical traits that distinguished species in different groups from each other, the data matrix of the raw (i.e. not normalised) value for each morpho-anatomical trait for all 460 individual fish was standardised by the maximum value of each trait to place them all on a scale of 0 - 100. These data were then averaged to produce a single value for each of the 72 species and used to create a shade plot. The depth of the shading for each trait denotes the percentage of the maximum value recorded for each species ranging from low (light grey) to high (black).

Morpho-anatomical trait data were available for 15 of the 16 finfish whose dietary composition had been determined in Cockburn Sound. The replicate data for these species were normalised, used to construct a Euclidian distance matrix, and subjected to nMDS ordination. To aid in the interpretation of the nMDS plot, vectors for traits that were correlated (Pearson $R > 0.6$) were overlaid. The pattern of differences in the morphologies of the 16 finfish species was then compared to their diet. A Euclidean distance matrix of the average normalised morpho-anatomical traits was constructed, as was a Bray-Curtis resemblance matrix of the transformed average dietary composition. These two matrices were subjected to the RELATE test (Clarke et al. 2014a) to determine whether they were correlated ($p < 0.05$). Each matrix was also used to construct an nMDS ordination and CLUSTER dendrogram.

2.3.1.3. Intraspecific comparisons

The above analyses identified whether a species was opportunistic or specialised in their feeding and dietary composition and the extent of overlap, i.e. competition for key prey taxa. However, dietary composition is known to change with (i) ontogeny, as an individual predator can potentially catch and process larger and/or more mobile prey, and (ii) spatially and (iii) temporally, due to differences in habitat and the availability and abundance of prey. Differences between sexes have been less studied than the above factors (Platell et al. 2024) but have been investigated for crabs previously (Laughlin 1982, de Lestang et al. 2000). As such, the purpose of this section was to describe how the diet of a species changes with increasing body size and, for species with enough samples, determine whether the dietary composition differed among length/width classes, regions (i.e. Owen Anchorage, North Cockburn Sound and South Cockburn Sound; Figure 1), and seasons (typically spring and autumn). Note that the influence of sex (i.e. female, male) was also investigated for blue swimmer crabs. As the purpose of these analyses was to investigate the dietary composition of a single species in more detail, a lower taxonomic resolution was used. Therefore, the 43 "*broad dietary categories"* were divided into 118 "*dietary categories"*. For example, the errant polychaete was separated into seven families (i.e. Eunicida, Glyceridae, Goniadidae, Lumbrineridae, Nereididae, Onuphidae, and Polynoidae) and unidentified errant polychaetes.

A data matrix of the volumetric contribution of each dietary category to the stomach contents of individuals was constructed for each species. Each matrix was subjected to the same suite of analyses where data were available, i.e. sufficient samples were obtained for all regions and seasons, and broadly followed the approach described above. Individuals of a species were randomly assigned to a group separately for each factor (e.g. length/width) pooling across the other factors (e.g. region and season) to remove their potentially confounding effect. These data were then averaged, square-root transformed, and used to construct Bray-Curtis resemblance matrices. Each matrix was used in a one-way ANOSIM test. Visual interpretation of the ANOSIM results was aided by the Bootstrap Averages Routine (Clarke et al. 2014a), using the Bray-Curtis resemblance matrix. The samples in that matrix were bootstrapped in metric multi-dimensional scaling (mMDS) space and the averages of repeated bootstrap samples (bootstrapped averages) were used to construct an mMDS ordination plot. Superimposed on each plot was i) a point representing the group average (i.e., the average of the bootstrapped averages) and ii) the associated, smoothed, and marginally bias-corrected 95% bootstrap region, in which 95% of the bootstrapped averages fall. If the stress value for the two-dimensional mMDS plot exceeded 0.2, the Bray-Curtis resemblance matrix was used to construct a distance-among-centroid matrix. This matric was then used to create a centroid nMDS plot.

If ANOSIM detected a significant difference in the factor (e.g. length class), a Canonical Analysis of Principal coordinates (CAP) analysis was conducted using the replicate data. This approach sought to find axes through the multivariate cloud of points that best discriminated among levels of the factor (i.e. particular length classes) and those dietary categories with the strongest correlation. Superimposed onto the CAP ordination are vectors for dietary categories whose volumetric contributions changed linearly (Pearson correlation > 0.5) relative to the CAP axes. Note that for factors with two levels (e.g. season and sex), the CAP ordination often only had a single axis and vectors could not be overlaid. In these cases, the same approach was conducted using Principal Coordinates analysis (PCO) instead of CAP, and thus an unconstrained rather than constrained ordination technique. To provide a complete visualisation of the volumetric contribution made by all dietary categories to the diet of a species, the transformed replicate data was displayed in shade plots. A shade plot was produced for each factor regardless of whether there was a significant difference or not.

2.3.2. Stable Isotopes

Where sample sizes were sufficient, SIA data were tested for differences across regions and seasons using Analysis of Variance (ANOVAs) in SPSS, the results of which were used to inform the mixing model design, i.e. combining/splitting mixing models by season and/or region.

Lipid content in animal tissue can affect $\delta^{13}C$ values (Post 2002, Kiljunen et al. 2006, Skinner et al. 2016), but C:N ratios of most consumers were <3.5 indicating that mathematical normalisation $\delta^{13}C$ values were generally not required (Skinner et al. 2016). However, normalisation of $\delta^{13}C$ was required for filter feeders (sea cucumbers *C. anceps* and *C. quadrangularis,* sea pen *Cavernularia* sp. and sea squirt *Herdmania* sp.), which had C:N ratios >4 (Table 9).

Correction factors were applied for isotopic enrichment factors across trophic levels (Trophic Enrichment Factor or TEFs). Carbon is a good indicator of diet source as carbon isotopes fractionate minimally through trophic levels, while nitrogen fractionates significantly through trophic levels and is therefore a good indicator of trophic position (Caut et al. 2009). While a range of TEFs have been used across studies TEFs of 0.5±0.19 and 2.3±0.24‰ were used, which are commonly employed for $\delta^{13}C$ and $\delta^{15}N$, respectively (McCutchan Jr et al. 2003, Pinzone et al. 2019). Sulfur isotopes are used far less commonly, but are known to help differentiate some sources in food web studies (Connolly et al. 2004). TEFs for $\delta^{34}S$ are less well studied, but we used TEFs of 0.0±0.02‰ (Mittermayr et al. 2014, Jinks et al. 2020). Since sources entering benthic detritus undergo decomposition rather than digestion and assimilation, different TEF values have been used, based on estimated values of fractionation in sedimentary POM (Lehmann et al. 2002, Hill & McQuaid 2009, Ólafsson et al. 2013). We used TEFs of -2.0±0.0 and -2.5±1.2‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively. Since $\delta^{34}S$ data could not be determined for sedimentary POM, this isotope was not used in the modelling for sedimentary POM.

Trophic level (TrL) was calculated for each consumer species using the average of $\delta^{15}N$ for all primary producers as the base (TrL = 1) and using the TFL for $\delta^{15}N$ for each trophic step, as justified above. TrL = $((\delta^{15}N_{consumer} - \text{mean}\delta^{15}N_{primary\ producer})/2.3) + 1$. All primary producers were used to determine the base TrL, since they all sources could potentially contribute to the food web. Indeed, albeit variable across species and functional groups, all sources did contribute to the nutrients assimilated by consumers (see Section 3.2).

Mixing models were used to predict the relative contribution of different base sources to sediment POM and invertebrates. For consumers, models were restricted to invertebrate feeding guilds since these guilds were typically in lower trophic levels, which provided greater certainty for applying appropriate fractionation levels. Many fish species consume macroinvertebrates (see Results), for which stable isotope data were missing (see Table 5) due to the low biomass of invertebrate infauna collected in WWMSP Project “Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound”. Fractionation of $\delta^{13}C$ and $\delta^{15}N$ with each trophic step varies considerably, while higher-level consumers can ingest prey from a range of different trophic levels, resulting in greater uncertainty in fractionation of $\delta^{13}C$ and $\delta^{15}N$ over multiple trophic levels. Since GCA data are available for a range of feeding guilds of fish, the focus of mixing models was to gain an understanding of the base food sources (primary producers) that contribute to the productivity of lower trophic levels that can then be applied to the food web model.

The number of sources used in mixing models is limited by the number of isotope tracers. Informative outputs from the mixing models can be provided by <7 sources when using two isotopes (Phillips et al. 2014), and in our case, three isotopes (C, N and S isotopes) were used initially. We used six sources (*Ecklonia, Sargassum, Padina, Laurencia, Posidonia* and seston) in the mixing models based on their potential to contribute to the food web. These included primary producers that could enter the food web of Cockburn Sound and Owen Anchorage via the detrital pathway as allochthonous material since large areas of the region consist of unvegetated habitats that comprise little autochthonous primary production. The kelp *Ecklonia radiata* is a major primary producer that forms an important detrital source that is transported across habitats in the study region (Wernberg et al. 2006, Crawley et al. 2009). Similarly, *Sargassum* spp. are major primary producers on reefs in temperate Western Australia (Coleman & Wernberg 2017), including reefs within Cockburn Sound (G. Hyndes, pers. obs). The brown alga *Padina* sp. was observed as a common primary producer on reefs in Cockburn Sound during the collection periods in summer and winter. Seagrass meadows in Cockburn Sound comprise predominantly *Posidonia sinuosa* and *P. australis* (Kendrick et al. 2002), which potentially contribute to the food sources directly or indirectly as detritus (Hyndes & Lavery 2005). In addition, epiphytes on seagrasses form significant food sources for a range of consumers (Smit et al. 2006). *Laurencia* spp. were collected during summer and winter as representative epiphytes, as this genus commonly occurred on seagrass during both collection periods.

Models were run using the MixSIAR package in R (MIXSIAR; Stock et al. 2018) for 3,000,000 iterations using uninformative priors, and convergence was assessed using Geweke and Gelman–Rubin diagnostic tests. Since ANOVA showed inconsistent differences across isotopes and among regions and seasons for those species with adequate sample sizes (Table 8), initial models were run for each feeding guild across the study area using $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$, and across regions and seasons when sample sizes were adequate. Initial scrutiny of the data using biplots, and the lack of convergence displayed in preliminary mixing models, indicated that $\delta^{34}S$ data could not be used for subsequent analyses. Mixing models require the isotope values of the mix (consumers) to fit within the polygon created by the isotope values of sources (primary producers) once TEFs have been applied. $\delta^{34}S$ values for consumers were typically more depleted than those of the primary producers and were generally highly variable (see Figs 84 - 99). Since there is no justification to adjust the TFLs based on the literature (see above), $\delta^{34}S$ was abandoned for mixing model analyses. Mixing models were therefore run using $\delta^{13}C$ and $\delta^{15}N$. Mixing model outputs have been presented for consumers where the models displayed convergence using Geweke and Gelman–Rubin diagnostic tests.

2.3.3. Meta-analysis

A total of 585 fish species from 144 families have been recorded across the Perth coast (Whisson & Hoschke 2021), of which 204 fish species were caught in Cockburn Sound and Owen Anchorage using otter trawls, benthic sleds, seine nets and baited remote underwater video (BRUV) as part of WWMSP Project “Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound”. While this project aimed to determine the diet of abundant species and/or those of fisheries importance, it was not possible to derive quantitative dietary data for all of them. However, as published dietary information is available for many local species (see Platell & Hall 2006), literature searches were conducted. The scientific name for each species was entered into FishBase (Froese & Pauly 2024), and information on the body shape category, habitat and maximum size were extracted. Where values were missing, they were supplemented using Fishes of Australia (Bray & Gomon 2024). Information on the trophic level of each species was derived from FishBase, using either an empirical study or estimated from known dietary items or from a similar species. The resulting data were compiled and compared, where possible, to data generated in the current study. As different databases contain different records (Calver et al. 2017, Ramm et al. 2021), literature searches were conducted using both Scopus and Google Scholar. Search terms were based on the scientific name and various common names of each species. Further searches were conducted using the genus or family if a species-level search failed to generate relevant scientific documents. Preferences were given to studies using contributions from volume or weight contributions rather than abundance or frequency of occurrence and those conducted in Cockburn Sound or south-western Australia. Dietary information was entered into a database at the lowest possible taxonomic resolution (noting this differed among studies) and aggregated to one of 28 categories, i.e. macrophytes (macroalgae and seagrass), phytoplankton, foraminiferans, poriferans, benthic cnidarians (e.g. corals and anthozoans), lophophorates (i.e. bryozoans and entoprocts), benthic tunicates, unidentified sessile “invertebrates” (including tunicates), annelids (mainly polychaetes), nemerteans, nematodes, zooplankton (i.e. planktonic crustaceans, pelagic tunicates, pelagic eggs/larvae and chaetognaths), small benthic crustaceans (e.g. harpacticoid copepods. amphipods, isopods and tanaids), large benthic crustaceans (e.g. stomatopods and decapods), unidentified crustaceans, hexapods and chelicerates, shelled molluscs (e.g. gastropods and bivalves), cephalopods, unidentified molluscs, echinoderms, cephalochordates, teleosts, elasmobranchs, aves (birds), marine reptiles, aquatic mammals, fish scales, skin and mucus, and sediment and detritus. These categories were chosen to be a trade-off between being too broad as to overgeneralise (e.g. invertivore) but also not being so narrow they overinflated differences between species based on the environment/habitat the sampling was conducted and the corresponding availability of prey (e.g. various species of copepod). Note that the taxonomic resolution was also influenced by the information provided in the source publication. The contributions assigned in the source material as solely “unidentified” (rather than unidentified molluscs) were not included, and the data for the other categories were re-standardised to total 100%.

These data were not analysed statistically but were used in the construction of the food web if data were not derived during the current study. For example, if SIA data were available but there was no corresponding GCA data (or vice versa), or they were deemed an important part of the Cockburn Sound ecosystem, but no data of any type was available (e.g. white shark). These data are provided as appendices for future reference.

3. Results

The results have been sequenced to present summary data on core components of the project that have allowed us to develop a conceptual food web model. This relies on the results of GCA (Section 3.1) and stable isotopes (Section 3.2).

3.1. Gut content analysis

This section describes the dietary composition of the 18 species of invertebrates and fishes, focusing initially on the description of the diets based on GCA for each of the focus species (Section 3.1.1), followed by interspecific comparisons (Sections 3.1.2 and 3.1.3), a functional analysis of a broader suite of species known to occur in Perth region based on a meta-analysis of published and unpublished data (Section 3.1.4), and intra-specific comparisons across sizes classes, regions and seasons for focal species were sufficient sample sizes were available for these comparisons).

3.1.1. Description of diet

3.1.1.1. Blue swimmer crab (*Portunus armatus*)

The cardiac stomachs of 219 blue swimmer crabs were examined, of which 163 (74%) contained food, with a mean fullness of 4.8 ± 0.2 SE (out of 10). The diet of this crab consisted of a relatively large number of small bivalves, which were usually crushed and sometimes almost entirely filling the stomach (Figure 3). In the stomachs where these bivalves did not dominate the contents, echinoids (sea urchins) typically made substantial contributions, presenting many small pieces of test (internal skeleton) and broken spines. Other small organisms were recorded including crustaceans and gastropods. Prey in the stomach showed high levels of mastication, consisting of only very small organisms or parts of organisms less than a few millimetres in diameter, for example, a single valve of a small bivalve or an operculum of a gastropod.

Molluscs were the largest contributor to the dietary content found in blue swimmer crabs at 43.8%V and occurred in 81.6%F of all stomachs (Table 5). Among these, small bivalves, mainly *Timoclea infans* (Veneridae), accounted for 32.7%V (Table 5). Other families of small bivalves included Tellinidae and Nuculanidae. Larger bivalves, which included *Arcuatula* sp. (Mytilidae) and *Solemya* spp. (Solemyidae), made up a further 4.3%V but were consumed regularly (23.9%F). Similarly, small gastropods made up a relatively small proportion of the diets (4.0%V) but were commonly recorded (30.1%F). Among the other prey taxa, echinoderms (18.1%V; 45.4%F) and arthropods (7.1%V; 30.7%F) made substantial contributions. Prey belonging to the former phyla, comprised almost exclusively of echinoids, with minute quantities of ophiurioids (brittle stars). Among the arthropods, unidentified large crustaceans represented the majority (6.8%V; 30.1%F), with minor contributions from small brachyurans (true crabs) and anomurans (hermit crabs). Substantial quantities of unidentified calcareous material (9.0%V) were ingested by most blue swimmer crabs (39.3%F). Sediment, included as inorganic material, was also consumed but in far smaller amounts and less frequently (3.0%V; 34.4%F; Table 5).

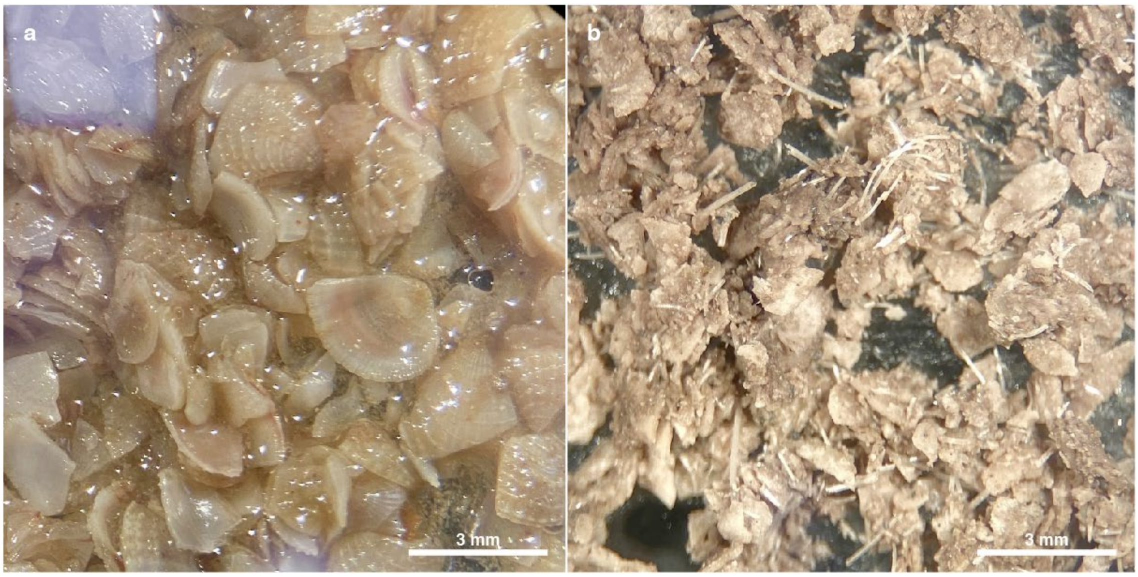


Figure 3. Photographs of the typical contents of cardiac stomachs from blue swimmer crabs, including (a) small bivalves, mainly Timoclea infans *(Veneridae), and (b) crushed sea urchins (Echinoidea spp.).*

3.1.1.2. Western rock octopus (*Octopus djinda*).

Of the 98 western rock octopus crops examined, only 47 contained content (48%), with a relatively low mean fullness of 2.5 ± 0.4. Dietary content was usually characterised by the presence of many small pieces of macro-crustaceans that were too fragmented to accurately identify to a low taxonomic level (Figure 4). However, some individuals entirely consumed cephalopod material, which despite high levels of mastication, could be identified by the presence of chromatophores and suckers.

Based on volume, the diet of western rock octopus was dominated by arthropods, with minor contributions from molluscs and chordates (i.e. 34.9, 6.6 and 0.5%V, respectively; Table 5). When accounting for the substantial quantity of unidentified organic material (57.4%V), the volume of the three major taxa increased to 83.1, 15.7 and 1.2%V, respectively. The arthropods consumed were all classified as unidentified large crustaceans due to their high levels of fragmentation, but they were comprised of at least brachyurans and alpheids (snapping shrimp). Such prey was ingested by most western rock octopus (72.3%F). Among the molluscan material, which was present in 10.6%F of crops, two-thirds of the volume was identified as octopus tissue and the remaining content as unidentified cephalopod. Teleost material only consisted of small fragments of hard structures including scales, spines and rays.

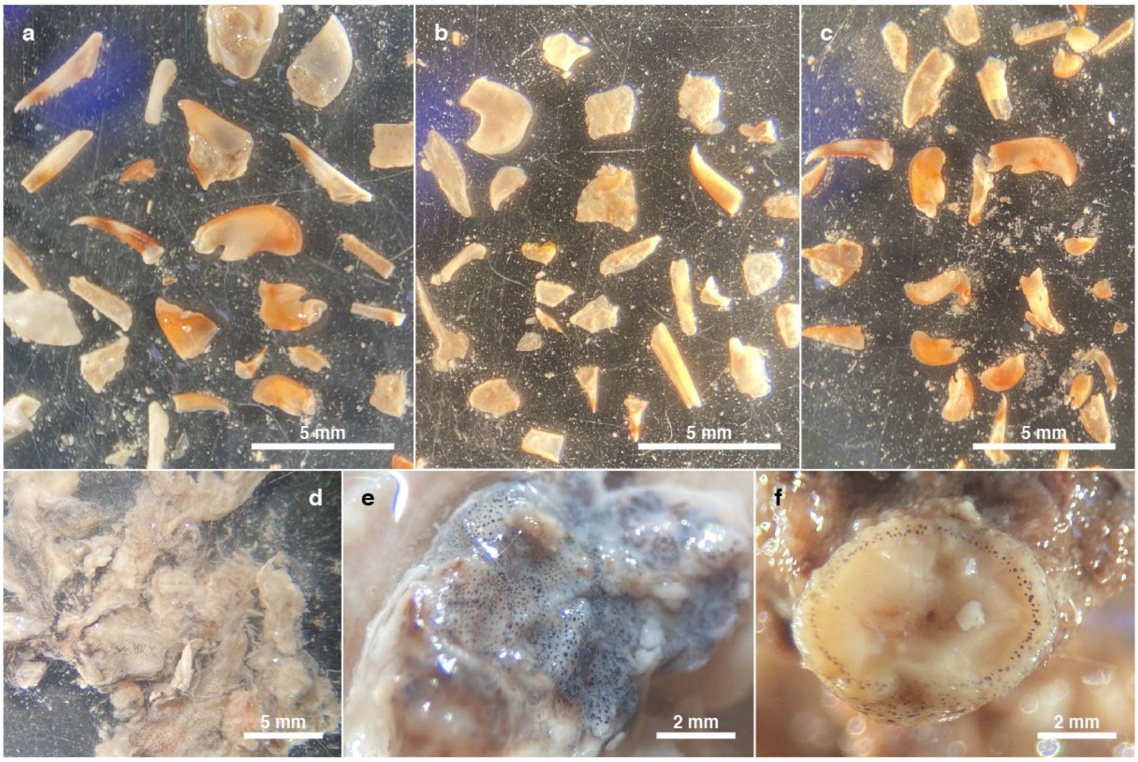


Figure 4. Photographs of the typical contents of the crops of western rock octopus including (a-c) highly fragmented macro-crustaceans; (d) cephalopod flesh and skin displaying high levels of mastication; (e) cephalopod skin containing chromatophores and (f) the suction cup from an octopus tentacle.

3.1.1.3. Blue sprat (*Spratelloides robustus*)

The gut contents of 129 blue sprat were examined of which 121 (94%) contained food, with a mean fullness of 6.5 ± 0.2. A single gut often contained hundreds or thousands of items, almost all of which were < 2 mm in length and showed variable levels of degradation (Figure 5). Blue sprat fed mainly on a range of planktonic crustaceans, but also ingested benthic invertebrates such as small crustaceans, gastropods and bivalves.

Arthropods accounted for 74.4%V, which increased to 92.8%V of identifiable content, and were present in every examined gut (100%F; Table 5). Planktonic crustaceans dominated the arthropods, representing 70.0% of the overall volume and comprised mainly copepods. However, cladocerans (water fleas) were also common and were the main prey items in some individual blue sprat (Table 5). Both calanoid and cyclopoid copepods were recorded, but these two taxa were often difficult to distinguish due to them missing defining features (e.g., intact antennae). Zoea larvae and barnacle cyprids (larvae) were also recorded, but not as frequently as copepods and cladocerans. Smaller contributions to the diet were made by small (non-planktonic) crustaceans, primarily harpacticoid copepods (4.5%V), small gastropods (3.0%V) and siphonophore larvae (2.2%V). These broad dietary categories were recorded in 47.1, 15.7 and 30.6%F of all examined blue sprat.

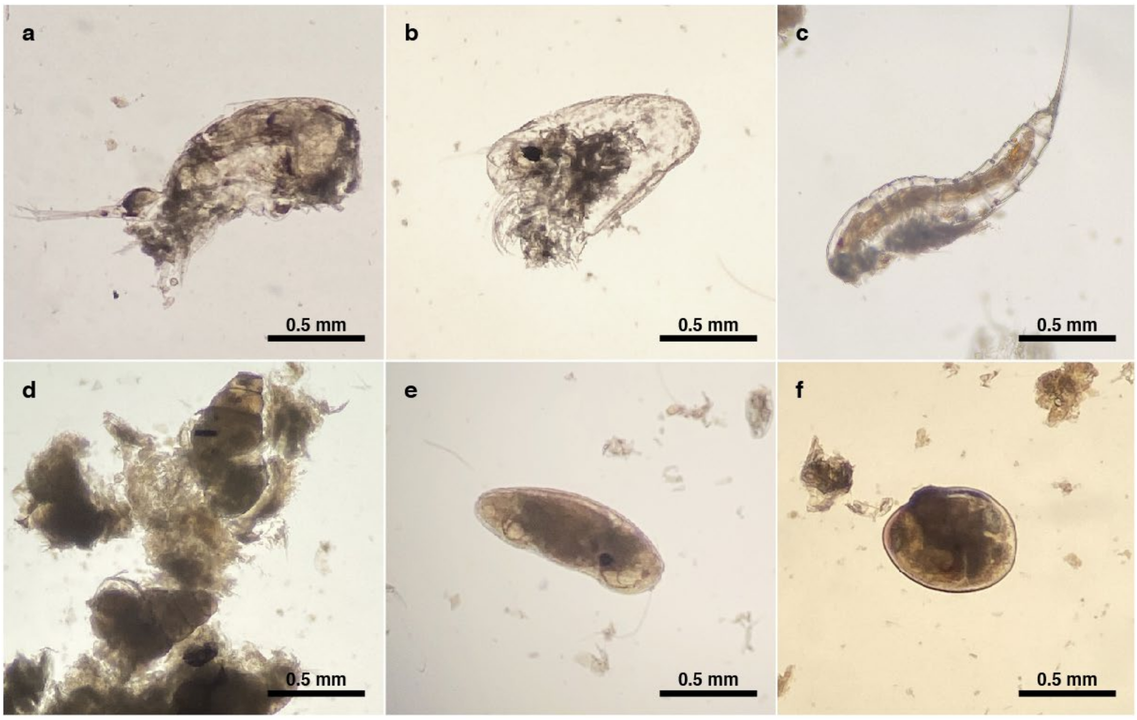
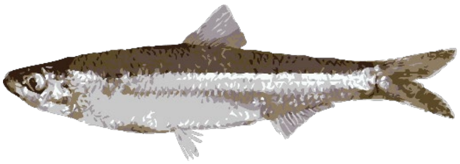


Figure 5. Photographs of the typical prey of blue sprat including a (a) copepod with a typical level of degradation (b) cladoceran, (c) harpacticoid copepod, (d) small gastropods and unidentifiable organic material, (e) barnacle cyprid larva, and (f) a small bivalve.



3.1.1.4. Sandy sprat (*Hyperlophus vittatus*)

The vast majority of 58 examined sandy sprat/whitebait (98%) contained food in moderate volumes with a mean gut fullness of 5.9 ± 0.3. Like the confaminial blue sprat, sandy sprat fed primarily on planktonic organisms, including adult and larval crustaceans and larval ascidians (Figure 6).

Based on volume, the diet of sandy sprat mainly comprised arthropods at 59.6%V (which increased to 93.5%V after excluding unidentifiable organic material), followed by chordates, unidentifiable eggs, cnidarians and molluscs, i.e. 2.5, 1.3, 1.3 and 0.4%V, respectively (Table 5). The first two taxa were consumed regularly, occurring in 96.5 and 19.3%F of all guts examined. The ingested arthropods were almost entirely planktonic crustaceans (56.8%V), i.e. copepods, cladocerans and crustacean zoea and nauplii. The remaining arthropods were small (non-planktonic) crustaceans, e.g. harpacticoid copepods and ostracods (seed shrimp), which contributed 2.8%V and were found in 47.4%F of guts. While only making a minimal contribution by volume (2.5%V), ascidian larvae were relatively commonly ingested (19.3%F). Unidentifiable eggs, likely from teleosts, siphonophore larvae and small bivalves were all consumed by 5.3%F of blue sprat.

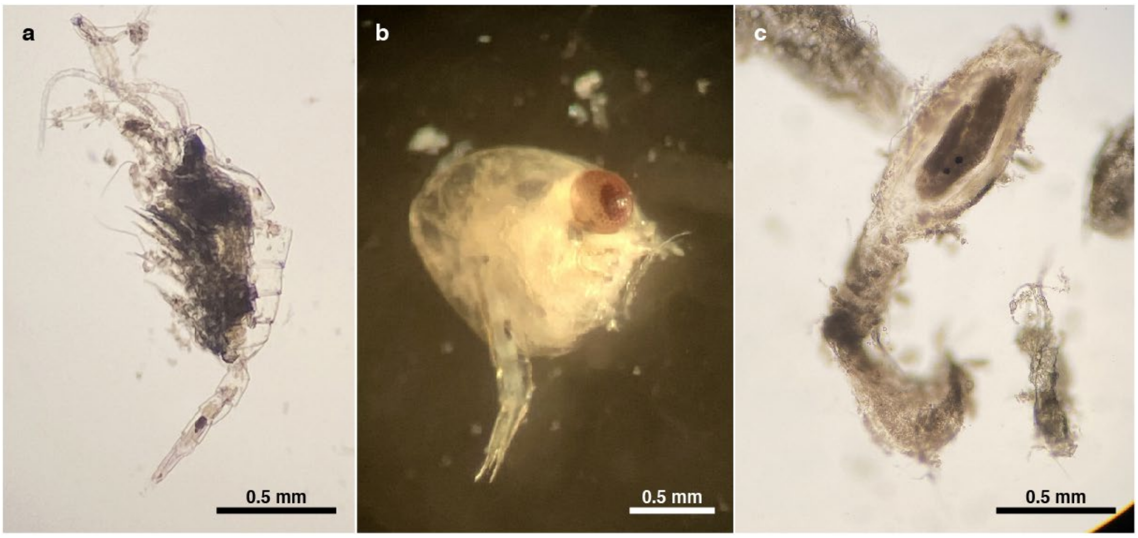


Figure 6. Photographs of the typical prey of sandy sprat including a (a) calanoid copepod, (b) zoea, and (c) an ascidian tadpole larva.

3.1.1.5. Longspine dragonet (*Pseudocalliurichthys goodladi*)

Almost all (99%) of the 285 longspine dragonet examined stomachs contained prey, with a mean fullness of 3.6 ± 0.1. The diet of this species typically featured a diverse mixture of small benthic prey including molluscs, arthropods, echinoderms (Figure 7).

Molluscs made the largest contribution identifiable items to the diet (19.1%V), followed by echinoderms (4.9%V), macrophytes (4.1%V), arthropods (3.3%V), foraminiferans (1.2%V) and annelids (1.1%V; Table 6). However, these contributions were relatively low given the large proportions of unidentifiable organic material (47.1%V) and inorganic material, i.e. sand and shell fragments (17.3%V; Table 6) present in the guts of this benthic fish species. Based on identifiable material only, the contributions of the six major taxa increased to 56.5, 14.5, 12.3, 9.9, 3.5 and 3.1%V, respectively. Moreover, some of these taxa were also frequently recorded with molluscs and echinoderms being present in 96.1 and 83.3%F of the guts, respectively, and arthropods in over half (53.5%F). Within the group of molluscs, small bivalves, including Carditidae, Tellinidae (Figure 7b) and *Timoclea infans*, accounted for 6.7% of the total volumetric content and were found in 57.8% of guts. Small gastropods, including *Finella* sp. and Eulimidae, contributed 5.2%V and 69.5%F and scaphopods (tusk shells) represented 4.0%V and 56.7%F (Table 6). Echinoids were the only echinoderms found (4.9%V; 83.3%F), and most of the arthropods recorded were small crustaceans (2.8%V; 46.1%F), e.g. ostracods, harpacticoid copepods (Figure 7c) and cumaceans (hooded shrimp).

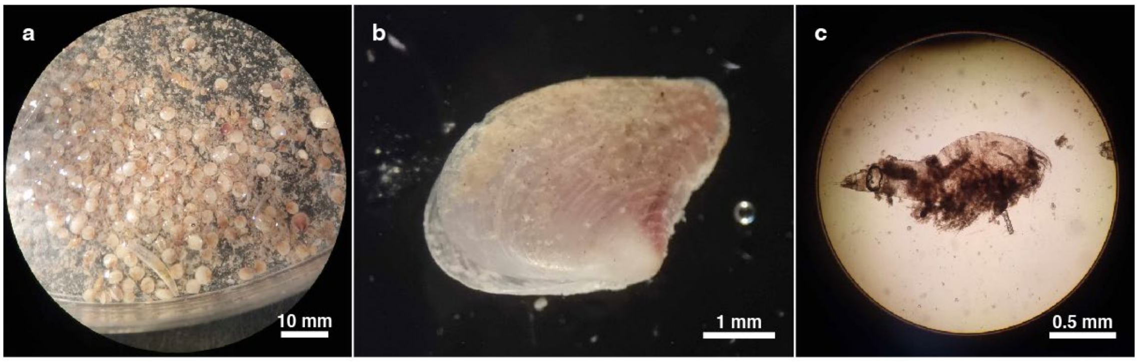


Figure 7. Photographs of the (a) contents of a typical gut of a longspine dragonet showing the numerous small prey items ingested including small bivalves, small gastropods, scaphopods and unidentifiable organic material. Common prey items, i.e. (b) a commonly occurring small bivalve Tellinidae sp. and (c) a copepod.

3.1.1.6. Soldier (*Gymnapistes marmoratus*)

Fifty of the 95 (53%) soldier stomachs contained food, with a mean gut fullness of 5.7 ± 0.4. This species consumed a diverse range of crustaceans and other benthic invertebrates, of which many were engulfed whole and subjected to minimal amounts of mastication (Figure 8). Some individuals ingested a single relatively large prey item that filled the gut, whereas others contained numerous smaller prey items.

Arthropods made the largest volumetric contribution to the diet at 77.4% and were also the most ingested major prey taxa, found in almost all guts (98.0%F; Table 6). Other taxa that made a substantial contribution were annelids (4.8%V) and molluscs (0.7%V), but these prey were ingested infrequently, i.e. 12.0 and 6.0%F, respectively. Small crustaceans, which represented 30.2%V, comprised mainly amphipods, with isolated occurrences of isopods and the leptostracan *Nebalia* sp.. Among the larger consumed arthropods, pleocyemates (true shrimp), small brachyurans and members of the Dendrobranchiata (prawns) made significant volumetric contributions, i.e. 15.0, 10.0 and 5.1%V, respectively, and included alpheids, callianassids (ghost shrimp) and penaeid prawns (Figure 8). Portunid crabs, including *Thalamita sima,* and anomurans, including small paguroids (hermit crabs), also made small volumetric contributions (<2% each). The annelids present were entirely made up of errant polychaetes which included nereids, while the molluscs comprised small gastropods and polyplacophora (chitons).

Figure 8. Photographs of the typical prey of solider including (a) an amphipod, usually found in abundances of between one and roughly twenty individuals per gut; (b) an isopod, found occasionally in low numbers; (c) a Nebalia *sp., found rarely with only one individual identified; (d) an alpheid (snapping) shrimp, found largely intact and almost filling the gut; (e) a callianassid (ghost shrimp), also largely intact and accounting for almost the entire gut content of the solider; (f) errant polychaete, showing a typically higher level of degradation than the crustaceans, but identifiable by its jaws and some parapodia and (g) a Polyplacophora sp. (chiton), showing its characteristic dorsal shell plates.*

3.1.1.7. Midget flathead (*Onigocia spinosa*)

A total of 212 stomachs from midget flathead were examined of which 83% contained food and had a mean gut fullness of 3.2 ± 0.2. Due to their ambush-feeding strategy, items extracted from the guts of this species comprised a broad variety of crustaceans, as well as relatively small numbers of polychaetes and teleosts, which were generally not masticated (Figure 9).

Most of the volume of the gut comprised arthropods (83.8%V), with prey belonging to this major taxon being recorded in 89.2% of specimens (Table 6). Annelids and chordates made minor contributions to the diets of midget flathead, i.e. 3.6 and 2.3%V, respectively, and were only infrequently ingested (<5%F). Of the arthropods, pleocyemates, which included carideans (true shrimp) such as alpheids, palaemonids (glass shrimp) and processids (night shrimp), contributed the largest volume (35.5%V) and was the most common (40.9%F), followed by fragment parts of large crustaceans (27.5%V; 34.7%F). Small crustaceans consisting solely of amphipods from several families, e.g. Corophiidae, Leucothoidae and Paracalliopiidae, represented 13.5%V and were found in 26.7%F of guts. Several groups of arthropods made relatively minor contributions to the overall diet, i.e. the 4.6%V by small brachyurans (e.g. *Ebalia intermedia*, *Dumea latipes* and *Halicarcinus ovatus*) and the 2%V and 0.6%V by squillids (i.e. *Belosquilla laevis*) and portunids (i.e. *Trionectes rugosus*), respectively. All annelids recorded were errant polychaetes and accounted for 3.6%V. The small contribution of teleosts (2.3%V) was largely unidentifiable.

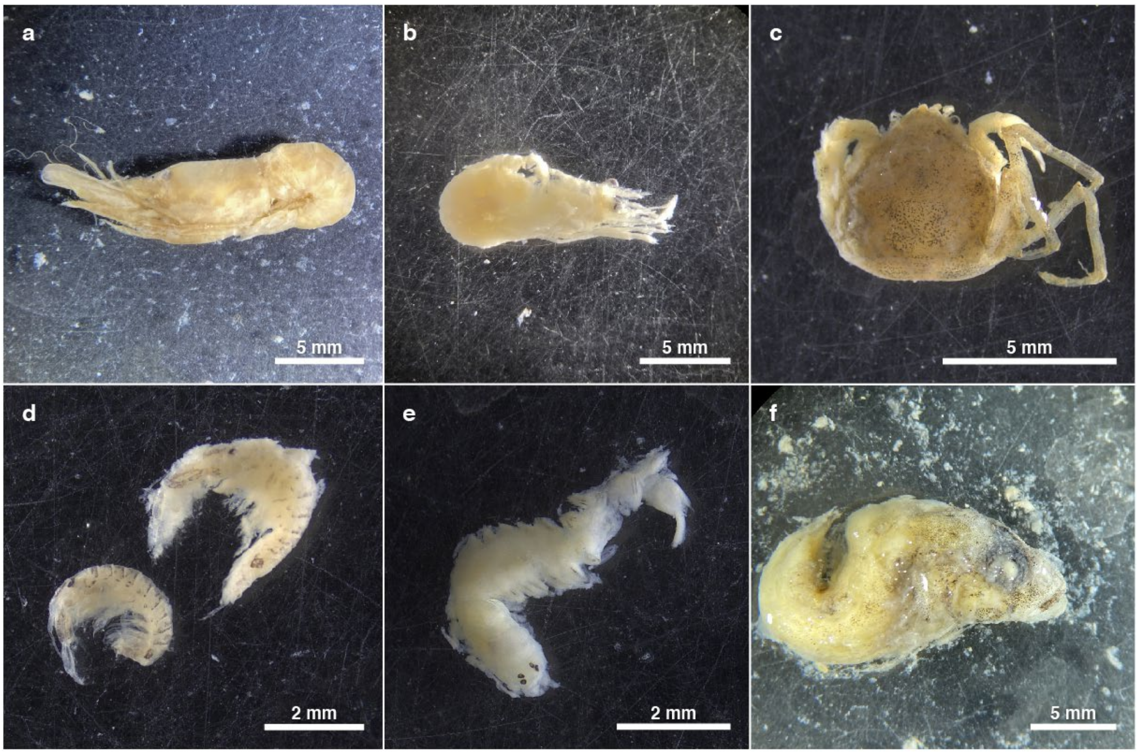


Figure 9. Photographs of the typical prey of midget flathead including (a) a snapping shrimp Alpheus *sp.; (b) the glass shrimp* Palaemon intermedius*; (c) the small brachyuran* Halicarcinus ovatus*; (d) corophiid amphipods; (e) a nereid polychaete and (f) a teleost Gobiidae sp..*

3.1.1.8. Skipjack trevally (*Pseudocaranx wrighti*)

Of the 155 guts of examined skipjack trevally 135 (87%) contained food with a mean gut fullness of 3.7 ± 0.2. A broad range of infaunal and epifaunal invertebrate species were ingested, with individual predators seeming to either consume sand and numerous small benthic prey items or larger epifaunal crustaceans in greatly reduced quantities (Figure 10).

Molluscs (28.0%V), arthropods (19.1%V) made substantial volumetric contributions to the diet, compared to annelids (7.4%V) and echinoderms (6.8%V; Table 6). The former two categories were recorded in ~75% of all skipjack trevally and echinoderms in 45.2%. The molluscan proportion of the diet comprised mainly small and large bivalves, both ~10%V and found in 50.4 and 26.7% of guts, respectively. Although small gastropods, scaphopods and unidentified bivalves each only represented ≤3%V, these taxa were commonly consumed (23.0 - 34.8%F). A wide range of arthropods in terms of both body size and position in the water column were ingested. This included benthic taxa such as small crustaceans (6.1%V and 57.8%F; e.g. amphipods, ostracods and cumaceans) and larger ones e.g. pleocyemates (2.1%V and 6.7%F; mainly alpheids), small brachyurans (1.4%V and 7.4%F; e.g. *Ebalia intermedia*) and unidentified large crustaceans (7.6%V and 50.4%F). Planktonic crustaceans, e.g. zoea and copepods, were also consumed, albeit in smaller quantities and less frequently (1.9%V; 3.7%F). Both errant (e.g. nereids and glycerids) and sedentary (e.g. sabellid) polychaetes were ingested in similar volumes and frequencies (~3.5%V; 8.9 - 11.9%F). The echinoderm component of the diet was mostly echinoids (6.0%V; 44.4%F).

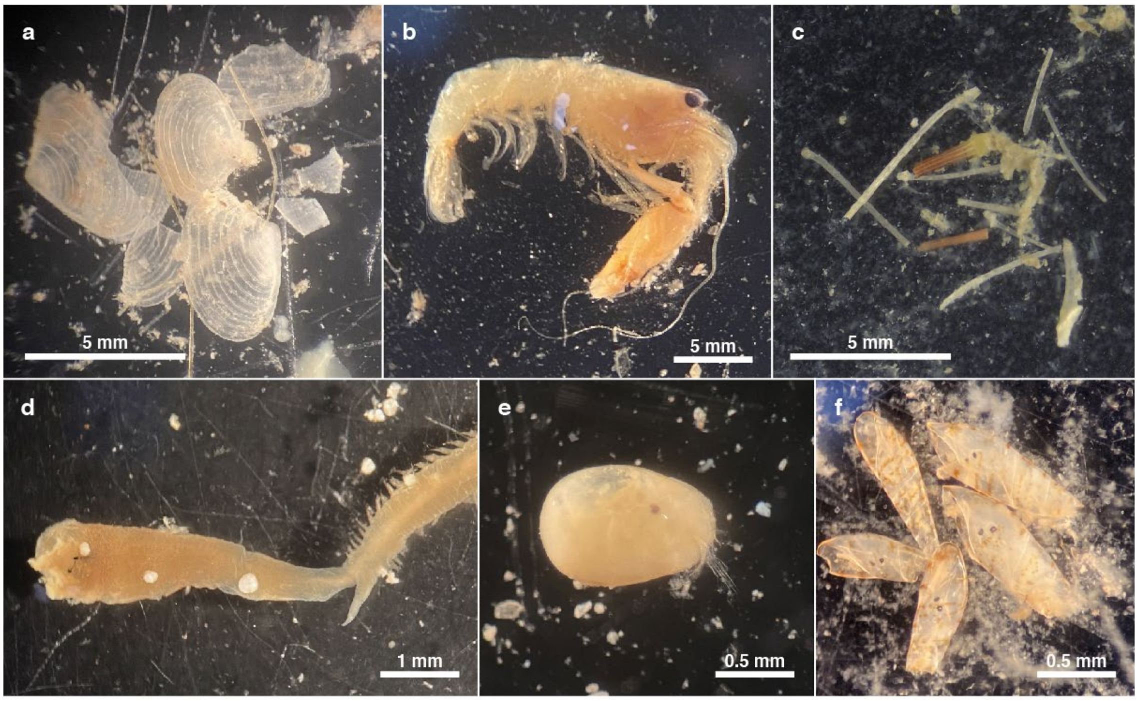
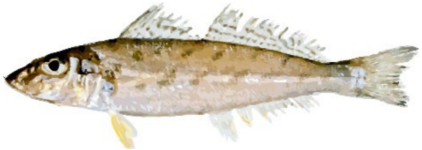


Figure 10. Photographs of the typical prey of skipjack trevally, including (a) small bivalves Tellinidae sp.; (b) a snapping shrimp Alpheus *sp.; (c) echinoid (urchin) spines; (d) an errant polychaete Glyceridae sp.); (e) an ostracod; and (f) a small gastropod Eulimidae sp..*



3.1.1.9. Western trumpeter whiting (*Sillago burrus*)

The guts of 174 western trumpeter whiting were examined of which 129 (74%) contained food, with a mean fullness of 4.9 ± 0.2. This species predated on a diversity of benthic organisms, with bivalves, errant and sedentary polychaetes, echinoderms, and a range of crustaceans all recorded frequently (Figure 11).

In terms of volumetric contributions to the diet, three major taxa were similarly abundant, i.e. annelids (23.8%V), molluscs (22.7%V), and arthropods (19.2%V) and ingested frequently (41.9 - 53.5%F; Table 7). While echinoderms made up a smaller contribution (8.5%V) of the total consumed volume, this taxon was recorded in 27.9%F of examined western trumpeter whiting. The annelid component of the diet included both errant (e.g. nereids, glycerids and lumbrinerids) and sedentary polychaetes, with those in the former broad dietary category making a larger contribution to the volume and being ingested more frequently (i.e. 16.4 vs 7.4%V; 38.0 vs 23.3%F). Large bivalves (i.e. *Solemya* sp. and to a lesser extent *Arcuatula* sp.) represented most of the mollusc component of the diets (16.1%V; 35.7%F), followed by small bivalves (mostly Tellinidae), which made a smaller contribution (3.8%V) and were ingested less frequently (17.1%F), and large gastropods (e.g. philinids (bubble snails) and *Arcuatula* sp.; 1.8%V). Ophiuroids made up almost the entire echinoderm portion of the diet at 8.2%V of the total content and were found in 23.3%F of guts (Table 7). Seven of the nine broad dietary categories of arthropods were consumed by western trumpeter whiting, with the unidentified large crustaceans (8.4%V), pleocyemates, including alpheids, asiids, callanassids and carids (4.4%V) and small brachyurans, including hymenosomatids (spider crabs) and the leucosiid *E. intermedia* (3.9%V) all making large contributions. While small crustaceans only represented 0.9%V, the amphipods, isopods, anthurids, tanaids in this category were recorded in 8.5%F of all fish examined. Fragments of plastic, ~2-3 mm in size, were found in one individual.

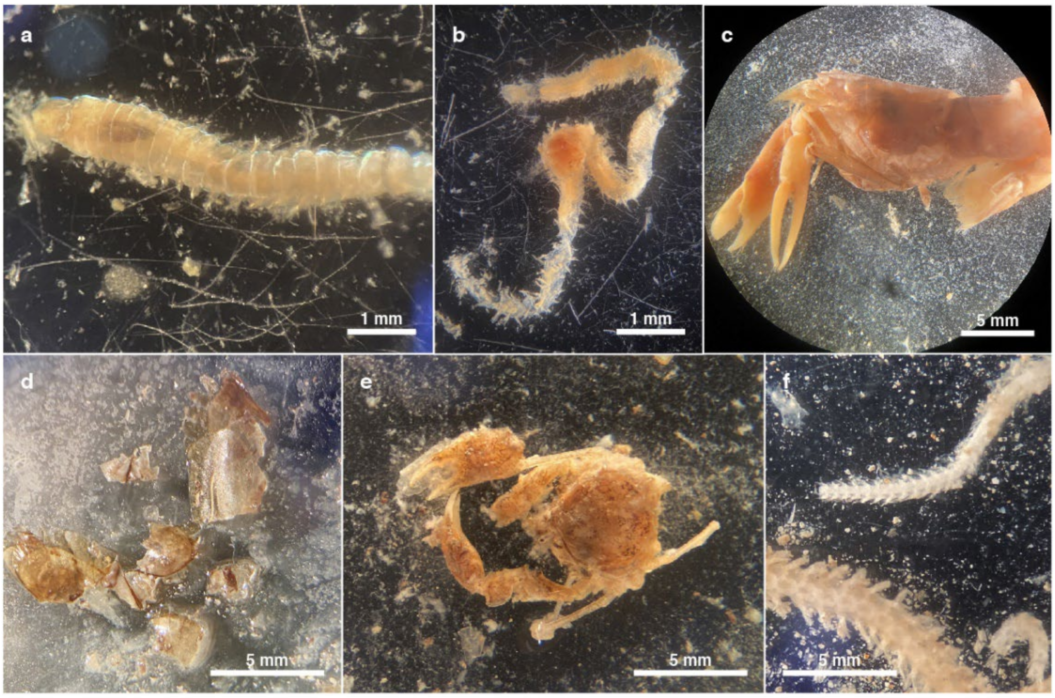


Figure 11. Photographs of the typical prey of western trumpeter whiting including (a) an errant polychaete Lumbrineridae sp. in good condition; (b) an unidentified errant polychaete displaying a more typical level of degradation; (c) a snapping shrimp Alpheus *sp. (d) fragments of the large bivalve* Solemya *sp.; (e) the small brachyuran Hymenosomatidae sp. and (f) arms of an ophiuroid.*

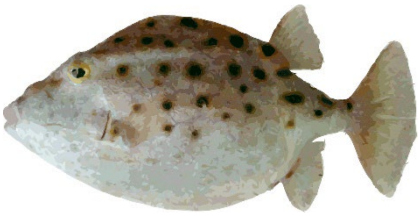
3.1.1.10. Western butterfish (*Pentapodus vitta*)

The guts of 146 western butterfish individuals were examined of which 139 (95%) contained prey. The mean gut fullness was 5.1 ± 0.2. This species showed a generalist feeding strategy, with a broad range of phyla and lower taxa making substantial contributions to its diet. Individual guts tended to feature an abundant and diverse range of organisms, with varying degrees of fragmentation due to mastication and digestive processes (Figure 12).

Of the total gut content, molluscs accounted for 16.7%V, echinoderms for 15.2%V, arthropods for 14.8%V, and annelids for 7.5%V (Table 7), which increased to 30.1, 27.3, 26.6 and 13.6%V, respectively, when only identifiable content was included. Chordates and macrophytes were also present at much smaller proportions (1.0% and 0.3% respectively). 37.9% of the overall volumetric makeup of the gut contents was unidentifiable organic material. The molluscs present included both large and small bivalves (4.8 and 2.3%V, respectively). Bivalve families were varied, with larger bivalves, including *Solemya* spp. and *Arcuatula* sp., while smaller bivalves included members of the Veneridae, Tellinidae and Nuculanidae families. The molluscs also included small and large gastropods (5.0 and 2.1%V, respectively), which featured a diverse range of families including Retusidae, Pyramidellidae and Eulimidae. Often small gastropods were too small and numerous to be practically identified and quantified with high precision. The large gastropods were almost entirely Philinidae, which were sometimes found intact, but often degraded due to the fragility of their shells and their soft flesh and only identifiable by the presence of the gizzard plates. The molluscs also featured small volumetric contributions from scaphopods (1.0%V) and octopus (0.6%V). The echinoderm portion was roughly evenly split between ophiuroids (brittle stars) and echinoids (sea urchins) representing 7.8 and 7.4%V of total gut content, respectively.

Figure 12. Photographs of the typical prey of western butterfish including (a) an ophiuroid with several arms still attached to the central disc; (b) an echinoid showing a high degree of fragmentation; (c) Philinidae sp.; (d) Arcuatula *sp. (Mytilidae), (e) the jaws of an errant polychaete of the order Eunicida and (f) the small crab* Ebalia intermedia.

A large portion of the arthropod component in the diet of western butterfish was unidentified large crustaceans (7.7%V). The high level of fragmentation made precise identification difficult. Small brachyurans including *Ebalia intermedia* and Hymenosomatoidea spp. (false spider crabs) accounted for 2.9%V. Anomurans, which made up 1.5%V, were primarily from the family Paguroidea. Alphaeidae spp. were the main component of the pleocyemates , which accounted for 1.2% of total gut content. Small crustaceans (including ostracods, tanaids and cumaceans), portunids (including *Thalamita sima*), and Dendrobranchiata all contributed less than 1.0%V each to the total gut content. Most annelids were errant polychaetes, which made up 4.0%V and included eunicids and Glyceridae spp., while sedentary polychaetes (1.6%V) included the families Cirratulidae and Serpulidae. The chordate content of the diet was entirely teleost, which was only found in small fragments and could not be identified to a lower taxonomic level.



3.1.1.11. Western smooth boxfish (*Anoplocarpus amygdaloides*)

A total of ten guts of western smooth boxfish were examined, all of which had content, with a mean gut fullness of 6.7 ± 0.7. Despite the low number of individual fish studied, each gut contained a high diversity of prey types. Contributions by phyla included arthropods (30.4%V), echinoderms (27.1%V), molluscs (6.6%V), macrophytes (6.5%V), annelids (4.5%V), and chordates (2.3%F; Table 7). The crustacean component mainly comprised small brachyurans (19.8%V), and unidentified large crustaceans (7.8%V), as well as the stomatopod (mantis shrimp) *Belosquilla laevis* (1.6%V) which occurred in just one of the examined guts (Table 7). Echinoids were present in 70%F of the examined fish and volumetrically accounted for 27.1%V of the total gut content. The plant matter present was entirely macroalgae and contributed 6.5%V. Molluscs included small gastropods and small bivalves (2.9 and 1.5%V, respectively), and the annelid component comprised both errant (2.5%V) and sedentary (2.0%V) polychaetes.

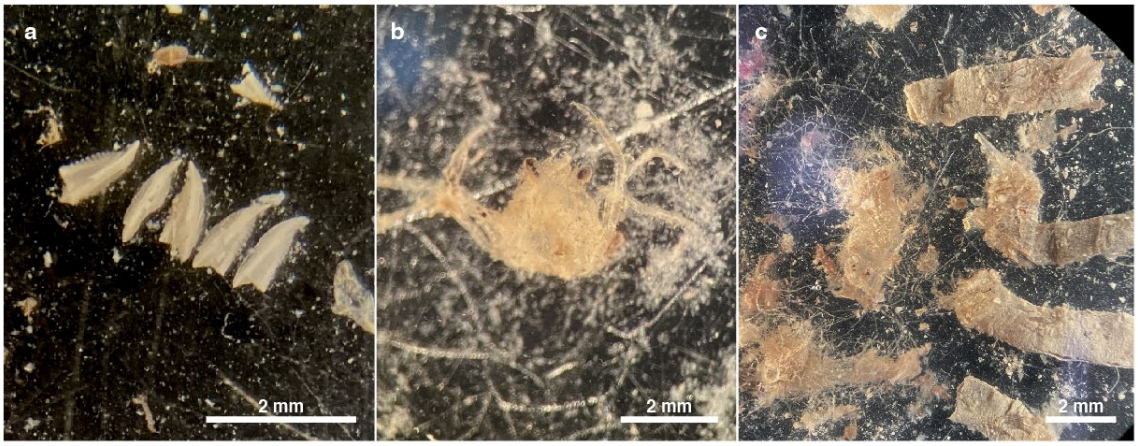


Figure 13. Photographs of the typical prey of western smooth boxfish including (a) teeth of a small sea urchin (Echinoidea); (b) small brachyuran of the family Hymenosomatidae, and (c) sedentary polychaetes in the family Sabellidae.

3.1.1.12. Snapper (*Chrysophrys auratus*)

A total of 109 snapper guts were examined of which 94 contained food, with a mean gut fullness of 5.9 ± 0.2. Snapper tended to consume a broad range of small benthic organisms, characterised by high numbers of very small organisms (less than a few millimetres) and high levels of mastication of the larger prey items (Figure 14).

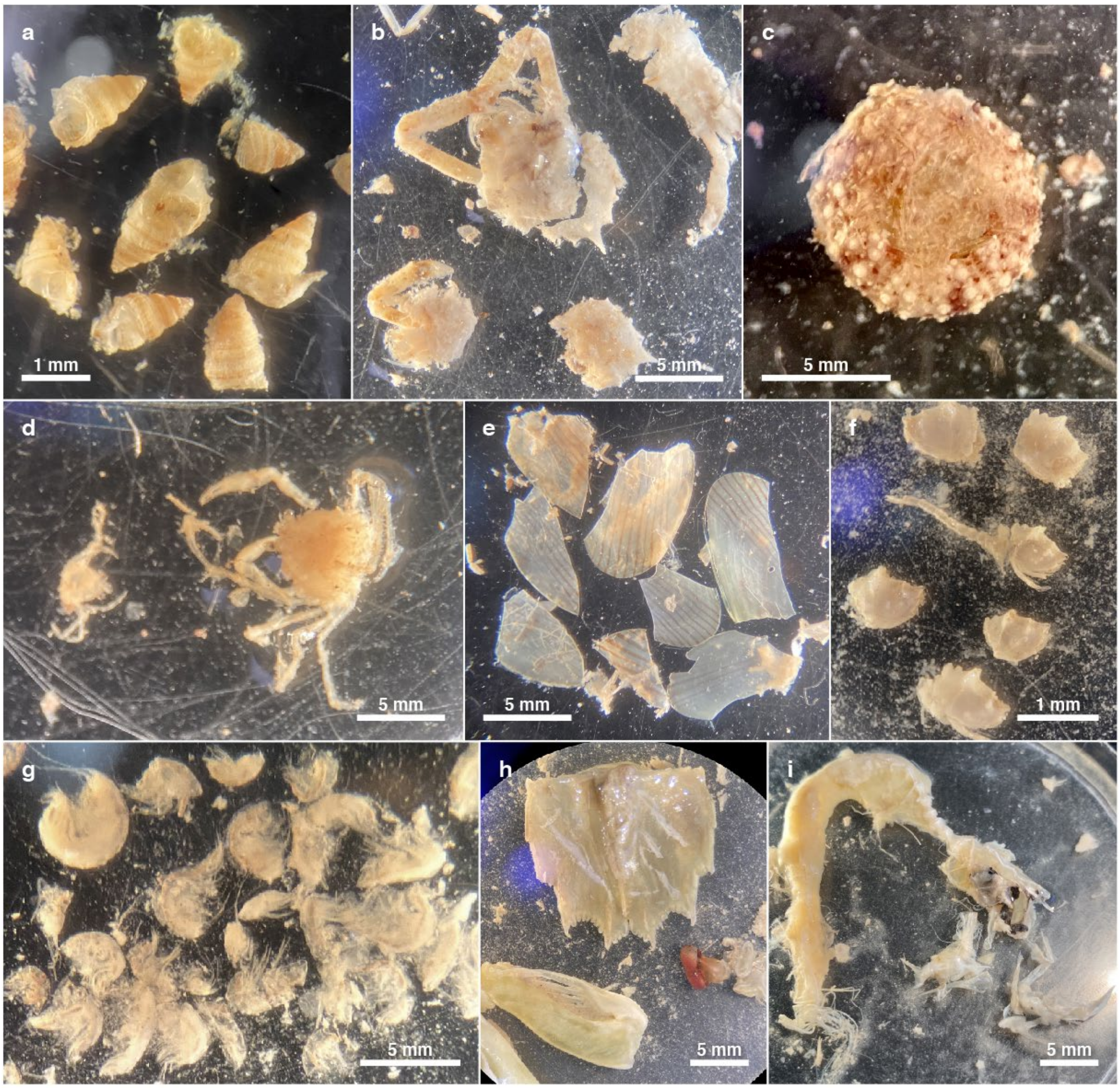
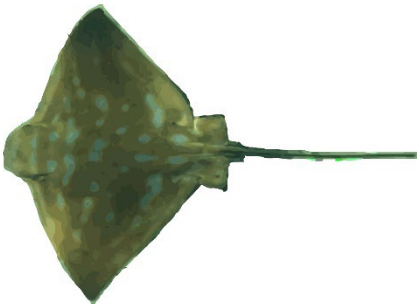


Figure 14. Photographs of the typical prey of snapper including (a) small gastropod Finella *sp.; (b) the small crab* Ebalia intermedia*; (c) mostly intact urchin test; (d) two individuals of Hymenosomatidae spp.; (e) the mytilid* Arcuatula *sp.; (f) cumaceans, including one mostly intact individual and severalcarapaces; (g) many amphipods from the gut of one snapper; (h) the mantis shrimp* Belosquilla laevis*, which was one of the few identifiable non-brachyuran macro-crustaceans due to its distinctive telson and raptorial claw; (i) and the Longspine Dragonet* Pseudocalliurichthys goodladi*.*

The diet of snapper featured a broad range of phyla including arthropods (40.5%V), molluscs (29.0%V), echinoderms (9.0%V), chordates (3.0%V), annelids (2.9%V) and poriferans (0.2%V; Table 7). Small brachyurans were the most important arthropod component, accounting for 16.9%V. Where these prey items could be identified, they were Hymenosomatoidea spp. (false spider crabs) or *Ebalia intermedia*. Macrocrustaceans, which included small brachyurans, often showed very high levels of mastication, making accurate identification difficult and resulted in unidentifiable large crustaceans (15.0%V) being the next largest contributing category to the arthropods. Small crustaceans comprised 5.8%V, with this category being almost entirely cumaceans and amphipods. Small gastropods (21.5%V) were the main molluscan component, which was dominated by *Finella* sp. (Scaliolidae), with a much smaller contribution from Retusidae spp.. Small gastropods were present in 69.1%F of guts and tended to be in very large abundance in the individual snapper they were recorded in but, due to their very small size, did not account for a large proportion of overall content by volumetric contribution. Large bivalves were also frequently found (42.6%F) and accounted for 6.8%V. More than half of these were *Arcuatula* sp., but they also included *Solemya* sp., as well as many bivalves in a similar size range which were too fragmented to identify further. The echinoderms present were mainly echinoids (6.7%V), but also included ophiuroids and asteroids (sea stars) in rare occurrences. Teleosts were the main chordate component but only contributed 2.0%V. Teleosts in the diet included the longspine dragonet (*P. goodladi)* and a clupeid. Unidentified ascidians accounted for just 1.0%V. Errant polychaetes accounted for 2.9%V of content, with nereids being the only identifiable polychaete present. A further 12.0%V of total gut content was unidentifiable organic material.



3.1.1.13. Southern eagle ray (*Myliobatis tenuicaudatus*)

A total of 34 southern eagle ray guts were examined and all contained food. The diet of the batiod consisted of a broad range of prey items, usually featuring large macrocrustaceans and large annelids, and often large gastropods. Prey items exhibited the effects of crushing mastication by their large tooth plates, especially in the cases of large crustaceans and gastropod shells. However, in many cases largely intact fragments with diagnostic features made identification to low taxonomic levels possible (Figure 15).

The main prey items were arthropods (34.9%V), annelids (20.8%V) and molluscs (8.2%V; Table 8). Chordates contributed another 3.3%V, while echinoderms were rare and accounted for just 0.4%V. Of the examined overall gut content examined, 29.4%V was unidentifiable organic material (Table 8). Within the crustaceans, portunids made the largest contribution (14.6%V). Most of the portunids were identified as *T. sima*, while far fewer were *Trionectes rugosus*, and others could only be identified as Portunidae due to degradation of the specimen (e.g., swimming legs occurred intact, but the rest of the body was missing or crushed beyond recognition). Squillidae (*Belosquilla laevis*) and Pleocyemata were well-represented at 6.7 and 6.6%V, respectively. The Pleocyemata featured an abundance of snapping shrimp (Alpheidae), and less commonly ghost shrimp (Callianassidae). Errant polychaetes featured in 61.8%F of guts and made up 14.9%V of the overall content, with many being identified as nereids, while others were too damaged to identify to family. Also present were sedentary polychaetes (4.5%V) and sipunculans (0.6%V). The molluscs present were primarily large gastropods (6.7%V) which were entirely separated from their shells. These were identifiable by the largely intact head-foot, large separate operculum, and sometimes the presence of small fragments of the crushed shell. Other mollusc groups included small gastropods, bivalves, and nudibranchs, but these all accounted for <1% of total volume each. Chordates were mainly teleosts which included Gobiidae, Sillaginidae and Engraulidae, as well as a small amount of ascidians.

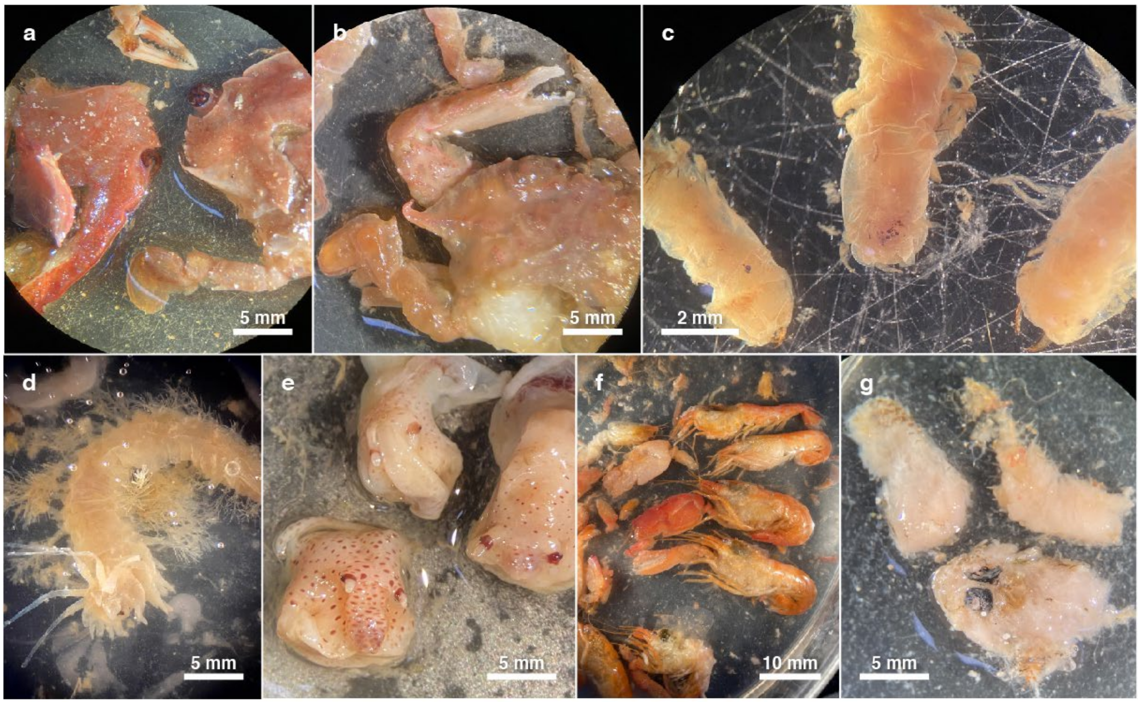


Figure 15. Photographs of the typical prey of southern eagle ray including (a) the crabs Thalamita sima *and (b)* Trionectes rugosus*; (c) nereid polychaetes; (d) errant polychaete Onuphidae sp.; (e) large gastropods with large portion of head-foot intact but shell entirely missing; (f) many alpheid shrimp found in one individual gut; and (g) fragments of teleost (Gobiidae sp.).*

3.1.1.15. Rusty flathead (*Inegocia japonica*)

The stomach contents of 318 rusty flathead were examined of which 271 (85%) contained food, with a mean fullness of 3.5 ± 0.1. The diet of this flathead comprised mainly crustaceans, ranging in size from amphipods to alpheid shrimp, stomatopods, small brachyurans and small fish. Many of the prey items were swallowed whole and therefore were not subjected to high levels of mastication and thus, if not digested, could be readily identified (Figure 16).

Arthropods made the largest contribution to dietary content (51.2%V) found in rusty flathead and occurred in 60.1%F of all guts; followed by chordates (34.4%V; 39.5%F; Table 8). Annelids made a minor contribution, representing 3.3%V and were consumed by 5.5%F of individuals. Among the arthropods, the pleocyemates, which included snapping shrimp, ghost shrimp, caridean shrimp and prawns, made the largest contribution (24.7%V) and were the most commonly ingested (31.0%F. Other than unidentified large crustaceans, the next most consumed were the stomatopod *Belosquilla laevis* (5.2%V; 5.9%F), small brachyurans (i.e. *Ebalia intermedia*) and the portunids *T. sima* and *Trionectes rugosus* (2,9%V; 4.8%F). The chordate component of the diet only comprised teleosts (34.4%V; 39.5%F), with species from nine families. In order of total volumetric contribution, these were Gobiidae (unidentified species; 7%V), Clupeidae (sandy sprat *H. vittatus*; 6%V); Callionymidae (longspine dragonet; *P. goodladi*; 4.5%V), Leptoscopidae (*Lesueurina platycephala*; 3%V), while the Apogonidae *Ostorhinchus rueppellii*, Carangidae *Pseudocaranx* sp., Gerreidae *Parequula melbournensis,* Monacanthidae *Monacanthus chinensis* and Pegasidae *Pegasus volitans.* Other species may also have been consumed as ~12%V of the teleost material was unidentifiable. All annelids consumed were errant and included eunicids.

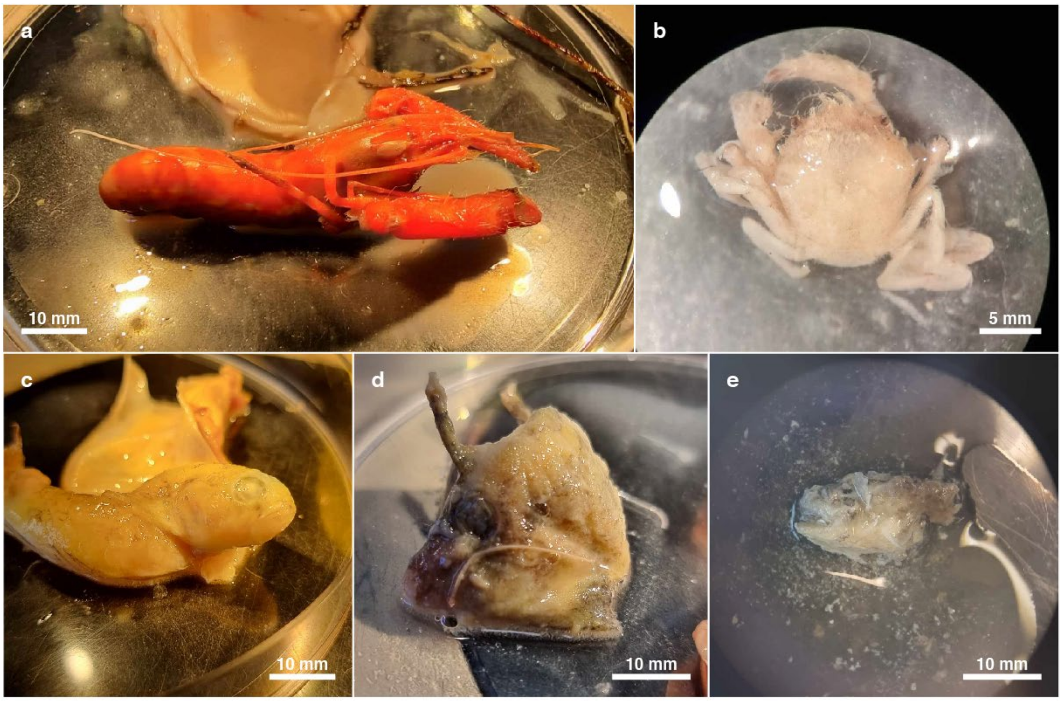


Figure 16. Photographs of the typical prey of rusty flathead including (a) an alpheid shrimp; (b) a small brachyuran and several teleosts such as (c) the southern longfin goby Favonigobius lateralis *(Gobiidae); (d) fan-bellied leatherjacket* Monacanthus chinensis *(Monacanthidae) and; (e) flathead sandfish* Lesueurina platycephala *(Leptoscopidae).*




3.1.1.15. Other flathead species

The diet of a small number of larger flathead species was also examined namely the longhead flathead (*Leviprora inops; n* = 18), longspine flathead (*Platycephalus grandispinis; n* = 50); southern bluespot flathead (*Platycephalus speculator; n* = 4) and the yellowtail flathead (*Platycephalus westraliae; n* = 5). Like the rusty flathead, these species utilise ambush feeding to consume relatively large prey items. Prey included penaeid prawns, brachyurans and a range of teleosts (Figure 17).

Arthropods were the main prey of the longhead flathead (65.2%V; 69.2%F), followed by chordates (15.0%V; 23.1%F; Table 8). For the longspine flathead, the relative importance of these main prey was reversed, with arthropods making a lower contribution (25.7%V; 29.3%F), chordates a larger one (42.6%V; 46.3%F). This flathead species also ingested considerable amounts of annelids (9.5%V) and relatively often (14.6%F). The arthropods ingested by the longhead flathead tended to be in the Pleocyemata group (43.8%V; 46.2%F) and included a range of caridean and snapping shrimp, the Dendrobranchiata, *i.e.* the prawn *Metapenaeopsis lindae* (7.7%V and 7.7%F) and the Portunidae (6.2%V; 7.7%F), *i.e. Halicarcinus rostratus* and *T. sima.* Of the identifiable arthropods in the stomachs of longspine flathead, small brachyurans (i.e. *Ebalia intermedia*), small crustaceans, i.e. amphipods, and pleocyemates (snapping shrimp) made the largest contributions. In both species, all the chordate material belonged to teleosts, with taxa from five families being identified. Most of this material in the longspine flathead was unidentifiable (13%V), and only the longspine dragonet (2%V) could be identified. Longspine flathead consumed greater volumes of teleosts than the other flathead. There teleost prey included gobies, e.g. striped sandgoby (*Acentrogobius pflaumii*; 11.6%V), flathead sandfish (7.3%V), longspine dragonet (7.3%V), sandy sprat (2.3%) and various whiting species (Sillaginidae sp.; 2.3%V).

Chordates comprised most of the stomach content of the small number of examined for yellowtail and southern bluespot flathead, i.e. 56.0 and 75.0%V, respectively (Table 9). The former species also consumed western butterfish (20%V), unidentified teleosts (20%V) and sandy sprat (16%V), while the latter species also consumed longspine dragonet (50%V) and western butterfish (25%V). Unidentified arthropods also contributed 15.0%V of the diet of southern bluespot flathead (Table 9).

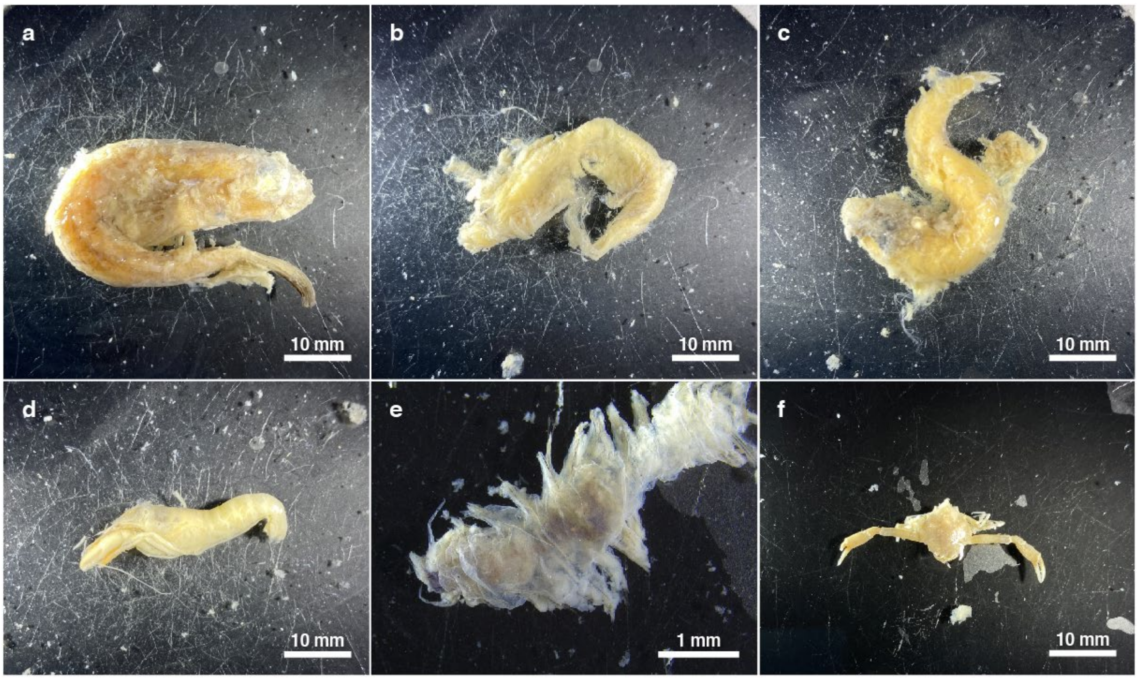


Figure 17. Photographs of the typical prey of various larger flathead species including (a) the introduced goby Acentrogobius pflaumii*; (b) longspine dragonet* Pseudocalliurichthys goodladi *(c) another goby* Favonigobius lateralis*; (d) snapping shrimp* Alpheus *sp.; (e) nereid polychaete and (f) small crab* Ebalia intermedia*.*

Table 5. Volumetric contribution (%V) and frequency of occurrence (%F) of each major taxa (bold face) and broad dietary category to the overall dietary composition of the blue swimmer crab, western rock octopus, blue sprat and sandy sprat.

	Blue swimmer crab		W. rock octopus		Blue sprat		Sandy sprat	
Major taxa & dietary categories	%V	%F	%V	%F	%V	%F	%V	%F
Foraminifera	**<0.1**	**3.1**	**–**	**–**	**0.2**	**4.1**	**–**	**–**
Porifera	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Cnidaria	**–**	**–**	**–**	**–**	**2.2**	**30.6**	**1.3**	**5.3**
Siphonophore larvae	–	–	–	–	2.2	30.6	1.3	5.3
Annelida	**<0.1**	**0.6**	**–**	**–**	**<0.1**	**0.8**	**–**	**–**
Errant polychaete	<0.1	0.6	–	–	–	–	–	–
Sedentary polychaete	–	–	–	–	–	–	–	–
Sipuncula	–	–	–	–	–	–	–	–
Unid polychaete	–	–	–	–	–	–	–	–
Polychaete larvae	–	–	–	–	<0.1	0.8	–	–
Arthropoda	**7.1**	**30.7**	**34.9**	**72.3**	**74.4**	**100.0**	**59.6**	**96.5**
Small crustacean	–	–	–	–	4.5	47.1	2.8	47.4
Pleocyemata	–	–	–	–	–	–	–	–
Dendrobranchiata	–	–	–	–	–	–	–	–
Squillidae	–	–	–	–	–	–	–	–
Unid large crustacean	6.8	30.1	34.9	72.3	–	–	–	–
Small brachyura	0.3	1.8	–	–	–	–	–	–
Portunidae	–	–	–	–	–	–	–	–
Anomura	<0.1	0.6	–	–	–	–	–	–
Planktonic crustacean	–	–	–	–	70.0	100.0	56.8	96.5
Mollusca	**43.8**	**81.6**	**6.6**	**10.6**	**3.4**	**19.0**	**0.4**	**5.3**
Small gastropod	4.0	30.1	–	–	3.0	15.7	–	–
Large gastropod	0.3	3.1	–	–	–	–	–	–
Small bivalve	32.7	60.1	–	–	0.4	8.3	0.4	5.3
Large bivalve	4.3	23.9	–	–	–	–	–	–
Unid bivalve	2.4	19.0	–	–	–	–	–	–
Nudibranchia	–	–	–	–	–	–	–	–
Scaphopoda	<0.1	1.2	–	–	–	–	–	–
Polyplacophora	–	–	–	–	–	–	–	–
Octopoda	–	–	4.3	4.3	–	–	–	–
Unid cephalopoda	–	–	2.3	6.4	–	–	–	–
Unid mollusca	–	–	–	–	–	–	–	–
Mollusc larvae	–	–	–	–	<0.1	1.7	–	–
Nematoda	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Bryozoa	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Echinodermata	**18.1**	**45.4**	**–**	**–**	**–**	**–**	**–**	**–**
Ophiuroidea	<0.1	0.6	–	–	–	–	–	–
Echinoidea	18.1	45.4	–	–	–	–	–	–
Asteroidea	–	–	–	–	–	–	–	–
Chordata	**–**	**–**	**0.5**	**4.3**	**–**	**–**	**2.5**	**19.3**
Unid ascidian	–	–	–	–	–	–	–	–
Ascidian larvae	–	–	–	–	–	–	2.5	19.3
Teleost	–	–	0.5	4.3	–	–	–	–
Macrophyte	**0.9**	**7.4**	**–**	**–**	**–**	**–**	**–**	**–**
Unidentifiable egg	**–**	**–**	**–**	**–**	**–**	**–**	**1.3**	**5.3**
Unid calcareous material	**9.0**	**39.3**	**0.2**	**2.1**	**–**	**–**	**–**	**–**
Unid organic material	**17.4**	**74.8**	**57.4**	**95.7**	**18.7**	**100.0**	**35.0**	**93.0**
Synthetic material	**<0.1**	**1.2**	**–**	**–**	**0.6**	**15.7**	**–**	**–**
Inorganic material	**3.0**	**34.4**	**0.4**	**6.4**	**0.5**	**5.0**	**–**	**–**
Number of guts examined		219		98		129		58
Number of guts with food		163		47		121		57
Mean fullness (± SE)		4.8 ± 0.2		2.5 ± 0.4		6.5 ± 0.2		5.9 ± 0.3

Table 6. Volumetric contribution (%V) and frequency of occurrence (%F) of each major taxa (bold face) and broad dietary category to the overall dietary composition of the longspine dragonet, soldier, midget flathead and skipjack trevally.

	Longspine dragonet		Soldier		Midget flathead		Skipjack trevally	
Major taxa & dietary categories	%V	%F	%V	%F	%V	%F	%V	%F
Foraminifera	**1.2**	**37.9**	**–**	**–**	**–**	**–**	**1.1**	**20.0**
Porifera	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Cnidaria	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Siphonophore larvae	–	–	–	–	–	–	–	–
Annelida	**1.1**	**9.2**	**4.8**	**12.0**	**3.6**	**5.7**	**7.4**	**20.7**
Errant polychaete	0.7	2.5	4.8	12.0	3.6	5.7	3.5	8.9
Sedentary polychaete	0.4	6.7	–	–	–	–	3.8	11.9
Sipuncula	–	–	–	–	–	–	–	–
Unid polychaete	–	–	–	–	–	–	–	–
Polychaete larvae	–	–	–	–	–	–	–	–
Arthropoda	**3.3**	**53.5**	**77.4**	**98.0**	**83.8**	**89.2**	**19.1**	**76.3**
Small crustacean	2.8	46.1	30.2	62.0	13.5	26.7	6.1	57.8
Pleocyemata	–	–	15.0	22.0	35.1	40.9	2.1	6.7
Dendrobranchiata	–	–	5.1	10.0	–	–	–	–
Squillidae	–	–	–	–	2.0	2.8	–	–
Unid large crustacean	0.6	9.2	14.1	40.0	27.5	34.7	7.6	50.4
Small brachyura	<0.1	0.4	10.0	22.0	4.6	7.4	1.4	7.4
Portunidae	–	–	1.9	2.0	0.6	0.6	–	–
Anomura	–	–	1.1	4.0	0.5	1.1	–	–
Planktonic crustacean	–	–	–	–	–	–	1.9	3.7
Mollusca	**19.1**	**96.1**	**0.7**	**6.0**	**–**	**–**	**28.0**	**74.1**
Small gastropod	5.2	69.5	0.5	4.0	–	–	2.8	34.8
Large gastropod	0.8	25.9	–	–	–	–	<0.1	0.7
Small bivalve	6.7	57.8	–	–	–	–	10.2	50.4
Large bivalve	0.5	17.0	–	–	–	–	10.9	26.7
Unid bivalve	1.9	29.4	–	–	–	–	3.0	25.9
Nudibranchia	–	–	–	–	–	–	–	–
Scaphopoda	4.0	56.7	–	–	–	–	1.1	23.0
Polyplacophora	–	–	0.2	2.0	–	–	–	–
Octopoda	–	–	–	–	–	–	–	–
Unid cephalopoda	–	–	–	–	–	–	–	–
Unid mollusca	–	–	–	–	–	–	–	–
Mollusc larvae	–	–	–	–	–	–	–	–
Nematoda	**0.1**	**2.5**	**–**	**–**	**–**	**–**	**–**	**–**
Bryozoa	**–**	**–**	**–**	**–**	**–**	**–**	**0.1**	**0.7**
Echinodermata	**4.9**	**83.3**	**–**	**–**	**–**	**–**	**6.8**	**45.2**
Ophiuroidea	–	–	–	–	–	–	0.9	4.4
Echinoidea	4.9	83.3	–	–	–	–	6.0	44.4
Asteroidea	–	–	–	–	–	–	–	–
Chordata	**<0.1**	**0.4**	**–**	**–**	**2.3**	**4.5**	**–**	**–**
Unid ascidian	–	–	–	–	–	–	–	–
Ascidian larvae	–	–	–	–	–	–	–	–
Teleost	<0.1	0.4	–	–	2.3	4.5	–	–
Macrophyte	**4.1**	**68.1**	**0.1**	**2.0**	**0.1**	**1.1**	**0.2**	**8.1**
Unidentifiable egg	**0.1**	**2.8**	**–**	**–**	**–**	**–**	**–**	**–**
Unid calcareous material	**1.8**	**25.9**	**<0.1**	**2.0**	**–**	**–**	**2.2**	**21.5**
Unid organic material	**47.1**	**98.9**	**17.0**	**74.0**	**8.9**	**11.4**	**30.1**	**85.9**
Synthetic material	**<0.1**	**1.1**	**–**	**–**	**–**	**–**	**–**	**–**
Inorganic material	**17.3**	**98.2**	**–**	**–**	**0.7**	**5.7**	**5.0**	**60.0**
Number of guts examined		285		93		212		155
Number of guts with food		282		50		176		135
Mean fullness (± SE)		3.6 ± 0.1		5.7 ± 0.4		3.2 ± 0.2		3.7 ± 0.2

Table 7. Volumetric contribution (%V) and frequency of occurrence (%F) of each major taxa (bold face) and broad dietary category to the overall dietary composition of the western trumpeter whiting, western butterfish, western smooth boxfish and snapper.

	W. trumpeter whiting		**W. butterfish**		**W. smooth boxfish**		**Snapper**	
Major taxa & dietary categories	%V	%F	%V	%F	%V	%F	%V	%F
Foraminifera	**0.2**	**0.8**	**0.1**	**1.4**	**–**	**–**	**0.2**	**5.3**
Porifera	**–**	**–**	**–**	**–**	**–**	**–**	**0.2**	**1.1**
Cnidaria	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Siphonophore larvae	–	–	–	–	–	–	–	–
Annelida	**23.8**	**51.9**	**7.5**	**35.3**	**4.5**	**40.0**	**2.9**	**8.5**
Errant polychaete	16.4	38.0	4.0	20.1	2.5	30.0	2.9	8.5
Sedentary polychaete	7.4	23.3	1.6	12.9	2.0	20.0	–	–
Sipuncula	–	–	–	–	–	–	–	–
Unid polychaete	–	–	1.9	8.6	–	–	–	–
Polychaete larvae	–	–	–	–	–	–	–	–
Arthropoda	**19.2**	**41.9**	**14.8**	**63.3**	**30.4**	**80.0**	**40.5**	**88.3**
Small crustacean	0.9	8.5	0.8	14.4	0.4	10.0	5.8	47.9
Pleocyemata	4.4	7.0	1.2	5.8	–	–	–	–
Dendrobranchiata	–	–	0.1	2.2	–	–	–	–
Squillidae	0.7	0.8	–	–	1.6	10.0	1.9	2.1
Unid large crustacean	8.4	21.7	7.7	44.6	7.8	40.0	15.0	71.3
Small brachyura	3.9	7.0	2.9	20.9	19.8	50.0	16.9	56.4
Portunidae	0.7	0.8	0.6	1.4	–	–	0.7	1.1
Anomura	–	–	1.5	4.3	0.8	10.0	0.1	1.1
Planktonic crustacean	0.2	1.6	–	–	–	–	–	–
Mollusca	**22.7**	**53.5**	**16.7**	**73.4**	**6.6**	**100.0**	**29.0**	**83.0**
Small gastropod	0.1	0.8	2.1	30.2	2.9	40.0	21.5	69.1
Large gastropod	1.8	2.3	5.0	17.3	–	–	–	–
Small bivalve	3.8	17.1	2.3	28.8	1.5	40.0	0.5	17.0
Large bivalve	16.1	35.7	4.8	29.5	–	–	6.8	42.6
Unid bivalve	1.0	4.7	0.7	13.7	2.2	60.0	0.2	7.4
Nudibranchia	–	–	–	–	–	–	–	–
Scaphopoda	–	–	1.0	12.9	–	–	–	–
Polyplacophora	–	–	–	–	–	–	–	–
Octopoda	–	–	0.6	0.7	–	–	–	–
Unid cephalopoda	–	–	0.2	0.7	–	–	–	–
Unid mollusca	–	–	–	–	–	–	–	–
Mollusc larvae	–	–	–	–	–	–	–	–
Nematoda	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Bryozoa	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Echinodermata	**8.5**	**27.9**	**15.2**	**61.2**	**27.1**	**70.0**	**9.0**	**39.4**
Ophiuroidea	8.2	23.3	7.8	32.4	–	–	1.8	10.6
Echinoidea	0.4	8.5	7.4	48.9	27.1	70.0	6.7	33.0
Asteroidea	–	–	–	–	–	–	0.5	2.1
Chordata	**–**	**–**	**1.0**	**8.6**	**2.3**	**20.0**	**3.0**	**5.3**
Unid ascidian	–	–	–	–	2.3	20.0	1.0	1.1
Ascidian larvae	–	–	–	–	–	–	–	–
Teleost	–	–	1.0	8.6	–	–	2.0	4.3
Macrophyte	**0.1**	**5.4**	**0.3**	**11.5**	**6.5**	**30.0**	**0.2**	**6.4**
Unidentifiable egg	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Unid calcareous material	**0.3**	**3.1**	**2.7**	**25.9**	**1.0**	**10.0**	**0.6**	**9.6**
Unid organic material	**23.1**	**89.1**	**37.9**	**98.6**	**20.4**	**80.0**	**12.0**	**78.7**
Synthetic material	**<0.1**	**0.8**	**–**	**–**	**–**	**–**	**–**	**–**
Inorganic material	**2.0**	**54.3**	**3.8**	**40.3**	**1.2**	**20.0**	**2.4**	**66.0**
Number of guts examined		174		146		10		109
Number of guts with food		129		139		10		94
Mean fullness (± SE)		4.9 ± 0.2		5.1 ± 0.2		6.7 ± 0.7		5.9 ± 0.2

Table 8. Volumetric contribution (%V) and frequency of occurrence (%F) of each major taxa (bold face) and broad dietary category to the overall dietary composition of the southern eagle ray, rusty flathead, longhead flathead and longspine flathead.

	S. eagle ray		Rusty flathead		Longhead flathead		Longspine flathead	
Major taxa & dietary categories	%V	%F	%V	%F	%V	%F	%V	%F
Foraminifera	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Porifera	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Cnidaria	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Siphonophore larvae	–	–	–	–	–	–	–	–
Annelida	**20.8**	**70.6**	**3.3**	**5.5**	**–**	**–**	**9.5**	**14.6**
Errant polychaete	14.9	61.8	3.3	5.5	–	–	9.5	14.6
Sedentary polychaete	4.5	35.3	–	–	–	–	–	–
Sipuncula	0.6	2.9	–	–	–	–	–	–
Unid polychaete	0.8	2.9	–	–	–	–	–	–
Polychaete larvae	–	–	–	–	–	–	–	–
Arthropoda	**34.9**	**82.4**	**51.2**	**60.1**	**65.2**	**69.2**	**25.7**	**29.3**
Small crustacean	–	–	2.4	4.4	–	–	1.6	4.9
Pleocyemata	6.6	23.5	24.7	31.0	43.8	46.2	3.0	4.9
Dendrobranchiata	0.1	2.9	–	–	7.7	7.7	–	–
Squillidae	6.7	29.4	5.2	5.9	–	–	–	–
Unid large crustacean	3.4	35.3	14.5	17.3	7.5	7.7	16.5	17.1
Small brachyura	2.8	17.6	2.9	4.8	–	–	3.7	7.3
Portunidae	14.6	35.3	1.5	1.5	6.2	7.7	1.0	2.4
Anomura	0.6	2.9	–	–	–	–	–	–
Planktonic crustacean	–	–	–	–	–	–	–	–
Mollusca	**8.2**	**32.4**	**0.3**	**2.2**	**2.7**	**15.4**	**1.5**	**2.4**
Small gastropod	0.6	2.9	<0.1	0.4	–	–	–	–
Large gastropod	6.7	20.6	–	–	–	–	–	–
Small bivalve	–	–	0.1	1.5	–	–	–	–
Large bivalve	0.1	2.9	–	–	–	–	1.5	2.4
Unid bivalve	0.5	2.9	–	–	–	–	–	–
Nudibranchia	0.2	5.9	–	–	–	–	–	–
Scaphopoda	–	–	–	–	1.2	7.7	–	–
Polyplacophora	–	–	–	–	–	–	–	–
Octopoda	–	–	–	–	–	–	–	–
Unid cephalopoda	–	–	–	–	1.5	7.7	–	–
Unid mollusca	–	–	0.2	0.4	–	–	–	–
Mollusc larvae	–	–	–	–	–	–	–	–
Nematoda	**–**	**–**	**<0.1**	**0.4**	**–**	**–**	**–**	**–**
Bryozoa	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Echinodermata	**0.4**	**2.9**	**0.1**	**0.4**	**–**	**–**	**–**	**–**
Ophiuroidea	0.4	2.9	–	–	–	–	–	–
Echinoidea	–	–	0.1	0.4	–	–	–	–
Asteroidea	–	–	–	–	–	–	–	–
Chordata	**3.3**	**20.6**	**34.4**	**39.5**	**15.0**	**23.1**	**42.6**	**46.3**
Unid ascidian	0.6	2.9	–	–	–	–	–	–
Ascidian larvae	–	–	–	–	–	–	–	–
Teleost	2.7	20.6	34.4	39.5	15.0	23.1	42.6	46.3
Macrophyte	**0.1**	**2.9**	**0.4**	**3.0**	**1.2**	**7.7**	**0.4**	**4.9**
Unidentifiable egg	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Unid calcareous material	**2.6**	**17.6**	**0.4**	**2.2**	**–**	**–**	**–**	**–**
Unid organic material	**29.4**	**94.1**	**9.0**	**10.3**	**15.8**	**23.1**	**18.5**	**19.5**
Synthetic material	**–**	**–**	**<0.1**	**0.4**	**–**	**–**	**–**	**–**
Inorganic material	**0.2**	**5.9**	**0.8**	**11.4**	**0.2**	**7.7**	**1.8**	**14.6**
Number of guts examined	34		318		18		50	
Number of guts with food	34		271		13		41	
Mean fullness (± SE)	3.6 ± 0.3		3.5 ± 0.1		4.4 ± 0.8		3.3 ± 0.4	

Table 9. Volumetric contribution (%V) and frequency of occurrence (%F) of each major taxa (bold face) and broad dietary category to the overall dietary composition of the southern bluespot flathead and yellowtail flathead.

	S. bluespot flathead		Yellowtail flathead	
Major taxa & dietary categories	%V	%F	%V	%F
Foraminifera	**–**	**–**	**–**	**–**
Porifera	**–**	**–**	**–**	**–**
Cnidaria	**–**	**–**	**–**	**–**
Siphonophore larvae	–	–	–	–
Annelida	**–**	**–**	**–**	**–**
Errant polychaete	–	–	–	–
Sedentary polychaete	–	–	–	–
Sipuncula	–	–	–	–
Unid polychaete	–	–	–	–
Polychaete larvae	–	–	–	–
Arthropoda	**15.0**	**25.0**	**4.0**	**20.0**
Small crustacean	–	–	–	–
Pleocyemata	–	–	–	–
Dendrobranchiata	–	–	–	–
Squillidae	–	–	–	–
Unid large crustacean	15.0	25.0	4.0	20.0
Small brachyura	–	–	–	–
Portunidae	–	–	–	–
Anomura	–	–	–	–
Planktonic crustacean	–	–	–	–
Mollusca	**–**	**–**	**–**	**–**
Small gastropod	–	–	–	–
Large gastropod	–	–	–	–
Small bivalve	–	–	–	–
Large bivalve	–	–	–	–
Unid bivalve	–	–	–	–
Nudibranchia	–	–	–	–
Scaphopoda	–	–	–	–
Polyplacophora	–	–	–	–
Octopoda	–	–	–	–
Unid cephalopoda	–	–	–	–
Unid mollusca	–	–	–	–
Mollusc larvae	–	–	–	–
Nematoda	**–**	**–**	**–**	**–**
Bryozoa	**–**	**–**	**–**	**–**
Echinodermata	**–**	**–**	**–**	**–**
Ophiuroidea	–	–	–	–
Echinoidea	–	–	–	–
Asteroidea	–	–	–	–
Chordata	**75.0**	**75.0**	**56.0**	**60.0**
Unid ascidian	–	–	–	–
Ascidian larvae	–	–	–	–
Teleost	75.0	75.0	56.0	60.0
Macrophyte	**10.0**	**25.0**	**–**	**–**
Unidentifiable egg	**–**	**–**	**–**	**–**
Unid calcareous material	**–**	**–**	**–**	**–**
Unid organic material	**–**	**–**	**38.0**	**40.0**
Synthetic material	**–**	**–**	**–**	**–**
Inorganic material	**–**	**–**	**2.0**	**20.0**
Number of guts examined		4		5
Number of guts with food		4		5
Mean fullness (± SE)		5.8 ± 1.3	3.5	± 1.6

3.1.2. Broad interspecific comparison and prey competition

Based on the modified Costello plots, which display the prey-specific abundance (%PSV) and frequency (%F) with which prey categories are consumed, blue swimmer crabs in Cockburn Sound are specialist bivalve feeders (i.e. 67%PSV; 69%F; Figure 18a). Other than echinoids, which contributed almost half of the dietary volume of the 46%PSV of crabs that consumed them, the remaining 11 prey categories were rarely ingested and then only in small volumes (typically <25%PSV). The western rock octopus showed population-level specialisation for decapods and stomatopods (i.e. 99%PSV; 85%F; Figure 18b). While each of the three other prey categories made a large contribution to the diet, indicating a specialist feeding strategy, each of these categories was only consumed by a low proportion of the octopuses examined. Therefore, while both species specialise in feeding on particular types of prey, crabs consume a broader range of “secondary” taxa (i.e. generalist). In contrast, if octopuses do not consume their usual prey, they target other cephalopods (including cannibalism) and teleosts and ingest relatively large volumes of those instead (i.e. individual-level specialisation). The small pelagic clupeid species, i.e. blue sprat and sandy sprat, showed very strong population-level specialisation for planktonic crustaceans (both = 88%PSV; 100%F; Figure 18c,d). Other than a small proportion of sandy sprat targeting siphonophore larvae, the remaining prey categories were relatively unimportant.

Rather than specialising in a particular suite of prey, longspine dragonets consumed 15 prey categories. However, none made a substantial volumetric contribution, suggesting this species has a generalist feeding strategy (Figure 19a). Several prey categories were consistently ingested by individuals in the population, most notably bivalves (82%F) and echinoids (84%F). The western smooth boxfish also exhibited a very similar, generalist feeding strategy to the longspine dragonets, preying rarely on a wide variety of rare categories, and frequently on echinoids (70%F) and bivalves (90%F), although the latter prey category made a minor contribution to overall diet (6%PSV; Figure 19b). Soldiers showed population-level specialisation for decapods and stomatopods (67.2%PSV; 60.0%F) and small crustaceans (64.8%PSV; 62.0%F; Figure 19c). While some degree of dietary niche breadth was evident due to considerable volumes of errant polychaetes (42%PSV) and portunids (100%PSV), this was typically at the individual level (i.e. 12 and 2%F, respectively). The feeding strategy of midget flathead was similar to that of the soldier, only with more specialisation for decapods and stomatopods (87%PSV; 83%F) and slightly less for small crustaceans (52%PSV; 29%F; Figure 19d).

Western trumpeter whiting showed a mixed feeding strategy. There was moderate specialisation by a substantial proportion of the population for bivalves and errant polychaetes (~56%PSV; 38-50%F) and to a smaller population extent for decapods and stomatopods, sedentary polychaetes and ophiuroids (Figure 20a). The remaining prey categories were consumed opportunistically either in large proportions by a small number of individuals, e.g. large gastropods and portunids, or rarely consumed, e.g. small crustaceans and small gastropods. Western butterfish have a highly generalised diet; consuming 19 of the 29 prey categories, the most of all species studied. Almost all the prey categories lie in the bottom left corner in the modified Costello plot, indicating they are rare prey, i.e. consumed in small quantities by a limited proportion of the population (Figure 20b). Bivalves were the most frequently consumed prey (56%F), however, they only accounted for 27% of the diet of those fish that consumed this type of prey. There was some individual-level specialisation on both cephalopods and portunids (78 and 72%PSV, respectively) but at very low frequencies (<2%F). Skipjack trevally and snapper were also generalists, albeit with individual-level specialisation for a few infrequently ingested prey categories (Figure 20c,d). However, unlike western butterfish, several prey categories were utilised by over half of the population of both species (%F >50). These were bivalves, decapods and stomatopods and small crustaceans for skipjack trevally, and the former two categories and small gastropods and small brachyurans for snapper, with these prey categories making moderate contributions to their diets (i.e. 20-46 and 18-35%PSV, respectively).

Southern eagle rays consumed prey from 17 categories, with most being rare, indicating a generalist feeding strategy (Figure 21a). Only errant polychaetes (37%PSV, 64%F) and decapods and stomatopods (36%PSV; 67%F) were ingested by a substantial proportion of the population. In contrast, the rusty, longhead and longspine flatheads all showed evidence of being specialist feeders, targeting decapods and stomatopods (i.e. 88-96%PSV; 27-73%F) and teleosts (66-93%PSV; 27-58%F; Figure 21b,c,d).

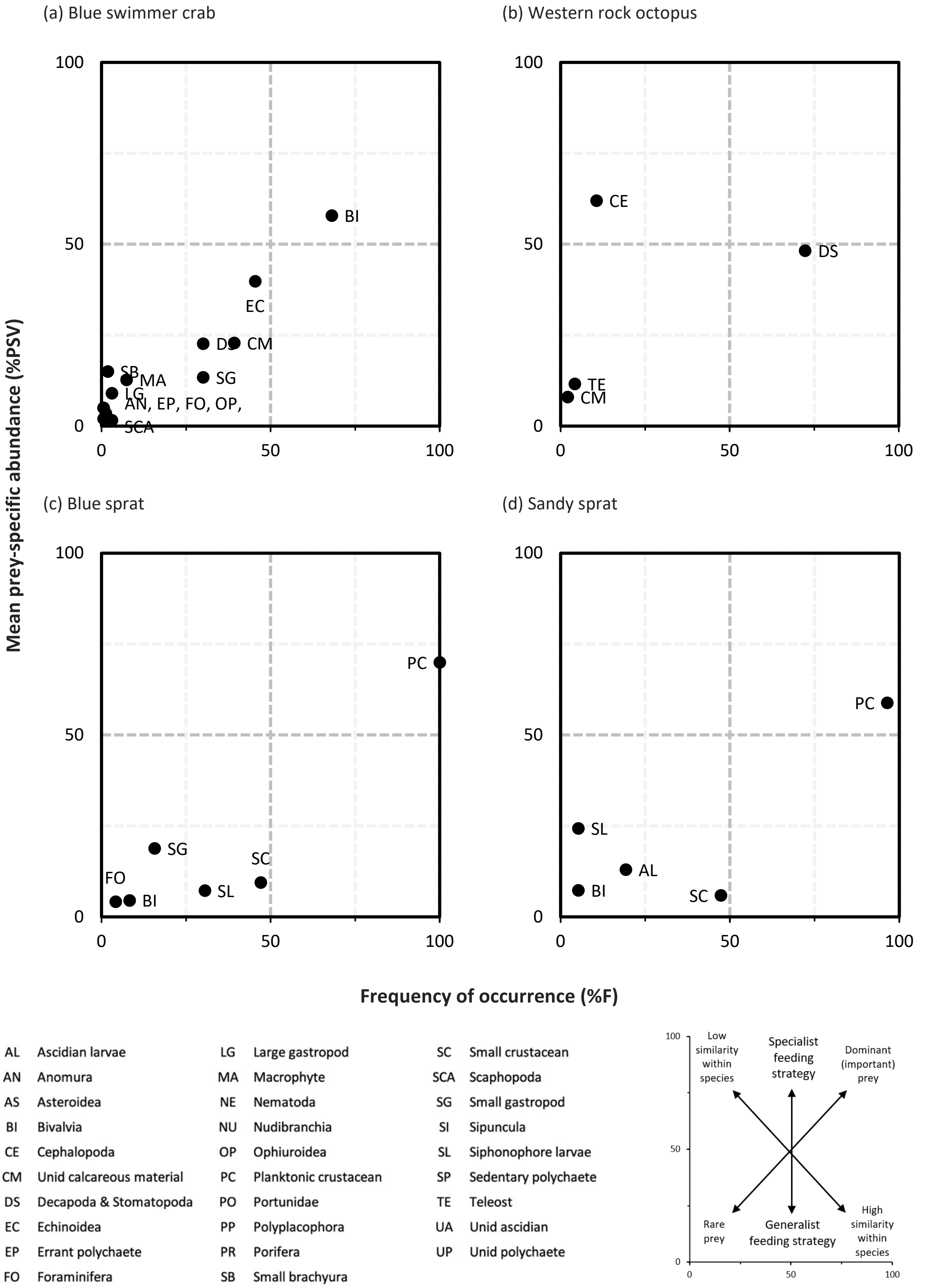
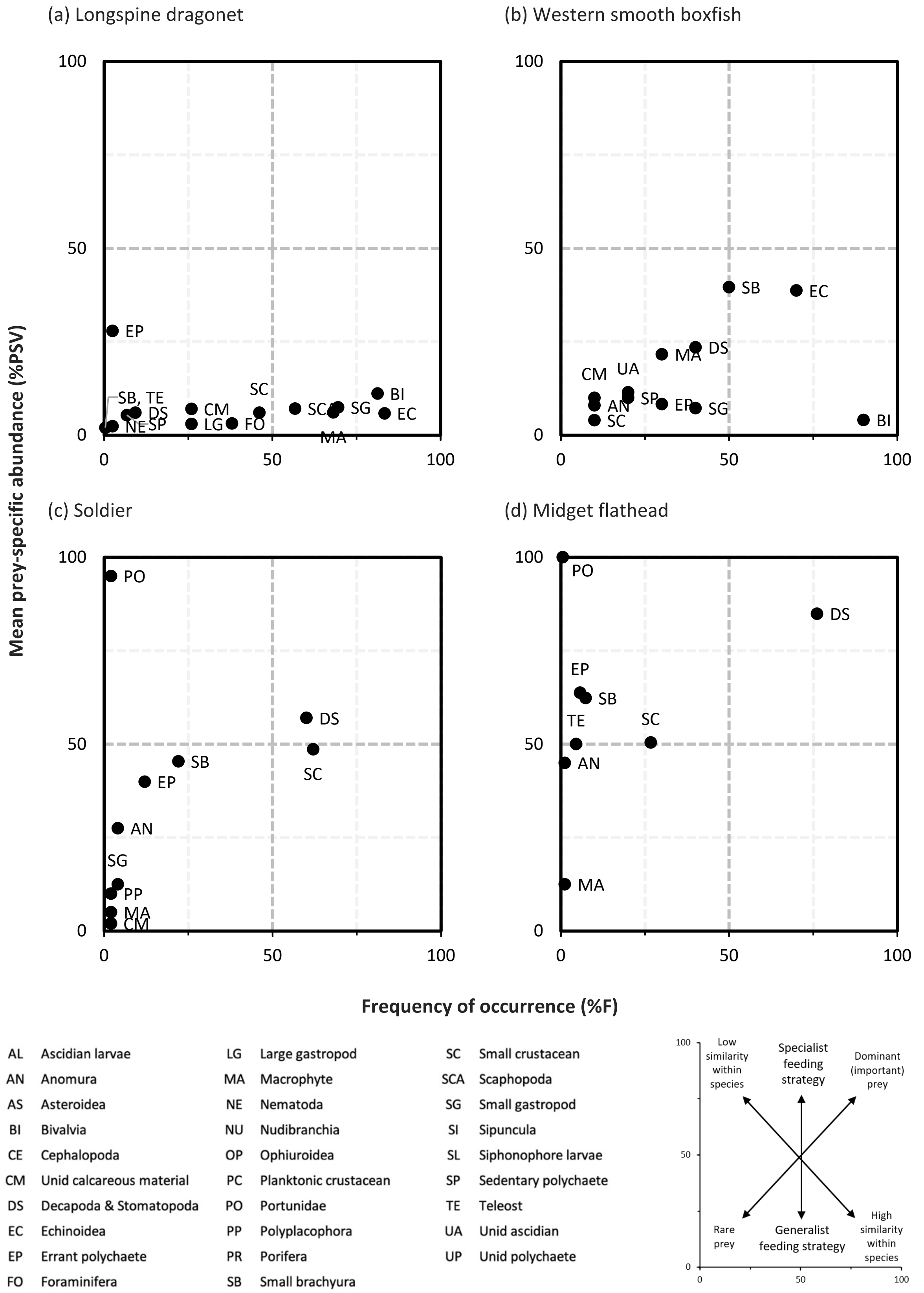
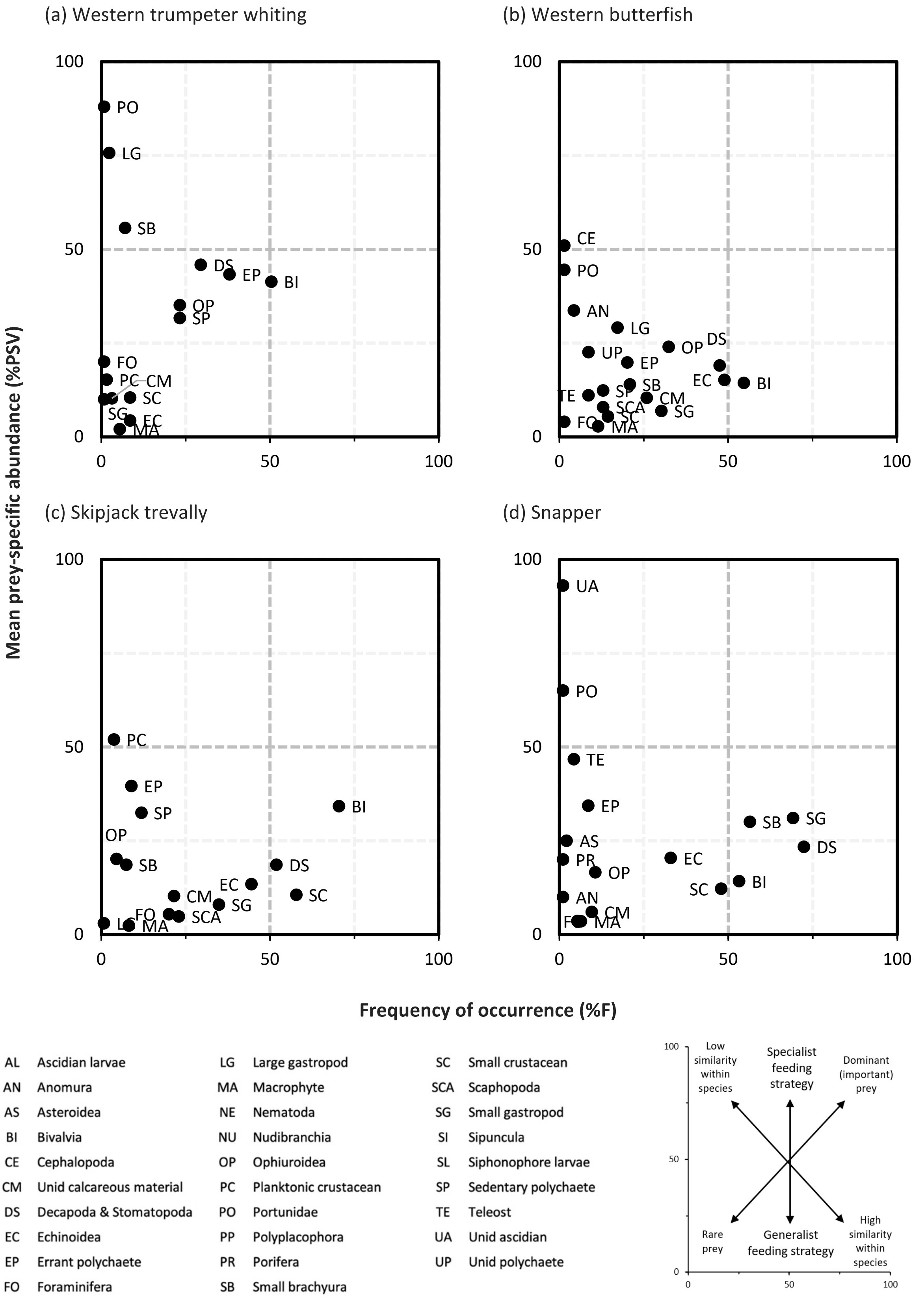


Figure 18. Modified Costello plots of the feeding strategy of (a) blue swimmer crab, (b) western rock octopus, (c) blue sprat and (d) sandy sprat based on the mean prey-specific abundance and frequency of occurrence of each of the broad dietary categories they consumed.



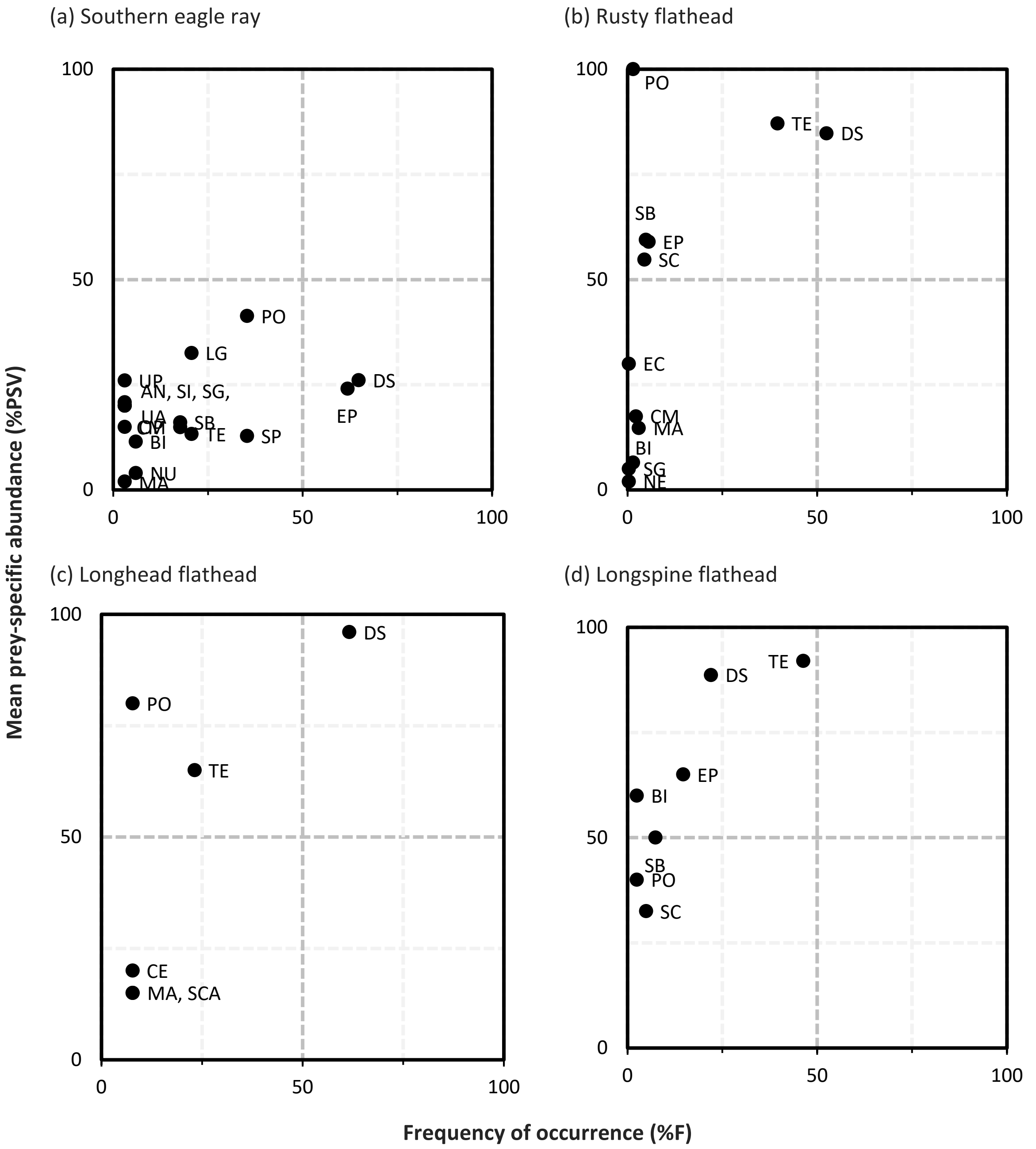
AL	Ascidian larvae	LG	Large gastropod	SC	Small crustacean
AN	Anomura	MA	Macrophyte	SCA	Scaphopoda
AS	Asteroidea	NE	Nematoda	SG	Small gastropod
BI	Bivalvia	NU	Nudibranchia	SI	Sipuncula
CE	Cephalopoda	OP	Ophiuroidea	SL	Siphonophore larvae
CM	Unid calcareous material	PC	Planktonic crustacean	SP	Sedentary polychaete
DS	Decapoda & Stomatopoda	PO	Portunidae	TE	Teleost
EC	Echinoidea	PP	Polyplacophora	UA	Unid ascidian
EP	Errant polychaete	PR	Porifera	UP	Unid polychaete
FO	Foraminifera	SB	Small brachyura		

Figure 19. Modified Costello plots of the feeding strategy of (a) longspine dragonet, (b) western smooth boxfish, (c) soldier and (d) midget flathead based on the mean prey-specific abundance and frequency of occurrence of each of the broad dietary categories they consumed.



AL	Ascidian larvae	LG	Large gastropod	SC	Small crustacean
AN	Anomura	MA	Macrophyte	SCA	Scaphopoda
AS	Asteroidea	NE	Nematoda	SG	Small gastropod
BI	Bivalvia	NU	Nudibranchia	SI	Sipuncula
CE	Cephalopoda	OP	Ophiuroidea	SL	Siphonophore larvae
CM	Unid calcareous material	PC	Planktonic crustacean	SP	Sedentary polychaete
DS	Decapoda & Stomatopoda	PO	Portunidae	TE	Teleost
EC	Echinoidea	PP	Polyplacophora	UA	Unid ascidian
EP	Errant polychaete	PR	Porifera	UP	Unid polychaete
FO	Foraminifera	SB	Small brachyura		

Figure 20. Modified Costello plots of the feeding strategy of (a) western trumpeter whiting, (b) western butterfish, (c) skipjack trevally and (d) snapper based on the mean prey-specific abundance and frequency of occurrence of each of the broad dietary categories they consumed.



AL	Ascidian larvae	LG	Large gastropod	SC	Small crustacean
AN	Anomura	MA	Macrophyte	SCA	Scaphopoda
AS	Asteroidea	NE	Nematoda	SG	Small gastropod
BI	Bivalvia	NU	Nudibranchia	SI	Sipuncula
CE	Cephalopoda	OP	Ophiuroidea	SL	Siphonophore larvae
CM	Unid calcareous material	PC	Planktonic crustacean	SP	Sedentary polychaete
DS	Decapoda & Stomatopoda	PO	Portunidae	TE	Teleost
EC	Echinoidea	PP	Polyplacophora	UA	Unid ascidian
EP	Errant polychaete	PR	Porifera	UP	Unid polychaete
FO	Foraminifera	SB	Small brachyura		

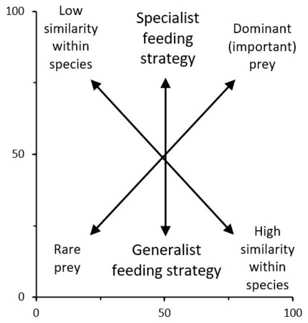


Figure 21. Modified Costello plots of the feeding strategy of (a) southern eagle ray, (b) rusty flathead, (c) longhead flathead and (d) longspine flathead based on the mean prey-specific abundance and frequency of occurrence of each of the broad dietary categories they consumed.

Pooling across the 18 species, five major taxa represented >99% of the overall volumetric contribution (Figure 21a). Arthropods made the largest contribution (50%V), followed by molluscs and chordates (both 17%V) and echinoderms and annelids (both 7%V). Foraminiferans, cnidarians, poriferans, bryozoans and nematodes were consumed in very small quantities (<0.3%V). There is a marked shift in diet among species (Figure 21b). Blue swimmer crab and longspine dragonet consumed a greater proportion of molluscs than all other species (57 and 62%V, respectively, vs 0-44%V), as well as relatively high volumes of echinoderms and smaller amounts of arthropods. Skipjack trevally, western trumpeter whiting, western butterfish, western smooth boxfish, snapper and the southern eagle ray had the broadest diet, consuming substantial amounts of annelids, in addition to molluscs, echinoderms and arthropods. The contribution of these major taxa varied among species, however, with annelids being consumed in greater quantities by western trumpeter whiting and southern eagle rays, whereas western butterfish and western smooth boxfish ingested more echinoderms. The diets of the latter species, together with snapper and the southern eagle ray, contained a greater proportion of arthropods. The western rock octopus, blue sprat, soldier, midget flathead and sandy sprat, all primarily ingested arthropods (83-94%V), with the octopus being the only one of these species that consumed substantial volumes of another taxon (i.e. 16%V molluscs). Although still substantial, the proportions of arthropods declined sequentially from 78%V in the longhead flathead to 7%V in the yellowtail flathead, which was accompanied by an increase in the volume of chordate prey (Figure 21b).

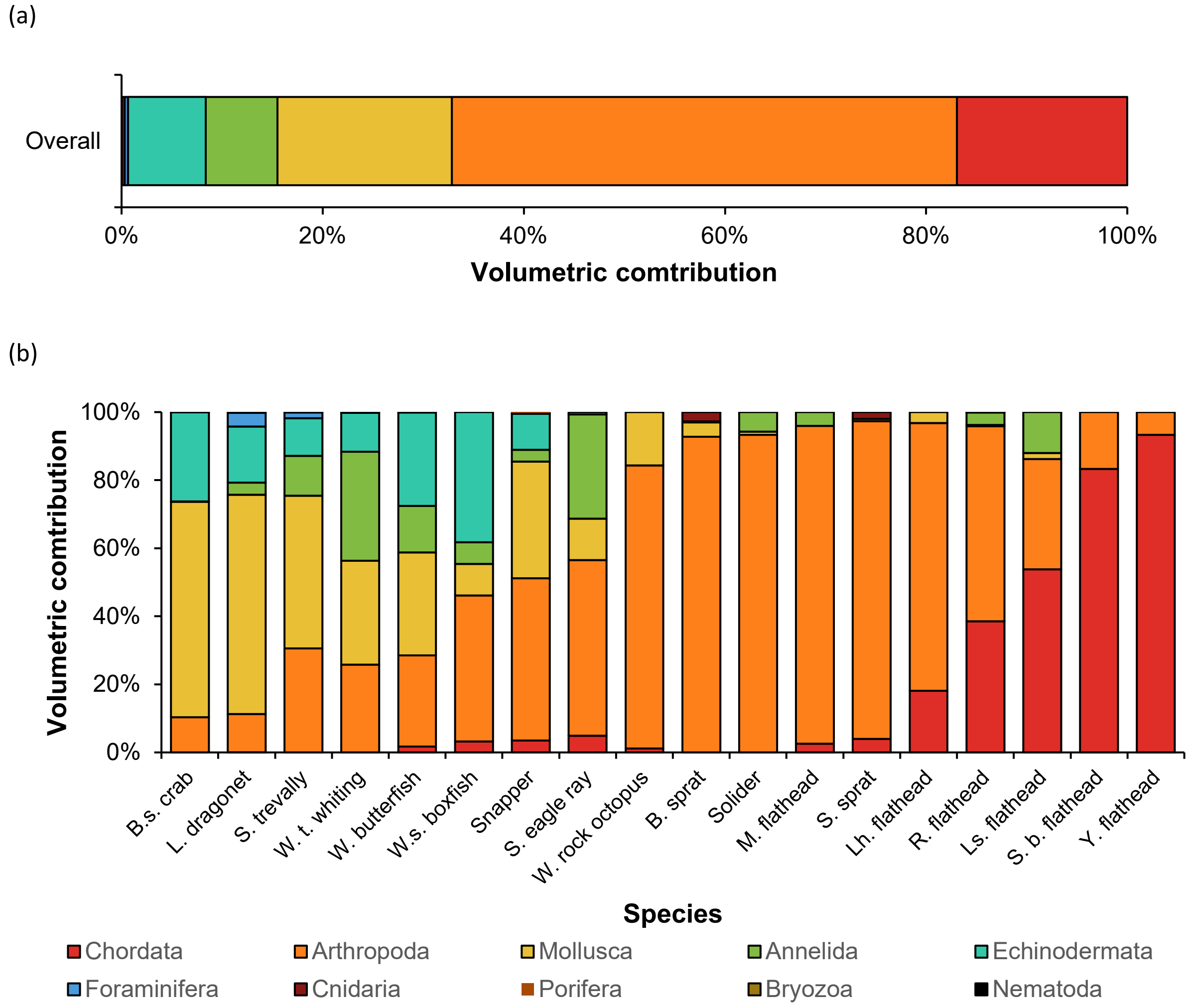


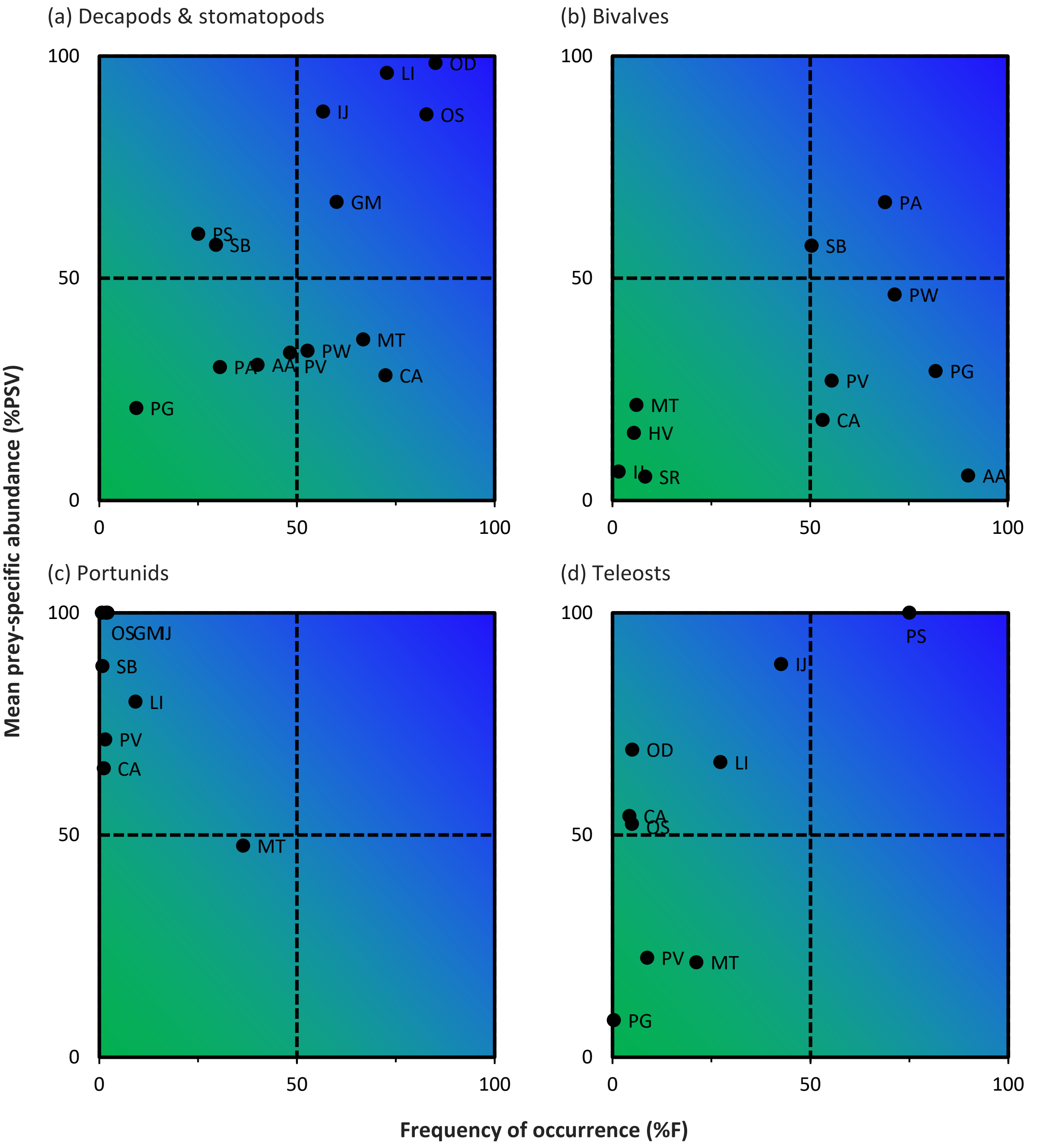
Figure 21. Mean percentage volumetric contribution of the key major prey taxa to the diets of 18 fish and invertebrate species in Cockburn Sound (a) overall and (b) individually, irrespective of season and region.

Modified Costello plots (Figures 22-24) allow the importance of a single prey category across multiple species of consumers to be visualised, and identifies those categories that are being heavily utilised by multiple species (i.e. interspecific competition). The prey category decapods and stomatopods was consumed by the greatest number of species, i.e. 14 of the 16, i.e. all except the small-bodied pelagic clupeids. This prey category appears particularly important (i.e. both %PSV and %F ≥ 50) to five of the species, the western rock octopus, midget flathead and longhead flathead as well as rusty flathead and soldier (Fig. 22a). While for another five species, either the %PSV or the %F value was >50% suggesting this prey was consumed in either large volumes by a moderate proportion of the consumers or was otherwise moderately important to a larger proportion of the consumers (Figure 22a). Among the species that ingested this prey, this category was only termed as rare for the longspine dragonet. This suggests that prey in this category are heavily targeted by multiple species and are likely the subject of dietary competition.

Bivalves were consumed by 11 species and for two of these, i.e. the blue swimmer crab and western trumpeter whiting, this prey was very important (i.e. both %PSV and %F ≥ 50). This prey category was consumed by more the half the individuals (53-90%F) of another five species, albeit to varying extents, ranging from 46%PSV in the western butterfish to only 6%PSV in the western smooth boxfish (Figure 22b). Although eight species consumed portunids and, for seven of these species, this prey category made up a large proportion of their diets (65-100%PSV), suggesting this prey is important but only a small percentage of individuals of these species conducted such feeding (1-9%F; Figure 22c). Thus, while this prey category is moderately important for the southern eagle ray, competition would seem to be low. Similarly, teleosts made a large contribution volumetrically to the diets of six of the 11 species that consumed them; however, only a large proportion of the population of the southern bluespot flathead, and to a lesser extent the longhead flathead, consumed this prey (75 and 43%PSV, respectively; Figure 22d).

Errant polychaetes, small crustaceans, small brachyurans and echinoids were all consumed by at least eight species, however, only one of these prey categories, namely small crustaceans, was very important for the soldier (Figure 23). This is because many of these species are generalist in their feeding strategy (see above). However, there is some evidence to suggest that there is moderate competition for particular prey consumers but only by a small number of species. This includes western trumpeter whiting and southern eagle rays for errant polychaetes, snapper and western smooth boxfish for small brachyurans and the latter species and longspine dragonets for echinoids.

Planktonic crustaceans were highly important for both the small pelagic clupeids, sandy sprat and blue sprat (i.e. ~87%PSV and 100%F), and these species are in direct competition for this food resource (Figure 24a). Small gastropods were consumed by 11 of the species, however, for all except snapper and longspine dragonets this food source was of limited importance (Figure 24b). Both macrophytes and large gastropods were broadly ingested but were not important for any of the studied species and, thus, there was no evidence of competition for these prey categories (Figure 24c,d).



AA	*Anoplocarpus amygdaloides* (western smooth boxfish)	OS	*Onigocia spinosa* (midget flathead)
CA	*Chrysophrys auratus* (snapper)	PA	*Portunus armatus* (blue swimmer crab)
GM	*Gymnapistes marmoratus* (Soldier)	PG	*Pseudocalliurichthys goodladi* (longspine dragonet)
HV	*Hyperlophus vittatus* (sandy sprat)	PS	*Platycephalus speculator* (southern bluespot flathead)
IJ	*Inegocia japonica* (rusty flathead)	PV	*Pentapodus vitta* (western butterfish)
LI	*Leviprora inops* (longhead flathead)	PW	*Pseudocaranx wrighti* (silver trevally)
MT	*Myliobatis tenuicaudatus* (southern eagle ray)	SB	*Sillago burrus* (western trimeter whiting)
OD	*Octopus djinda* (western rock octopus)	SR	*Spratelloides robustus* (blue sprat)

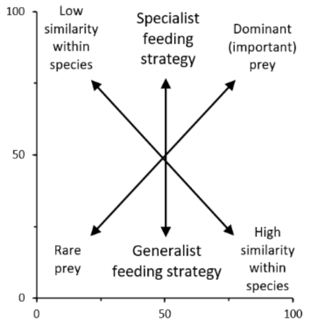
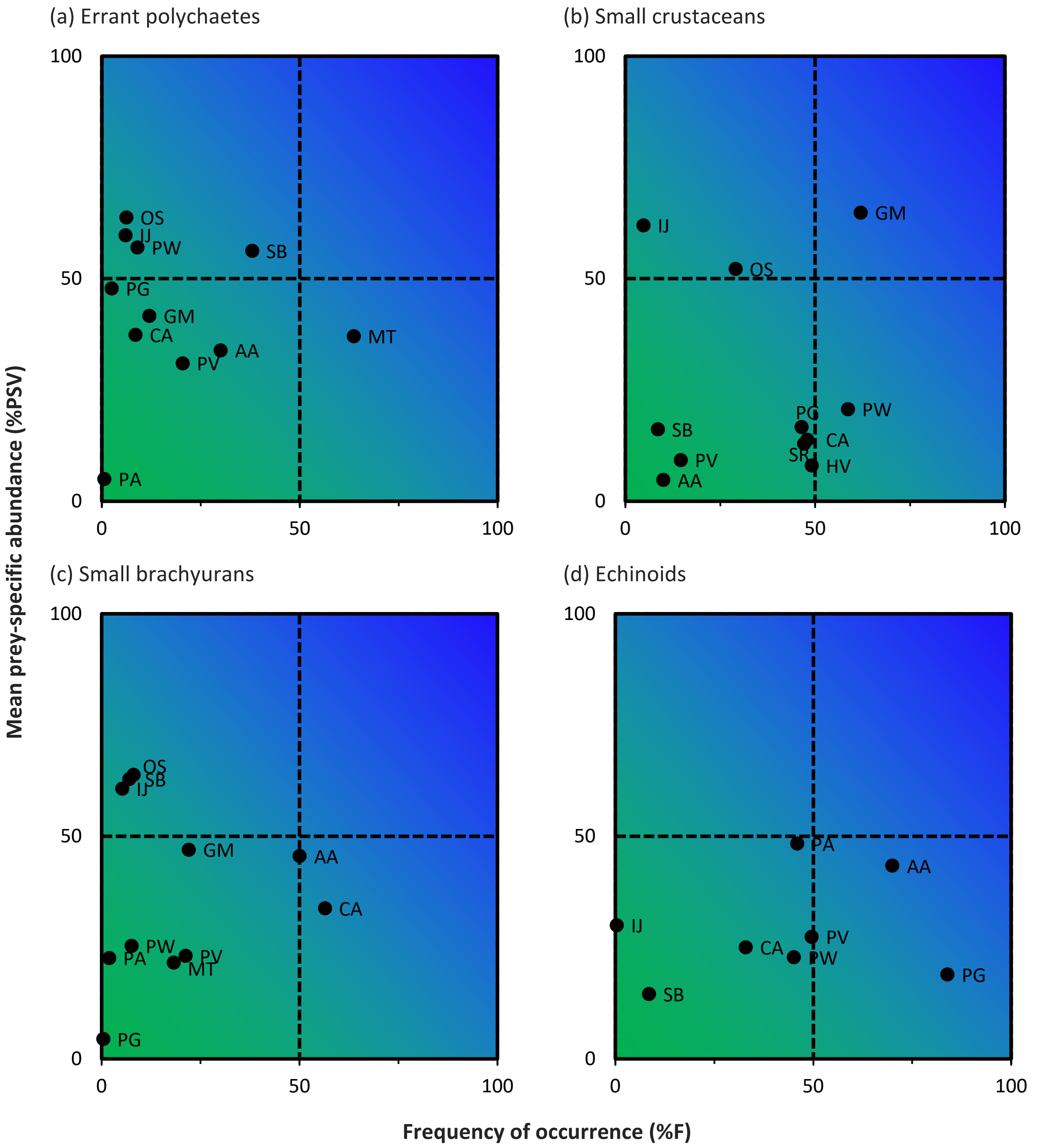


Figure 22. Modified Costello plots of the importance of (a) decapods & stomatopods, (b) bivalves, (c) portunids and (d) teleosts based on the mean prey-specific abundance and frequency of occurrence of each broad dietary category to the 16 predator species for which >10 individuals were examined for GCA. Shading from green to blue indicates the increasing importance of that prey to particular species.



AA	*Anoplocarpus amygdaloides* (western smooth boxfish)	OS	*Onigocia spinosa* (midget flathead)
CA	*Chrysophrys auratus* (snapper)	PA	*Portunus armatus* (blue swimmer crab)
GM	*Gymnapistes marmoratus* (Soldier)	PG	*Pseudocalliurichthys goodladi* (longspine dragonet)
HV	*Hyperlophus vittatus* (sandy sprat)	PS	*Platycephalus speculator* (southern bluespot flathead)
IJ	*Inegocia japonica* (rusty flathead)	PV	*Pentapodus vitta* (western butterfish)
LI	*Leviprora inops* (longhead flathead)	PW	*Pseudocaranx wrighti* (silver trevally)
MT	*Myliobatis tenuicaudatus* (southern eagle ray)	SB	*Sillago burrus* (western trimeter whiting)
OD	*Octopus djinda* (western rock octopus)	SR	*Spratelloides robustus* (blue sprat)

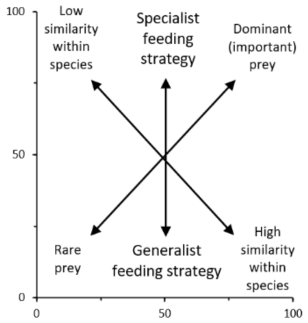


Figure 23. Modified Costello plots of the importance of (a) errant polychaetes, (b) small crustaceans, (c) Small brachyurans and (d) echinoids based on the mean prey-specific abundance and frequency of occurrence of each broad dietary category to the 16 predator species for which >10 individuals were examined for GCA. Shading from green to blue indicates the increasing importance of that prey to particular species.

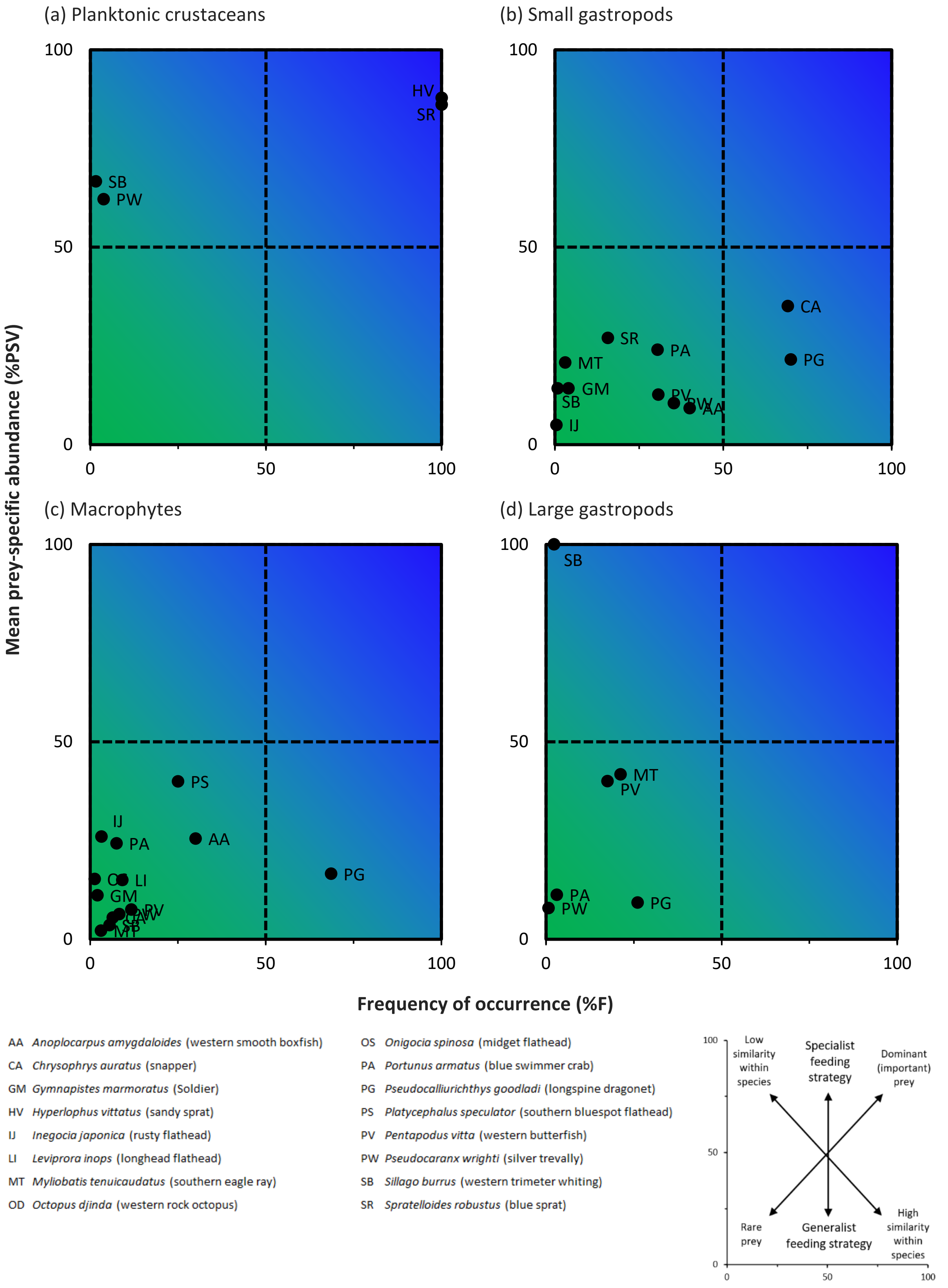


Figure 24. Modified Costello plots of the importance of (a) planktonic crustaceans, *(b) small gastropods, (c) macrophytes and (d) large gastropods based on the mean prey-specific abundance and frequency of occurrence of each broad dietary category to the 16 predator species for which >10 individuals were examined for GCA. Shading from green to blue indicates the increasing importance of that prey to particular species.*

3.1.3. Interspecific differences in diet

The dietary composition at the broad dietary category level of the 16 species for which ≥10 individuals were examined for GCA differed significantly overall (Global $R = 0.837$; $p = 0.001$) and also amongst all 120 pairwise comparisons (Table 10), i.e. each species consumed a significantly different composition of prey. The diets of the two small baitfish, i.e. blue sprat and sandy sprat, were the most distinct with pairwise R values of 0.903-1.000 to all other species (except compared to each other $R = 0.244$). The points representing these species lay on the top left of the nMDS plots well separated from those of all other species (Figure 25). The uniqueness of the dietary composition was due to the overwhelming dominance of planktonic crustaceans, which was identified by SIMPER as typifying the diet of both sprat species (Figure 26; Table 10). This prey was otherwise only consumed in low quantities by skipjack trevally and western trumpeter whiting. The next most distinct group of predator species were those with points on the bottom half of the ordinations, i.e. longspine dragonet, blue swimmer crabs, snapper, western smooth boxfish, western butterfish and western trumpeter whiting (Figure 25). While these species had different diets from each other ($R = 0.485 – 0.925$), the magnitudes of those differences were smaller than those of the baitfish ($R = 0.903 – 1.000$) and the remaining fish and octopus ($R = 0.531 – 1.000$; Table 10). Species in the group containing the longspine dragonet consumed a relatively broad diet of small benthic prey, e.g. small crustaceans, small bivalves, small gastropods, echinoids and some larger crustaceans. Differences among these species were due to blue swimmer crabs and snapper feeding on a smaller range of taxa, with greater volumetric contributions from small bivalves and calcareous material for crabs and small gastropods, small brachyurans and unidentified large crustaceans for snapper. Conversely, western butterfish has the broadest and most consistent diet, which unlike many other species in this group, also consumed teleosts (Figure 26). The western smooth boxfish, longspine dragonet and, to a lesser extent, the western butterfish, were the only predators that consumed macrophytes in relatively substantial volumes.

Table 10. R-statistic values for pairwise comparisons of the diet of 16 species (n ≥10) at the broad dietary category level. All comparisons were significant (p = 0.001). Coloured shading from red to green denotes the magnitude of the R-statistic.

Species	HV	SR	PG	PA	PW	AA	CA	PV	SB	MT	GM	OS	LI	IJ	PlG
SR	0.244														
PD	1.000	1.000													
PA	1.000	1.000	0.874												
PW	0.999	0.995	0.575	0.569											
AA	0.984	0.978	0.909	0.888	0.871										
CA	0.941	0.903	0.776	0.780	0.549	0.571									
PV	1.000	1.000	0.686	0.656	0.454	0.745	0.485								
SB	0.990	0.990	0.925	0.863	0.618	0.811	0.629	0.487							
MT	0.998	0.998	0.985	0.983	0.949	0.712	0.811	0.864	0.655						
GM	0.921	0.913	0.910	0.933	0.806	0.680	0.580	0.866	0.785	0.729					
OS	0.998	0.997	0.997	0.996	0.914	0.935	0.789	0.952	0.872	0.875	0.378				
LI	0.915	0.924	0.912	0.926	0.916	0.531	0.871	0.916	0.875	0.577	0.573	0.731			
IJ	1.000	1.000	1.000	1.000	0.987	0.949	0.849	0.966	0.923	0.796	0.733	0.565	0.804		
PlG	0.967	0.969	0.959	0.960	0.945	0.703	0.768	0.920	0.847	0.678	0.646	0.815	0.413	0.588	
OD	1.000	1.000	1.000	1.000	0.994	0.900	0.809	0.975	0.906	0.959	0.630	0.872	0.730	0.961	0.616

HV, Hyperlophus vittatus *(sandy sprat); SR,* Spratelloides robustus *(blue sprat); PG,* Pseudocalliurichthys goodladi *(longspine dragonet); PA,* Portunus armatus *(blue swimmer crab); PW,* Pseudocaranx wright *(skipjack trevally); AA,* Anoplocarpus amygdaloides *(western smooth boxfish); CA,* Chrysophrys auratus *(snapper); PV,* Pentapodus vitta *(western butterfish); SB,* Sillago burrus *(western trumpeter whiting); MT,* Myliobatis tenuicaudatus *(southern eagle ray); GM,* Gymnapistes marmoratus *(soldier); OS,* Onigocia spinosa *(midget flathead); LI;* Leviprora inops *(longhead flathead); IJ,* Inegocia japonica *(rusty flathead); PlG,* Platycephalus grandispinis *(longspine flathead); OD,* Octopus djinda *(western rock octopus).*

The four flathead species formed a broad group on the top right of the plot (Figure 25). These species consumed a smaller range of prey, focusing on various types of crustaceans and teleosts, and did not target molluscs and echinoderms like the more generalist predator species (Figure 26). There was a tendency for the dietary composition of the various flathead species to change according to their maximum size. For example, the smallest of these species, the midget flathead (mean TL in the current study 92 mm; maximum TL in the literature 250 mm; Table 1; Appendix 4) consumed small crustaceans and members of the Pleocyemata group (mainly snapping shrimp). Rusty flathead (mean = 147 mm TL and maximum 350 mm TL) predated on smaller volumes of small crustaceans and some teleosts and the longspine flathead (mean TL 211 mm and maximum 380 mm TL) mainly fed on teleosts (Figure 26; Table 11). Among the remaining species, the southern eagle ray consumed gastropods, polychaetes and portunids, while soldier and western rock octopus were more targeted in their diet, predating mainly on small crustaceans and unidentified large crustaceans, respectively.

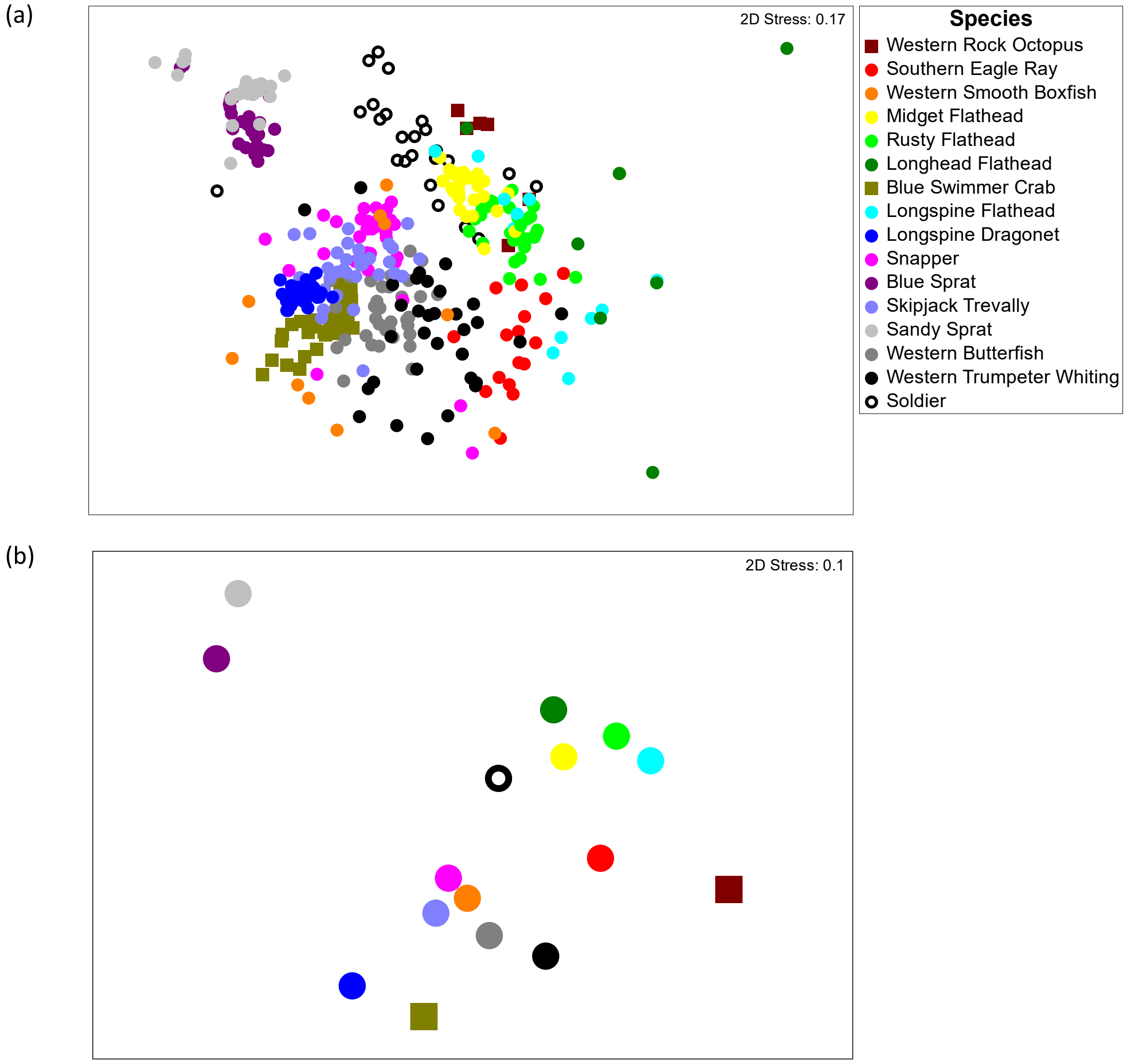


Figure 25. nMDS ordination plots based on (a) replicate and (b) mean square-root transformed percentage contribution of each broad dietary category to the diet of each of the 16 species.

A simple food web showing the main taxa predated on by the 16 studied species is provided in Figure 27. It highlights the distinctness of blue sprat and sandy sprat in feeding almost exclusively in the pelagic zone and targeting pelagic crustaceans (zooplankton). In contrast, most of the other predators focused on a range of benthic taxa, and particularly various types of crustaceans. Other epifauna, e.g. errant polychaetes, echinoids and small gastropods were also consumed in relatively large volumes. With the exception of small bivalves, infaunal species were less prevalent in the diets. No species directly consumed macrophytes in large volumes. Most species, other than the two sprats and western rock octopus, consumed a broad range of prey.

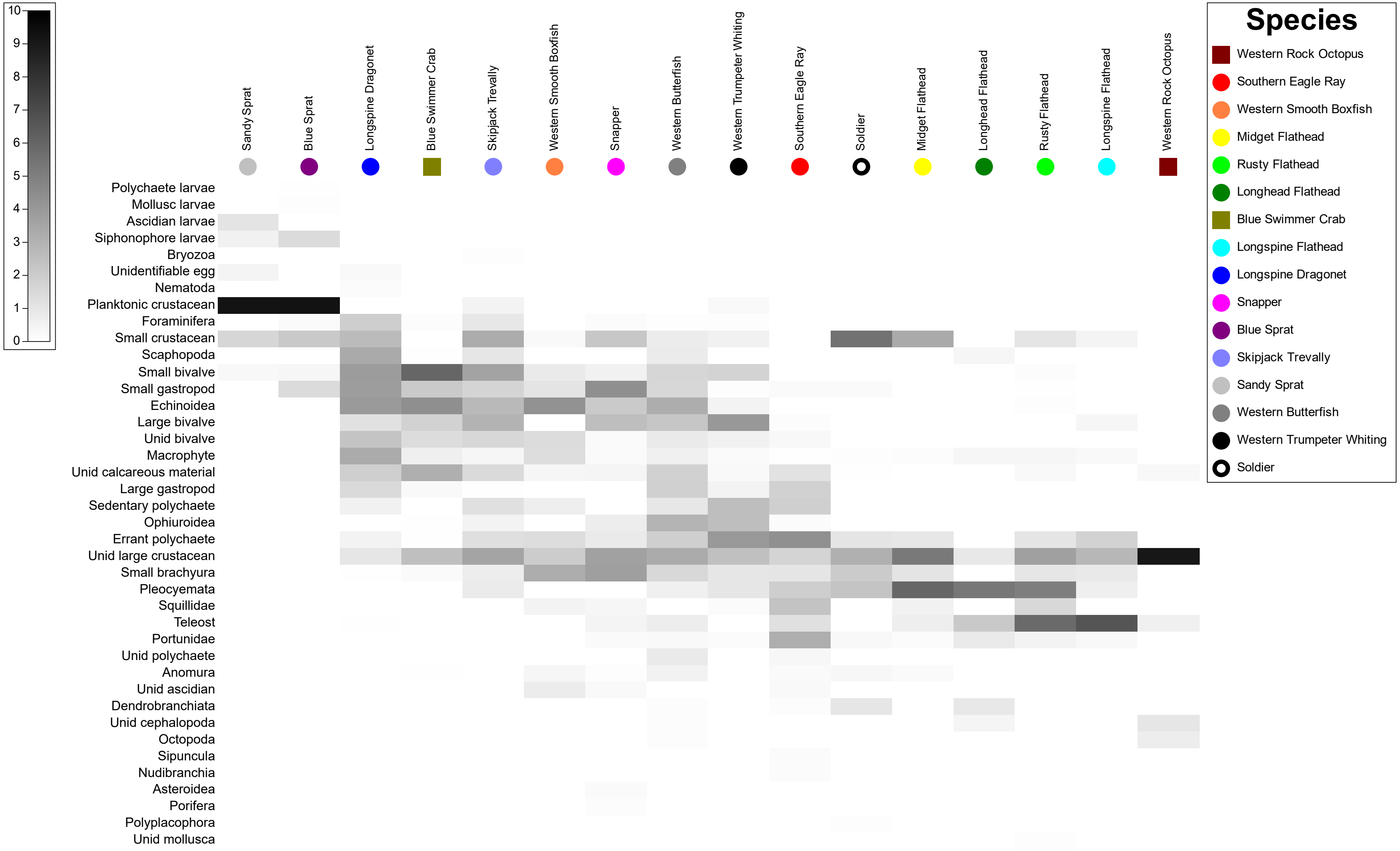


Figure 26. Shade plot of the square-root transformed percentage volumetric contribution of each broad dietary category to the diet of each of the 16 species. Shade from white to black represent a scale of relative contributions from 0 to 10, with the latter representing 100%.

Table 11. Broad dietary categories that typified the dietary composition of each of the 16 species (n≥10), together with the mean percentage volumetric contribution (%V), the percentage of the similarity of the diet that category contributed (%Sim) and the "signal-noise ratio" (Sim/SD). The overall Bray-Curtis similarity of the dietary composition for each species is also provided.

Sandy sprat			Similarity: 77.18
Broad dietary category	%V	Sim/SD	%Sim
Planktonic crustacean	84.82	4.26	88.56

Longspine dragonet			Similarity: 80.54
Broad dietary category	%V	Sim/SD	%Sim
Echinoidea	15.60	8.94	14.19
Small gastropod	14.59	6.81	13.30
Small bivalve	14.98	4.15	12.78
Scaphopoda	10.96	5.88	11.47
Macrophyte	10.76	4.71	10.90
Small crustacean	7.08	3.75	8.49

Skipjack trevally			Similarity: 56.85
Broad dietary category	%V	Sim/SD	%Sim
Unid large crustacean	12.67	2.19	16.75
Small bivalve	13.03	1.86	16.52
Small crustacean	10.43	2.22	15.52
Large bivalve	8.82	0.99	11.36
Echinoidea	7.51	1.34	11.09

Snapper			Similarity: 54.15
Broad dietary category	%V	Sim/SD	%Sim
Small gastropod	19.10	1.36	24.38
Small brachyura	14.14	1.31	20.06
Unid large crustacean	13.47	1.33	19.46
Large bivalve	6.40	1.11	11.82

Western trumpeter whiting			Similarity: 47.97
Broad dietary category	%V	Sim/SD	%Sim
Large bivalve	16.16	1.52	27.23
Errant polychaete	16.00	1.25	25.13
Ophiuroidea	6.45	0.98	13.56
Sedentary polychaete	6.50	0.85	12.48

Soldier			Similarity: 41.74
Broad dietary category	%V	Sim/SD	%Sim
Small crustacean	30.58	1.16	58.10
Unid large crustacean	9.49	0.61	19.67

Longhead flathead			Similarity: 26.47
Broad dietary category	%V	Sim/SD	%Sim
Pleocyemata	28.20	0.59	90.70

Longspine flathead			Similarity: 45.46
Broad dietary category	%V	Sim/SD	%Sim
Teleost	44.36	1.39	79.68

Blue sprat			Similarity: 79.77
Broad dietary category	%V	Sim/SD	%Sim
Planktonic crustacean	85.56	5.52	76.98

Blue swimmer crab			Similarity: 66.82
Broad dietary category	%V	Sim/SD	%Sim
Small bivalve	35.88	3.47	35.10
Echinoidea	19.18	1.92	22.59
Unid calcareous material	9.67	1.66	14.31

Western smooth boxfish			Similarity: 28.50
Broad dietary category	%V	Sim/SD	%Sim
Echinoidea	18.06	0.76	40.18
Small brachyura	10.30	0.50	21.88
Unid bivalve	1.85	0.67	11.40

Western butterfish			Similarity: 47.80
Broad dietary category	%V	Sim/SD	%Sim
Echinoidea	10.37	1.40	15.94
Unid large crustacean	10.69	1.37	15.91
Ophiuroidea	8.64	1.12	13.42
Large bivalve	4.88	0.97	8.63
Unid calcareous material	3.17	1.01	7.14
Errant polychaete	3.53	0.76	6.49
Small gastropod	2.40	1.08	6.46

Southern eagle ray			Similarity: 40.55
Broad dietary category	%V	Sim/SD	%Sim
Errant polychaete	18.84	1.35	33.27
Portunidae	9.99	0.74	17.08
Squillidae	5.57	0.73	12.19
Sedentary polychaete	3.57	0.58	8.36

Midget flathead			Similarity: 64.97
Broad dietary category	%V	Sim/SD	%Sim
Pleocyemata	35.64	2.45	42.13
Unid large crustacean	27.25	1.89	34.46

Rusty flathead			Similarity: 65.71
Broad dietary category	%V	Sim/SD	%Sim
Teleost	33.99	2.47	37.36
Pleocyemata	25.20	2.38	31.26
Unid large crustacean	13.76	1.58	21.08

Western rock octopus			Similarity: 76.10
Broad dietary category	%V	Sim/SD	%Sim
Unid large crustacean	81.90	3.49	98.60

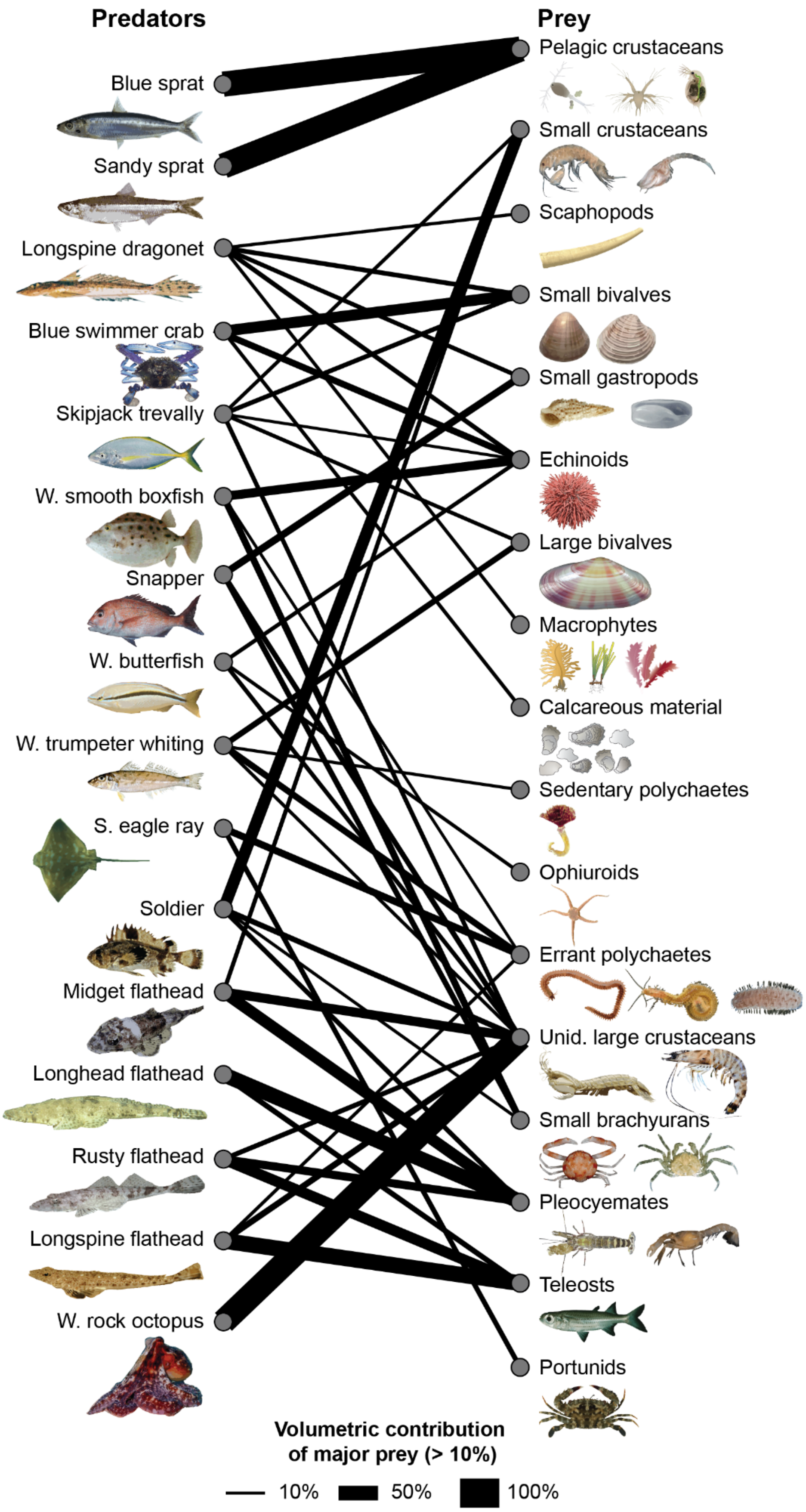


Figure 27. Simplified food web of the diet of the 16 species. Note only broad dietary categories that contributed ≥10% of the volume of prey to the diet of each predator were included.

3.1.4. Functional analyses

Using the CLUSTER-SIMPROF routine, the 72 fish species for which morpho-anatomical traits were recorded belong to one of 25 clusters (Figure 28; Appendix 1). Species in clusters *a* to *f* were particularly distinct and lay along the top of the nMDS plot (Figure 29; Appendix 3). Cluster *a* comprised heavily dorsoventrally flattened species such as the southern eagle ray, southern fiddler ray and western shovelnose ray, which were unique in having their mouth located on their underside (low oral gape position) and being relatively wide (high oral gape shape; Figure 30). Clusters *b, d*, and *f* all comprised exclusively pipefish and cluster *c* Bearded leatherjacket and Tubemouth. Species in these clusters were highly elongated (body elongation), had small mouths (oral gape surface) and limited mouth protrusion (mouth protrusion length). Differences between these clusters were due, in part, to the high values for body transversal surface (Smooth pipefish; *c*), fins surface to body size ratio (*b*) and caudal fish aspect ratio (spotted pipefish; *d;* Figure 30). The latter species lacks a caudal fin. Two species of seahorse (Western Australia and shorthead) comprised cluster *e,* which had many similar traits to the above pipefish, only with a greater head tuberosity and a lower caudal peduncle throttling.

Cluster *g* (rough bullseye) and *h* (globefish and western smooth boxfish) were relatively distinct due to their body shapes. Rough bullseye have a deep body (body transversal shape) and proportionally large caudal fin (caudal fin aspect ratio) and those in the latter cluster, have a short, round body (body elongation; Figure 30). Fish assigned to clusters *i* (spadenose and green clingfish), *j* (various flathead) and *l* (longspine dragonet, flathead sandfish and spiny gurnard) are all relatively dorsoventrally flattened. The clingfish (*i*) had high values for body transversal surface and small gill rakers. The flathead species all possessed large eyes, caudal peduncle throttling and oral gape size in keeping with their benthic ambush-feeding strategy. Oral gape size was smaller in the species in cluster *l*, however, their mouth had more protrusion and their pectoral fins were larger (greater value for pectoral fin position). Species in cluster *p* (two plotosid catfish, Port Jackson shark and gummy shark) are also benthic, and differentiated from species in the other benthic clusters due to a lower mouth protrusion and eye size.

The remaining clusters comprised species with a fusiform body shape, with the points on the nMDS plots being located in the centre of the ordination (Figure 29). Among these species, those in clusters *k* and *o* were more elongated and those in the latter cluster, which comprised various clupeids including blue sprat, sandy sprat and the engraulid Australian anchovy, had the longest gill raker length (Figure 30). Trevally and snapper (cluster *n*) were also relatively distinct due to their high values for caudal peduncle throttling and pectoral fin aspect ratio, as were the silverbiddies (Gerreidae) based on their extensive mouth protrusion.

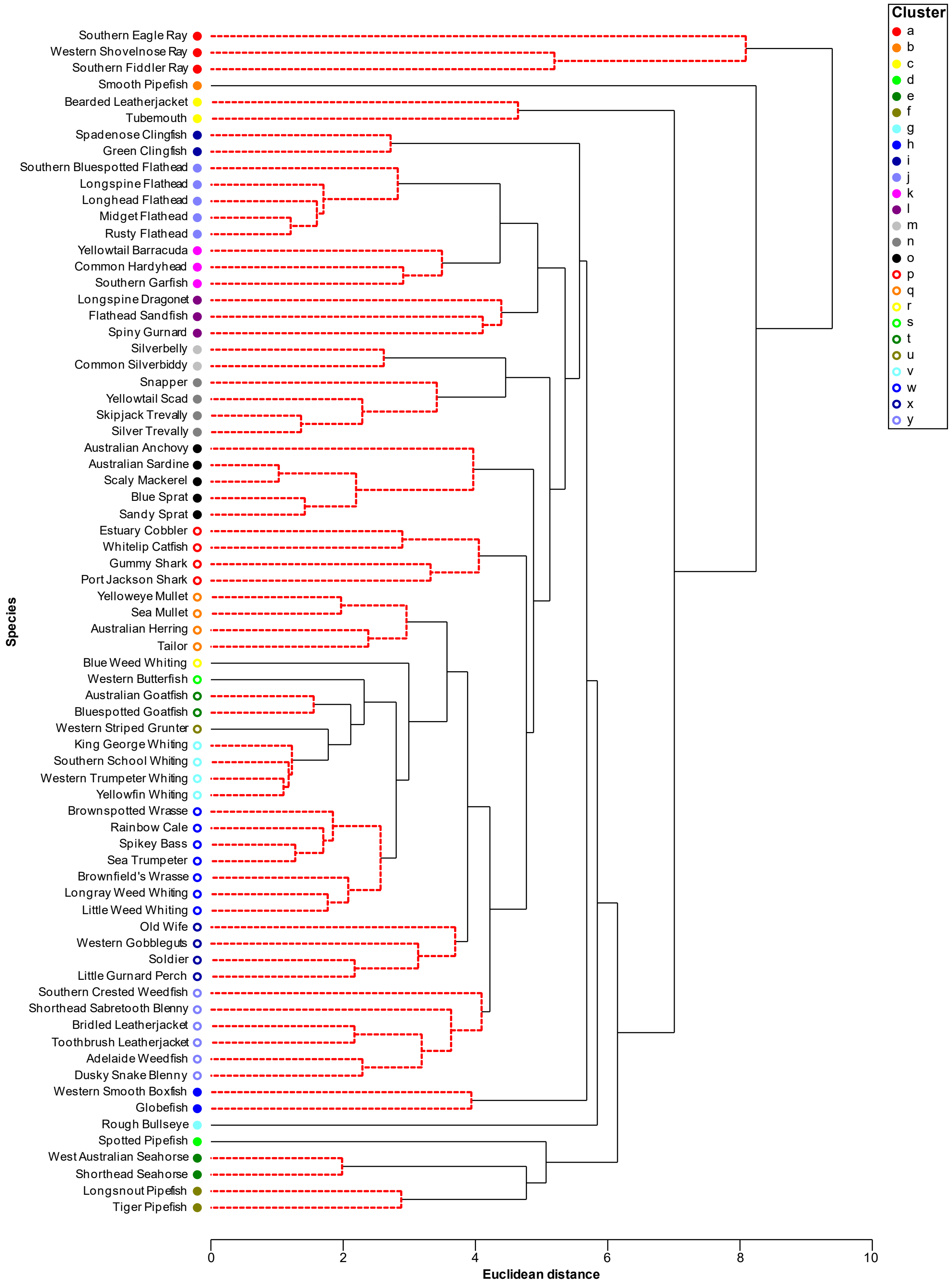


Figure 28. Dendrogram derived from cluster analysis using the average value of each of the 17 morpho-anatomical traits for each of the 72 fish species analysed from Cockburn Sound. Species joined by a dashed red line represent those whose traits were shown by SIMPROF not to be significantly different from each other (p > 0.05), but to be significantly different from those species in all other groups. Groups are denoted by different coloured symbols and labelled from most (a) to least distinct (y).

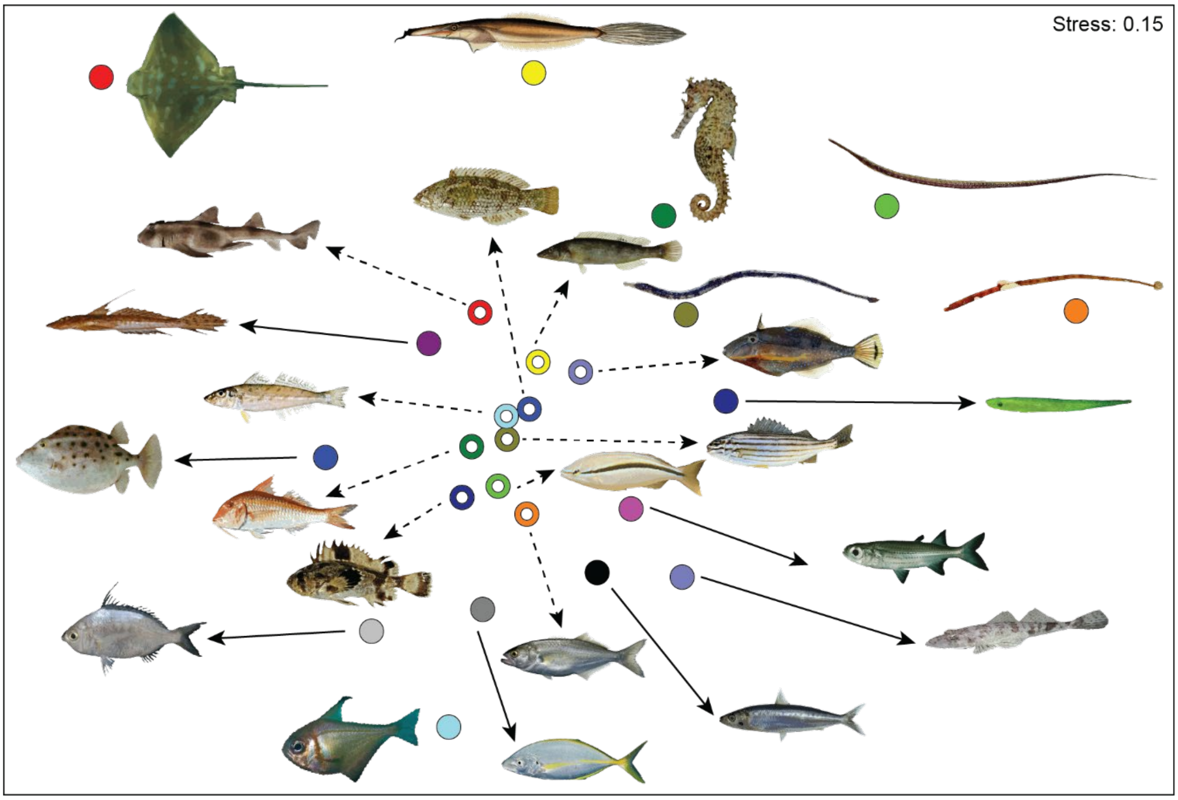


Figure 29. Centroid nMDS plot showing the relationships between the 25 cluster groups of fish based on their morpho-anatomical traits. Icons depict the broad morphology of a species in each of the groups. Symbol codes are given in Figure 28. Solid and dashed lines show a fish assigned to clusters denoted with solid and hollow circles, respectively.

Of the 15 finfish species for which both morpho-anatomical and dietary data were available, the southern eagle ray had the most distinct body shape due to its lack of head protuberosity and mouth protrusion and its unique oral gape shape (Figure 31a,c; and see Appendix 3 for replicate samples). Blue sprat and sandy sprat were clustered together, distinct due to the gill raker length, as were (i) snapper and skipjack trevally, (ii) western butterfish and western trumpeter whiting and (iii) the various flathead species. This pattern of differences among species was significantly related to those of dietary composition (Rho = 0.336; $p = 0.020$), indicating that there is a link between morphology and diet for these species. This result reflected the distinctness of blue sprat and sandy sprat as elongated filter-feeding planktivores with large gill rakers (left side of both ordinations and dendrograms) and the similar diets of a range of benthic species of flathead and the southern eagle ray (top of ordinations and right side of dendrogram; Figure 31). The only species whose morphology and diet did not match up was the longspine dragonet, which has a similar body shape to the ambush-feeding flatheads but consumed a broad range of small benthic prey, including molluscs, as did the western smooth boxfish.

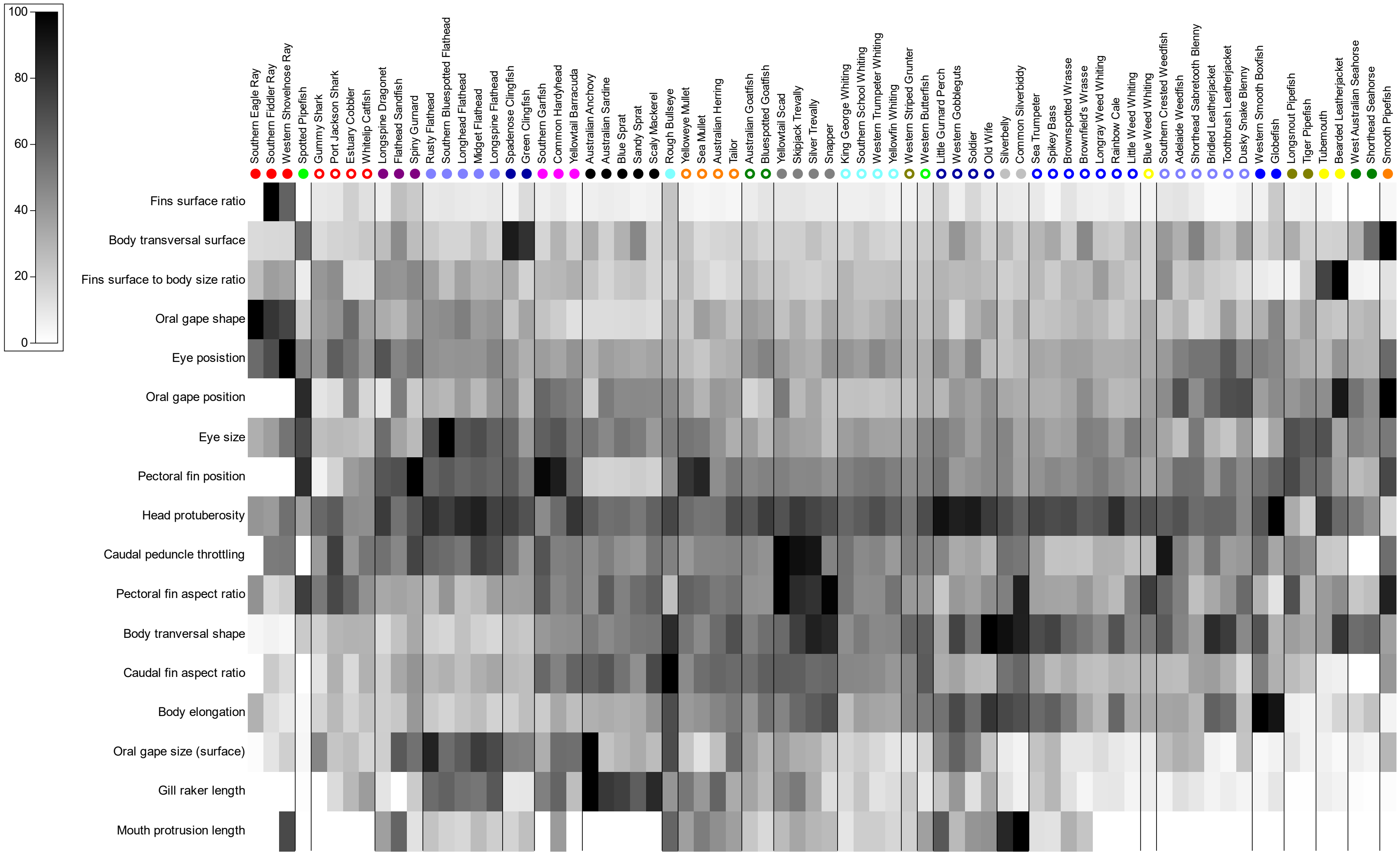
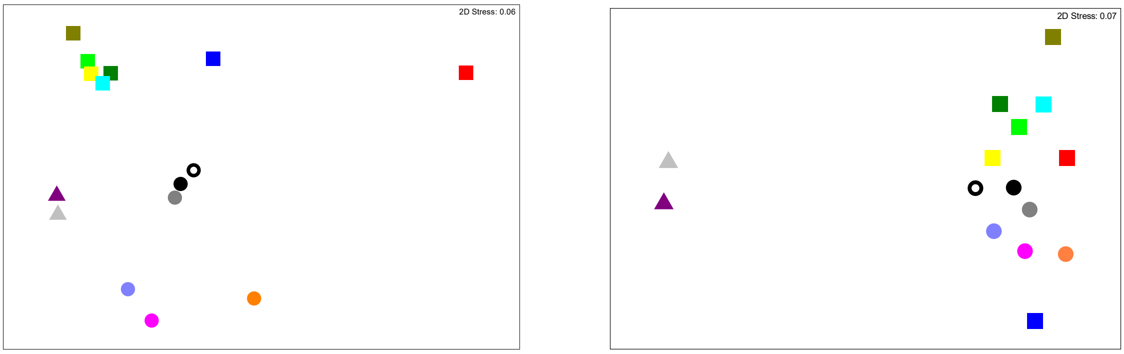


Figure 30. Shade plot of the average value of each of the 17 morpho-anatomical traits, expressed as a percentage of the maximum value for an individual species. Symbol codes are given in Figure 28.

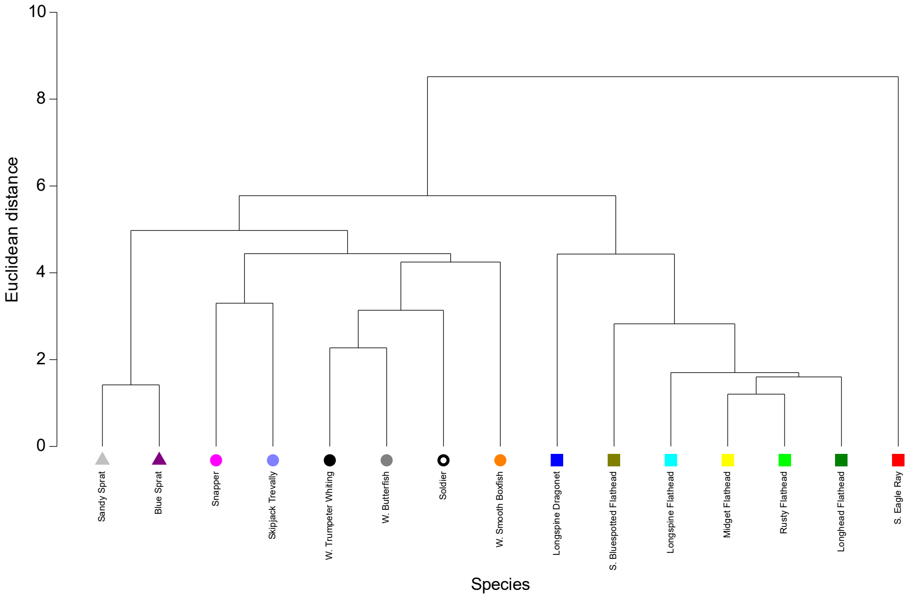


(a) Morphology

(b) Dietary composition

(c) Morphology

(d) Dietary composition



(d) Dietary composition

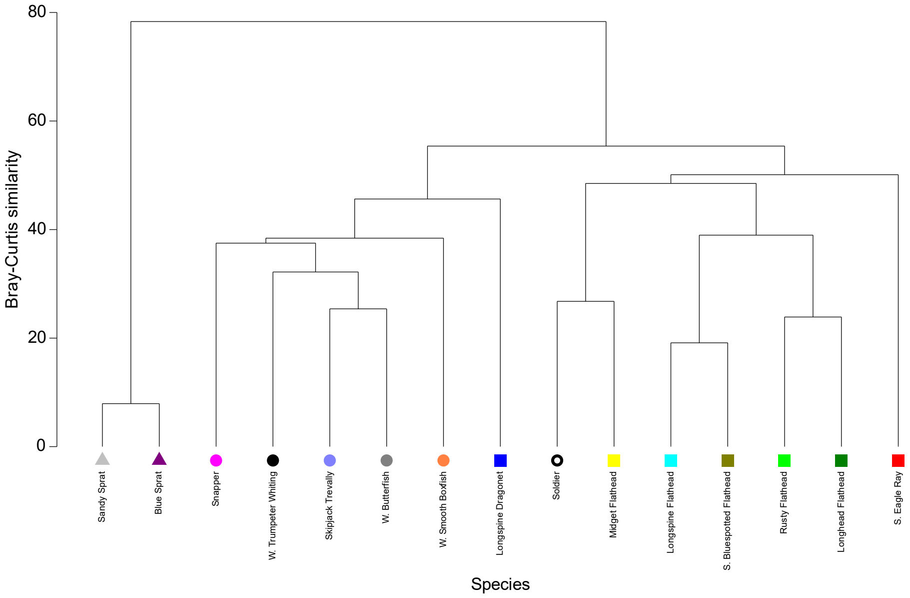


Figure 31. (a,b) Centroid nMDS plot and (c,d) cluster dendrogram constructed from (a,c) an Euclidean distance matrix of the mean morpho-anatomical traits or (b,d) a Bray-Curtis resemblance matrix of the mean dietary composition for 15 finfish species.

3.1.5. *Intraspecific differences in diet*

3.1.5.1. Blue swimmer crab (*Portunus armatus*)

The diet of blue swimmer crabs was dominated by molluscs and echinoderms, with substantial contributions from calcareous material and arthropods in some carapace width (CW) classes (Figure 32). There was no marked ontogenetic shift in diet. The proportion of molluscs varied between 37 and 86%V, while the contribution of echinoderms ranged from 7% to 31%V in crabs across size categories. Calcareous material comprised ~10%V of the volume in crabs in all but the three smallest CW classes.

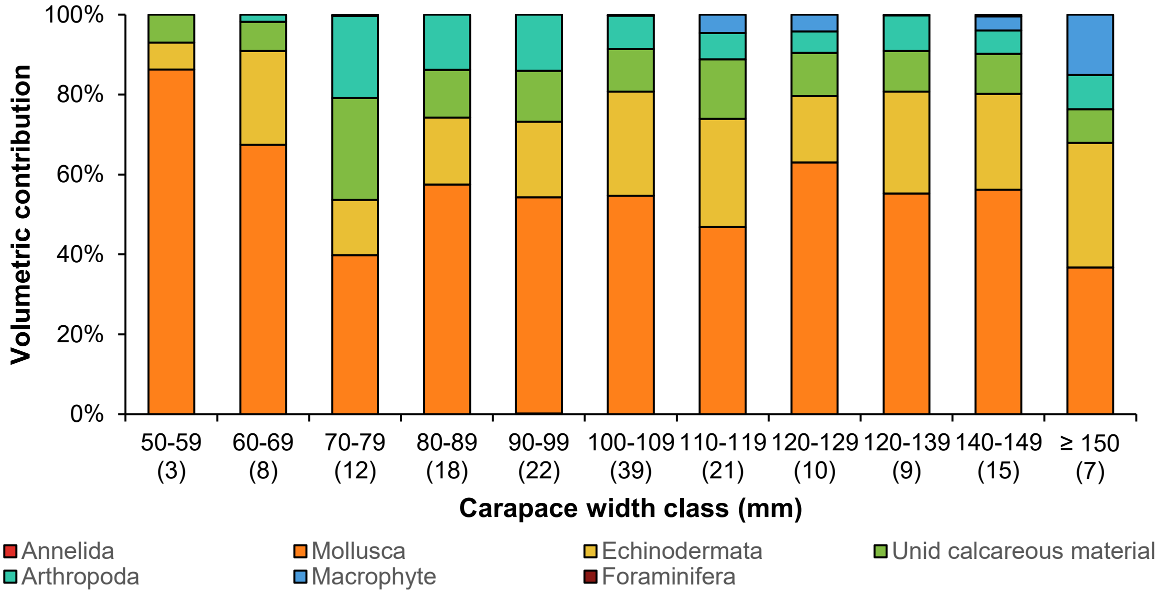


Figure 32. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing carapace width classes of blue swimmer crabs. n = 164 overall and for each width class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among CW classes (Global *R* = 0.164; *p* = 0.004). Among the 10 pairwise comparisons, five were different and were typically the smaller vs the larger individuals i.e. 60 vs 80 and 120, 80 vs 120 and 140 and 100 vs 140 mm CW (*R* = 0204 – 0.491). The points representing the 60 mm CW class on the bootstrapped mMDS plot were relatively dispersed and the 95% confidence regions encompassed the entirety of that of the 80 mm CW class and also part of the 100 mm CW class (Figure 33a). Except for the 60 mm CW class, the average for each of the classes was arranged in a line along the *x*-axis of the ordination. This pattern was also apparent in the CAP plot, with the vectors indicating that the bivalve *Arcatula* sp. was more abundant in crabs in the 60 mm CW class and unidentified bivalves and gastropods in the larger individuals, i.e. 100 mm CW (Figure 33b). In contrast, some prey taxa, e.g. the bivalve *Timoclea infans* and echinoids were consumed by crabs of all sizes (Figure 33c).

Regional differences in dietary composition were significant overall (Global *R* = 0.406; *p* = 0.001) and among all pairwise comparisons (*R* = 0.312-0.517; *p* = 0.003-0.020). The extent of the differences was greatest between North and South Cockburn Sound, with these regions separated along the *x*-axis of the bootstrapped mMDS plot (Figure 34a). The separation of regions on the CAP plot matched that on the mMDS with diets of crabs in North Cockburn Sound characterized by tellinid bivalves and unidentified crustaceans, those in South Cockburn Sound by a range of bivalves, most notably

Arcuatula sp., and those in Owen Anchorage by small gastropods (Figure 34b). Echinoids, *T. infans* and unidentified bivalves were consistently ingested by blue swimmer crabs in all regions (Figure 34c).

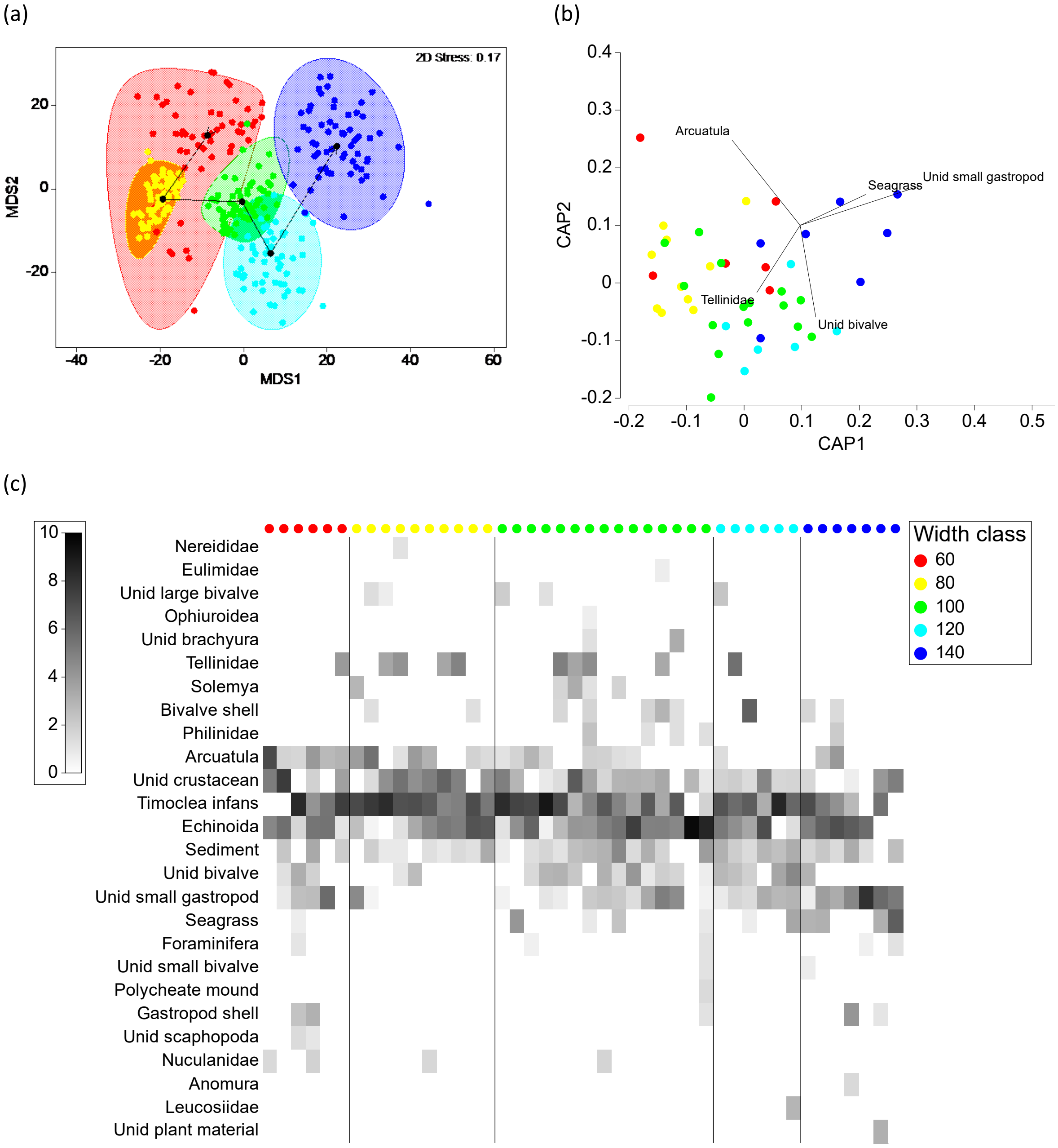


Figure 33. (a) mMDS plot constructed from the bootstrap averages of blue swimmer crabs of different carapace width classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of blue swimmer crabs of different carapace width classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of female and male blue swimmer crabs, with vertical lines highlighting a shift in size class.

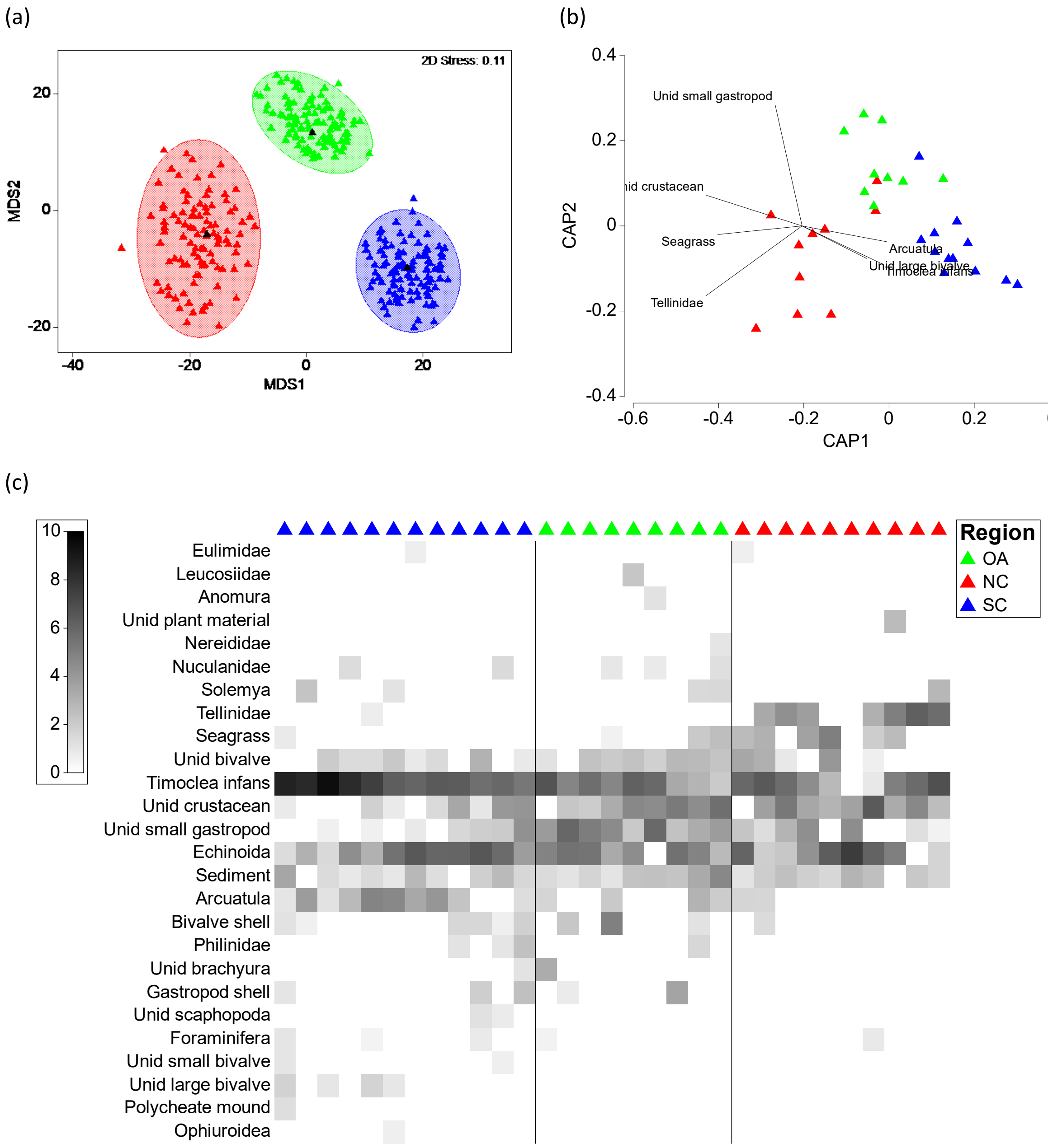


Figure 34. (a) mMDS plot constructed from the bootstrap averages of blue swimmer crabs from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of blue swimmer crabs from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of blue swimmer crabs from different regions of Cockburn Sound.

Among the factors investigated, the most pronounced difference in dietary composition of blue swimmer crabs was detected among seasons (Global $R = 0.652$; $p = 0.001$), with clear separation of the points representing spring and autumn on the mMDS plot (Figure 35a). A broader range of dietary categories were found in the stomachs in spring, including *Arcuatula* sp., *T. infans,* echinoids, unidentified small gastropods, unidentified crustaceans, tellinid bivalves, and unidentified bivalves (Figure 35b,c). Several less nutritious categories such as seagrass, bivalve shell and sediment were predominantly consumed in spring and rarely ingested in autumn. The diet in autumn was less diverse and dominated by *Arcuatula* sp., *T. infans,* echinoids, unidentified small gastropods, and unidentified crustaceans.

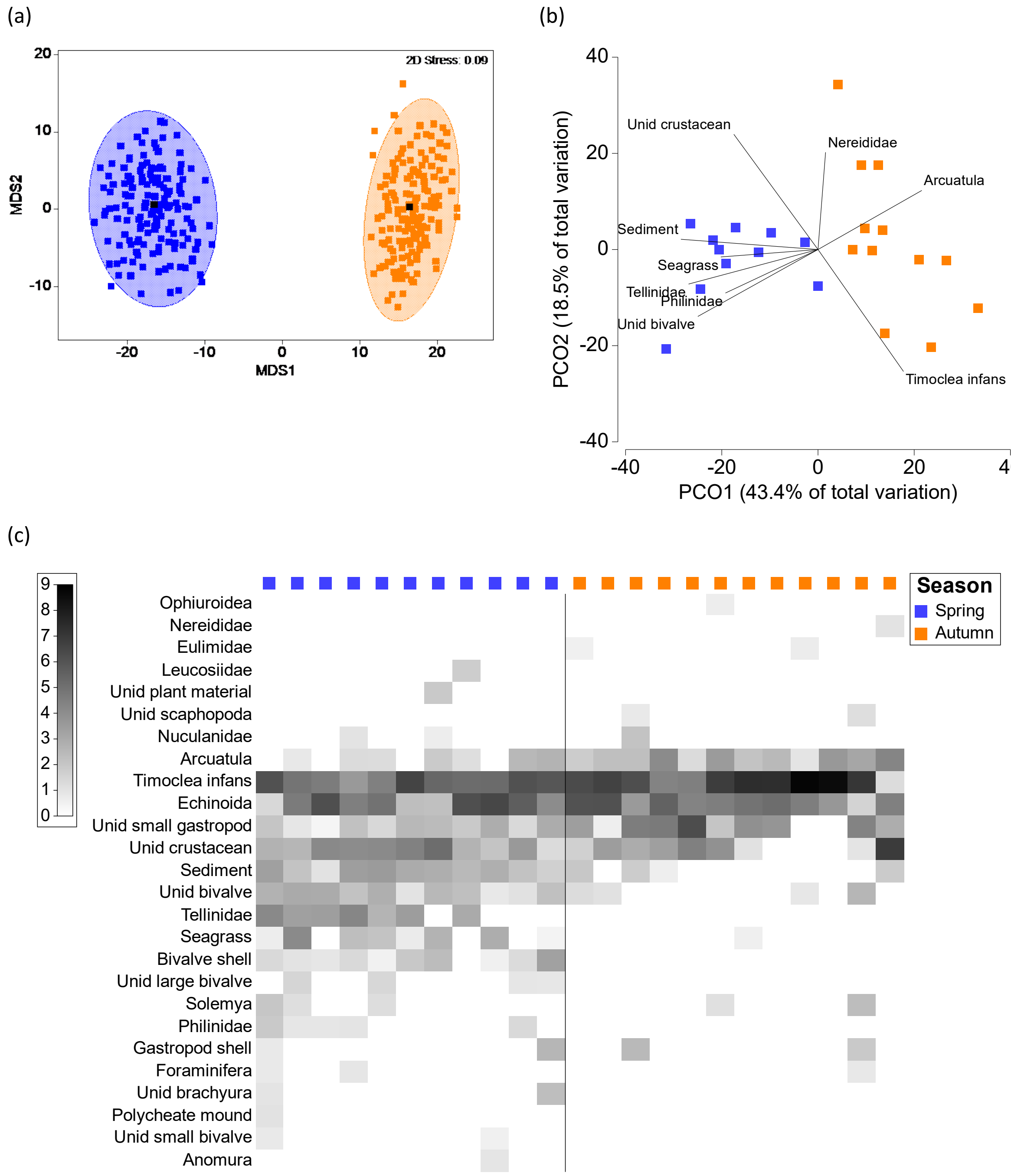
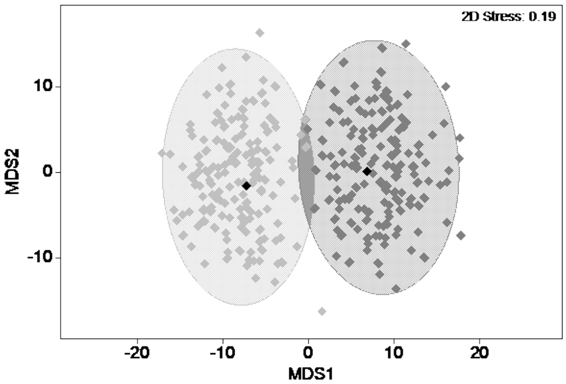


Figure 35. (a) mMDS plot constructed from the bootstrap averages of blue swimmer crabs caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of blue swimmer crabs caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of blue swimmer crabs caught in different seasons.

The dietary composition of blue swimmer crabs was found to not differ significantly among sexes according to ANOSIM (Global *R* = 0.028; *p* = 0.244), with there also being an overlap of the two 95% confidence regions on the bootstrapped mMDS plot (Figure 36a). The most commonly ingested dietary categories, i.e. the bivalves *Arcatula* sp. and *T. infans,* small gastropods, unidentified crustaceans and echinoids were consumed by individuals of both sexes and in relatively equal quantities (Figure 36b). Only tellinid bivalves occurred more frequently in female than male blue swimmer crab stomachs, whereas the reverse was true for the head-shield slugs (Philinidae).

(a)



(b)

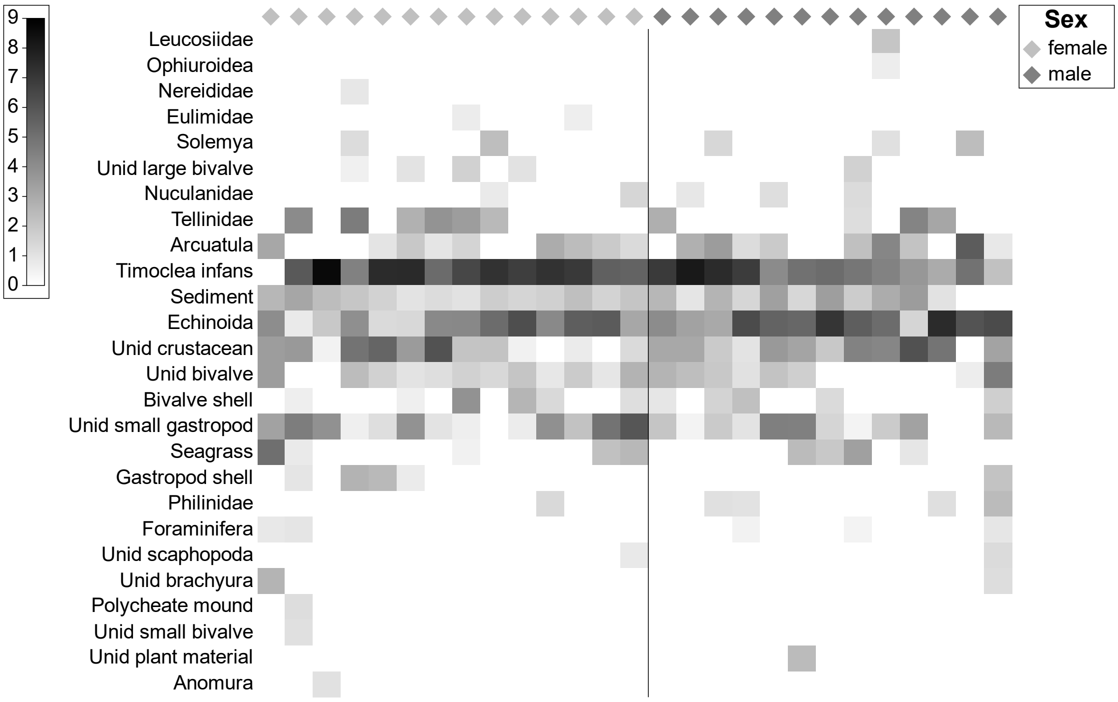
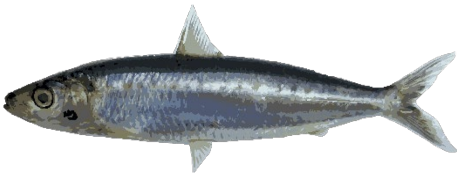


Figure 36. (a) mMDS plot constructed from the bootstrap averages of female and male blue swimmer crabs. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of female and male blue swimmer crabs.



3.1.5.2. Blue sprat (*Spratelloides robustus*)

The diet of blue sprat was dominated by arthropods, which contributed between 85 and 99%V of the volume of the gut contents in each TL class (Figure 37). The only notable contributions from other major taxa were molluscs in the 40-49 TL mm class (10%V) and cnidarians in all except the 60-69 mm TL class (~3%V).

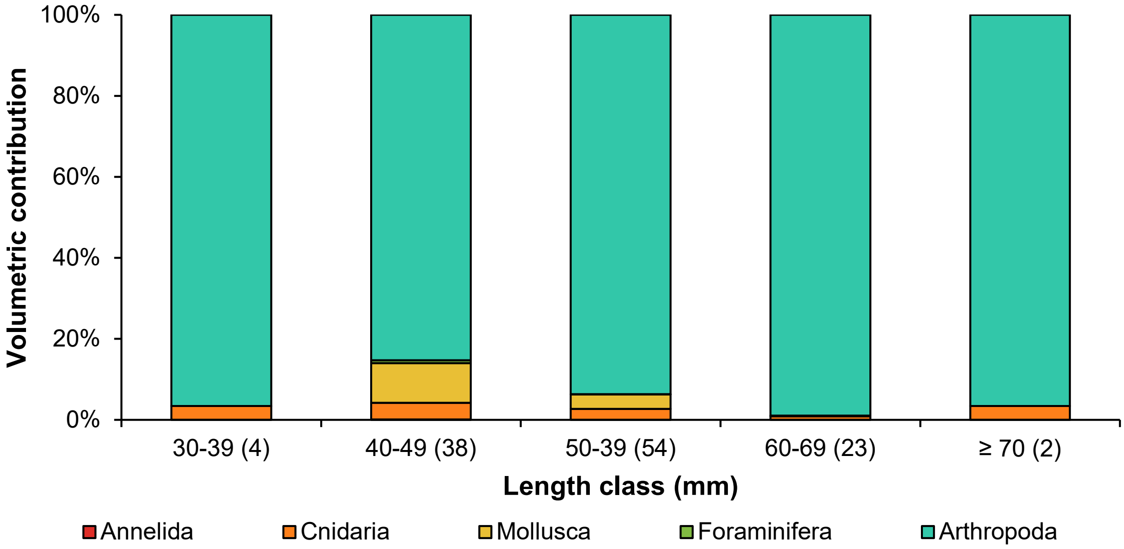


Figure 37. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of blue sprat. n = 121 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes (Global *R* = 0.420; *p* = 0.001) and all three pairwise comparisons (*R* = 0.264-0.763; *p* = 0.002-0.080). The biggest difference was between blue sprat in the 40-49 vs >60 mm TL classes and the points representing the three classes are aligned in sequential order on the mMDS plot with no overlap of their 95% confidence regions (Figure 38a). This pattern was also apparent along axis 1 in the CAP plot, with the vectors indicating that calanoid and harpacticoid copepods made a larger contribution to the diet of blue sprat <60 mm TL as did cladocerans in individuals >60 mm TL (Figure 38b). Small gastropods and bivalves were mainly consumed by the smallest fish. Unidentified copepods and unidentified crustaceans made amongst the largest contributions to the diet of blue sprat but were consumed by fish in all size classes (Figure 38c).

Regional differences in dietary composition were significant and moderately large overall (Global *R* = 0.543; *p* = 0.001) and also differed among all three pairwise comparisons (*R* = 0.357-0.681; *p* = 0.20-0.003). Differences were greatest between Owen Anchorage and the two regions of Cockburn Sound, with the former region well separated from the others at the top of the bootstrapped mMDS plot (Figure 39a). Unidentified copepods, unidentified crustaceans and cladocerans were abundant in the diets of blue sprat from all regions but selected as vectors of the CAP plot due to the lower range of prey consumed by fish from Owen Anchorage (Figure 39b,c). Cladocerans were more frequently ingested and in greater volumes by blue sprat in Owen Anchorage, whereas the reverse was true for harpacticoid copepods. Unidentified small gastropods and bivalves were only consumed in the two regions of Cockburn Sound with dietary differences between these two regions due, in part, to greater contributions of siphonophore larvae in South Cockburn Sound and calanoid copepods and unidentified crustacean larvae in North Cockburn Sound (Figure 39c).

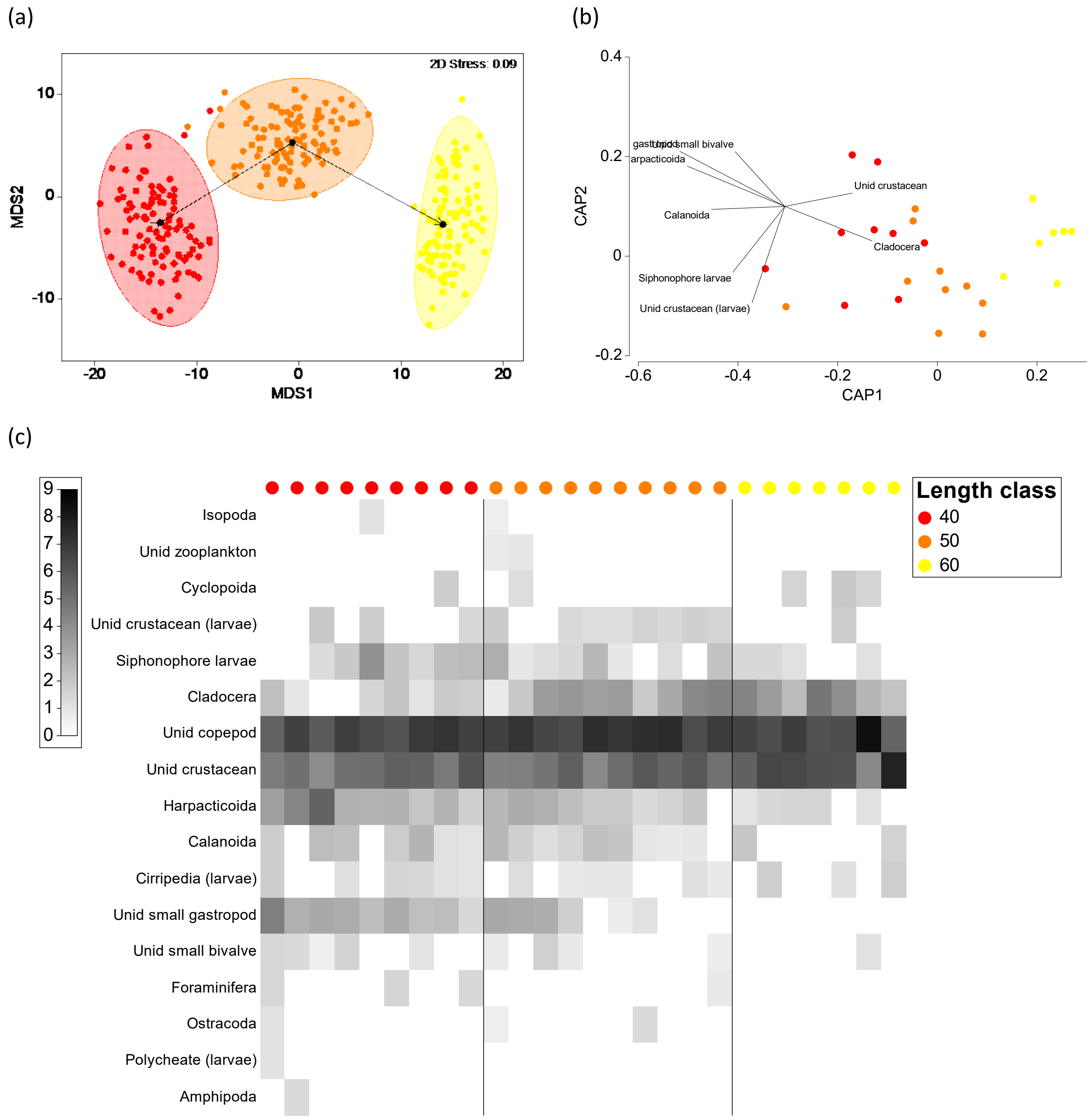


Figure 38. (a) mMDS plot constructed from the bootstrap averages of blue sprat of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of blue sprat of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of blue sprat of different total length classes.

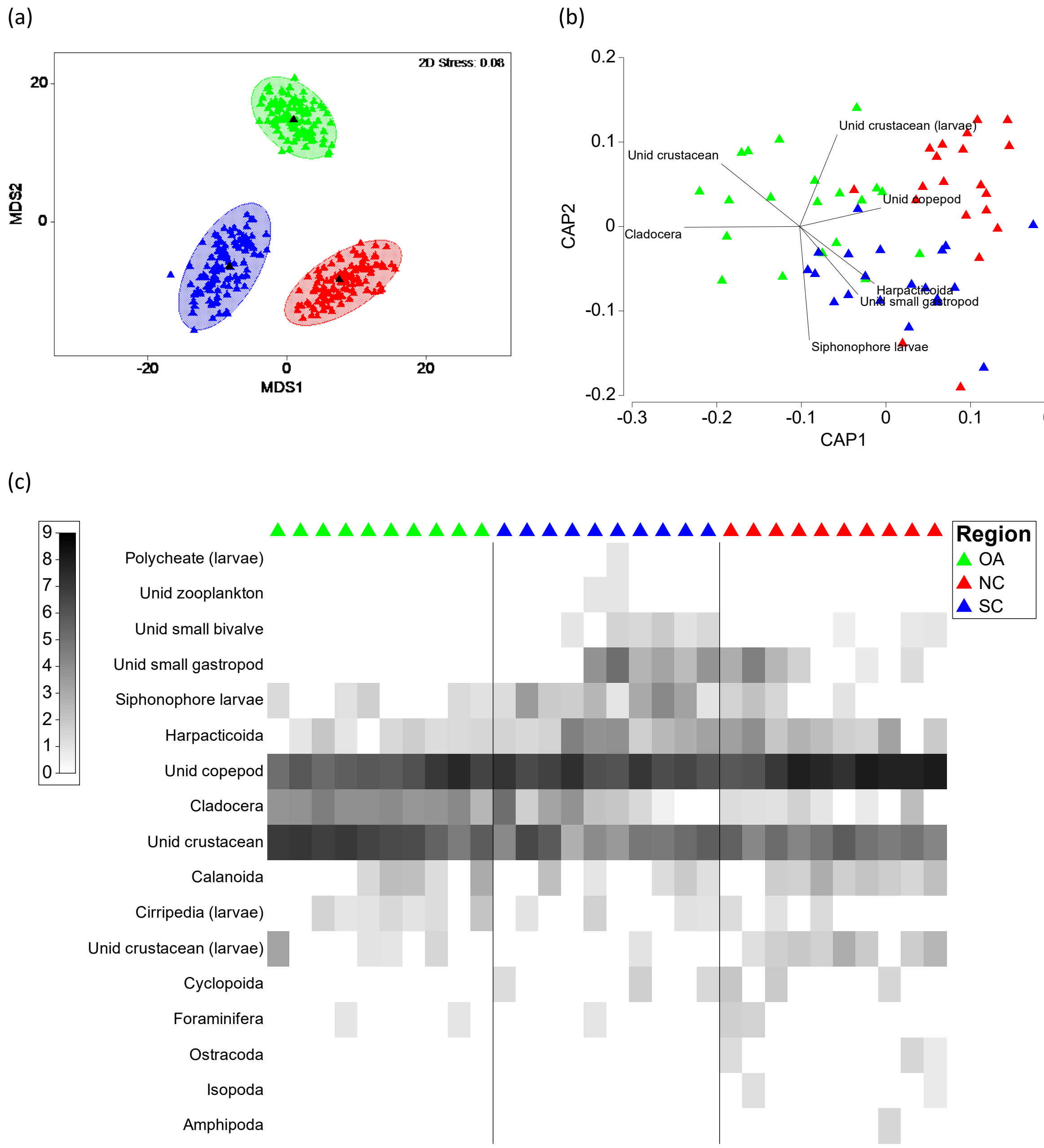
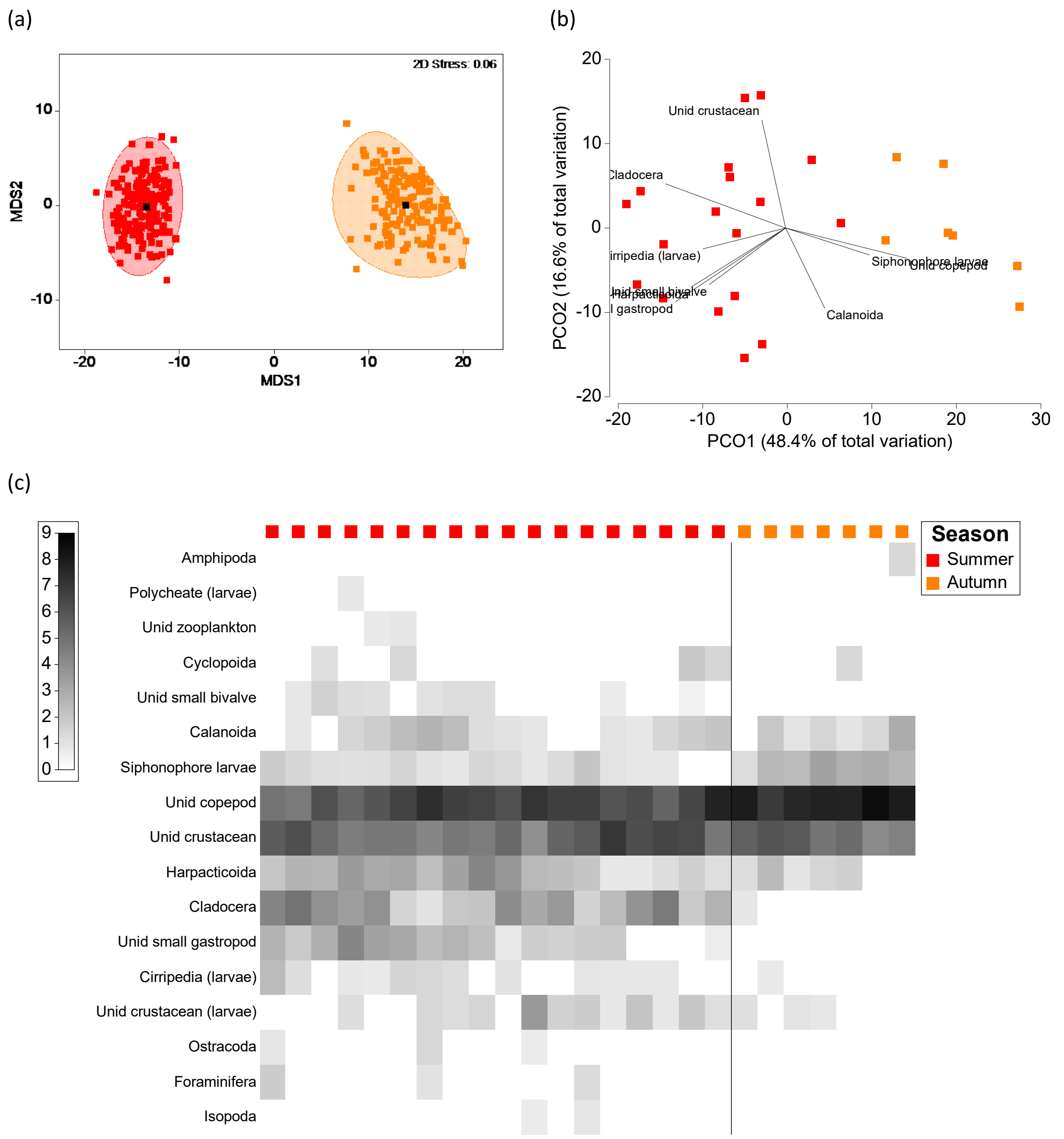


Figure 39. (a) mMDS plot constructed from the bootstrap averages of blue sprat from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of blue sprat from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of blue sprat from different regions of Cockburn Sound.

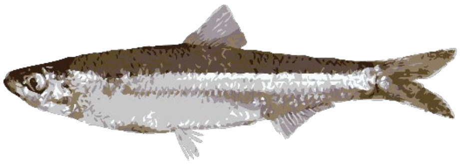
Among the factors investigated, the most pronounced difference in dietary composition in blue sprat was detected among seasons (Global *R* = 0.727; *p* = 0.001), with clear separation of the points representing summer and autumn on the mMDS plot (Figure 40a). Unidentified copepods and unidentified crustaceans were consumed in the greatest volumes in both seasons, together with lower amounts of calanoid and harpacticoid copepods and siphonophore larvae. Differences between the seasons were due to a broader range of prey consumed in summer including small bivalves, small gastropods and cladocerans (Figure 40b,c).


(a)

(b)

(c)

Figure 40. (a) mMDS plot constructed from the bootstrap averages of blue sprat caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of blue sprat caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of blue sprat caught in different seasons.



3.1.5.3. Sandy sprat (*Hyperlophus vittatus*)

The diet of sandy sprat/whitebait was dominated by arthropods that contributed between 80 and 100%V of the total gut volume in each TL class, with small contributions of both chordates and cnidarians (Figure 41). The smallest three TL classes almost exclusively consumed arthropods (98-100%V) but the contribution of this major taxa declined to 80 to 86%V in individuals >79 mm TL. Sandy sprat between 80-89 mm TL consumed chordates (7%V), and in the two larger classes, both, chordates and cnidarians were ingested (typically both ~5%V of the mean total volume).

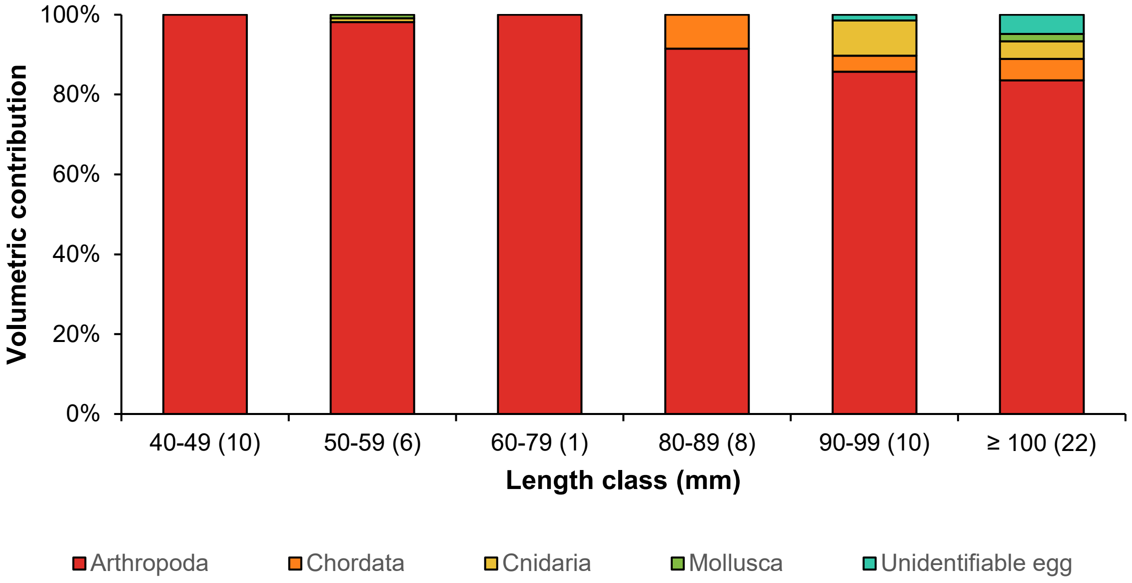


Figure 41. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of sandy sprat. n = 57 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes (Global *R* = 0.424; *p* = 0.003). Sandy sprat in the 40-60 mm TL class had a different diet to those in the two larger classes (*R* = 0.708 and 0.594; *p* = 0.029 and 0.008), which were similar (*R* = -0.063; *p* = 0.627). The bootstrapped averages for the 40-50 mm TL class were completely distinct from those of the 80-100 and > 100 mm TL classes, with the 95% confidence regions for the two latter classes almost entirely overlapping on the mMDS plot (Figure 42a). Similarly, the points for the two larger TL classes intermingled on the CAP ordination (Figure 42b). Unidentified copepods and crustaceans dominated the diets of sandy sprat in all TL classes, together with harpacticoid copepods and unidentified crustacean larvae. These four dietary categories, together with cladocerans, were the only prey consistently ingested by 40-60 mm TL sandy sprat, with larger individuals also consuming unidentified pelagic ascidians and, calanoid copepods, albeit less frequently.

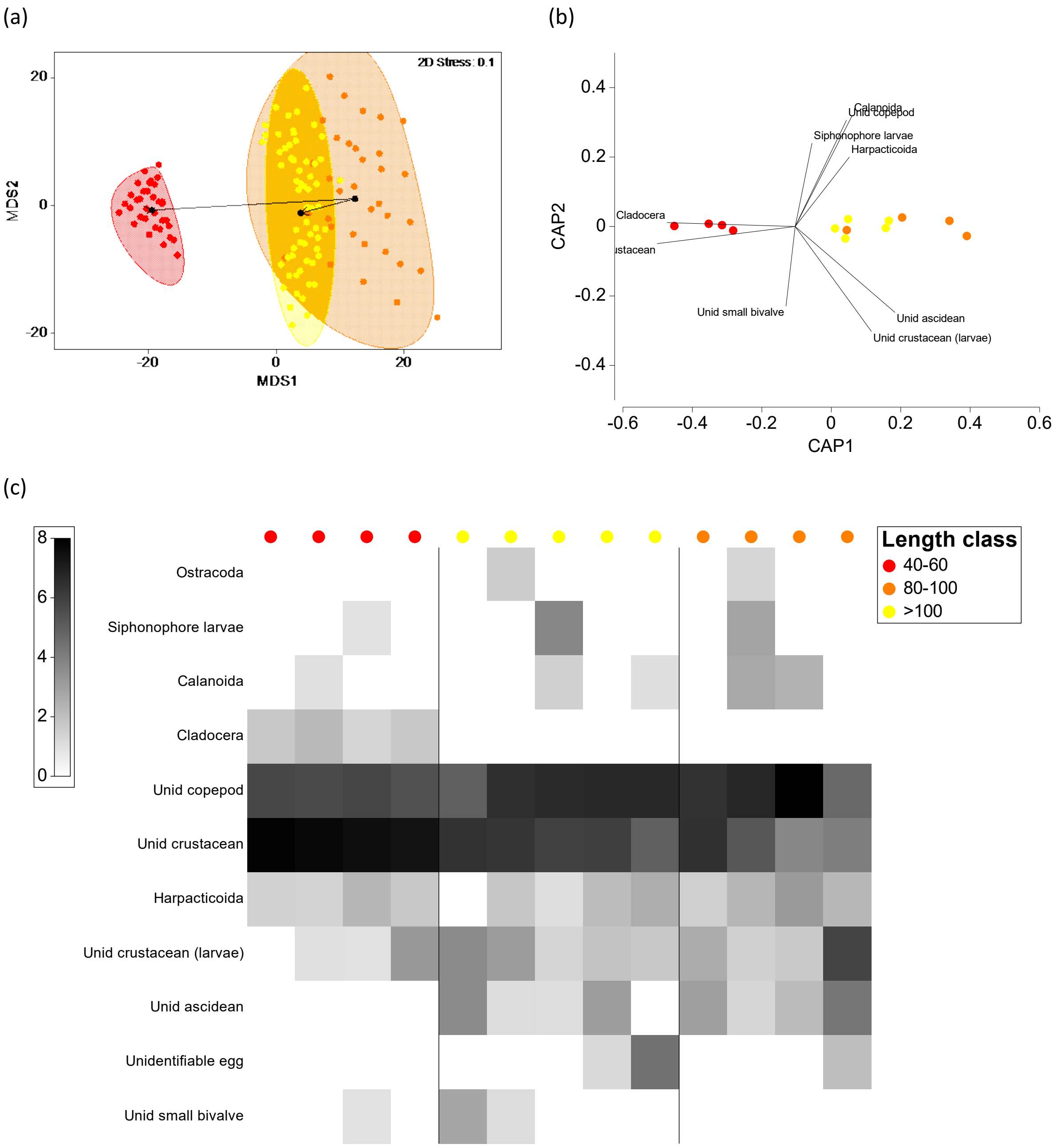


Figure 42. (a) mMDS plot constructed from the bootstrap averages of sandy sprat of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of sandy sprat of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of sandy sprat of different total length classes.

Relatively large regional differences in dietary composition were detected overall (Global R = 0.497; p = 0.008) and in all three pairwise comparisons (R = 0.406-0.615; p = 0.008-0.048; Figure 43a). Unidentified copepods, unidentified crustaceans and harpacticoid copepods were consumed by sandy sprat in all regions and in relatively similar volumes. However, cladocerans were only ingested in Owen Anchorage, and calanoids in South Cockburn Sound (Figure 43b,c). Unidentified pelagic ascidians occurred more consistently in the stomachs of sandy sprat in both Owen Anchorage and South Cockburn Sound, whereas siphonophore and unidentified crustacean larvae were ingested in greater volumes in North Cockburn Sound.

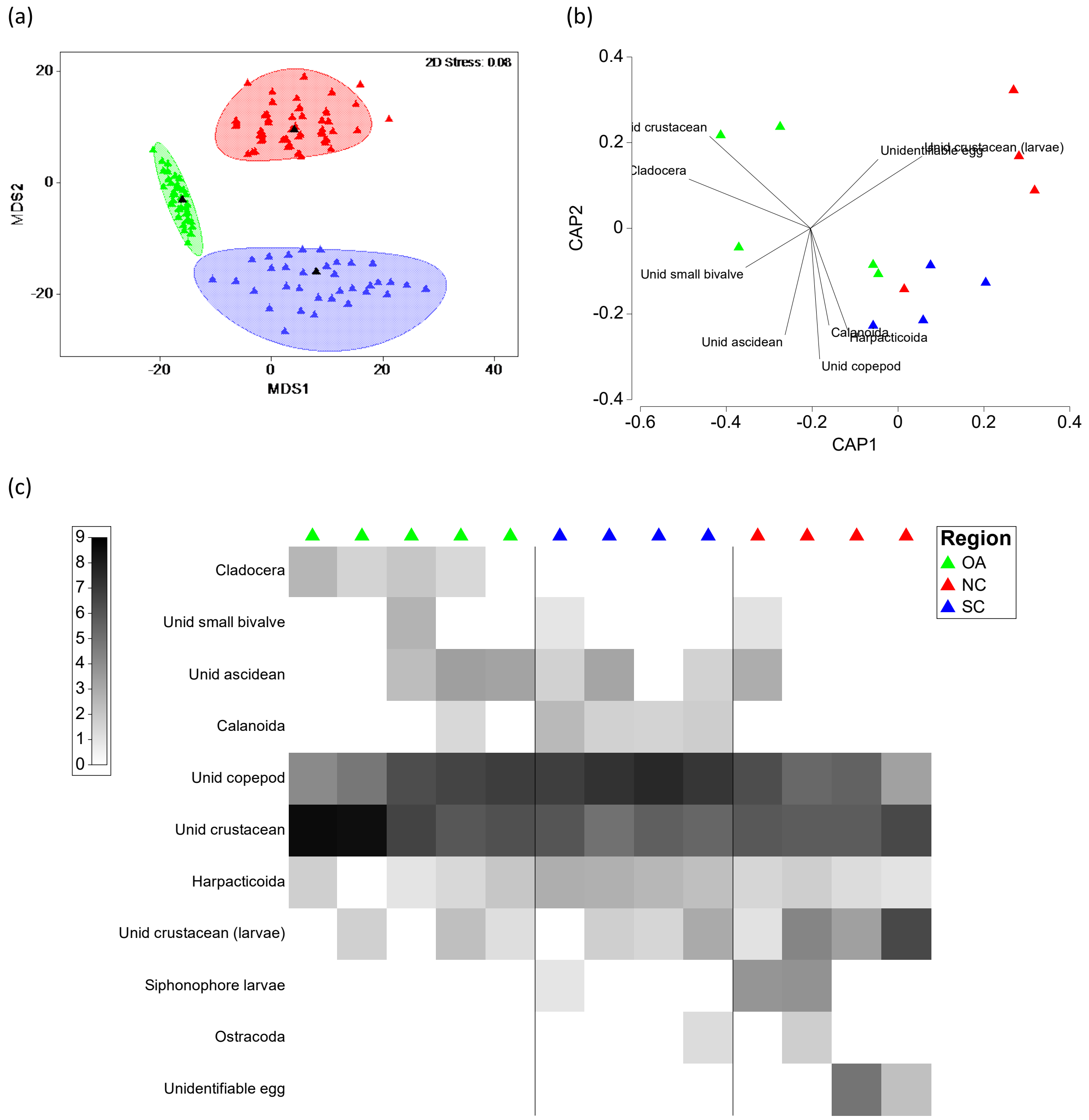


Figure 43. (a) mMDS plot constructed from the bootstrap averages of sandy sprat from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of sandy sprat from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of sandy sprat from different regions of Cockburn Sound.

The dietary composition of sandy sprat was also found to differ among seasons (Global *R* = 0.530; *p* = 0.002), with clear separation of the points representing spring and autumn on the mMDS plot (Figure 44a). Although unidentified crustaceans and unidentified copepods typified the diet in both seasons, the former dietary category was consumed in greater volumes in spring and the latter in autumn (Figure 44b,c). Cladocerans and unidentified crustacean larvae were also consumed more in spring and unidentified ascidians and calanoid copepods in autumn.

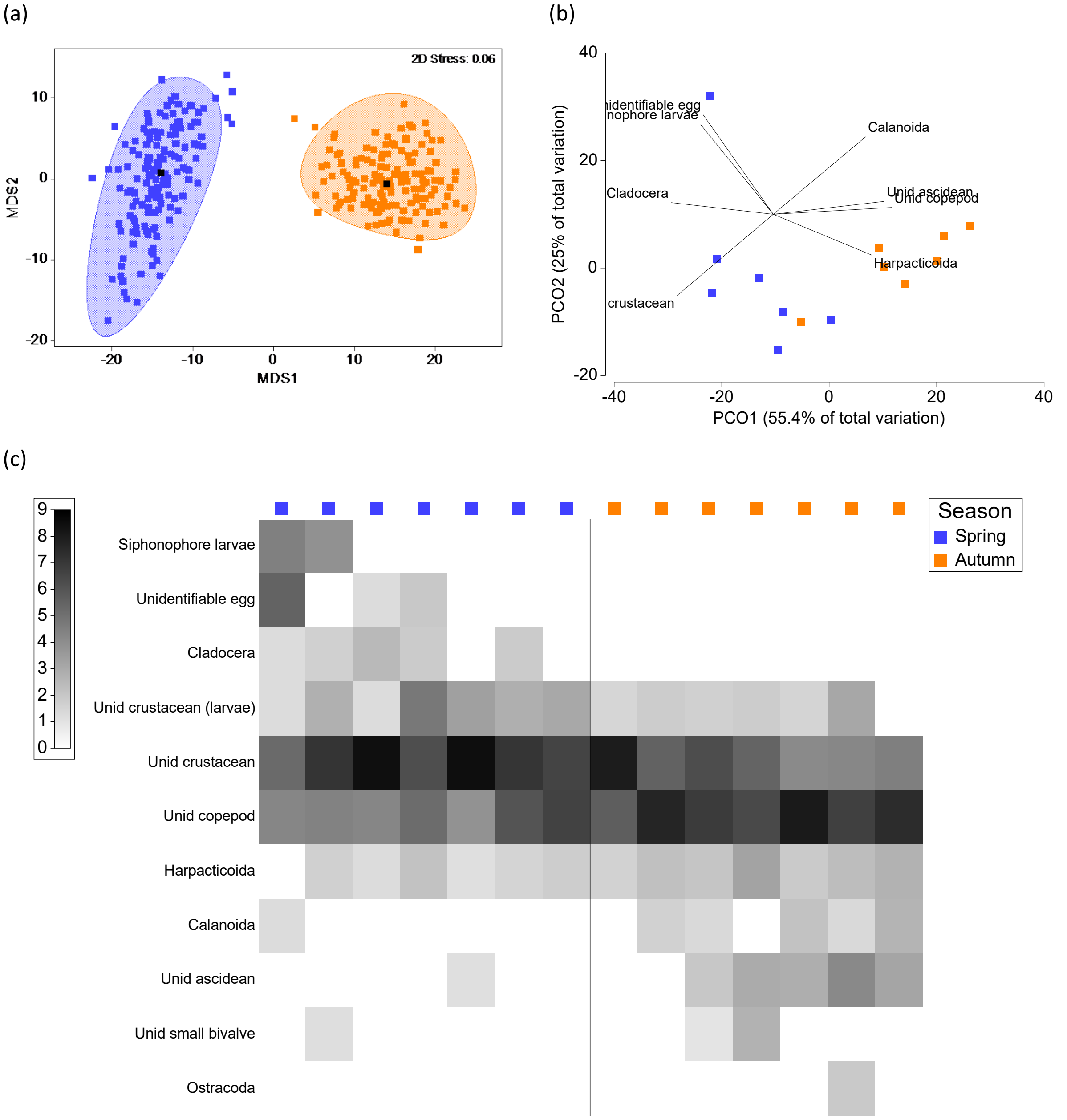


Figure 44. (a) mMDS plot constructed from the bootstrap averages of sandy sprat caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of sandy sprat caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of sandy sprat caught in different seasons.

3.1.5.4. Longspine dragonet (*Pseudocalliurichthys goodladi*)

The diet of longspine dragonets comprised a broad range of taxa with molluscs making the largest contribution and which exceeded 39% of the volume in each TL class (Figure 45). Echinoderms and arthropods each typically contributed >10%V. Ontogenetic shifts were present but mainly in relation to the amount of calcareous material ingested by individuals increasing in size from 60 to 100 mm TL. Echinoderms were typically contributed ~5-10%V. Annelids comprised a very small component of the diet of individuals in most length classes (< ~3%V) but represented almost 16%V of the total volume on the 14 longspine dragonets > 140 mm TL. The contribution of other taxa, e.g. foraminiferans were consistent among length classes (2.1-5.7%V).

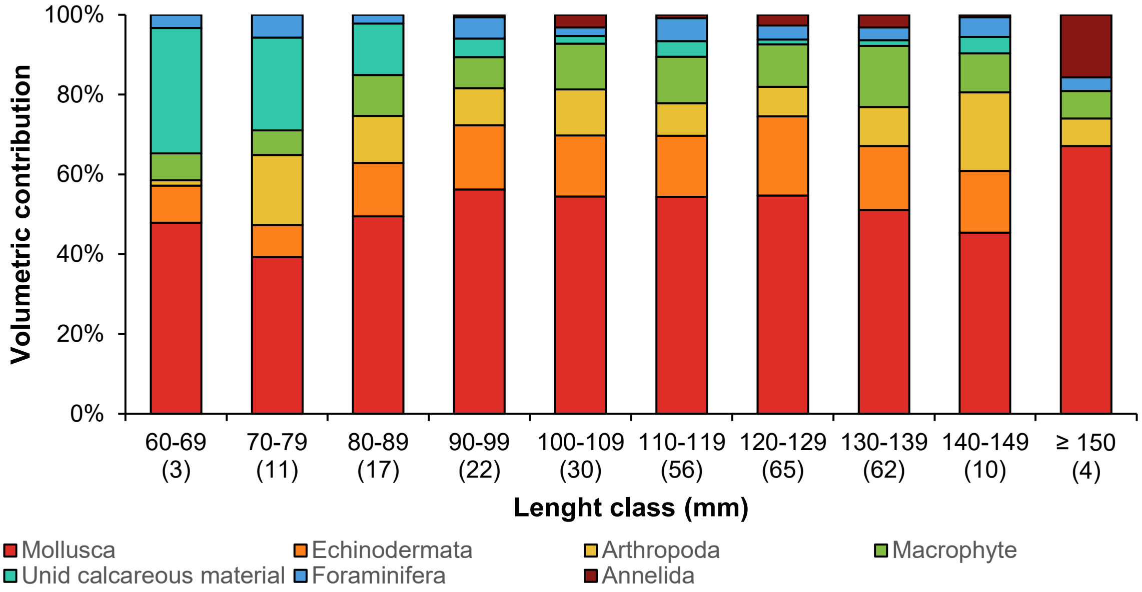


Figure 45. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of longspine dragonet. n = 280 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes overall (Global *R* = 0.234; *p* = 0.001) and in 10 of the 15 pairwise comparisons (*R* = 0.124-0709; *p* = 0.001-0.035). The only comparisons that were not significant were 60-70 vs both 80-99 and 100-109 mm and 120-129 vs 100-109, 110-119 and 129-130 mm TL. There was a generally sequential pattern in the distribution of the points representing the various TL classes along the *x*-axis of the mMDS plot, albeit with overlapping of the 95% confidence regions of the largest classes (Figure 46a). When subjected to constrained ordination, the points for the fish < 109 mm TL (smallest three classes) typically lay on the left side of the CAP1 axis (values < 0) and those for the larger three classes, > 110 mm TL on the right (values > 0; Figure 46b). A suite of dietary categories such as echinoids, and molluscs in the families Eulimidae, Carditidae, Scalilidae and Gadilidae were consumed by longspine dragonets of all body sizes. Individuals in the three smaller TL classes, tended to consume larger volumes of ostracods, unidentified plant material, tellinids and eulimid molluscs, whereas, algae, sedentary polychaetes, nassarid gastropods, cumaceans and brachyurans were ingested in greater quantities by larger fish.

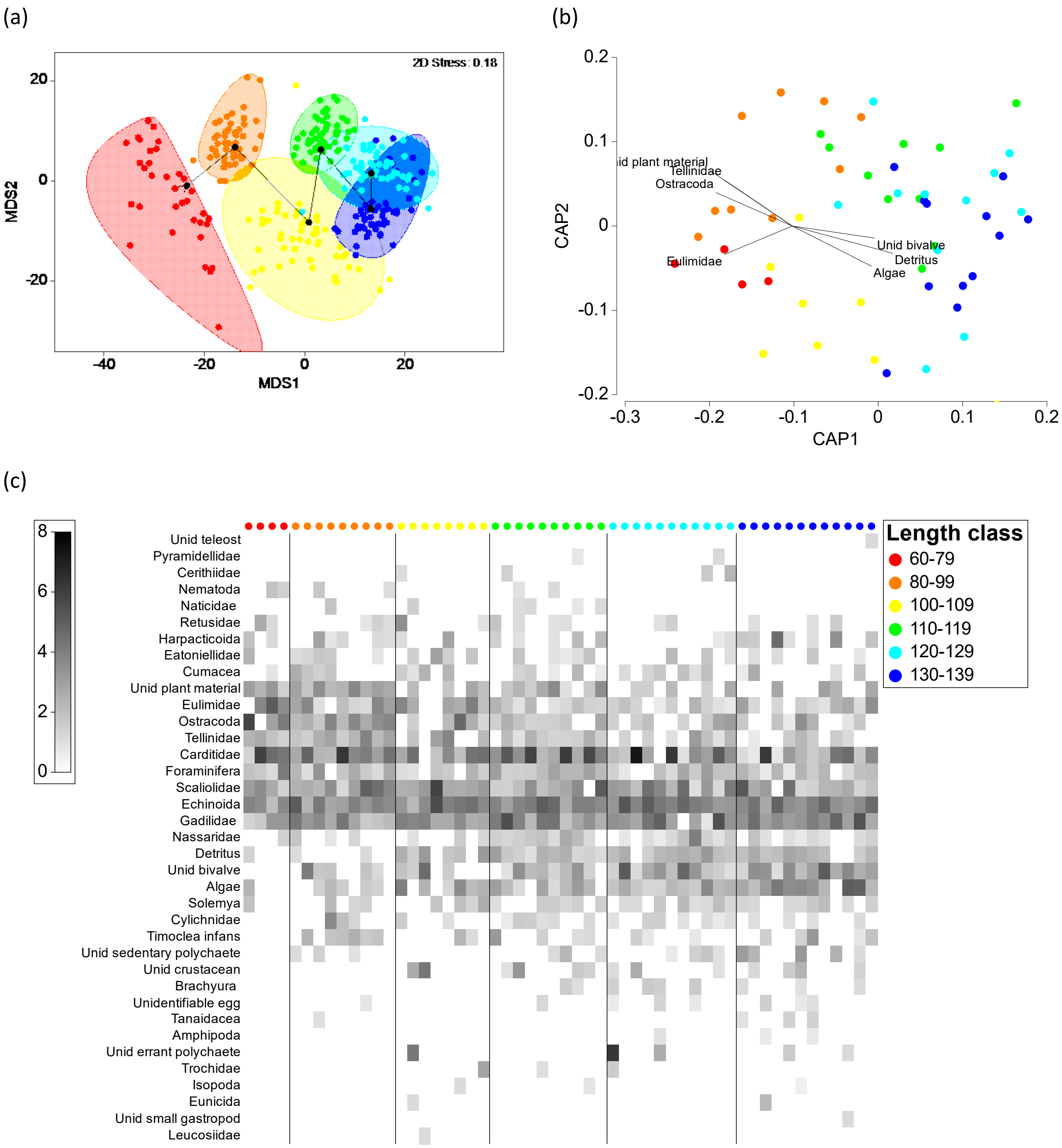


Figure 46. (a) mMDS plot constructed from the bootstrap averages of longspine dragonet of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) CAP plot illustrating differences in the dietary composition of longspine Dragonet of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of longspine dragonet of different total length classes.

Significant regional differences in dietary composition were detected overall (Global R = 0.381; p = 0.001) and among all three pairwise comparisons (R = 0.313-0.501; all p = 0.001). The differences were greatest between Owen Anchorage and the two regions of Cockburn Sound, with the former region clearly separated from the other two along the x-axis of the bootstrapped mMDS plot (Figure 47a). Most of the main dietary categories were ingested by fish in all regions, with the exception of unidentified bivalves and plant material in Owen Anchorage. Longspine Dragonet in this region consumed greater volumes of ostracods and foraminiferans (Figure 47b). Greater ingestion of scaliolids and fewer carditids helped to distinguish the diets of dragonets in South Cockburn Sound from those in North Cockburn Sound, respectively (Figure. 47c).

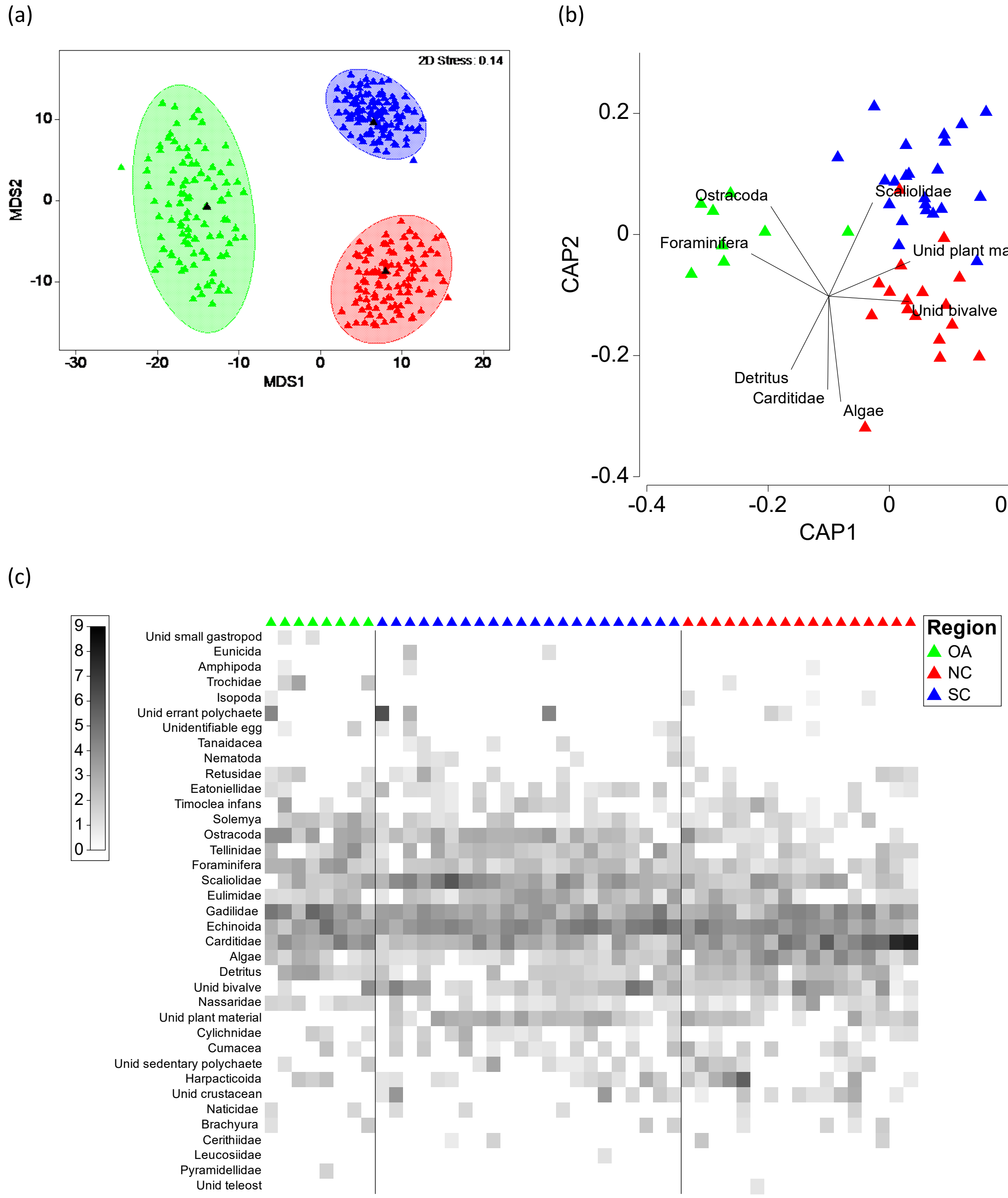


Figure 47. (a) mMDS plot constructed from the bootstrap averages of longspine dragonet from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of longspine dragonet from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of longspine dragonet from different regions of Cockburn Sound.

There was a very pronounced shift in dietary composition between spring and autumn (Global *R* = 0.956; *p* = 0.001), with clear separation on the mMDS and PCO plots (Figure 48a,b). A narrow range of dietary categories was consumed in spring, with the diets in this season dominated by cumaceans, nassarid and scaliolid gastropods, gadilid scaphopods and echinoids. A far broader range of prey was ingested in autumn, including all of those key categories consumed in spring except for cumaceans, together with tellinid and carditid bivalves, ostracods, harpacticoid copepods and eulimid, eatoniellid and retusid gastropods (Figure 48c).

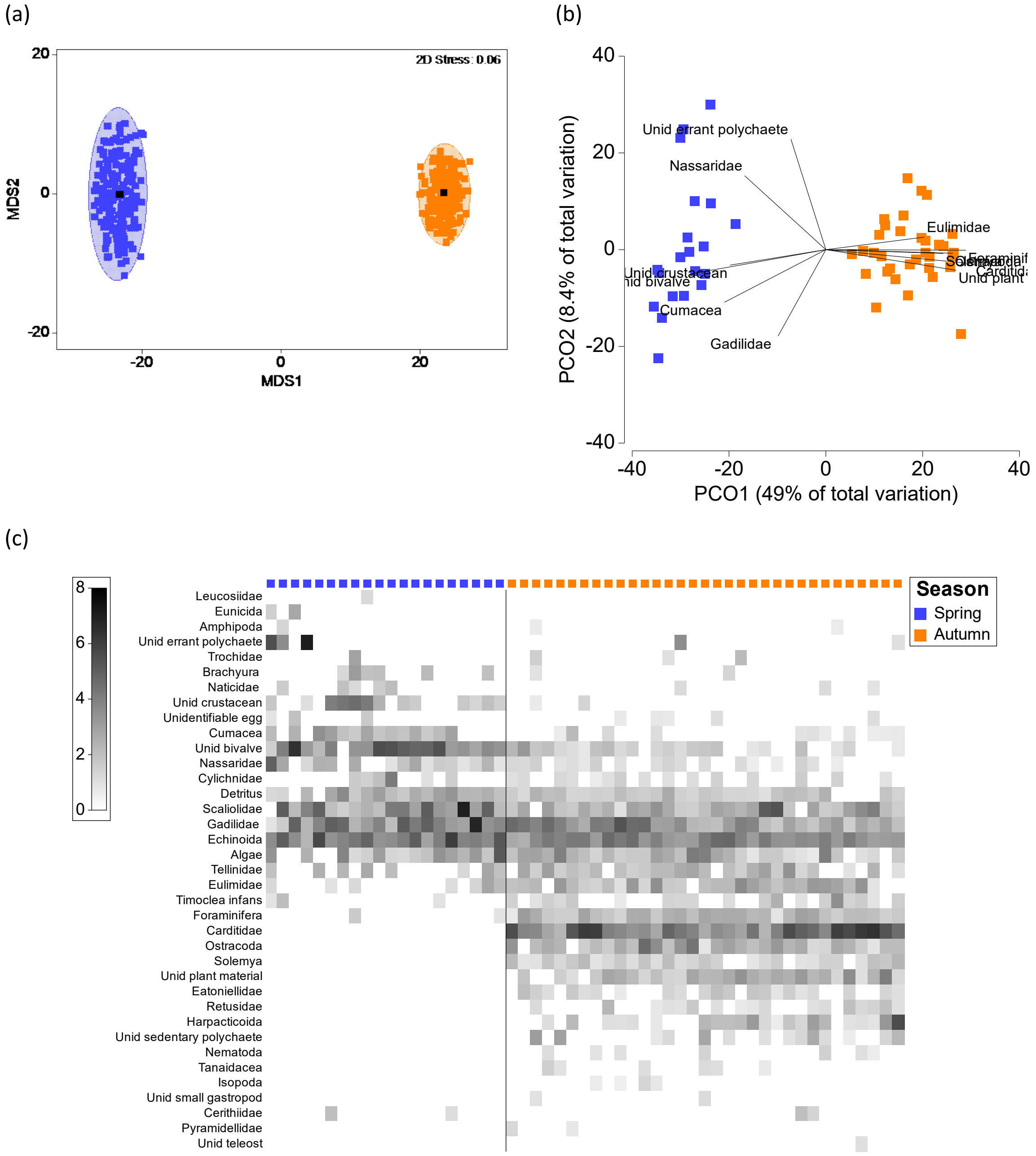


Figure 48. (a) mMDS plot constructed from the bootstrap averages of longspine dragonet caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of longspine dragonet caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of longspine dragonet caught in different seasons.

3.1.5.5. Soldier (*Gymnapistes marmoratus*)

The diet of soldier was dominated by arthropods, with prey in this major taxon representing between 67 and 100% of the total dietary volume (Figure 49). The only other notable contribution was made by annelids in the 50-59 mm TL class (33%V) and, to a lesser extent, in the 60-69 and 70-79 mm TL classes (7 and 2%V, respectively). Although consumed, molluscs and macrophytes were only present in three of the eight classes and only represented to up ~3%V of the diet in those fish.

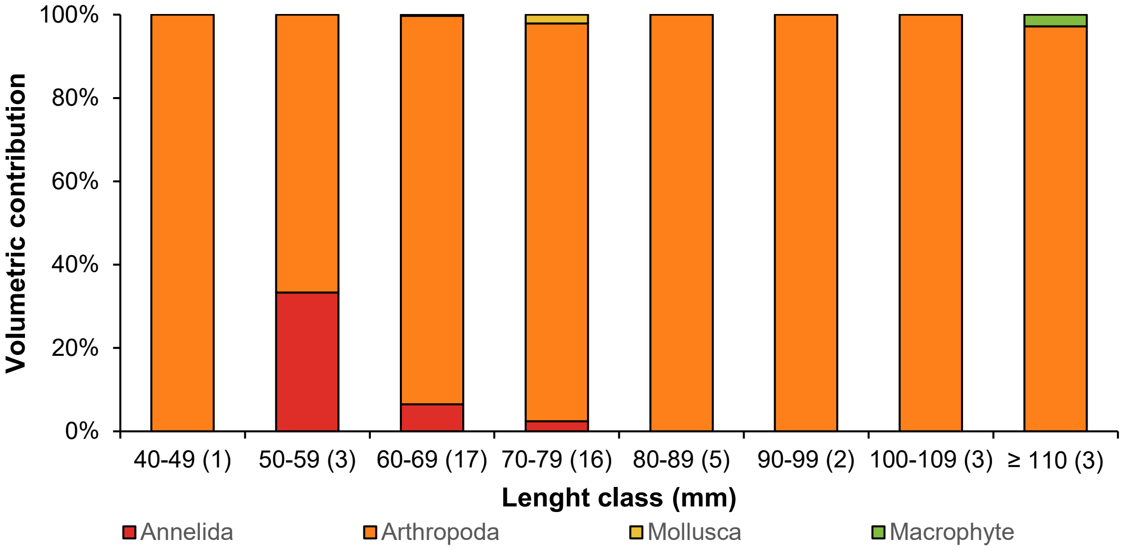


Figure 49. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of soldier. n = 50 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes overall (Global *R* = 0.321; *p* = 0.020), with those differences due to the largest class of Solider (> 90 mm) being different to the other two (*R* = 0.431 and 0.624; *p* = 0.015 and 0.006 for <70 and 70-90 mm, respectively). There was no difference between the diet of fish in the two smaller classes (*R* = 0.091; *p* = 0.175). This pattern is shown on the two ordination plots where the points representing these two TL classes intermingle and, on the mMDS plot, there is substantial overlap of the 95% confidence regions (Figure 49a,b). Soldiers < 90 mm TL fed mainly on amphipods, and less frequently on unidentified crustaceans and brachyurans. Some of the smallest fish (< 70 mm TL) also consumed isopods and some of the slightly larger ones (70-90 mm TL) also caridean shrimp. Soldiers in the largest class (> 90 mm TL) targeted slightly larger crustaceans switching from amphipods to axiids, alpheids and portunids and also other crustaceans and brachyurans that could not be identified in more detail (Figure 49c).

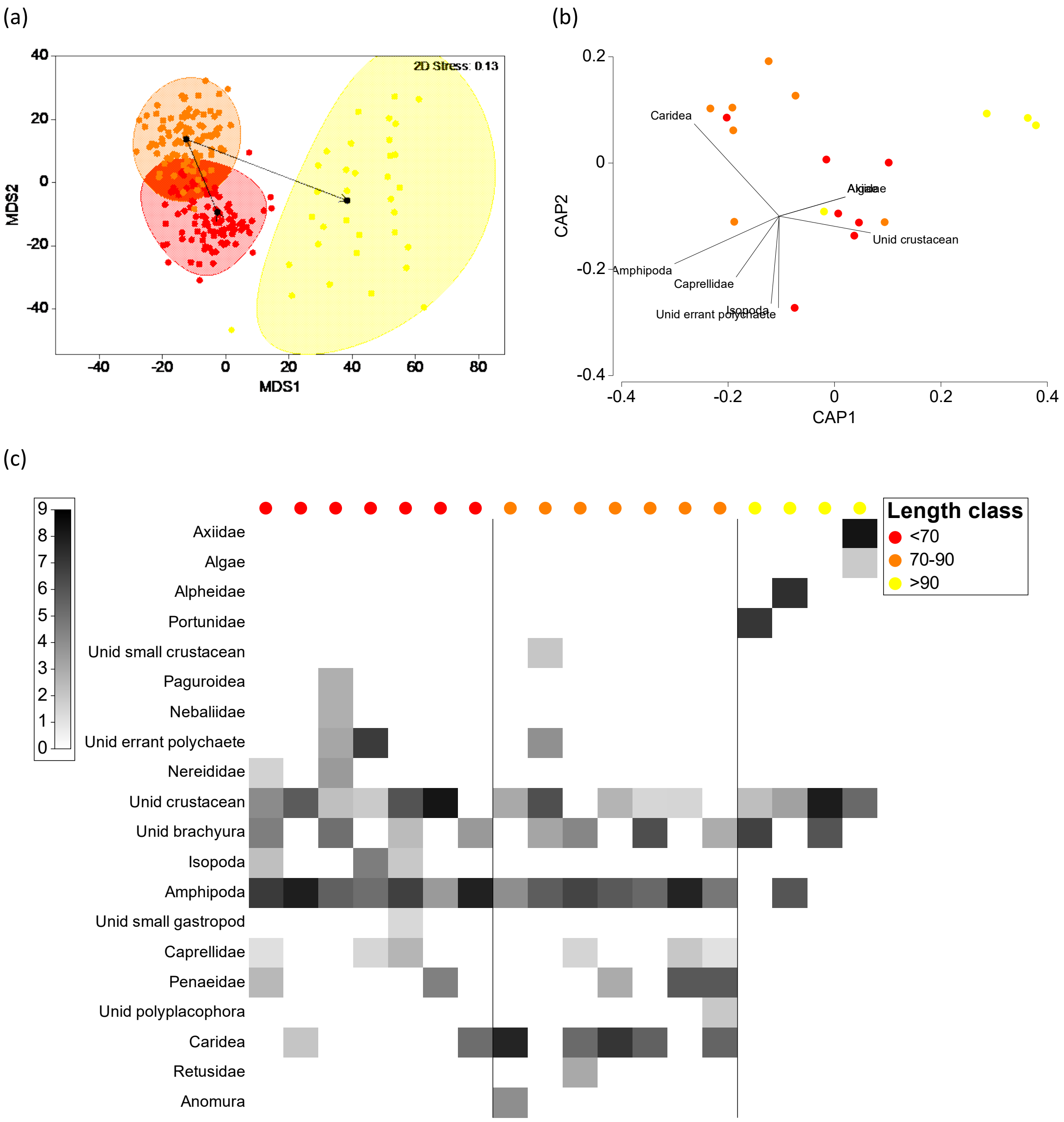


Figure 50. (a) mMDS plot constructed from the bootstrap averages of soldier of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) CAP plot illustrating differences in the dietary composition of soldier of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of soldier of different total length classes.

There was no significant difference in diet among regions (Global *R* = 0.082; *p* = 0.095). The 95% confidence regions for all three areas overlapped, particularly those of Owen Anchorage and North Cockburn Sound (Figure 51a). The lack of a difference was due to the main dietary categories, i.e. unidentified crustaceans and amphipods, being consumed by fish in most replicates from each region and the other categories, aside from caridean shrimp, being infrequently ingested (Figure 51b).

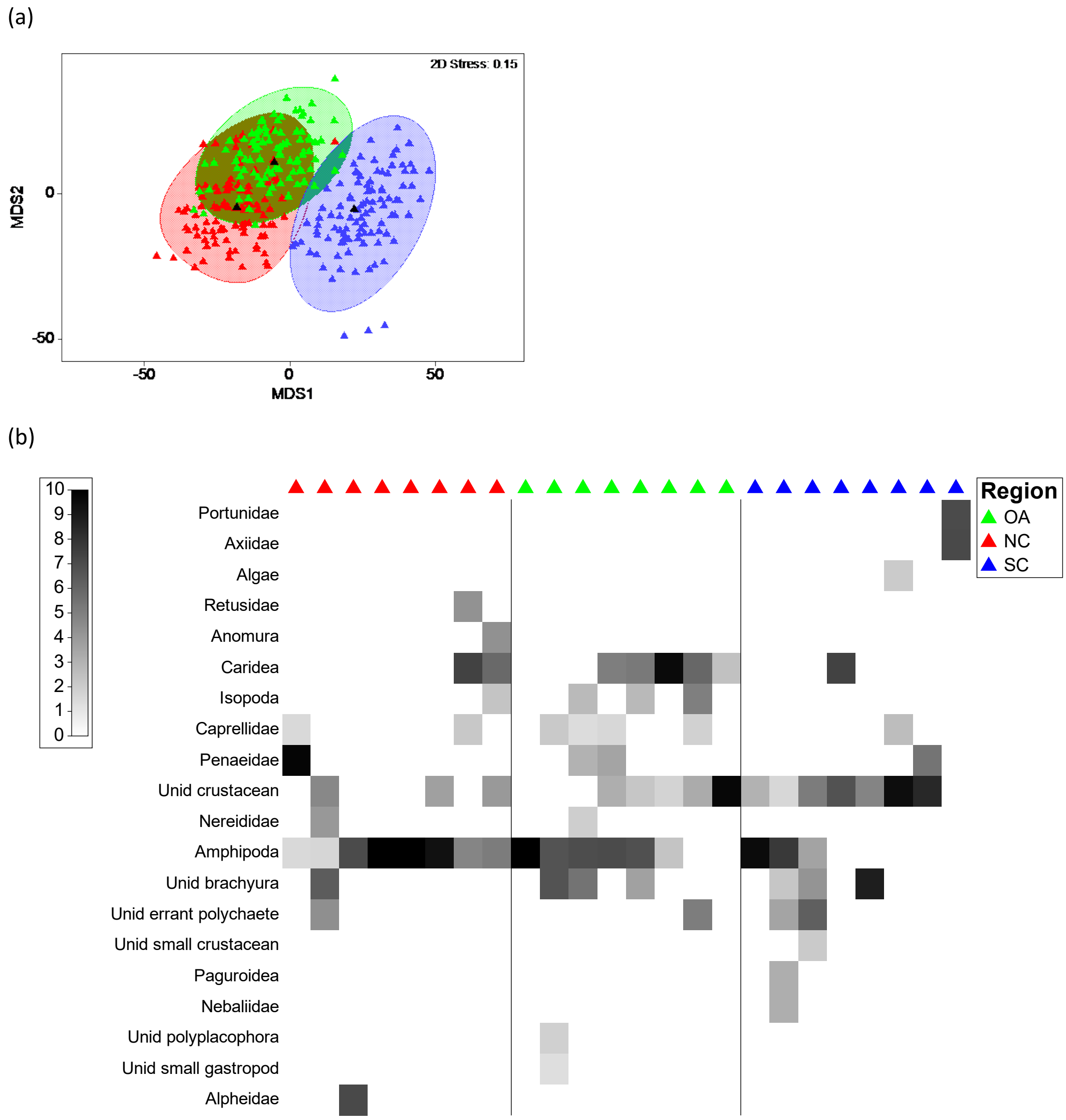


Figure 51. (a) mMDS plot constructed from the bootstrap averages of soldier from different regions of Cockburn Sound. Group averages (black symbols) and approximate 95% region estimates fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of soldier from different regions of Cockburn Sound. Vectors provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of soldier from different regions of Cockburn Sound.

The diets of soldier were also found not to differ among seasons (Global *R* = -0.046; *p* = 0.598), with a slight overlap of the 95% confidence regions representing spring and autumn on the mMDS plot (Figure 52a). Fish in both seasons predominantly consumed amphipods, caprellids, unidentified brachyurans and unidentified crustaceans in similar frequency of occurrences and volumes. Aside from carideans and penaeids, which formed a greater component of the diet in autumn, none of the commonly ingested dietary categories were predated on only in a particular season (Figure 52b).

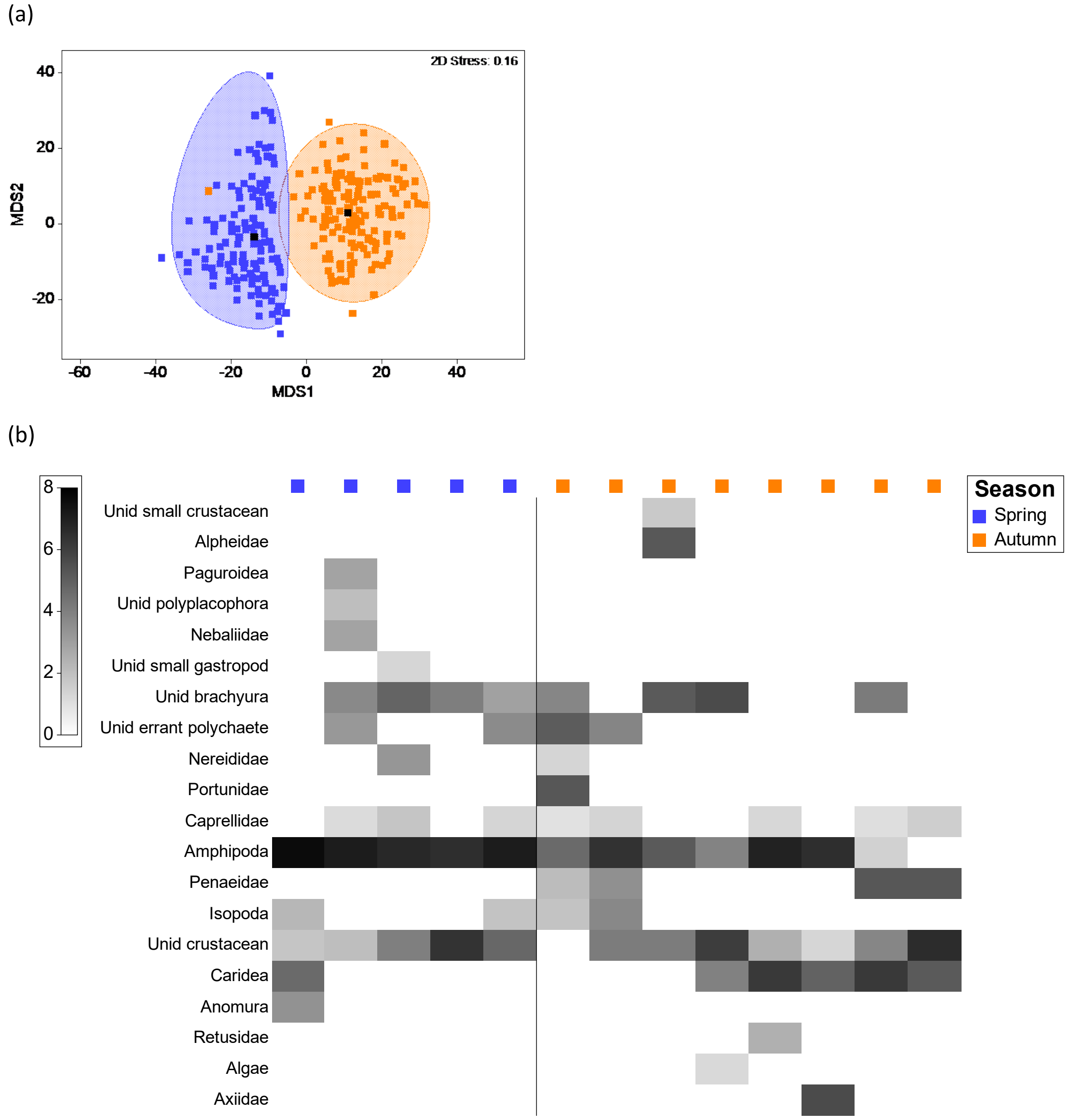


Figure 52. (a) mMDS plot constructed from the bootstrap averages of soldier caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of soldier caught in different seasons.

3.1.5.6. Midget flathead (*Onigocia spinosa*)

The diet of midget flathead was dominated by arthropods, which comprised 86 to 100% of the overall volume (Figure 53). Annelids were recorded in half of the length classes, i.e. those between 60 and 109 mm TL, in which they represented up to 7%V of the total diet. Chordates were present in a similar size range of individuals and were a substantial component of the diet in the 110-119 mm TL class, representing almost 14%V. Macrophytes were essentially only consumed by individuals between 120-129 mm TL but were unlikely to have been targeted given their absence in other length classes.

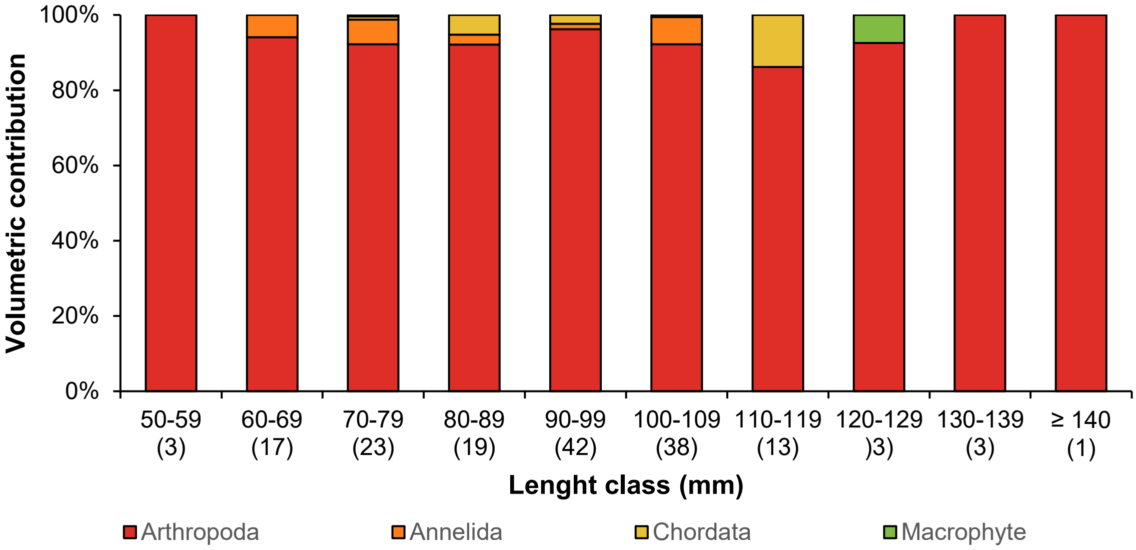
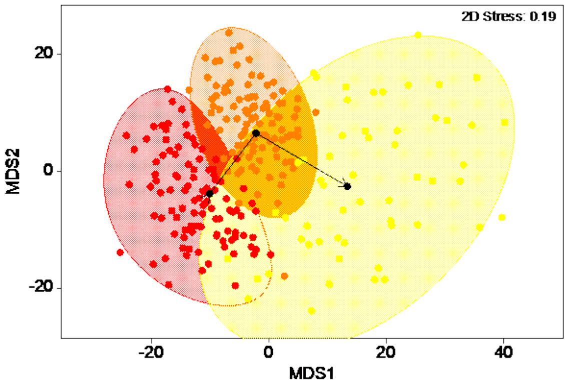


Figure 53. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of midget flathead. n = 162 overall and for each length class given in parentheses.

No significant difference in dietary composition at the dietary category level was detected among TL classes (Global $R = 0.009$; $p = 0.417$). While there was a shift in the position of the average of the bootstrapped averages for each TL class along the *x*-axis of the mMDS plot, the points intermingled and the confidence regions overlapped significantly (Figure 54a). Each of the four consistently ingested dietary categories, i.e. amphipods, caridean shrimp, brachyurans and unidentified crustaceans, contributed similar volumes to the diet of midget flathead in each TL class. Moreover, the other prey were infrequently ingested and often not by a particular size of fish. The diets of midget flathead also did not differ among regions (Global $R = 0.011$; $p = 0.400$), due to the same four dietary categories being consumed by fish in each region (Figure 55). There was, however, a shift in dietary composition among seasons (Global $R = 0.009$; $p = 0.417$), albeit the extent of the difference was relatively small (Figure 56a). Amphipods and caridean shrimp typified the diet in both seasons, although the former dietary category was consumed in consistently greater volumes in spring and the latter in autumn. Brachyurans and leucosiid crabs were also ingested in greater quantities in spring (Figure 56b).

(a)



(b)

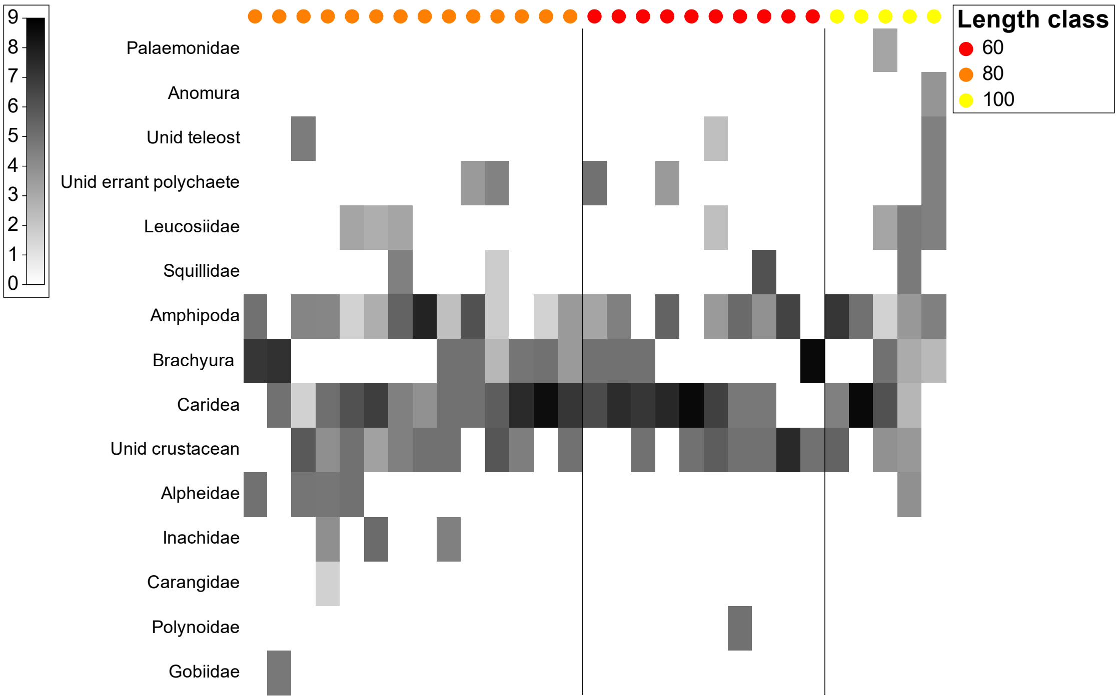
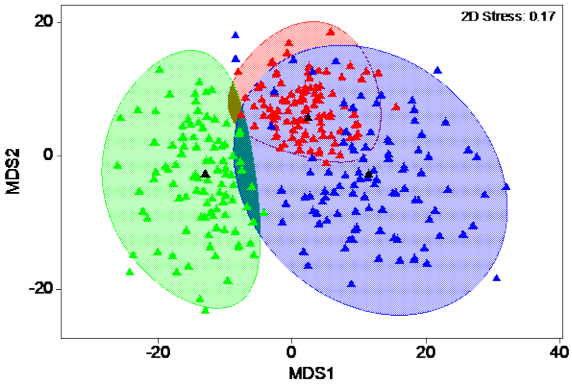


Figure 54. (a) mMDS plot constructed from the bootstrap averages of midget flathead of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of midget flathead of different total length classes.

(a)



(b)

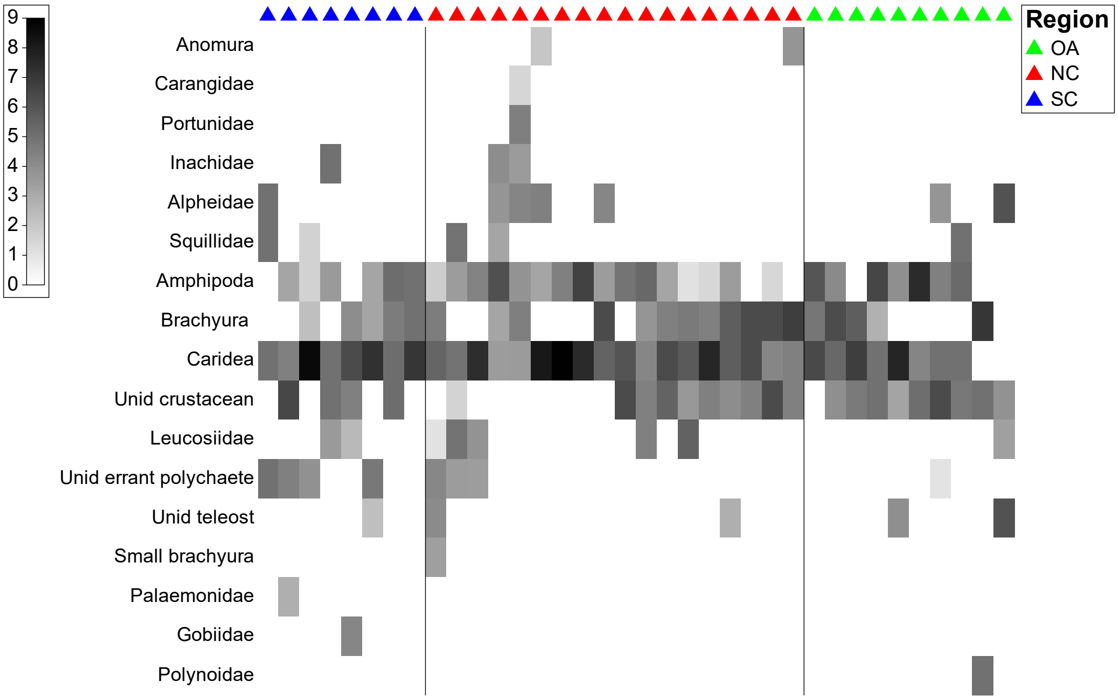


Figure 55. (a) mMDS plot constructed from the bootstrap averages of midget flathead from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of midget flathead from different regions of Cockburn Sound.

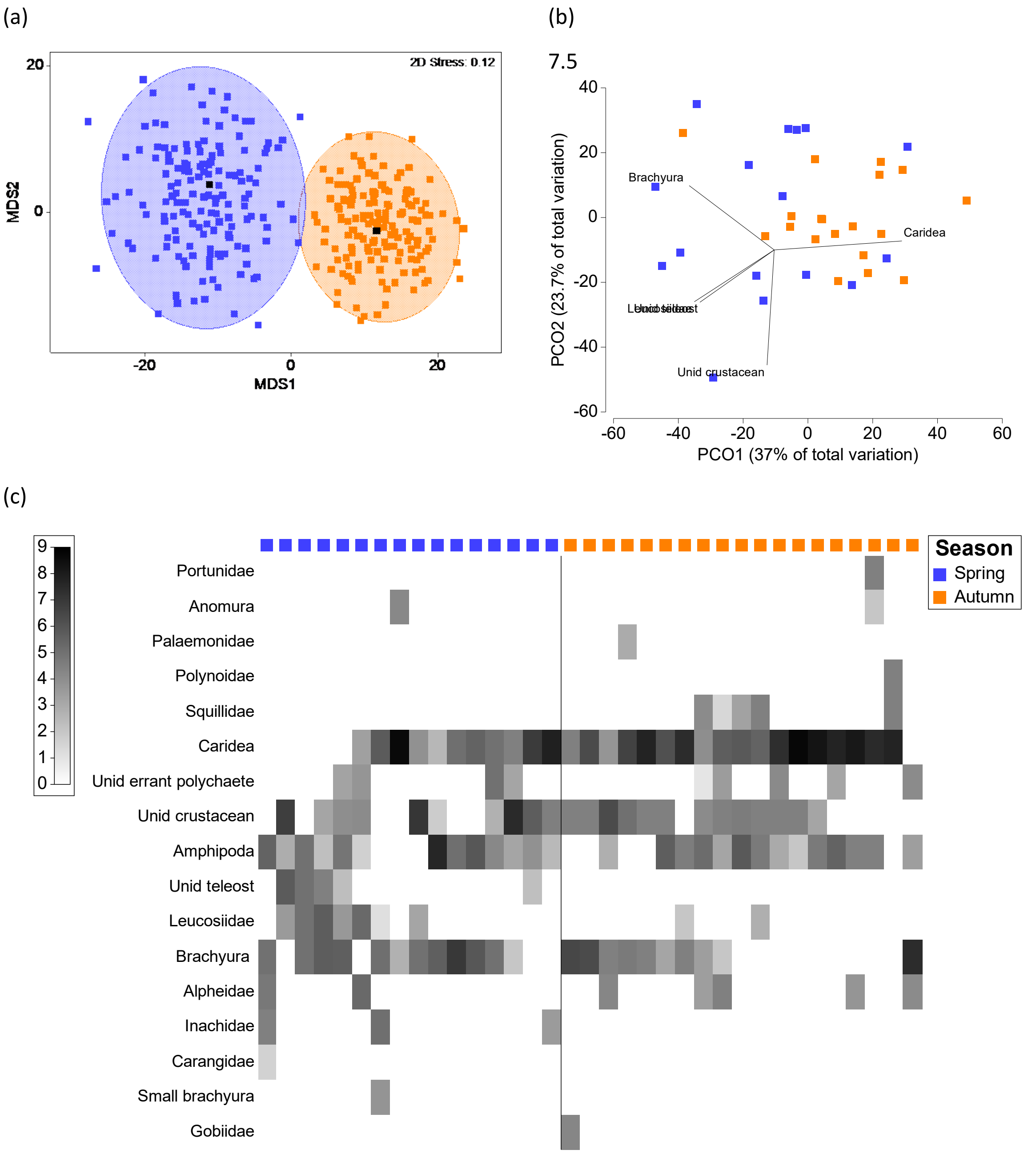
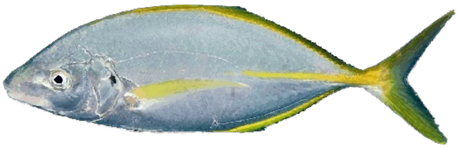


Figure 56. (a) mMDS plot constructed from the bootstrap averages of midget flathead caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of midget flathead caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of midget flathead caught in different seasons.



3.1.5.7. Skipjack trevally (*Pseudocaranx wright*)

The diet of skipjack trevally was variable across length clasess, but typically dominated by arthropods (mean volume = 56%V) and molluscs (mean = 27%V) with substantial contributions from echinoderms and annelids in some length classes, i.e. up to 22 and 15%V, respectively (Figure 57). Individuals > 100 mm TL contained a greater proportion of molluscs, echinoderms and annelids.

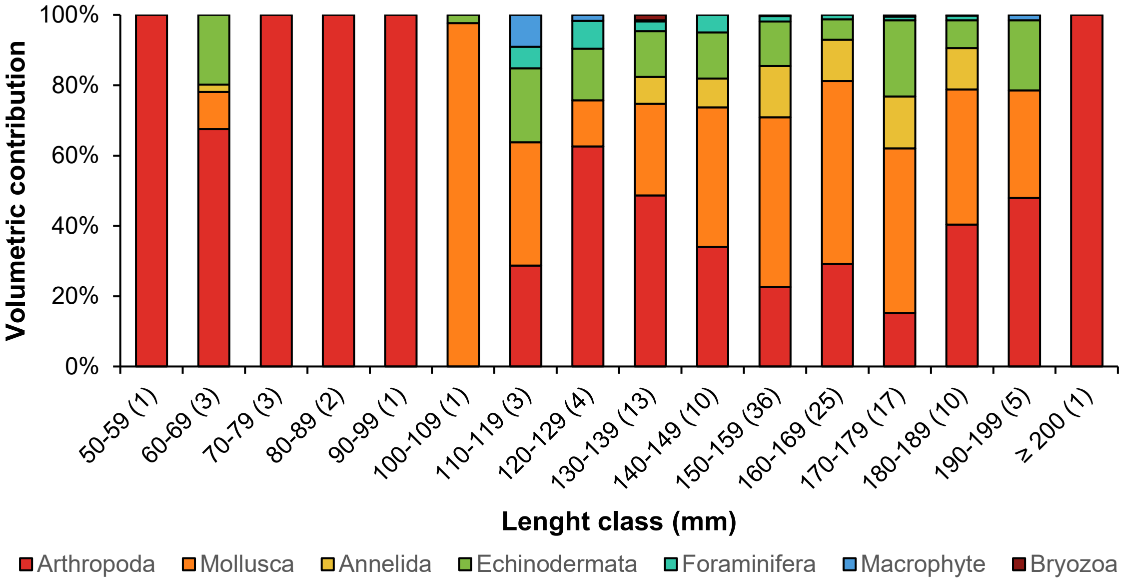


Figure 57. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of skipjack trevally. n = 135 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes overall (Global *R* = 0.265; *p* = 0.003) and in all six pairwise comparisons (*R* = 0.153-0.386; *p* = 0.002-0.0029). The points representing each class on the bootstrapped mMDS plot were discrete and arranged in an arc from left to right (Figure 57a). The relatively low global and pairwise *R*-statistic values reflect the fact that most of the main dietary categories (e.g. echinoids) were ingested by fish in all TL classes, but there were differences in their volumetric contribution. Thus, skipjack trevally < 130 mm TL primarily consumed unidentified crustaceans and unidentified copepods, with minor contributions from tellinid bivalves, echinoids and cumaceans (Figure 57b,c). The volumes of each of these three categories increased in fish of 130-149 mm TL and other molluscs such as *T. infans*, eulimids, small gastropods, scaphopods and unidentified bivalves were also ingested. Molluscs dominated the diets of fish between 150 and 169 mm TL, with large volumes of tellenids and unidentified large bivalves being ingested, and smaller quantities of unidentified bivalves, scaphopods, together with echinoids, cumaceans and unidentified crustaceans. These dietary categories were also consumed by 170-189 mm TL skipjack trevally, as were some larger crustaceans, e.g. brachyurans and caridean and alpheid shrimp, which were rarely consumed by smaller fish.

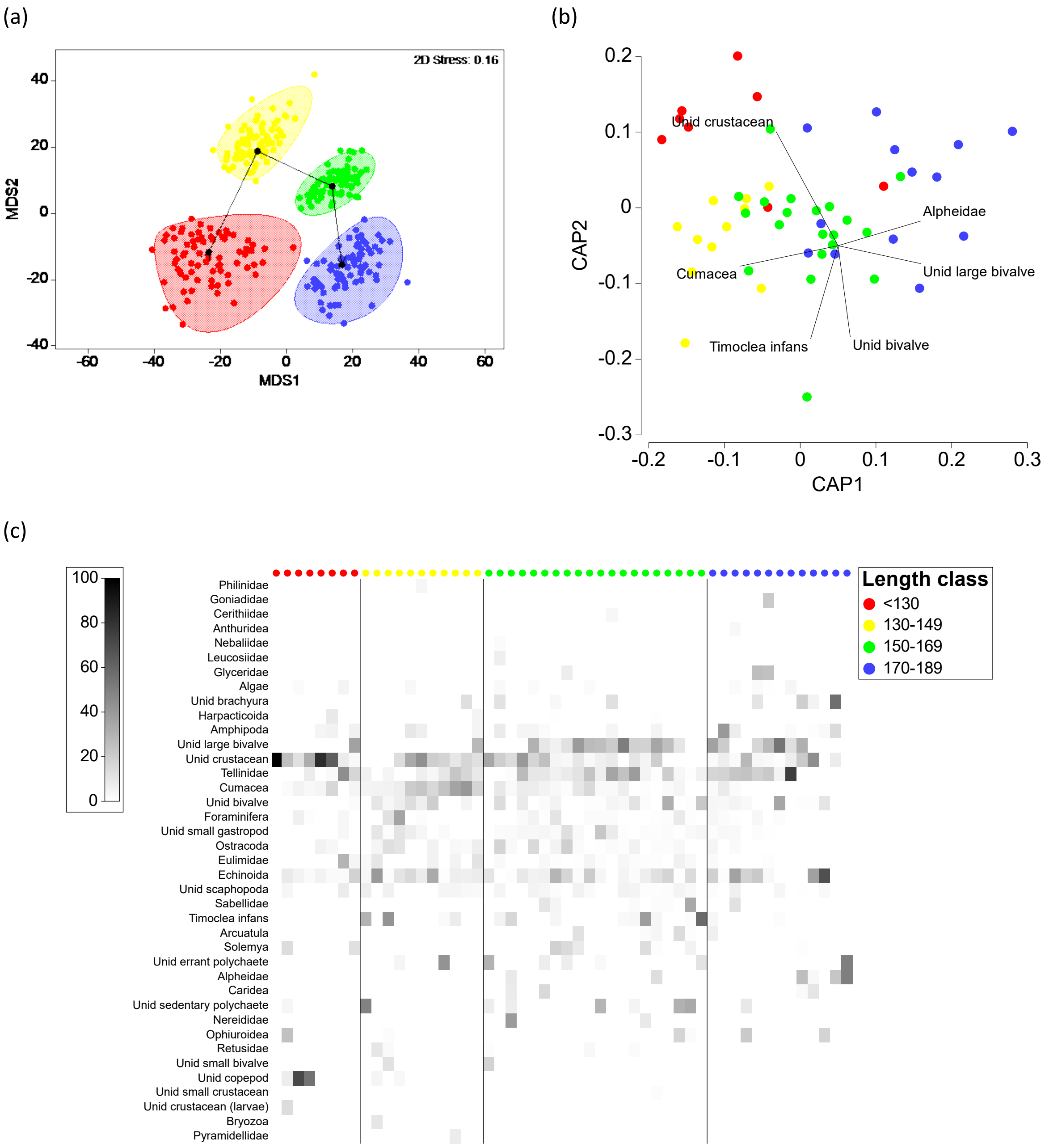


Figure 58. (a) mMDS plot constructed from the bootstrap averages of skipjack trevally of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) CAP plot illustrating differences in the dietary composition of skipjack trevally of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of skipjack trevally of different total length classes.

Regional differences in dietary composition were significant and moderately large overall (Global *R* = 0.614; *p* = 0.001) and among all three pairwise comparisons (*R* = 0.208-0.829; *p* = 0.001-0.003). The differences were greatest for comparisons involving Owen Anchorage, with this region being most discrete on the mMDS and CAP plots (Figure 59a,b). The diet of skipjack trevally in Owen Anchorage comprised several types of mollusc, including unidentified large bivalves, *Solemya* spp., tellinids, eulimids, small gastropods and scaphopods, together with sabellid polychaetes, ostracods, cumaceans and other unidentified crustaceans. Sabellids and large bivalves (including *Soemya* spp.) were rarely consumed in both Cockburn Sound regions, fish in South Cockburn Sound instead ingesting larger volumes of smaller bivalves, including tellinids and *T. infrans*, together with echinoids and cumaceans. The diet of skipjack trevally in North Cockburn Sound was similar to those in South Cockburn Sound, only that fish in the northern region also consumed some larger crustaceans, i.e. brachyurans, alpheids and carideans (Figure 59c).

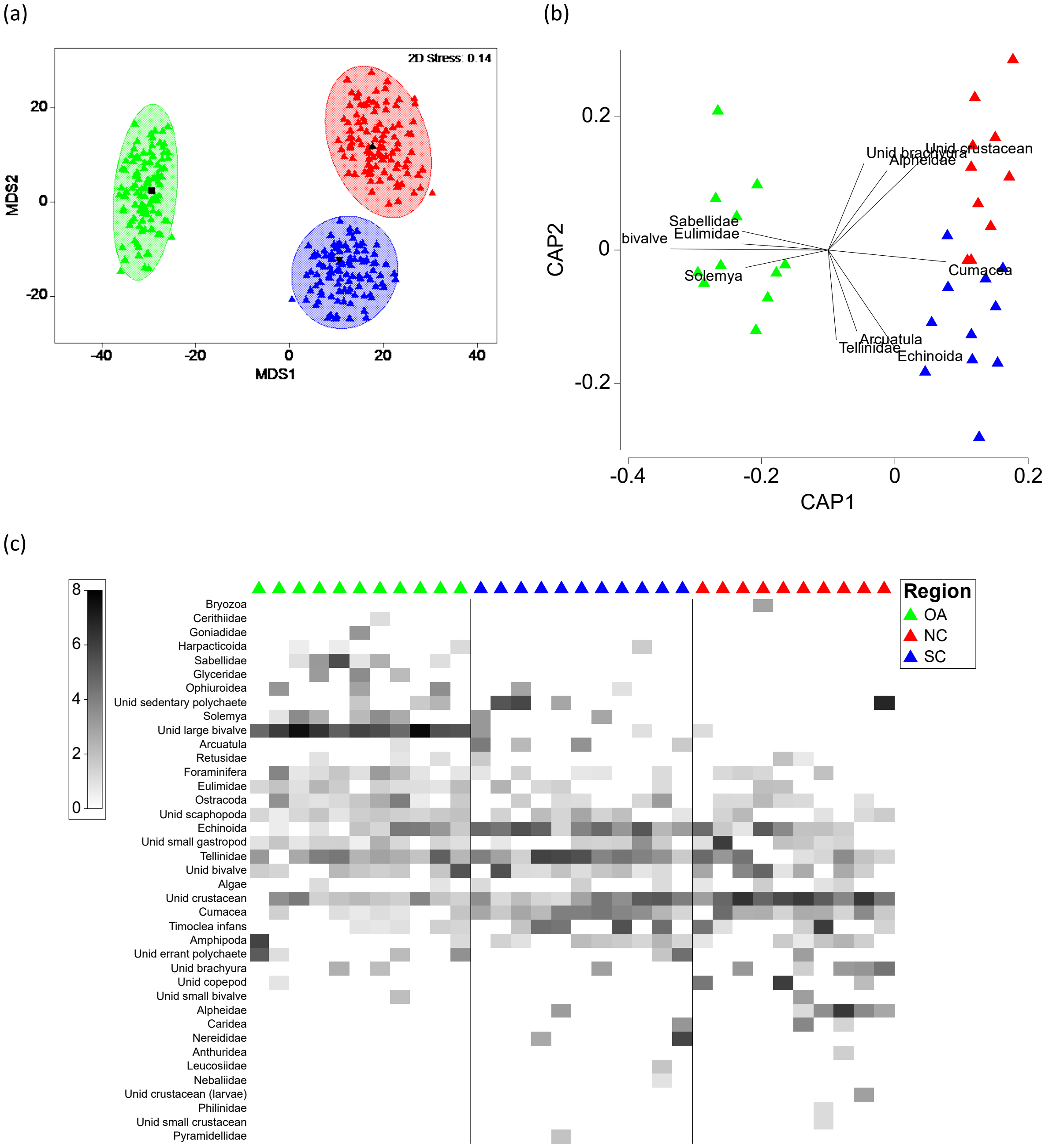


Figure 59. (a) mMDS plot constructed from the bootstrap averages of skipjack trevally from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of skipjack trevally from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of skipjack trevally from different regions of Cockburn Sound.

There was a marked seasonal difference in the dietary composition of skipjack trevally (Global R = 0.700; p = 0.001), with clear separation of the points representing spring and autumn on the mMDS plot (Figure 60a). Although many of the dietary categories were consumed in both seasons, unidentified large bivalves, tellinids, eulimids and cumaceans were consumed in consistently greater volumes by skipjack trevally in spring. In contrast, more *T. infans*, echinoids and several larger crustaceans, e.g. brachyurans, alpheids and carideans were consumed in autumn.

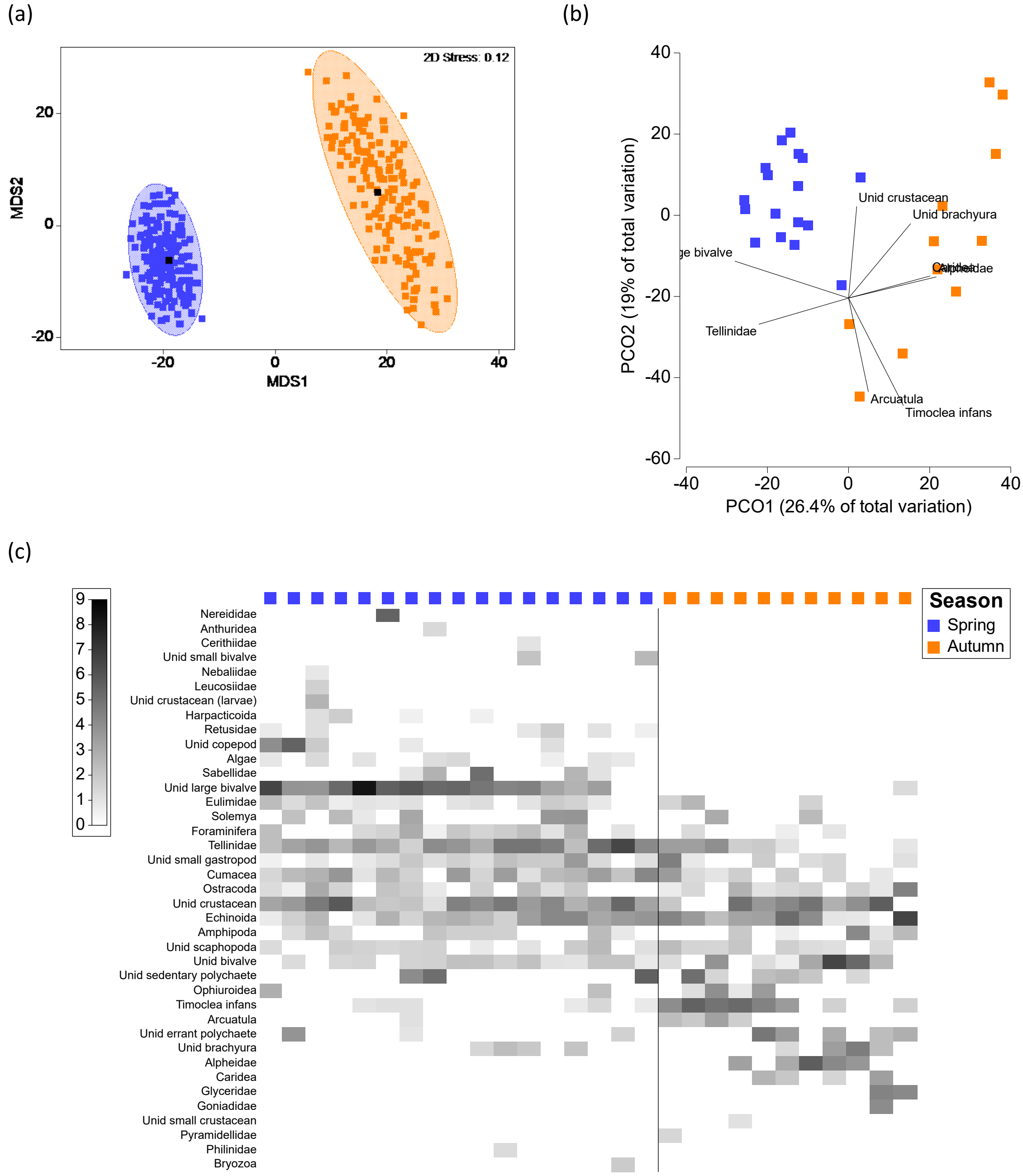
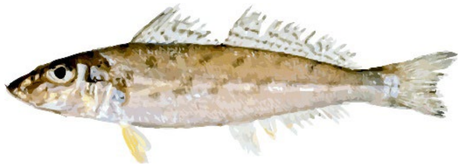


Figure 60. (a) mMDS plot constructed from the bootstrap averages of skipjack trevally caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of skipjack trevally caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of skipjack trevally caught in different seasons.



3.1.5.8. Western trumpeter whiting (*Sillago burrus*)

The diet of western trumpeter whiting comprised arthropods, annelids, molluscs and, to a lesser extent, also echinoderms (Figure 61). There was no clear ontogenetic shift in diet across the major taxa, with the relative contribution of the three major taxa varying inconsistently among length classes.

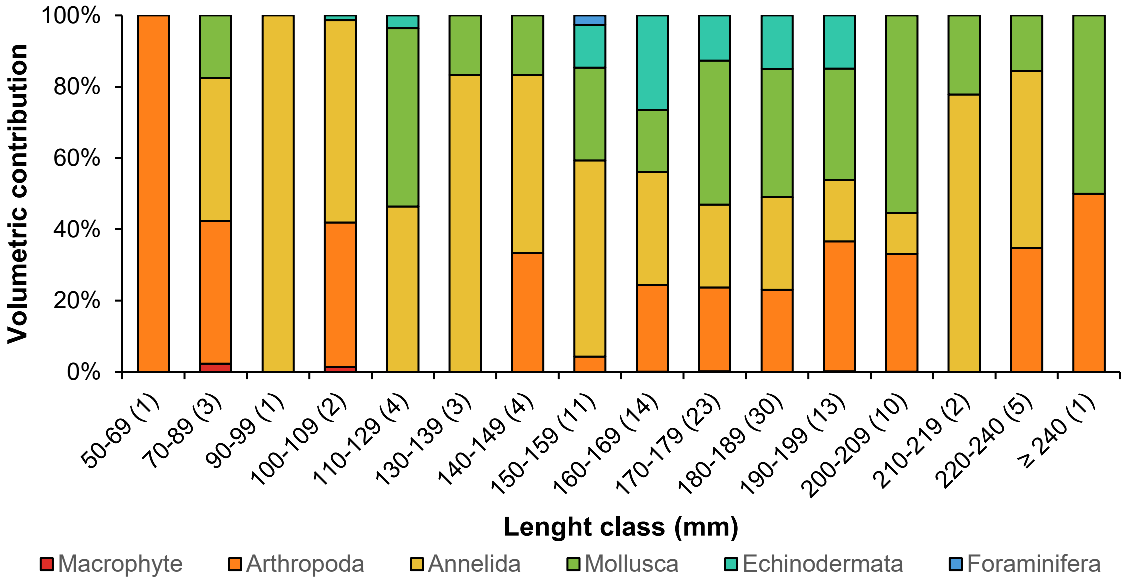


Figure 61. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of Western trumpeter whiting. n = 127 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes (Global *R* = 0.137; *p* = 0.033). Among the three pairwise comparisons, only that between 175-200 vs > 200 mm TL was significant (*R* = 0.232; *p* = 0.034), albeit that between 150-175 and > 200 mm TL was fairly close to being significant (*R* = 0.168; *p* = 0.081) and the points representing both of the smaller length classes did not overlap with those from fish > 200 mm TL on the bootstrapped mMDS plot (Figure 62a). Western trumpeter whiting of 150-174 mm TL consumed mainly unidentified errant and sedentary polychaetes, the bivalve *Solemya* spp., ophiuroids, echinoids and unidentified crustaceans (Figure 62b,c). These dietary categories also made substantial contributions to the diets of 175-200 mm TL fish. While unidentified errant polychaetes and *Solemya* spp. were a key component of the diet of fish > 200 mm TL. These larger individuals also consumed unidentified brachyurans and not echinoids or ophiuroids (Figure 61c).

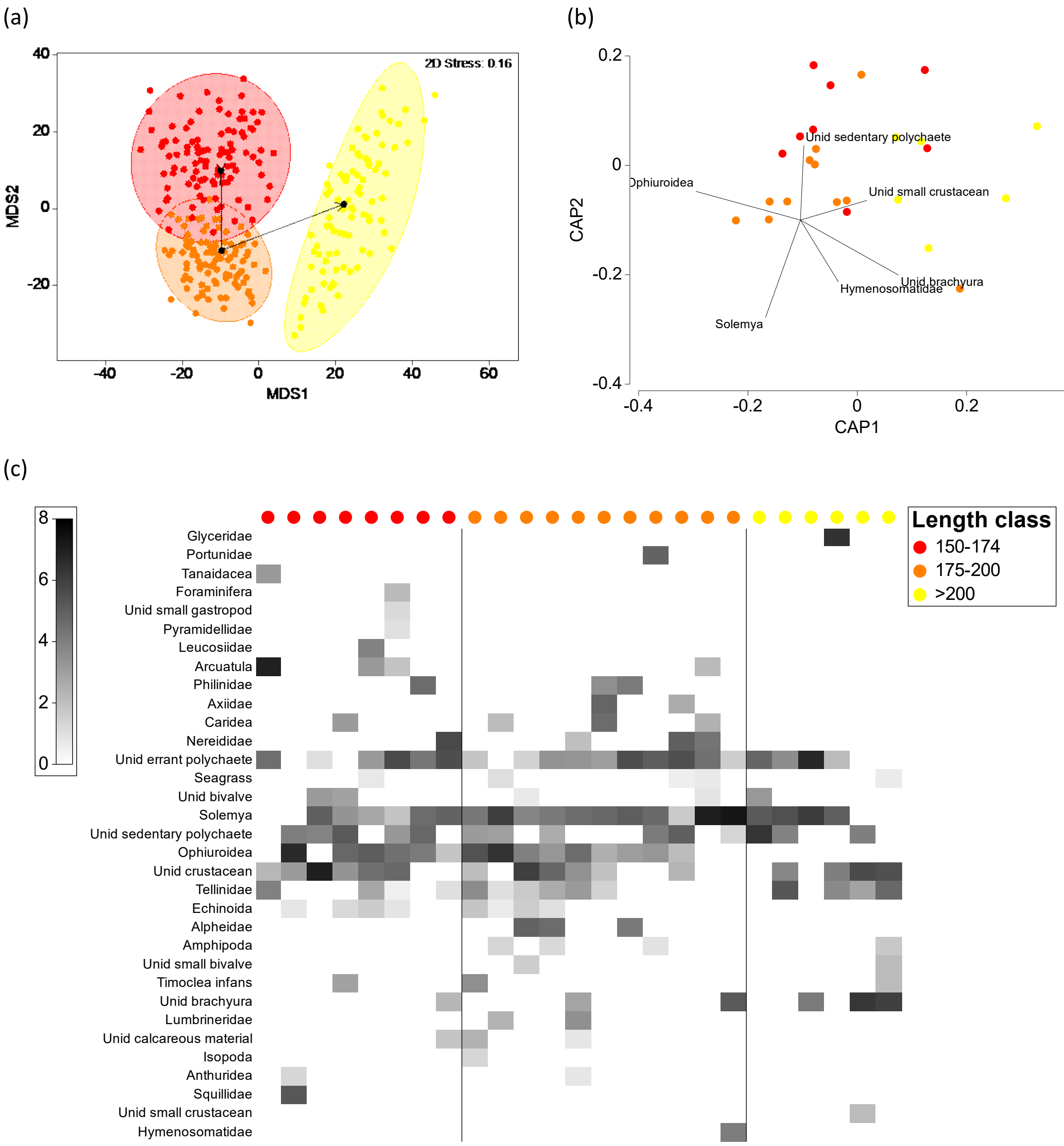


Figure 62. (a) mMDS plot constructed from the bootstrap averages of western trumpeter whiting of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) CAP plot illustrating differences in the dietary composition of western trumpeter whiting of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western trumpeter whiting of different total length classes.

Dietary composition differed significantly among regions overall (Global R = 0.348; p = 0.001) and among all three pairwise comparisons (R = 0.182-0.448; p = 0.001-0.008). The differences were greatest for comparisons involving Owen Anchorage (R = 0.422 and 0.4048) and least between North and South Cockburn Sound (R = 0.182), with these regions separated along the x-axis of the bootstrapped mMDS plot (Figure 62a). The separation of regions on the CAP plot matched that on the mMDS with diets of western trumpeter whiting in Owen Anchorage being typified by *Solemya* spp. and unidentified sedentary polychaetes, errant polychaetes and ophiuroids also being consumed in relatively large volumes by some fish (Figure 62b,c). *Solemya* spp. and ophiuroids made a far lower contribution to the diet in North Cockburn Sound, with unidentified errant polychaetes and tellinid bivalves being consumed in greater volumes. Echinoderms, i.e. ophiuroids and echinoids, were ingested in larger volumes in South Cockburn Sound than in other regions, as were unidentified crustaceans.

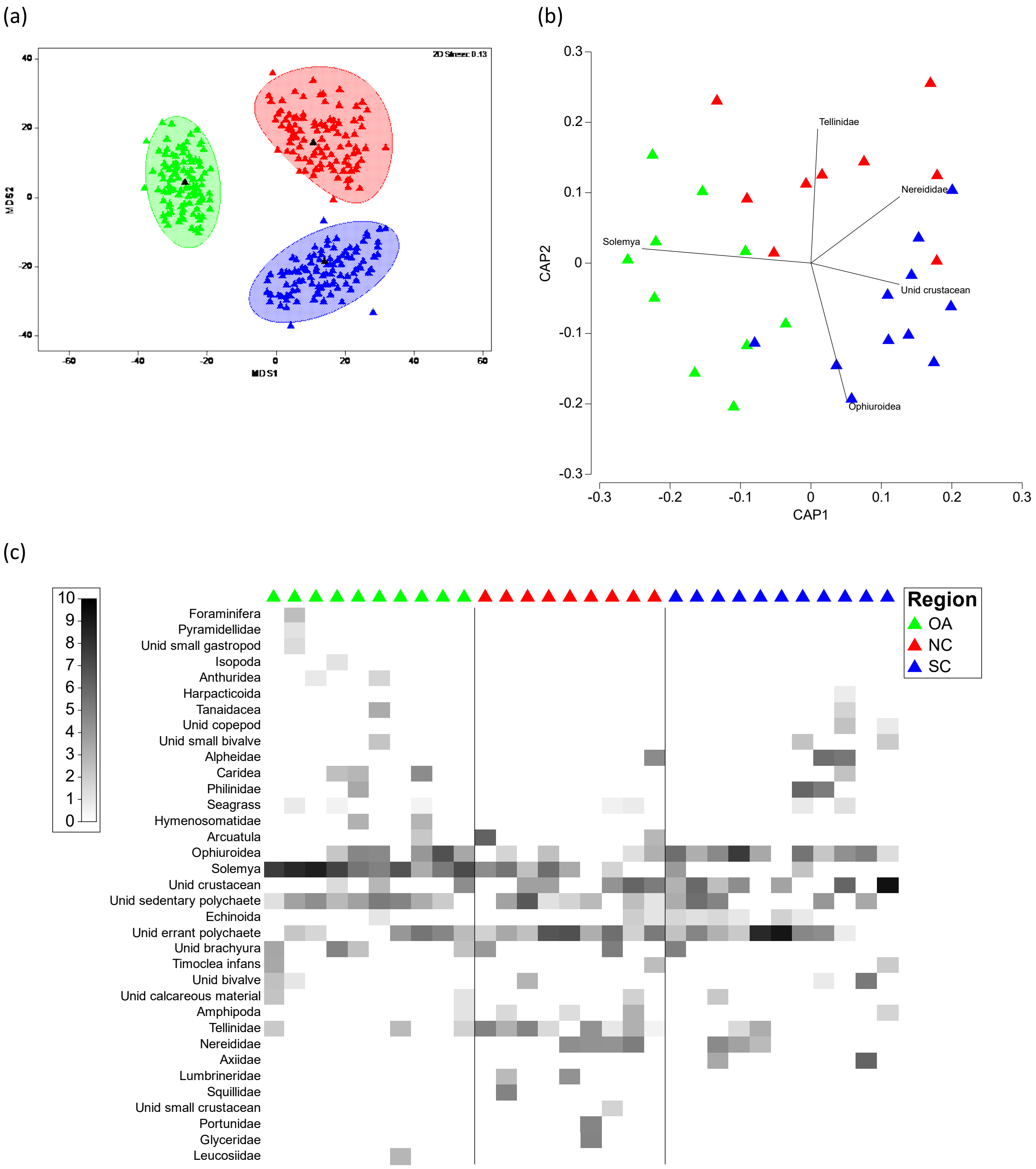


Figure 63. (a) mMDS plot constructed from the bootstrap averages of western trumpeter whiting from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of western trumpeter whiting from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western trumpeter whiting from different regions of Cockburn Sound.

Diet was also shown to vary among seasons (Global $R = 0.282$; $p = 0.002$), with the points representing spring and autumn forming discrete groups on the mMDS and PCO plots (Figure 63a,b). *Solemya* spp. unidentified crustaceans, unidentified sedentary polychaetes, errant polychaetes and ophiurids typified the diet in spring, as did *Solemya* spp., unidentified errant polychaetes and ophiurids in autumn. Despite the similarities in key dietary categories, unidentified crustaceans were consumed in greater volumes in spring as were tellinids and unidentified brachyurans, while the same was true for unidentified errant polychaetes and *Solemya* spp. in autumn (Figure 64c).

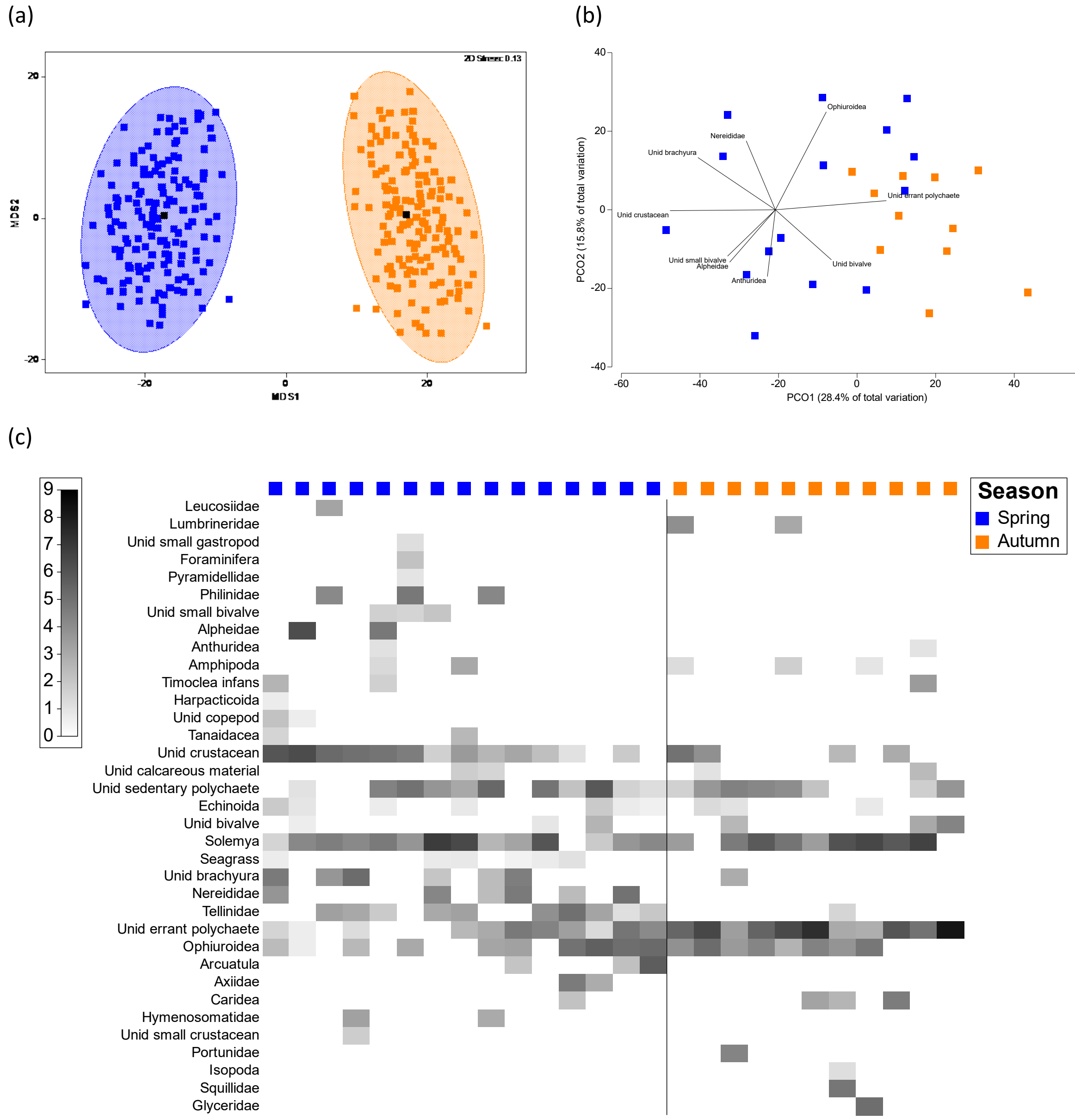


Figure 64. (a) mMDS plot constructed from the bootstrap averages of western trumpeter whiting caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of western trumpeter whiting caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western trumpeter whiting caught in different seasons.

3.1.5.9. Western butterfish (*Pentapodus vitta*)

The diet of western butterfish comprised seven major taxa with four of them, i.e. echinoderms, molluscs, arthropods and annelids being the most ingested and representing between 89 and 100% of the average total volume (Figure 65). The proportion of echinoderms tended to be greater in the larger fish, representing <2%V in those smaller than 90 mm TL and up to 62%V in fish > 180 mm TL. Chordates were only recorded in western butterfish > 140 mm TL, averaging 2.3% of the volume, but with a maximum of 10%V in the 140-149 mm TL class. Conversely, there was a decline in the volumetric contribution of annelids from 44 and 69%V in the two smallest TL classes to > 10% in four of the five largest TL classes. The proportions of molluscs and arthropods were variable, ranging from 0-50%V and 0-29%V, respectively, but did not undergo a sequential shift with ontogeny.

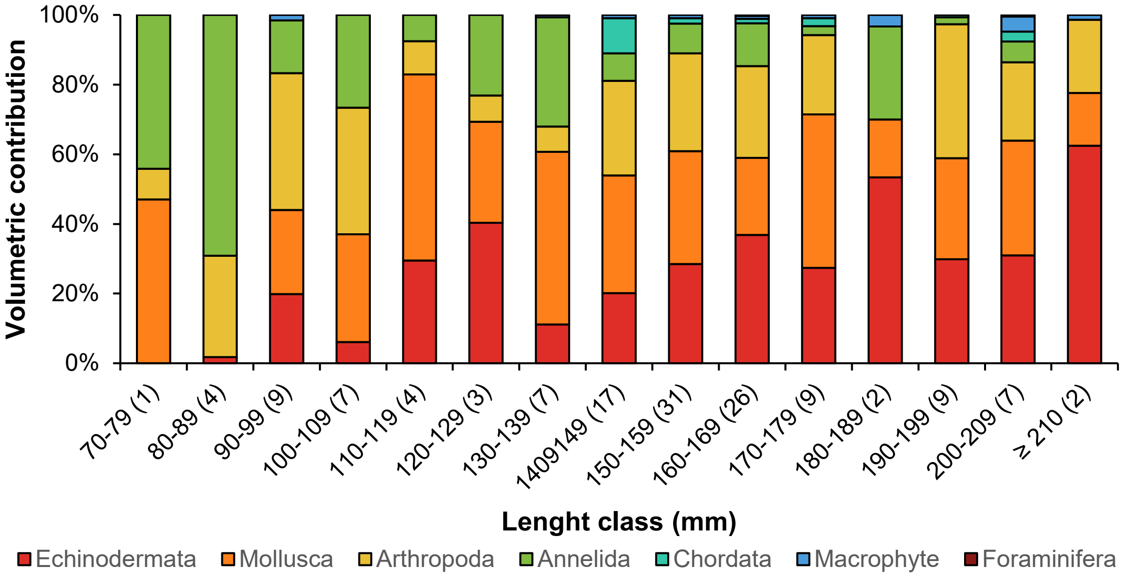


Figure 65. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of western butterfish. n = 138 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes (Global *R* = 0.172; *p* = 0.004). However, of the 28 pairwise comparisons, only eight were significantly different and were typically the smaller vs the larger individuals i.e. < 100 vs 150-159, 160-169 and > 190, 100-119 vs 150-159, 160-169 and > 190 and 120-129 vs both 150-159 and > 190 mm TL (*R* = 0.241-0400; *p* = 0.001-0.042). The relatively low *R*-statistic values reflect, in part, the broad range of prey this species fed on and precluded the use of two-dimensional bootstrapped mMDS ordination. Both the centroid nMDS and CAP plots support the ANOSIM results and indicate a shift in diet between western butterfish < 140 and > 140 mm TL (Figure 66a,b). Smaller fish had a narrower diet comprising predominantly polychaetes (unidentified errant, unidentified sedentary and unidentified polychaetes), together with unidentified crustaceans, *Solemya* spp. and retusids. In larger fish, polychaetes were less frequently ingested and in lower volumes and unidentified crustaceans, *Solemya* sp. and retusids still made a substantial contribution. A range of other dietary categories were recorded in larger fish including philinids, ophiuroids, echinoids and unidentified brachyurans (Figure 66c). Teleosts were also consumed infrequently by larger fish.

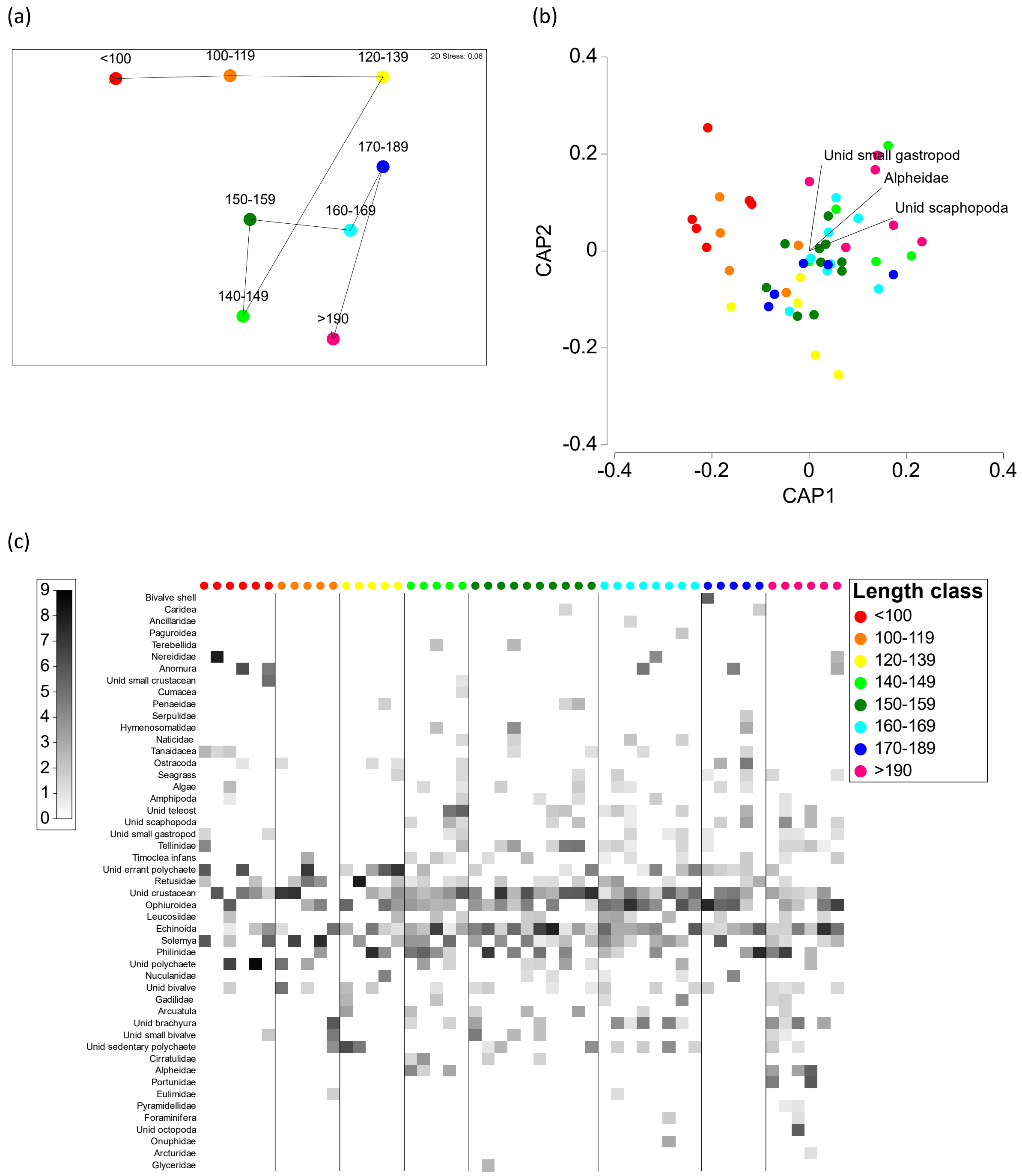


Figure 66. (a) centroid nMDS, with length classes sequentially connected by a black line, and (b) CAP plot illustrating differences in the dietary composition of Western Butterfish of different total length classes (mm). Vectors are provided on (b) for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western butterfish of different total length classes.

Regional differences in dietary composition were significant overall (Global *R* = 0.261; *p* = 0.001) and among all three pairwise comparisons (*R* = 0.113-0.494; *p* = 0.001-0.043). The differences were greatest between Owen Anchorage and South Cockburn Sound and least between the two regions in Cockburn Sound. This is reflected in the arrangement of the points on the mMDS plot (Figure 67a). Western butterfish in Owen Anchorage consumed anomurans and *Solemya* spp., leucosiids and retusids in greater volumes than fish in other regions (Figure 67b,c). Other prey, such as echinoids, ophiuroids and unidentified crustaceans also made substantial contributions to the diet of fish in this region but did so in North and South Cockburn Sound. The most notable difference in South Cockburn Sound was the ingestion of philinid gastropods, unidentified bivalves, polychaetes and *T. infans*.

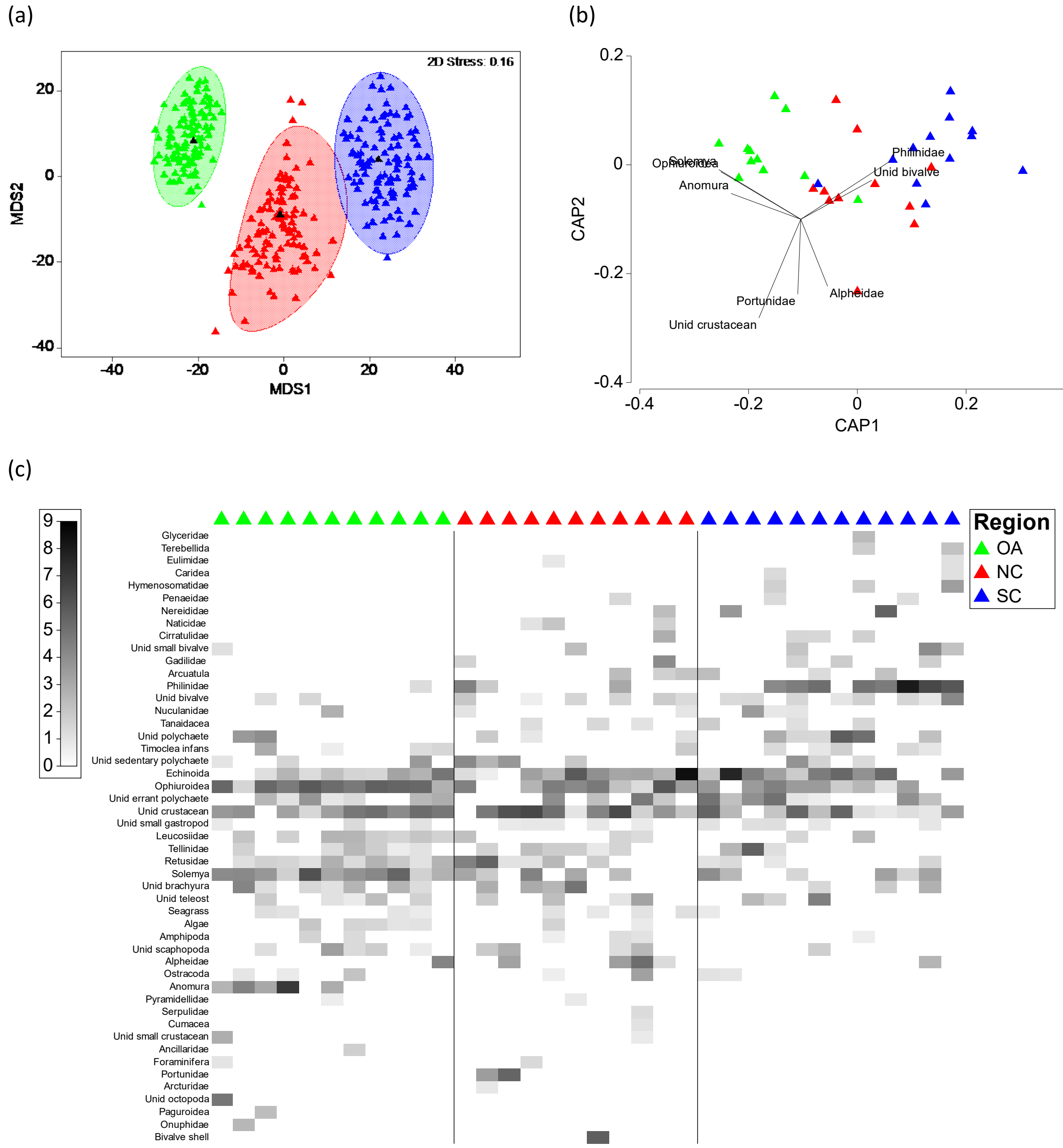


Figure 67. (a) mMDS plot constructed from the bootstrap averages of western butterfish from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of western butterfish from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western butterfish from different regions of Cockburn Sound.

The dietary composition of western butterfish also differed between the two seasons (Global $R = 0.407$; $p = 0.001$), with clear separation of the points representing spring and autumn on the mMDS and CAP plots (Figure 68a,b). A far broader range of prey was ingested during spring, including philinids, unidentified polychaetes, tellinids and leucosiids. Other dietary categories such as ophiuroids, *Solemya* spp. and retusids were ingested in greater volumes in spring than in autumn. In the latter season, western butterfish mainly consumed echinoids, ophiuroids, unidentified errant polychaetes, unidentified sedentary polychaetes and unidentified crustaceans (Figure 68c).

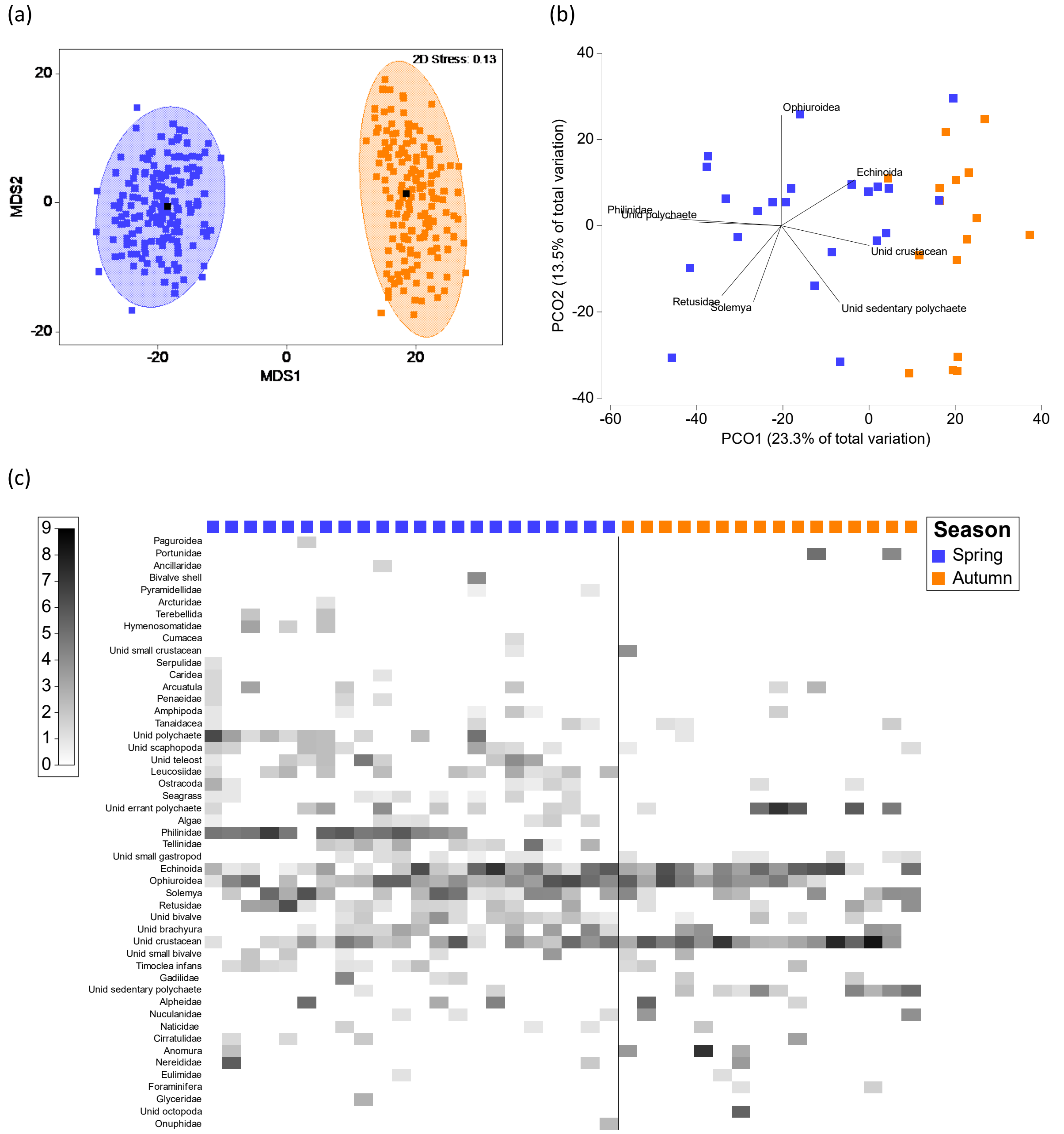
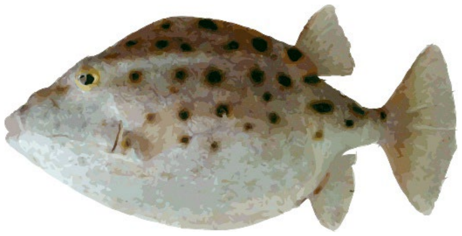


Figure 68. (a) mMDS plot constructed from the bootstrap averages of western butterfish caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of western butterfish caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western butterfish caught in different seasons.



3.1.5.10. Western smooth boxfish (*Anoplocarpus amygdaloides*)

The diet of western smooth boxfish comprised six major taxa ranging from macrophytes to chordates (Figure 69). Arthropods made the largest contribution to the diets of fish in both size classes (~37%V). There was, however, a decrease in the volume of annelids (26 vs 3%V) and also macrophytes and molluscs (both 13% vs ~ 4-6%V) in individuals > 150 mm TL, which was accompanied by an increase in the volume of echinoderms from 7 to 46%V. Chordates made up ~3%V of the diets in both length classes.

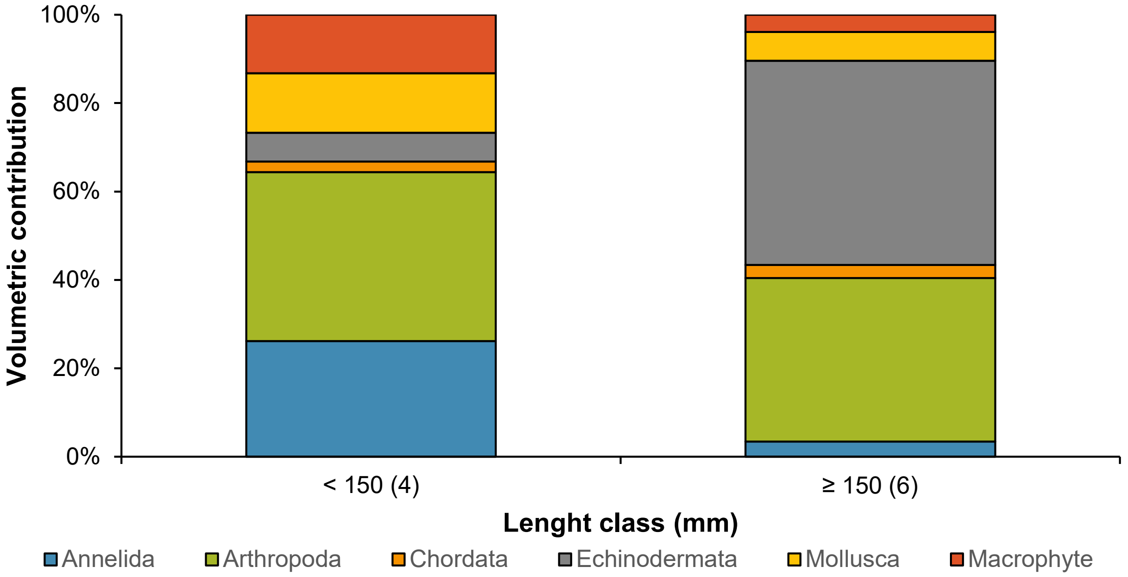


Figure 69. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of western smooth boxfish. n = 10 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected between the two TL classes (Global *R* = 0.349; *p* = 0.029). The bootstrapped averages for the < 150 mm TL class were more dispersed than those representing larger fish but there was no overlap of the 95% confidence regions (Figure 70a). This reflected greater variability in the diets of smaller western smooth boxfish with only unidentified crustaceans being recorded in more than 50% of individuals in that class (Figure 70c). In contrast, echinoids and the bivalve *T. infans* were recorded in most of the larger individuals. These two taxa were rarely ingested by smaller individuals which instead consumed greater volumes of errant polychaetes and unidentified crustaceans (Figure 70b,c).

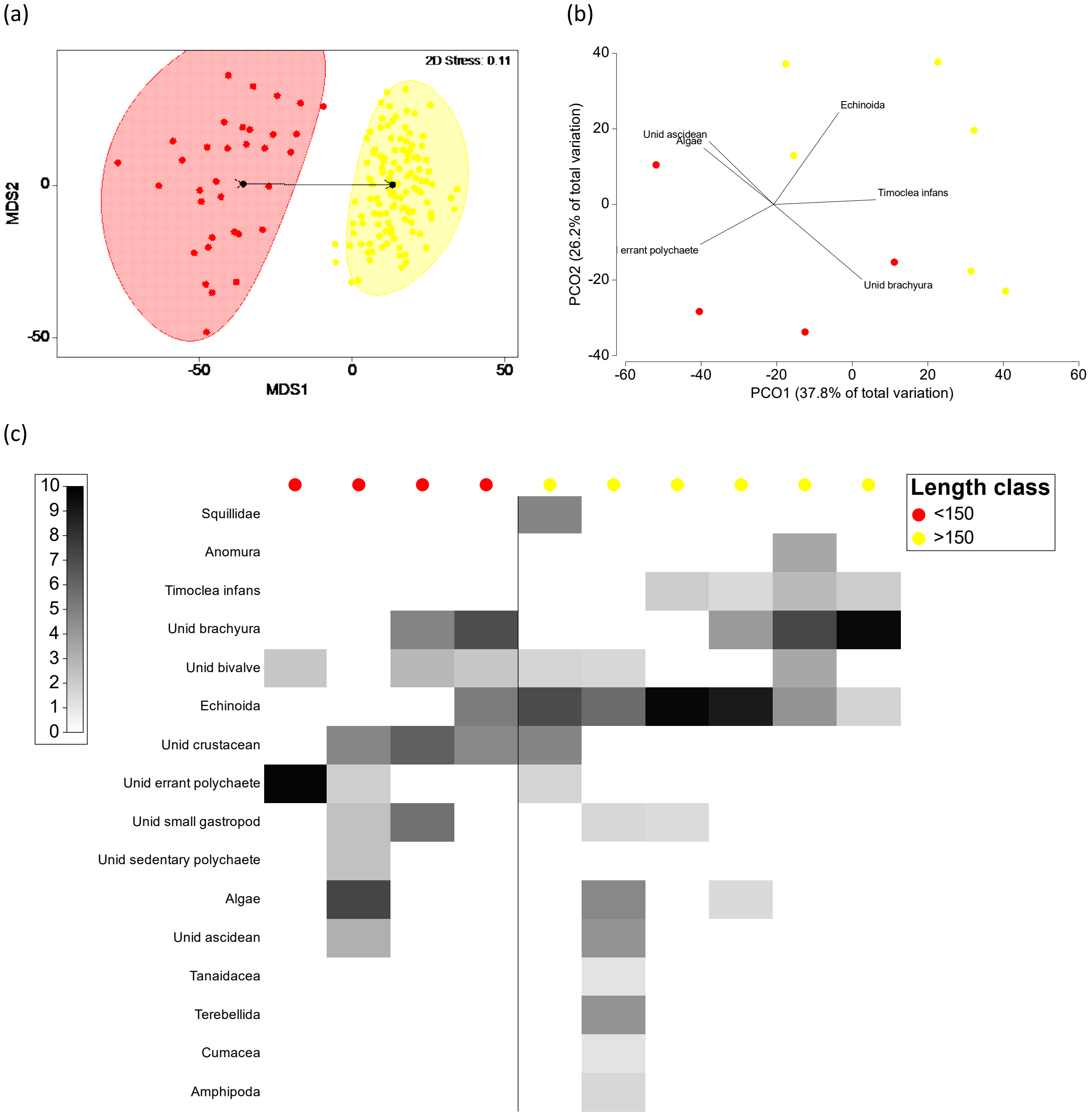


Figure 70. (a) mMDS plot constructed from the bootstrap averages of western smooth boxfish of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) CAP plot illustrating differences in the dietary composition of western smooth boxfish of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of western smooth boxfish of different total length classes.

3.1.5.11. Snapper (*Chrysophrys auratus*)

Overall, the diet of snapper was dominated by molluscs, arthropods and echinoderms and there was a clear difference in dietary composition among size classes (Figure 71). At least 80%V of the diet of smaller fish (100-149 mm TL) comprised molluscs and arthropods, with the contribution of molluscs decreasing sequentially from 67% to 28%V among the four length classes, while those of arthropods increased sequentially from 29% to 71%V. Annelids and echinoderms made a substantial contribution to diets of 110-119 mm TL snapper as did the latter major taxa in fish between 120 and 129 mm in length. Snapper in the largest size class (> 150 mm TL) ranged from 169-895 mm TL and consumed arthropods, echinoderms and chordates in roughly equal volumes (~26%V) and lower volumes of molluscs (14%V; Figure 71).

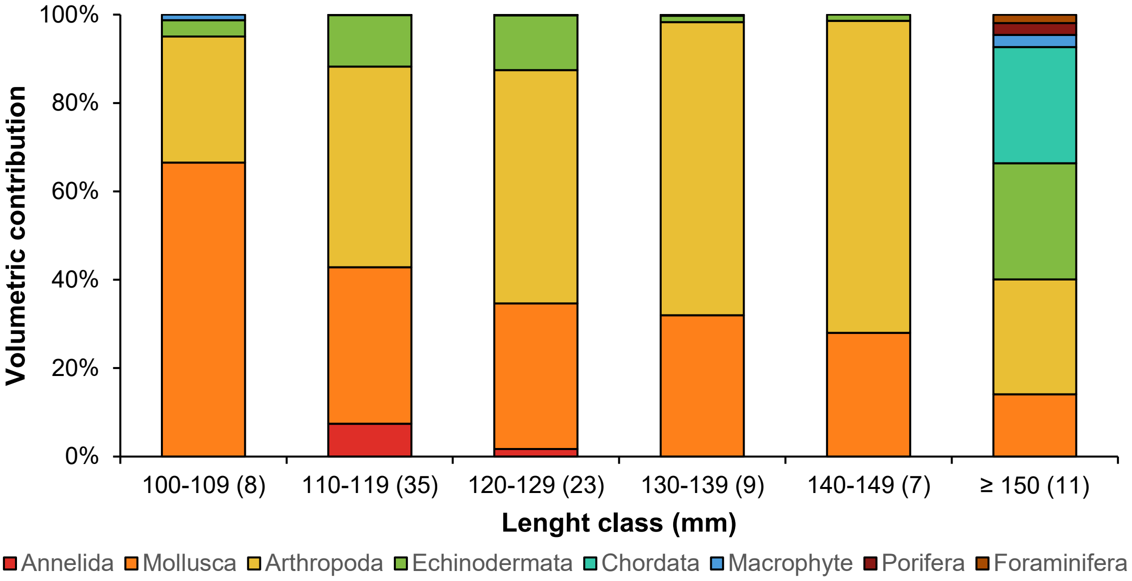


Figure 71. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of snapper. n = 97 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes (Global $R = 0.666$; $p = 0.001$) and all pairwise comparisons were significant ($p = 0.020 – 0.002$). The extent of the differences was least between the two smallest classes, i.e. 100-124 and 124-129 mm TL ($R = 0.547$) and most between each of those and > 200 mm TL ($R = 0.680$ and 0.881, respectively). The sequential shift in diet was mirrored in the arrangement of the points on both the mMDS and CAP plots (Figure 72a,b). Snapper in the smallest TL class consumed the broadest range of dietary categories, with their diet typified by minute gastropods in the Scaliolidae, the bivalves *Arcuatula* sp. and Retusidae spp., and small crustaceans such as cumaceans and amphipods (Figure 72b,c). Slightly larger snapper also consumed scaliolids, albeit in a lower volume and instead ingested unidentified brachyurans, crustaceans and large bivalves. Of the aforementioned dietary categories, only echinoids were consumed by the largest size class of snapper and instead, these individuals ingested teleosts (e.g. clupeid and callionymids), portunids and squillids.

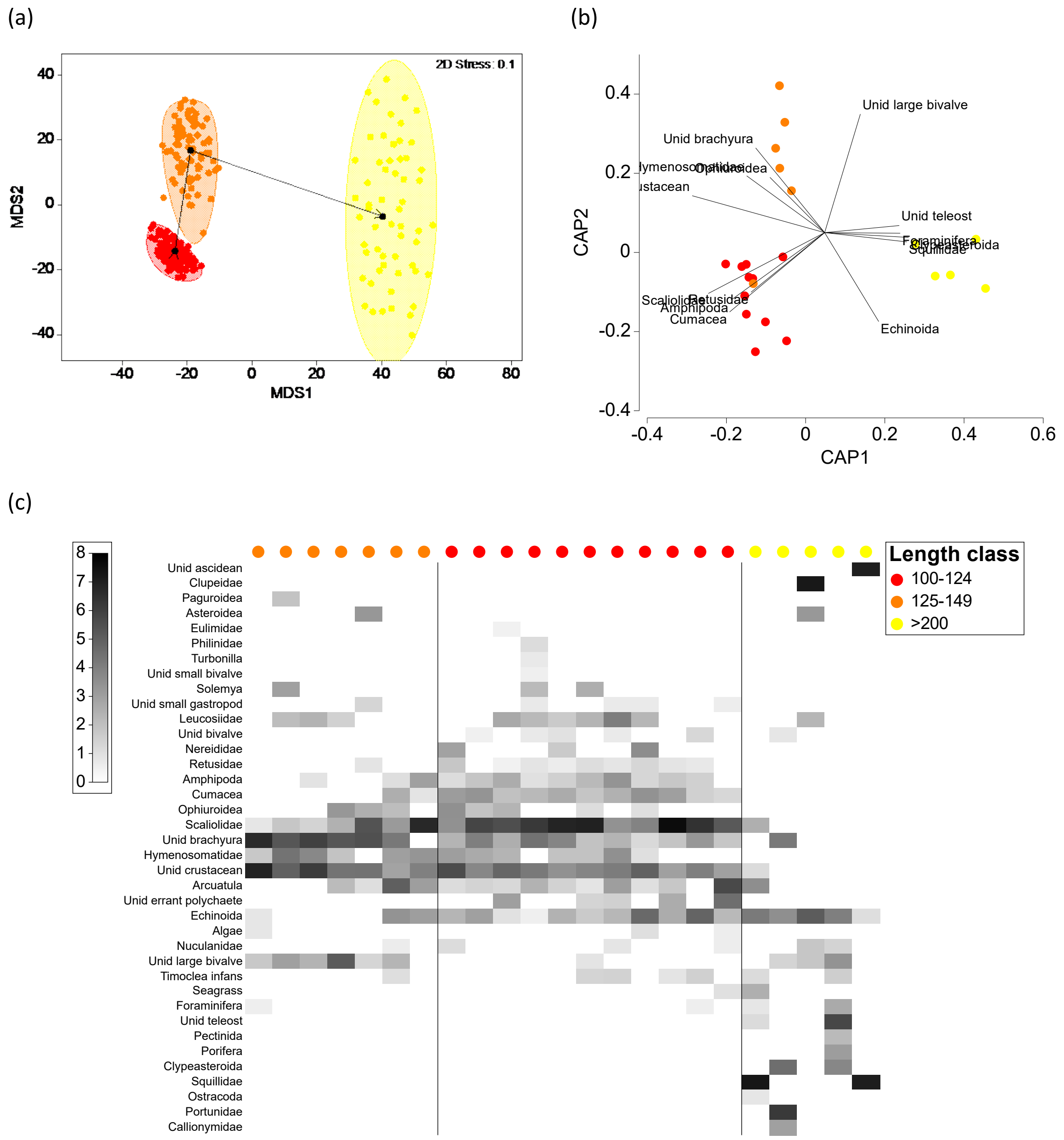


Figure 72. (a) mMDS plot constructed from the bootstrap averages of snapper of different total length classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided, with length classes sequentially connected by a black line. (b) CAP plot illustrating differences in the dietary composition of snapper of different total length classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of snapper of different total length classes. Snapper in the > 200 mm TL class ranged from 656 to 895 mm TL.

As the adult snapper (i.e. > 200 mm TL) were obtained with line-fishing only and from the D9 shipwreck, these individuals were not included in the regional comparison, which was restricted to small individuals collected via trawling. A significant difference was detected in the diet of snapper among regions overall (Global *R* = 0.545; *p* = 0.001) and all three pairwise comparisons (*R* = 0.215-0.943; *p* = 0.002-0.040). The differences were greatest between Owen Anchorage and each of the two regions in Cockburn Sound, with the points representing the former region being well separated on the left of the mMDS and CAP plots (Figure 73a,b). Snapper in Owen Anchorage had the narrowest diet and consumed mainly scaliolids, unidentified crustaceans, hymenosamatid crabs, and unidentified large bivalves (Figure 73c). While the first two dietary categories were consumed by snapper in all regions, the latter two were more prevalent in the diets of fish from Owen Anchorage. Snapper in both North and South Cockburn Sound consumed relatively large volumes of cumaceans and amphipods and those in South Cockburn Sound also echinoids (Figure 73c).

Despite sampling being undertaken, no snapper were caught by WWMSP Project "Spatial Distributions and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound" in autumn, therefore, no seasonal comparison could be conducted.

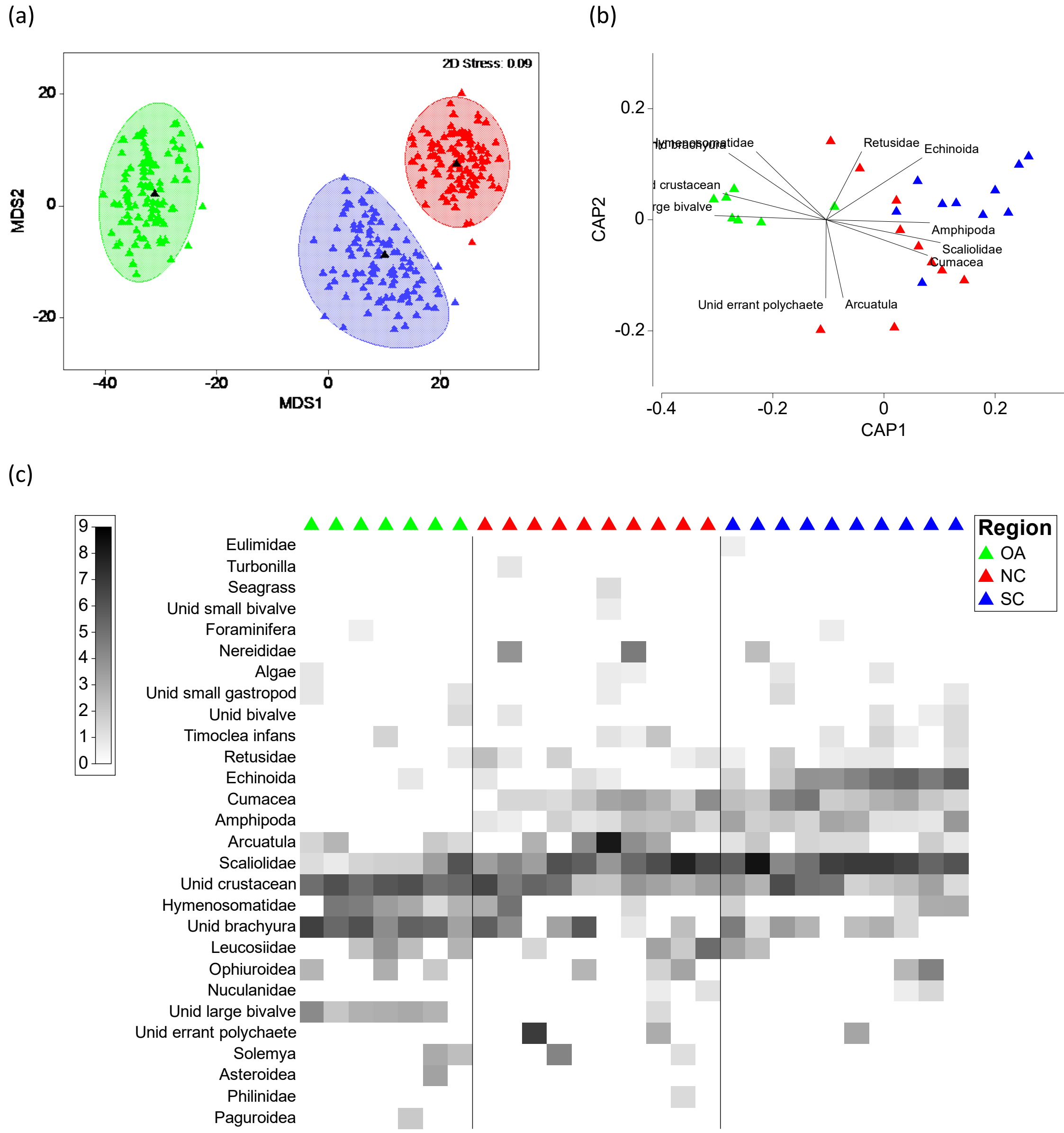
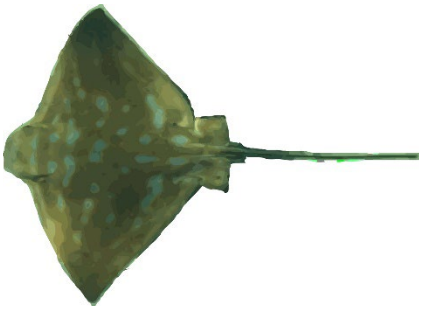


Figure 73. (a) mMDS plot constructed from the bootstrap averages of snapper from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of snapper from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of snapper from different regions of Cockburn Sound.



3.1.5.12. Southern eagle ray (*Myliobatis tenuicaudatus*)

The diet of southern eagle rays was dominated by arthropods and annelids and, to a lesser extent, molluscs (Figure 74). There was a sequential increase in the contribution of arthropods from 39 to 58%V with increasing disk width (DW), and a lower proportion of molluscs in the diets of the individuals in the largest two classes. Chordates were not consumed by rays < 500 mm DW and represented up to 13%V of the volume in the 600-699 mm DW class.

When statistically analysed using data at the diet category level, however, no significant difference was detected in dietary composition between the two DW classes (Global *R* = -0.056; *p* = 0.690). The bootstrapped averages representing each class intermingled on the mMDs plot and there was substantial overlap of the 95% confidence regions (Figure 75a). The lack of a difference was due to those dietary categories that made the largest and most consistent contributions to the volume, i.e. portunid crabs, squillids and errant and sedentary polychaetes, being consumed by rays in both DW classes (Figure 75b).

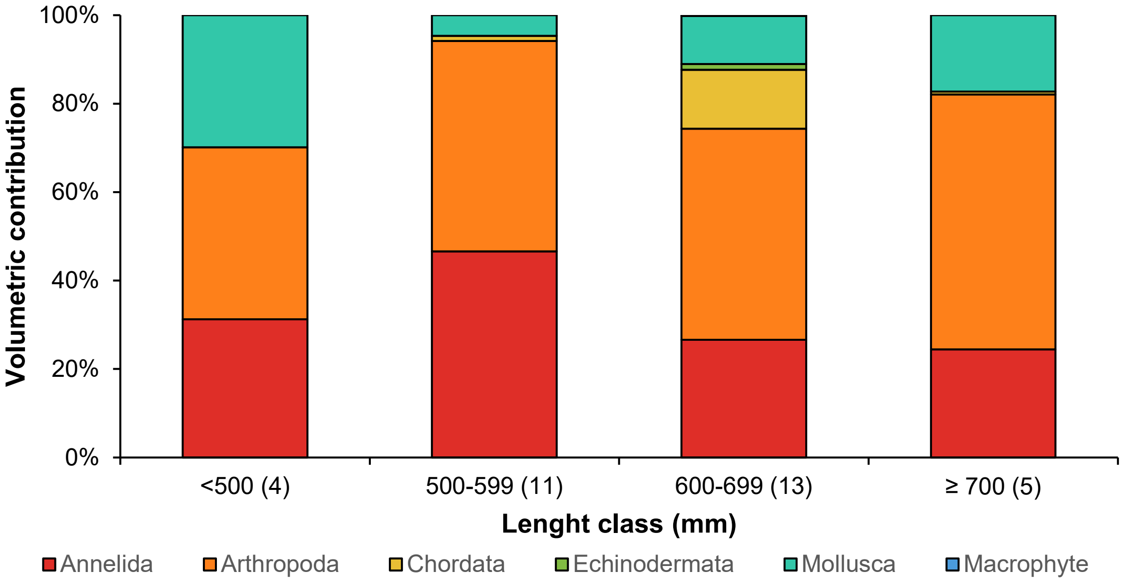


Figure 74. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of southern eagle ray. n = 33 overall and for each length class given in parentheses.

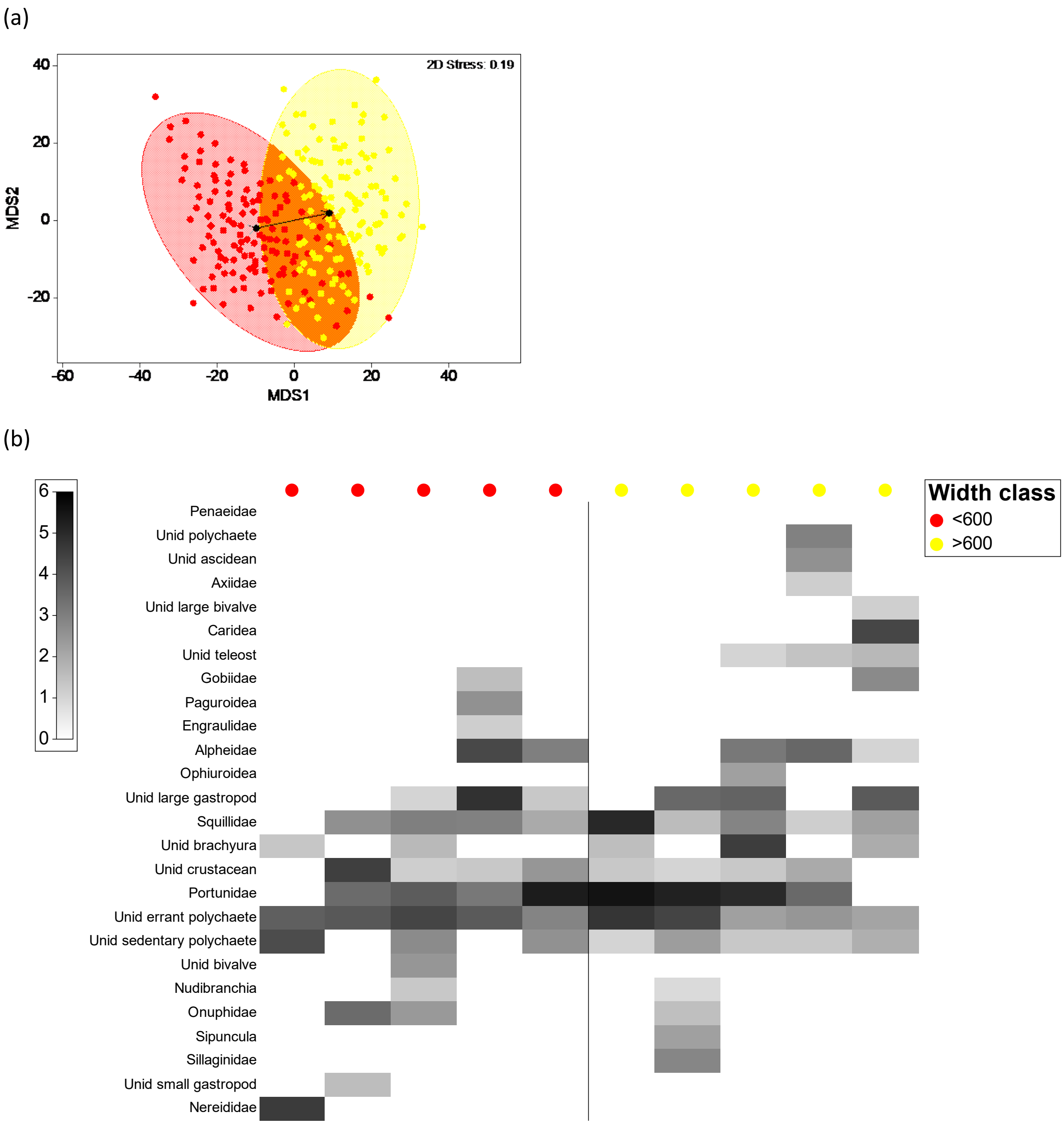


Figure 75. (a) mMDS plot constructed from the bootstrap averages of southern eagle rays of different disk width classes (mm). Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of southern eagle rays of different disk width classes. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of southern eagle rays of different disk width classes.

3.1.5.13. Rusty flathead (*Inegocia japonica*)

The diet of rusty flathead was dominated by arthropods and chordates, and with annelids making a substantial contribution in several length classes (Figure 76). There was a tendency for the volume of arthropods to decrease with increasing length class and for those of chordates to increase.

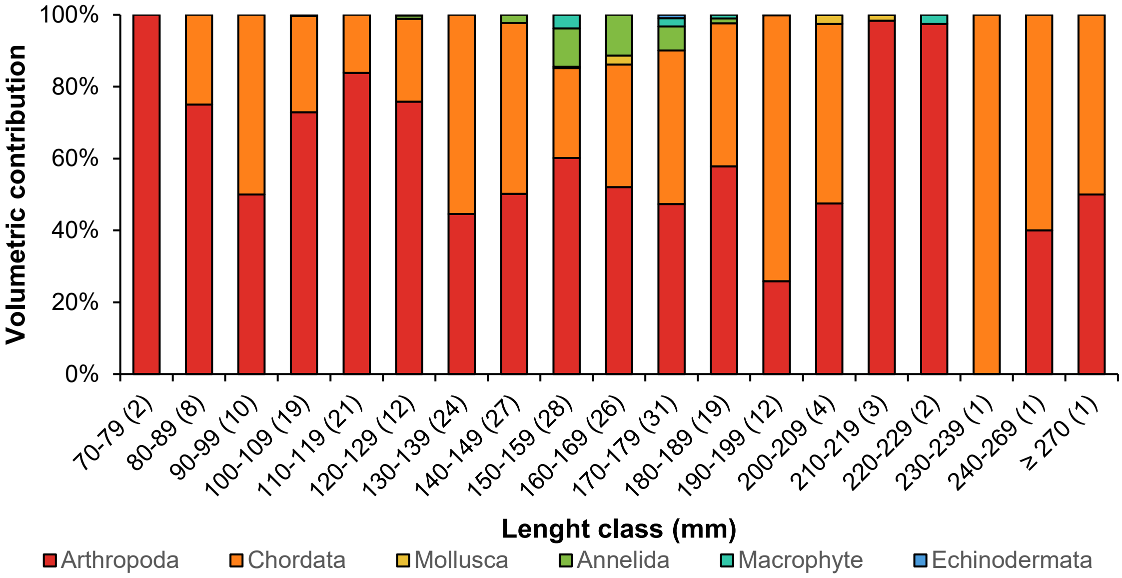
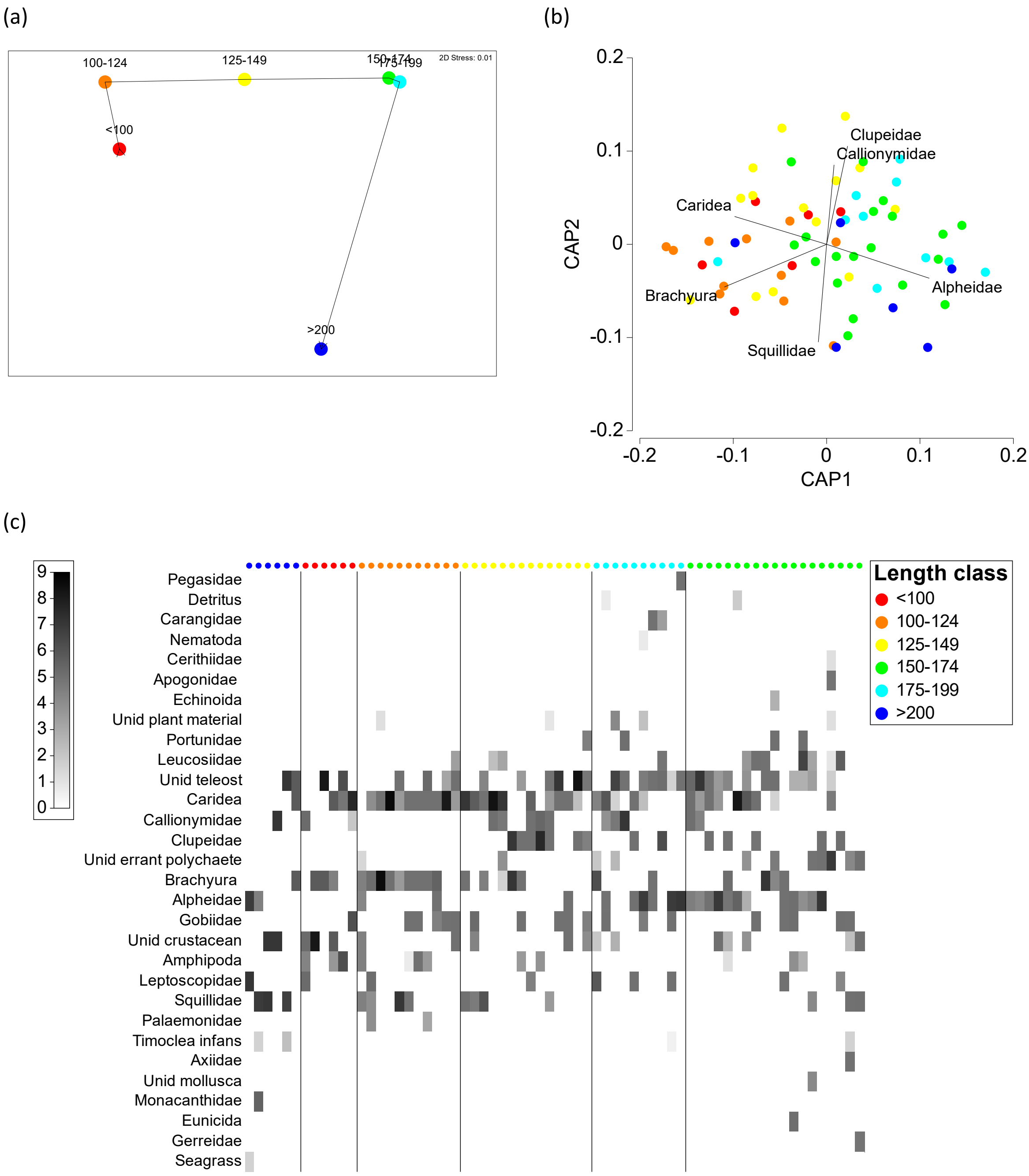


Figure 76. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of Rusty flathead. n = 251 overall and for each length class given in parentheses.

A significant difference in dietary composition at the dietary category level was detected among TL classes (Global *R* = 0.180; *p* = 0.002). Among the 15 pairwise comparisons, 11 differed significantly (*R* = 0.118-0.148; *p* = 0.002-0.230), with only <100 vs 125-149, < 100 vs >200; 150-174 vs 175-199 and 175-199 vs > 200 mm TL not being different. Typically, the largest differences in diet were between fish in the TL class that were most different in body size (i.e. smallest vs largest individuals). The point representing each TL class on the centroid nMDS plot followed a clockwise order, with most being separate except for 150-174 and 175-199 mm TL (Figure 77a). When subjected to constrained ordination, the points for the fish < 149 mm TL (smallest three classes) typically lay on the left side of the CAP1 axis (values < 0) and those for the larger three classes, > 150 mm TL on the right (values > 0; Figure 77b). Rusty flathead in the smallest two length classes (i.e. < 124 mm TL) consumed mainly caridean shrimp, brachyurans and some amphipods, with carideans, together with some teleosts (e.g. clupeids and gobiids) increasing in volume in individuals of 125-149 mm TL (Figure 77c). Rusty flathead in the largest three classes consumed mainly alpheids and unidentified teleosts.

(a)

(b)



(c)

Figure 77. (a) centroid nMD , with length classes sequentially connected by a black line, and (b) CAP plot illustrating differences in the dietary composition of rusty flathead of different total length classes (mm). Vectors are provided on (b) for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of rusty flathead of different total length classes.

Regional differences in dietary composition were detected, albeit the extent of the difference was fairly low (Global *R* = 0.121; *p* = 0.001). At a pairwise level, Owen Anchorage was different from both regions of Cockburn Sound (*R* = 0.305-0.301; both *p* = 0.001) and there was no difference between North and South Cockburn Sound (*R* = 0.004; *p* = 0.364). The distinctness of the diets of fish caught in Owen Anchorage is reflected in their points being well separated from those of the other regions on the bootstrapped mMDS plot and, to a lesser extent, the CAP ordination (Figure 78a,b). Rusty flathead in Owen Anchorage had a narrow diet with alpheids being the only dietary category occurring in all samples and was also in large volumes (Figure 77c). This prey was also consumed by individuals in North and South Cockburn Sound, but less frequently. Instead, other crustaceans such as carideans, brachyurans, squillids, and fish such as unidentified teleosts, gobiids and callionymids were ingested.

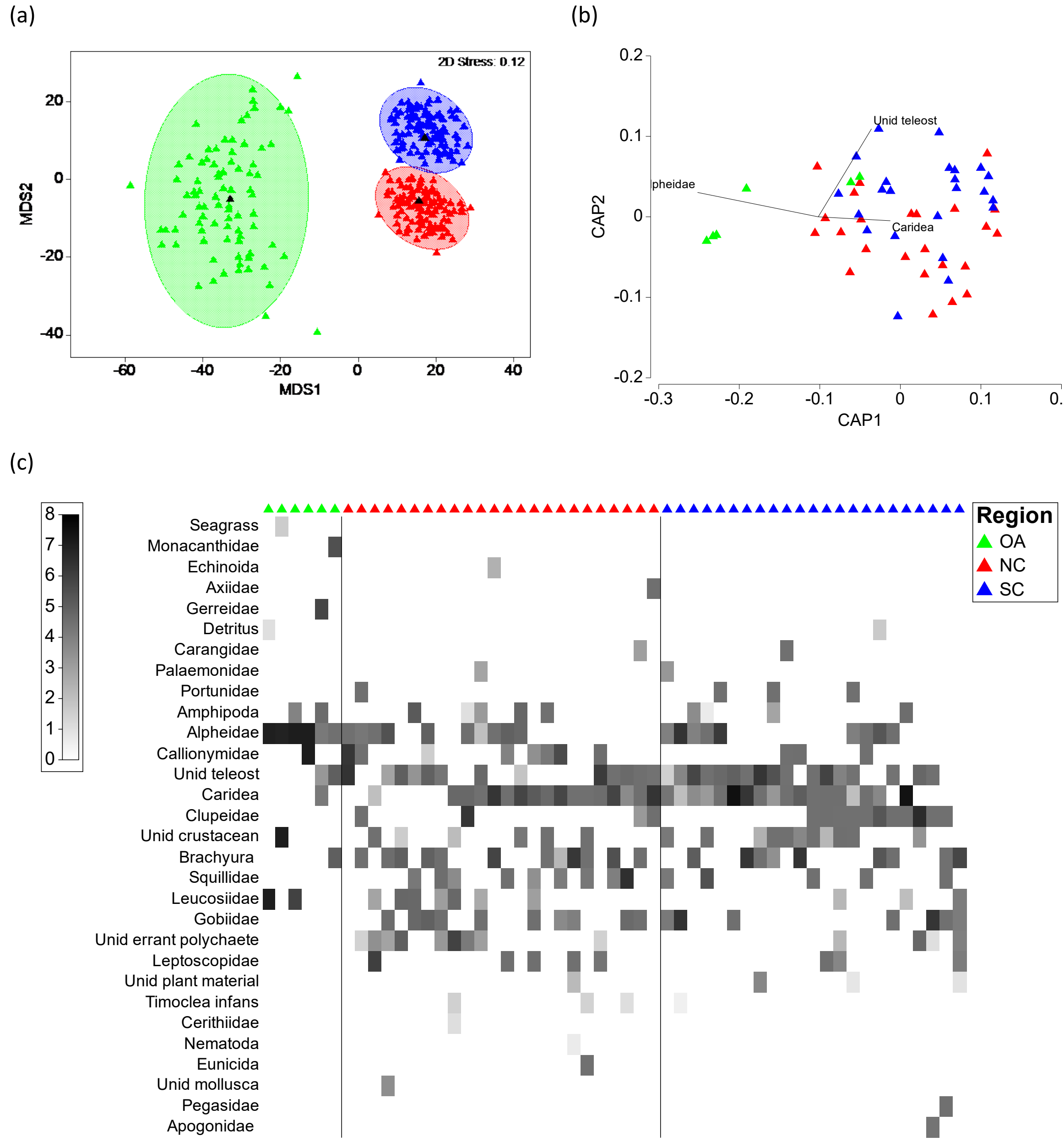


Figure 78. (a) mMDS plot constructed from the bootstrap averages of rusty flathead from different regions of Cockburn Sound. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) CAP plot illustrating differences in the dietary composition of rusty flathead from different regions of Cockburn Sound. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.5) relative to the CAP axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of rusty flathead from different regions of Cockburn Sound.

The dietary composition of rusty flathead also differed among seasons (Global *R* = 0.432; *p* = 0.001), with clear separation of the points representing spring and autumn on the mMDS plot (Figure 79a). Clupeids, alpheids, carideans and unidentified teleosts dominated the diet of rusty flathead in spring, with greater volumes of clupeids, leucosiid crabs and errant polychaetes ingested in that season than in autumn. The diet in autumn also contained alpheids, carideans and unidentified teleosts but, unlike in spring, also gobiids, callionymids, squillids and brachyurans (Figure 79b,c).

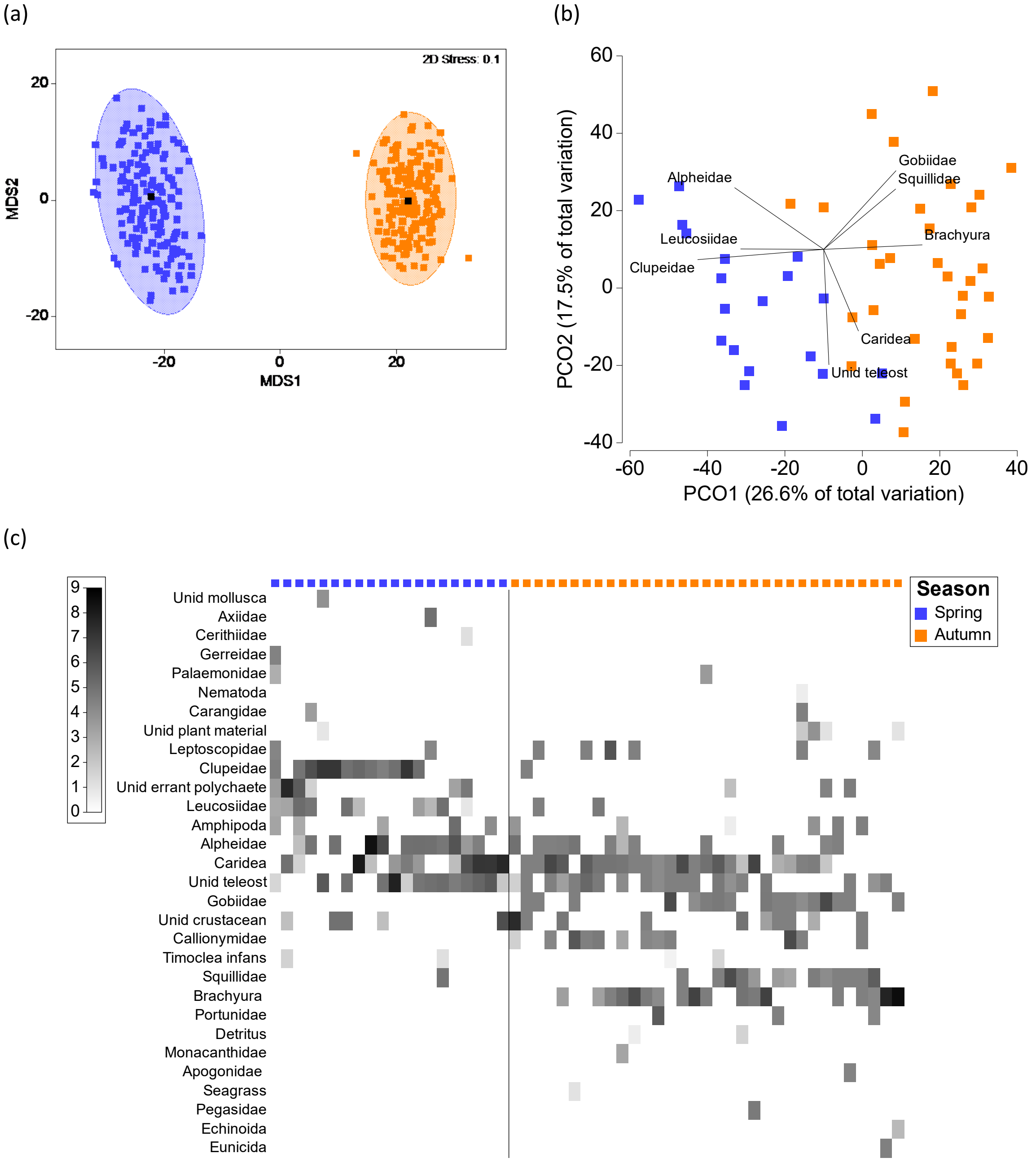
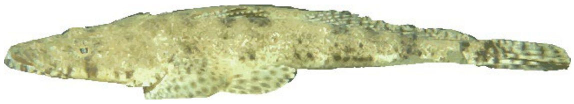


Figure 79. (a) mMDS plot constructed from the bootstrap averages of rusty flathead caught in different seasons. Group averages (black symbols) and 95% confidence regions fitted to the bootstrap averages are provided. (b) PCO plot illustrating differences in the dietary composition of rusty flathead caught in different seasons. Vectors are provided for dietary categories whose volumetric contribution changed in a linear direction (Pearson correlation > 0.6) relative to the PCO axes. (c) Shade plot of the square-root transformed percentage volumetric contribution of each dietary category to the diet of rusty flathead caught in different seasons.



3.1.5.14. Other flathead species

The diet of longhead flathead comprised mainly arthropods and chordates (combined 91-100% of the total volume; Figure 80a). The contribution of arthropods decreased with increasing body size, sequentially from 96%V in individuals < 200 mm to 50%V in fish > 300 mm TL. Conversely, the volume of chordates increased from 4 to 50%V. Molluscs were consumed by Longhead Flathead between 200 and 299 mm TL and represented ~9%V of the total volume of fish in this class. Longspine flathead consumed mainly arthropods and chordates, with the former prey decreasing with increasing body size as did the contribution of annelids (Figure 80b). In contrast, the volume of chordate prey increased from 20%V in individuals < 200 mm TL to 67%V in those > 250 mm TL.

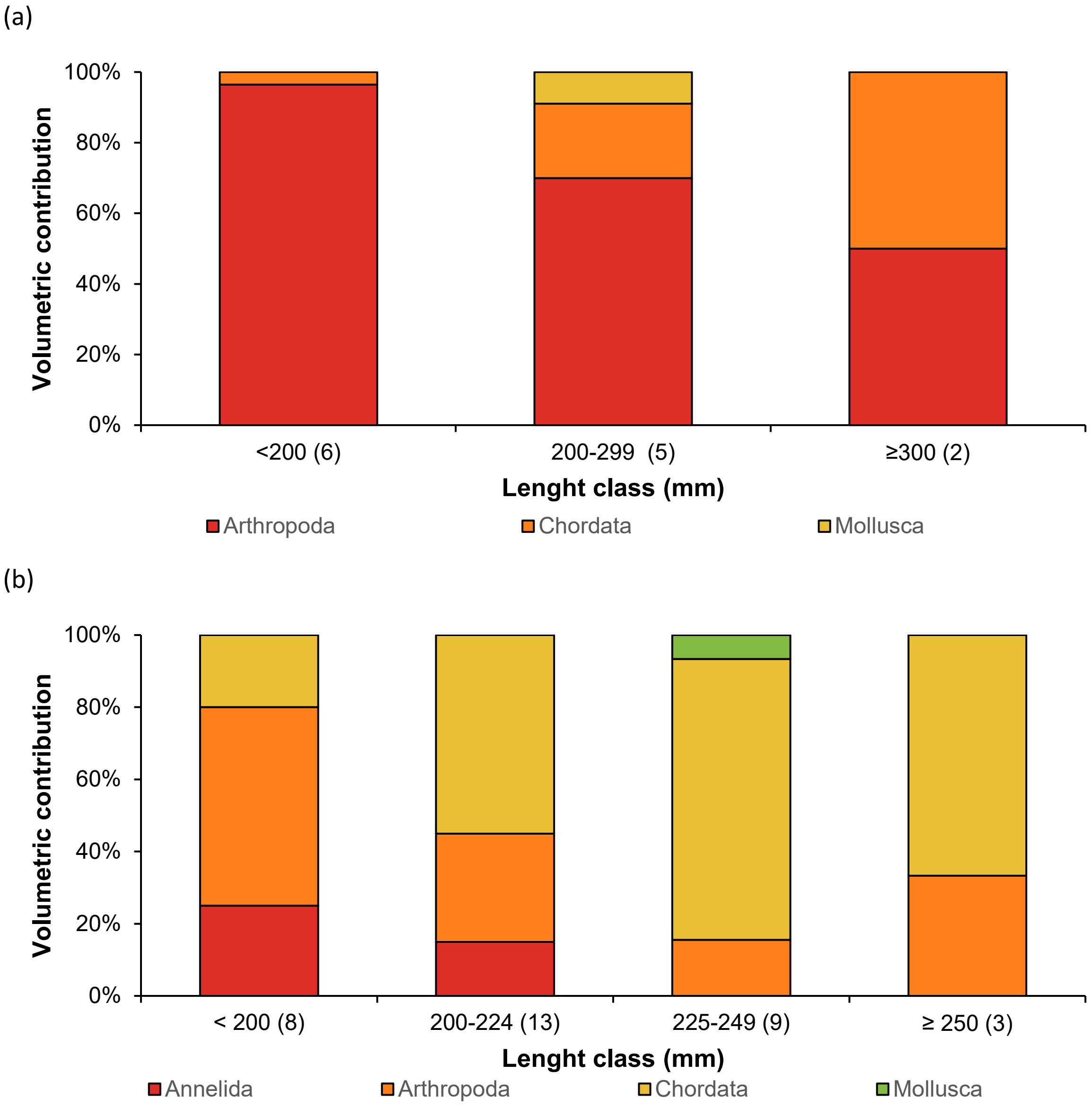


Figure 80. Mean percentage volumetric contributions of key major prey taxa to the diets of increasing total length classes of (a) longhead flathead (n = 13) and (b) longspine flathead (n = 33). n for each length class given in parentheses.

3.2. Stable isotope analysis

This section describes the results of SIA, initially focusing on the stable isotope values of potential sources that drive the food web in Cockburn Sound (Section 3.2.1), followed by the variability of stable isotopes in the sedimentary POM and the sources of inputs into the POM (Section 3.2.2), a summary of the stable isotope signatures in different functional groups of consumers including invertebrates, fishes, penguins and marine mammals (Section 3.2.3) and the variability in those signatures for key consumer species for which sufficient samples sizes were available for analyses (Section 3.2.4). Subsequently, summaries of the stable isotope signatures, along with the predicted sources that contribute to the assimilated nutrients of key invertebrates (Section 3.2.5) and fishes (Section 3.2.6) are presented.

3.2.1. Carbon, nitrogen and sulphur isotopic variation of sources and sedimentary POM

All macrophytes had mean δ^{15}N values <6.6‰, with the brown algae *Ecklonia radiata* and *Sargassum* spp. and the red algae *Laurencia* spp. having the most enriched δ^{15}N values (Figure 81). The brown alga *Padina* sp. and the red alga *Sarconema* sp. had more depleted δ^{15}N values but fit within the range for δ^{13}C for these macroalgae (~-13 to -19‰). The brown alga *Hydroclathus* sp. had higher δ^{13}C values and similar to the seagrass *Amphibolis* spp. (~ -13‰), while δ^{13}C for the seagrass *Posidonia* was further enriched at ~-9‰. Seston (phytoplankton and suspended particulate material) had more depleted δ^{13}C values (-23.5‰). For δ^{34}S, macroalgae had elevated values (19.3-23.1‰) compared to seagrass (16.5-17.7‰, Figure 81). The mean δ^{34}S value for seston fell within the range of those for macroalgae.

Figure 81. Bi-plots of δ^{13}C vs δ^{15}N and δ^{13}C vs δ^{34}S of different primary producers, invertebrates, functional groups of finfish, and penguins and dolphins within the Cockburn Sound study region.

3.2.2. Sedimentary POM

Combined across all regions, depths and seasons, sedimentary particulate organic matter (POM) had a mean δ^{13}C value (-18.1‰) similar to *E. radiata* and *Sarcomena* sp., while δ^{15}N was similar to the latter macroalga and seagrasses (Figure 81). No δ^{34}S data were available for POM due to the low concentration of sulphur in the sediments.

Both δ^{13}C and δ^{15}N for sedimentary POM were highly variable across the study region (Figure 82). δ^{13}C was influenced by region and depth, as indicated by the interaction between the two factors in the PERMANOVA (Table 12). In comparison, δ^{15}N differed between shallow and deep waters. Sedimentary POM from shallow areas in Owen Anchorage tended to have more depleted δ^{13}C values than sedimentary POM from deeper areas in that region and from both shallow and deep areas in both regions in Cockburn Sound.

Mixing models indicated differences in the proportionate contributions of sources within the study region. Models suggested that seston, and to a lesser extent, *Posidonia* spp. contributed to the sediment POM in the shallow areas of Owen Anchorage, while a mix of these two sources and *E. radiata* contributed to the POM in the deeper waters of Owen Anchorage (Figure 83). In comparison, *E. radiata* and to a lesser extent *Posidonia* spp. contributed to the POM in deeper waters of both North and South Cockburn Sound, while POM in shallow areas in North Cockburn Sound likely consists of a mix of different sources (Figure 83). The mixing model results for POM in shallow areas of South Cockburn Sound cannot be interpreted due to the distributions showing bimodality.

Table 12. Results of three-way PERMANOVA testing for differences in δ^{13}C and δ^{15}N for sedimentary Particulate Organic Matter across Seasons, Regions and Depth in Cockburn Sound. All factors were fixed. Bolded P values signify statistically significant results.

Stable isotope	**Source**	***df***	**MS**	***P***
δ^{13}C	Season (S)	1	3.284	0.211
	Region (R)	**2**	**10.851**	**0.006**
	Depth (D)	1	0.175	0.770
	S x R	1	0.558	0.773
	S x D	2	1.209	0.445
	R x D	**1**	**10.008**	**0.007**
	S x R x D	2	3.561	0.897
	Residual	43	1.781	
δ^{15}N	Season (S)	1	0.878	0.352
	Region (R)	2	1.000	0.369
	Depth (D)	**1**	**4.273**	**0.045**
	S x R	1	0.563	0.579
	S x D	2	1.486	0.226
	R x D	1	0.070	0.931
	S x R x D	2	0.444	0.798
	Residual	43	0.986	

Figure 82. Bi-plots of δ^{13}C vs δ^{15}N for sedimentary POM at across depths, regions and seasons compared to the overall mean values (±SE) for primary producers within the Cockburn Sound study region.

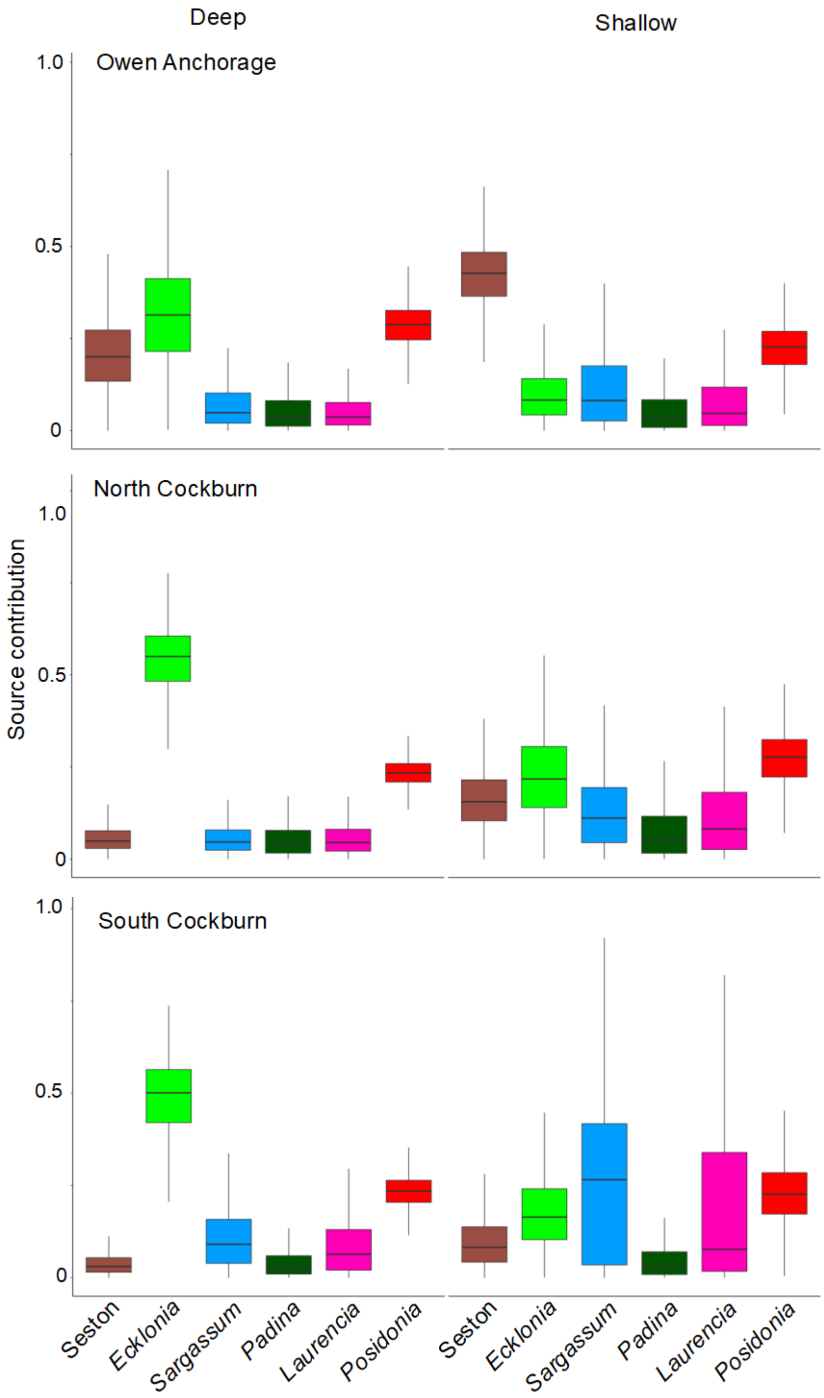


Figure 83. Proportional contributions of different sources to sedimentary POM in deep and shallow areas within the three regions of the study region (Owen Anchorage, North Cockburn Sound and South Cockburn Sound) based on Mixing models (MixSiar) of $\delta^{13}C$ vs $\delta^{15}N$. Note the source distributions for POM in shallow areas of South Cockburn Sound showed bimodality.

3.2.3. Functional groups of consumers

Zooplankton had a similarly depleted mean $\delta^{13}C$ to seston, while its mean $\delta^{15}N$ value was enriched by about 2‰ (Figure 81), suggesting that seston forms its main food source. The mean $\delta^{34}S$ value was similar to those of macroalgae.

The mean $\delta^{13}C$ for filter-feeding invertebrates (sea cucumbers, sea squirts and sea pen) was depleted compared to other benthic invertebrates, between those of seston and POM (Figure 81). However, the mean $\delta^{13}C$ values differed across species (see below) indicating different sources contributed to the different species. For $\delta^{15}N$, the mean value for filter-feeding invertebrates was enriched in $\delta^{15}N$ by ~2.5‰, suggesting a combined source of seston and resuspended POM as food sources.

In contrast to filter-feeding invertebrates, the mean $\delta^{13}C$ values of other functional groups of benthic invertebrates were similar to those of macroalgae, while mean $\delta^{15}N$ values (~8-11‰) were enriched compared to those for sources (Figure 81). The mean $\delta^{15}N$ for benthic generalist invertebrates (prawns and crabs) was the least enriched, whereas that of benthopelagic carnivores was the most enriched. The mean $\delta^{15}N$ for benthic detritivore invertebrates (sea stars) was slightly higher than those of prawns and crabs, while the mean $\delta^{13}C$ was also slightly enriched (Figure 81).

In terms of mean $\delta^{34}S$, filter-feeding invertebrates had more depleted values than those of macroalgae, but slightly more enriched than seagrasses. Mean $\delta^{34}S$ of benthic generalists and benthic detritivores were more depleted than those for filter-feeding invertebrates (Figure 81).

Feeding guilds of fish, including teleosts and elasmobranchs, had enriched mean $\delta^{15}N$ values compared to most benthic invertebrates (except filter-feeding invertebrates) with values ranging between 9 and 12‰ (Figure 81). In terms of $\delta^{13}C$, mean values generally sat in the range of the macroalgae, ranging from -19.5 to -16‰. Pelagic piscivores had a higher mean $\delta^{15}N$ at ~12‰ compared to those of other feeding guilds (Figure 81). These guilds of fish had similar mean $\delta^{34}S$ values to those of benthic invertebrates (Figure 81).

Little penguins had the most enriched mean $\delta^{15}N$ compared to all consumers, with their mean $\delta^{13}C$ value being slightly more depleted than pelagic carnivorous fish (Figure 81). Indo-Pacific bottlenose dolphins and Australian sealions had similar mean $\delta^{15}N$ values to those of pelagic piscivorous fish, but their mean $\delta^{13}C$ was slightly more enriched than fish. Mean $\delta^{34}S$ of little penguins fell within the range of macroalgae (Figure 81).

Table 13. Mean $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$, Carbon to Nitrogen ratios (C:N) and Trophic Levels (TrL) of different taxa of primary producers and invertebrate, fish, mammal and bird feeding guilds collected from the Cockburn Sound study region.

Group	Function group/Guild	Species	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$	C:N	TrL
Primary producer	Seagrass	*Amphibolis*	-13.01	4.34	16.47	23.24	1.00
Primary producer	Seagrass	*Posidonia*	-9.05	4.17	17.74	28.07	1.00
Primary producer	Brown algae	*Ecklonia*	-19.08	6.51	21.47	22.20	1.00
Primary producer	Brown algae	*Hydroclathrus*	-12.77	4.09	21.53	17.82	1.00
Primary producer	Brown algae	*Sargassum*	-16.37	5.61	20.40	23.21	1.00
Primary producer	Brown algae	*Padina*	-16.77	4.13	19.30	19.56	1.00
Primary producer	Red algae	*Laurencia*	-14.55	6.29	20.70	16.20	1.00
Primary producer	Red algae	*Sarconema*	-17.03	3.95	22.70	21.26	1.00
Primary producer	Seston	Seston	-23.46	4.70	21.32		1.00
Detritus	Sediment POM	Sediment POM	-18.10	3.84			
Invertebrate	Zooplankton	Zooplankton	-23.18	6.47			1.70
Invertebrate	Benthic detritivore	*A. angulatus*	-13.96	8.65	13.08	4.02	2.64
Invertebrate	Benthic detritivore	*S. inspinosus*	-16.00	9.32	14.24	3.94	2.94
Invertebrate	Suspension Feeder	*C. anceps*	-19.54	6.67	16.84	4.50	1.78
Invertebrate	Suspension Feeder	*C. quadrangularis*	-21.64	7.08	15.05	4.60	1.96
Invertebrate	Suspension Feeder	*Cavernularia* sp.	-21.02	9.12	18.63	4.46	2.85
Invertebrate	Suspension Feeder	*Herdmania* sp.	-21.00	7.07	18.75	13.62	1.96
Invertebrate	Benthic Generalist	*M. fusca*	-15.24	6.79	11.74	3.36	1.84
Invertebrate	Benthic Generalist	*M. lindae*	-15.92	8.70	15.80	3.30	2.67
Invertebrate	Benthic Generalist	*P. armatus*	-17.25	8.44	13.42	3.37	2.55
Invertebrate	Benthic Generalist	*P. latisulcatus*	-17.11	8.96	10.45	3.17	2.78
Invertebrate	Benthic Generalist	*T. sima*	-16.01	7.82	15.80	3.42	2.28
Invertebrate	Benthic Generalist	*X. rugosus*	-16.76	8.30	11.65	3.36	2.49
Invertebrate	Benthic Carnivore	*B. laevis*	-17.46	9.59	15.70	3.48	3.05
Invertebrate	Benthic Carnivore	*O. djinda*	-15.90	9.40	16.92	3.51	2.97
Invertebrate	Benthopelagic Carnivore	*S. australis*	-17.90	11.93	18.41	3.45	4.07
Invertebrate	Benthopelagic Carnivore	*A. cultratum*	-17.06	8.96	17.57	3.25	2.78
Invertebrate	Benthopelagic Carnivore	*A. novaehollandiae*	-16.82	9.19	15.54	3.33	2.88
Fish	Detritivore	*M. cephalus*	-13.83	8.78		3.41	2.70
Fish	Benthic Omnivore	*A. amygdaloides*	-17.28	10.48		3.29	3.44
Fish	Benthic Omnivore	*A. spilomelanurus*	-17.61	9.16	17.99	3.31	2.86
Fish	Benthic Omnivore	*H. melanochir*	-18.38	10.08		3.26	3.26
Fish	Benthic Omnivore	*P. humeralis*	-16.47	9.98		3.30	3.22
Fish	Benthic Omnivore	*P. octolineatus*	-17.01	10.92	17.25	3.41	3.63
Fish	Benthic Invertivore	*A. forsteri*	-17.53	10.72	12.19	3.30	3.55
Fish	Benthic Invertivore	*A. vincentiana*	-15.39	11.20		2.68	3.75
Fish	Benthic Invertivore	*C. auratus*	-17.86	12.02	16.79	3.26	4.11
Fish	Benthic Invertivore	*O. rueppellii*	-17.42	10.86		3.26	3.60
Fish	Benthic Invertivore	*P. goodladi*	-17.22	10.09		3.25	3.27
Fish	Benthic Invertivore	*P. melbournensis*	-18.71	10.86	17.01	3.29	3.60
Fish	Benthic Invertivore	*P. vitta*	-17.25	11.30	9.65	3.38	3.80
Fish	Benthic Invertivore	*P. wrighti*	-18.38	11.61	15.18	3.34	3.93
Fish	Benthic Invertivore	*S. bassensis*	-17.91	11.17	10.06	3.27	3.74
Fish	Benthic Invertivore	*S. burrus*	-17.74	11.72	6.15	3.28	3.98
Fish	Benthic Invertivore	*S. schomburgkii*	-14.41	11.63		3.24	3.94
Fish	Benthic Invertivore	*U. australiae*	-17.66	10.81		3.48	3.58
Fish	Benthic Invertivore	*C. macrocephalus*	-16.30	8.88		3.15	2.74
Fish	Benthic Carnivore (Ambush)	*L. platycephala*	-17.60	10.63		3.37	3.50
Fish	Benthic Carnivore (Ambush)	*G. marmoratus*	-16.08	8.85		3.33	2.73
Fish	Benthic Carnivore (Ambush)	*I. japonica*	-16.68	10.90	14.66	3.21	3.62
Fish	Benthic Carnivore (Ambush)	*O. spinosa*	-16.90	10.80	15.45	3.27	3.58
Fish	Benthic Carnivore (Ambush)	*P. grandispinis*	-16.98	12.24		3.22	4.20
Fish	Benthic Carnivore (Elasmobranch)	*H. portusjacksoni*	-19.52	9.24		2.74	2.90
Fish	Benthic Carnivore (Elasmobranch)	*M. antarcticus*	-17.72	12.46		2.71	4.30
Fish	Benthic Carnivore (Elasmobranch)	*M. tenuicaudatus*	-16.53	10.16		2.70	3.30
Fish	Benthopelagic Carnivore	*P. georgianus*	-18.12	10.88		3.25	3.61
Fish	Pelagic Planktivore	*A. vaigiensis*	-18.08	11.43	17.64	3.20	3.85
Fish	Pelagic Planktivore	*E. australis*	-19.56	10.68	17.48	3.34	3.52
Fish	Pelagic Planktivore	*H. vittatus*	-18.99	10.44	17.36	3.30	3.42
Fish	Pelagic Planktivore	*S. robustus*	-18.82	10.63		3.44	3.51
Fish	Pelagic Planktivore	*S. sagax*	-19.85	9.65		3.30	3.08
Fish	Pelagic Planktivore	*S. lemuru*	-19.41	10.07		3.22	3.26
Fish	Pelagic Planktivore	*T. novaezelandiae*	-19.54	11.64	18.25	3.33	3.94
Fish	Pelagic Piscivore	*C. brevipinna*	-18.29	12.35		2.71	4.25
Fish	Pelagic Piscivore	*S. obtusata*	-19.21	11.69	19.60	3.26	3.97
Mammal	Indopacific Bottlenose Dolphin	*T. aduncus*	-16.36	12.08			4.13
Mammal	Australian sealion	*N. cinerea*	-15.85	11.57			3.91
Bird	Little penguin	*E. minor*	-20.61	13.76	19.51	3.21	4.86

3.2.4. *Isotopic variation of consumers across regions and seasons*

Only four invertebrate species and nine fish species were collected with sufficient sample size to compare stable isotope variation across regions and seasons. Of those species, there was no consistent difference across regions or seasons (Table 14). Several species, including the western king prawn *Panaeus latisulcatus*, the western gobbleguts *Ostorhinchus rueppellii* and the skipjack trevally *Pseudocaranx wrighti* displayed a regional and/or seasonal difference in δ^{13}C or δ^{15}N, while a few other species displayed an interaction between region and season (e.g. swimmer crab *Thalamita sima,* blue sprat *Spratelloides robustus*). As a result, further analyses are based on combined regions and seasons, except where mixing models indicated differences across these factors.

Table 14. Summary of three-way ANOVA results of δ^{13}C, δ^{15}N and δ^{34}S for consumer species that had adequate sample sizes collected for three regions and two seasons across the study region. Bolded P values signify statistically significant results.

		δ^{13}C			δ^{15}N			δ^{34}S		
Species	**Source**	**df**	**MS**	**p**	**df**	**MS**	**p**	**df**	**MS**	**p**
Invertebrates										
Belosquilla	Region (R)	2	1.0	0.094	2	0.6	0.164			
laevis	**Season (S)**	**1**	**9.9**	**<0.001**	**1**	**25.3**	**<0.001**			
(Mantis shrimp)	R x S	2	0.2	0.652	2	2.5	0.102			
	Res	24			24					
Panaeus	**Region (R)**	**2**	**2.3**	**0.049**	2	0.1	0.891	2	20.3	0.063
latisulcatus	Season (S)	1	1.4	0.160	1	17.5	**<0.001**	1	7.4	0.279
(W. king prawn)	R x S	2	1.0	0.253	2	0.8	0.528	2	3.7	0.537
	Res	23			23			12		
Portunus	**Region (R)**	**2**	**3.4**	**<0.001**	2	1.6	0.102*	**2**	**19.9**	**0.020***
armatus	**Season (S)**	**1**	**3.6**	**0.003**	1	17.7	<0.001*+	1	9.3	0.136*
(B. swimmer crab)	R x S	2	0.3	0.394	2	0.3	0.741*	2	9.9	0.106*
	Res	24			24			12		
Thalamita	**Region (R)**	2	0.0	<0.001*+	2	8.0	**<0.001**			
sima	**Season (S)**	1	0.0	<0.001*+	1	13.7	**<0.001**			
(F. L. swimmer crab)	**R x S**	2	0.0	0.001*+	2	4.0	**0.002**			
	Res	24			24					
Finfish										
Anoplocapros	**Region (R)**	**2**	**0.2**	**0.043***	2	0.3	0.530			
amygdaloides	**Season (S)**	1	0.0	0.274*	**1**	**9.5**	**<0.001**			
(W. Smooth boxfish)	R x S	2	0.0	**0.035***	2	0.5	0.267			
	Res	23			23					
Gymnapistes	**Region (R)**	**2**	**2.7**	**0.010**	**2**	**1.4**	**0.004**			
marmoratus	**Season (S)**	**1**	**3.6**	**0.011**	1	0.0	0.717			
(Soldier)	R x S	2	0.3	0.546	2	0.4	0.165			
	Res	23			23					
Inegocia	**Region (R)**	**2**	**2.1**	**<0.001**	**2**	**2.2**	**<0.001**			
japonica	**Season (S)**	**1**	**4.0**	**<0.001**	1	0.0	0.572			
(Rusty flathead)	R x S	2	0.2	0.172	2	0.0	0.778			
	Res	23			23					
Onigocia	**Region (R)**	**2**	**1.3**	**0.008**	**2**	**2.0**	**0.005**			
spinosa	**Season (S)**	**1**	**2.5**	**0.002**	1	0.3	0.363			
(Midget flathead)	R x S	2	0.1	0.520	2	0.5	0.204			
	Res	24			24					
Ostorhinchus	Region (R)	2	0.3	0.560	2	2.9	**0.014**			

rueppellii	**Season (S)**	**1**	**10.2**	**<0.001**	1	2.4	0.051
(Gobbleguts)	R x S	2	1.1	0.103	2	1.2	0.144
	Res	24			24		
Helotes	Region (R)	2	5.0	0.261	2	1.3	0.463
octolineatus	**Season (S)**	1	9.9	0.106	**1**	**8.4**	**0.035**
(W. striped grunter)	R x S	2	7.4	0.142	2	1.7	0.384
	Res	24			24		
Pseudocaranx	Region (R)	2	4.1	**0.049**	2	0.0	0.895
wrighti	Season (S)	1	4.7	0.058	1	0.1	0.393
(Skipjack trevally)	R x S	2	0.6	0.603	2	0.1	0.425
	Res	24			24		
Sillago	Region (R)	2	0.0	0.036^{*+}	2	6.5	**0.006**
burrus	Season (S)	1	0.0	0.252*	1	3.1	0.098
(W. trumpeter	R x S	2	0.0	0.258*	2	0.6	0.582
whiting)	Res	24			24		
Spratelloides	**Region (R)**	2	0.8	0.051	**2**	**4.7**	**<0.001**
robustus	**Season (S)**	**1**	**6.4**	**<0.001**	**1**	**9.1**	**<0.001**
(Blue sprat)	R x S	2	0.4	0.221	2	2.8	**<0.001**
	Res	24			24		

* = Transformed data; + = Did not meet assumptions of normal distribution, *P* value accepted ≤0.01.

3.2.5. Invertebrates

The mean $\delta^{13}C$ values for the suspension-feeding sea pen (*Cavernularia* sp.), the red box sea cucumber (*Cercodemas anceps)* and spiny sea cucumber (*Colochirus quadrangularis)* lay between those of seston and *Ecklonia* and sediment POM, while that of the sea squirt (*Herdmania* sp.) was far more enriched and was closer to that of *Posidonia* (Figure 84). The mean $\delta^{15}N$ value was most enriched for sea pen (~9‰) compared to ~7‰ for the other three species. Of the filter-feeding species whose $\delta^{34}S$ were determined, mean values for the sea cucumber were depleted compared to that of the sea pen (Figure 84). With the exception of the sea pen, which had a Trophic Level (TrL) of 2.85, the trophic level for the other suspension feeders were close to 2 (Table 13).

Mixing models suggest that seston contributes predominantly to the assimilated diet of the spiny sea cucumber, with a median proportional contribution of ~0.6 compared to <0.1 for other potential sources (Figure 85). In contrast, seagrass (*Posidonia*) appeared to be the main food source assimilated by the sea squirt (median contribution ~0.7 cf <0.1 for other potential sources).

Compared to most suspension feeders, the mean $\delta^{13}C$ values for asteroids (sea stars) were more enriched and similar to macroalgae, with those for *S. inspinosus* being more similar to brown algae, while those for *A. angularus* were more enriched (Figure 86). Both species had similar mean $\delta^{15}N$ (~9‰), which was ~2.5‰ above the mean $\delta^{15}N$ values for macroalgae. Mean $\delta^{34}S$ values for both species were depleted compared to all sources. The mixing model for *S. inspinosus* suggests that *Ecklonia* contributed almost 50% to the assimilated material for this species (Figure 85). The TrL for these two species were 2.9 and 2.6, respectively (Table 13).

The mean $\delta^{13}C$ values for benthic generalist feeders (decapods) were all mid-range of those for sources (Figure 87). For $\delta^{15}N$, the mean values were generally enriched compared to those of the sources, except that for the velvet prawn *Metapenaeopsis fusca*. All six species had generally depleted $\delta^{34}S$ values compared to the sources. The TrL for all but *M. fusca* (1.8) lay between 2.3 and 2.7 (Table 13).

Based on mixing models, median proportional contributions of base sources were <0.25 for Linda's velvet prawn (*Metapenaeopsis lindae)* while the brown alga *Padina* appeared to make the greatest contribution to assimilated material for *M. fusca* (median proportion = ~0.4 cf <0.2) (Figure 88). For benthic generalist feeders that showed differences between seasons, *Ecklonia* and/or *Padina* made the greatest contributions to material assimilated by the blue swimmer crab (*Portunus armatus),* western king prawn (*Panaeus latisulcatus)* and pink swimmer crab (*Trionectes rugosus)*, with median proportional contributions ranging from ~0.2-0.5 (Figure 89). Median proportional contributions for other potential sources were typically below 0.2.

The mean δ^{13}C, δ^{15}N and δ^{34}S values for benthic carnivores, i.e. the mantis shrimp *Belosquilla laevis* and western rock octopus (*Octopus djinda)* were within the range of other invertebrates, with δ^{13}C values within the range of those for algae (Figure 90). Mantis shrimp had more depleted δ^{13}C values compared to the octopus. In terms of the bentho-pelagic carnivorous invertebrates, the mean δ^{13}C and δ^{15}N values for the cuttlefishes *Ascarosepion novaehollandiae* and *Ascarosepion cultratum* were also within the range of benthic invertebrates (Figure 91). The mean δ^{13}C for the southern squid (*Sepioteuthis australis)* was similar to a range of benthic invertebrates, but more depleted than that of the octopus (cf Figures 89 and 91), while its mean δ^{15}N was greater than all other invertebrates (Figure 91). This high δ^{15}N for southern squid resulted in a high TrL of 4.1 compared to those of other benthic and bentho-pelagic carnivores whose TrLs were close to 3 (Table 13).

Mixing models suggested that mantis shrimp assimilate nutrients from a range of base sources, with seston making the greatest median proportional contribution (~0.3) (Figure 90). Similarly, a range of base sources contributed to octopus, with *Padina* making the greatest median contribution at ~0.3 (Figure 91). Mixing models suggested that the cuttlefish *A. cultratum* appeared to derive its nutrients mainly from seston (>0.3), followed by a range of brown and red algae (Figure 92). In comparison, the cuttlefish *A. novaehollandiae* assimilated nutrients indirectly from a combination of brown algae and seston in both seasons, with median contributions generally >0.25 (Figure 93). While mixing models for the southern squid (*Sepioteuthis australis*) did not meet convergence requirements, its higher TrL (4.1 vs <3; Figure 92) compared to other cephalopods indicates that it is feeding on prey at higher trophic levels.

Figure 84. Bi-plots of δ^{13}*C vs* δ^{15}*N and* δ^{13}*C vs* δ^{34}*S of sources and filter-feeding invertebrates within the Cockburn Sound study region: red box sea cucumber (*Cercodemas anceps*), spiny sea cucumber (*Colochirus quadrangularis*), brown sea squirt (*Herdmania *sp.) and sea pen (*Cavernularia *sp.).*

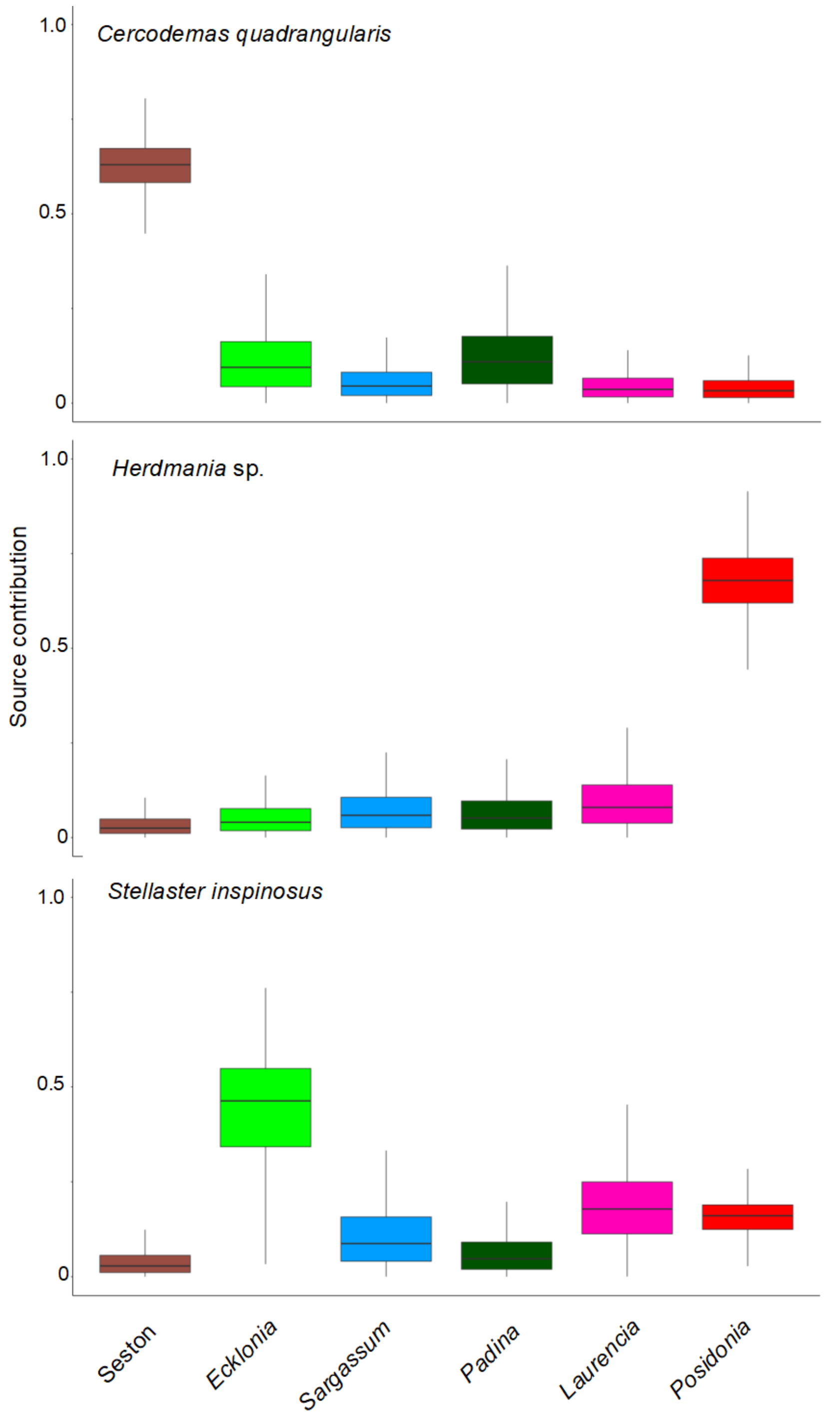


Figure 85. Box-and-whisker plots showing distributions of source contributions determined by Mixing Models using ^{13}C *and* ^{15}N *stable isotope ratios for the filter-feeding spiny sea cucumber (*Colochirus quadrangularis*) and brown sea squirt (*Herdmania sp.*) and the detritivorous sea star (*Stellaster inspinosus*) collected across the Cockburn Sound study region. Box-and-whisker plots show indicate 2.5th, 25th, 50th (median), 75th, and 97.5th percentiles.*

Figure 86. Bi-plots of $\delta^{13}C$ *vs* $\delta^{15}N$ *and* $\delta^{13}C$ *vs* $\delta^{34}S$ *of sources and benthic detritivore invertebrates (asteroids) within the Cockburn Sound study region: sea stars (*Archaster angulatus *and* Stellaster inspinosus*).*

Figure 87. Bi-plots of $\delta^{13}C$ *vs* $\delta^{15}N$ *and* $\delta^{13}C$ *vs* $\delta^{34}S$ *of sources and benthic generalist invertebrates (decapods) within the Cockburn Sound study region: velvet prawn (*Metapenaeopsis fusca*), Linda's velvet prawn (*Metapenaeopsis lindae*), blue swimmer crab (*Portunus armatus*), western king prawn (*Panaeus latisulcatus*), four-lobed swimming crab (*Thalamita sima*) and pink swimmer crab (*Trionectes rugosus*).*

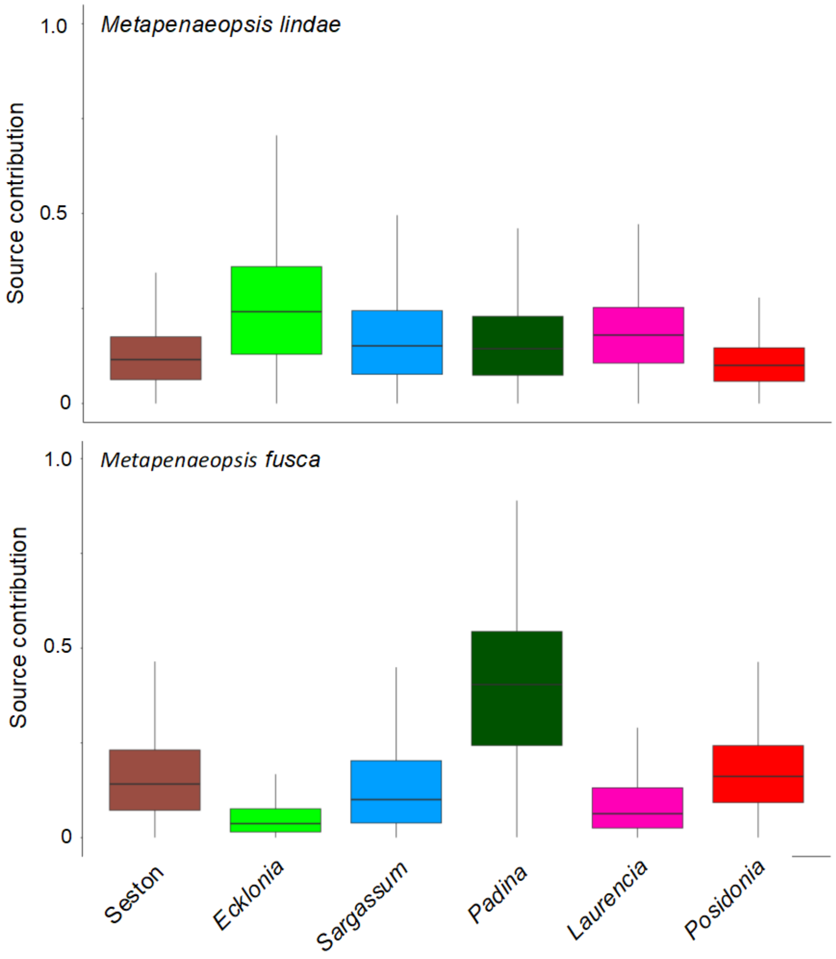


Figure 88. Box-and-whisker plots showing distributions of source contributions determined by Mixing Models using ^{13}*C and* ^{15}*N stable isotope ratios for the benthic generalists velvet prawn* (Metapenaeopsis fusca) *and Linda's velvet prawn* (Metapenaeopsis lindae) *collected across the Cockburn Sound study region. Box-and-whisker plots show indicate 2.5th, 25th, 50th (median), 75th, and 97.5th percentiles.*

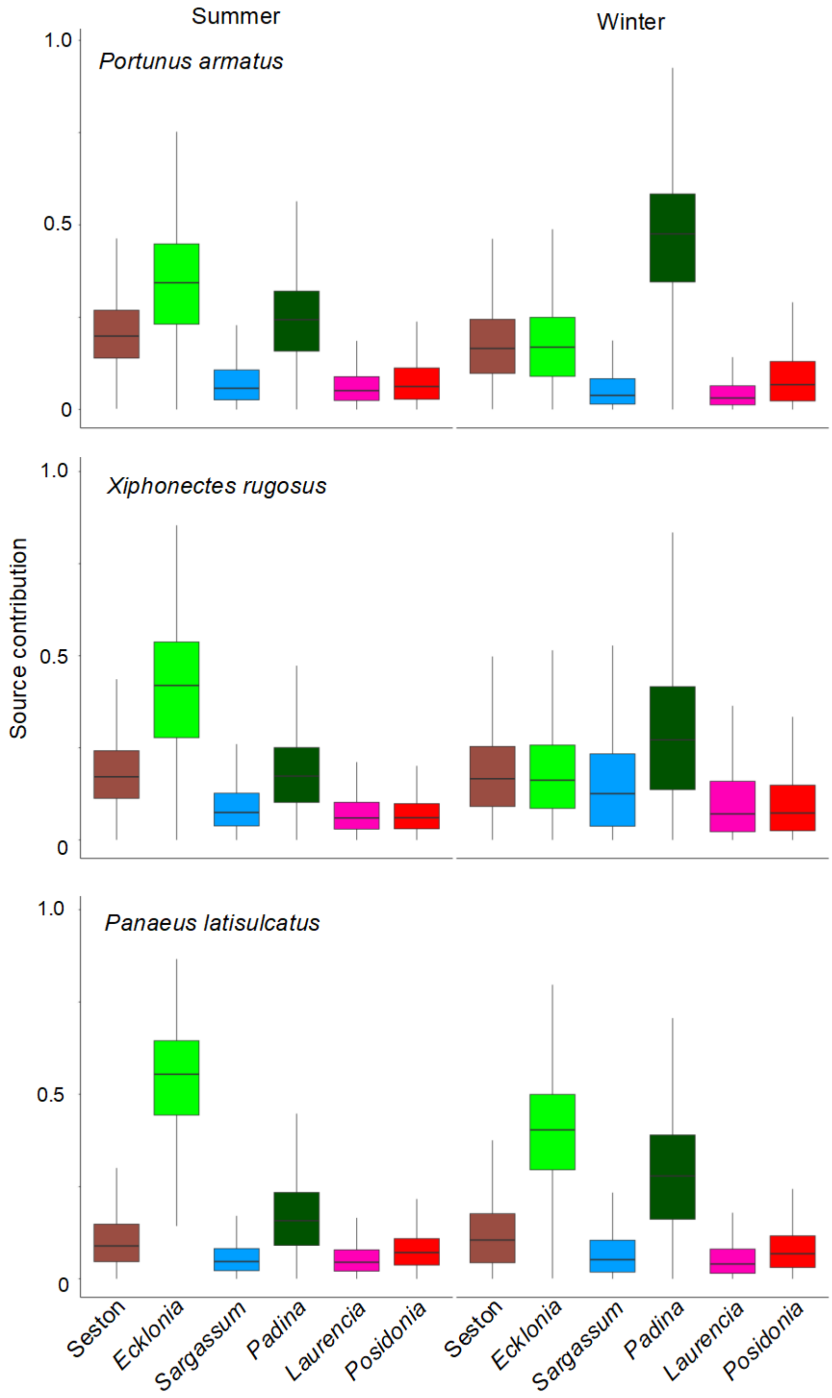


*Figure 89. Box-and-whisker plots showing distributions of source contributions determined by Mixing Models using ^{13}C and ^{15}N stable isotope ratios for the benthic generalists blue swimmer crab (*Portunus armatus*), western king prawn (*Panaeus latisulcatus*) and pink swimmer crab (*Trionectes rugosus*) collected across the Cockburn Sound study region in summer and winter. Box-and-whisker plots show indicate 2.5th, 25th, 50th (median), 75th, and 97.5th percentiles.*

*Figure 90. Bi-plots of δ^{13}C vs δ^{15}N and δ^{13}C vs δ^{34}S of sources, invertebrates and benthic-carnivore invertebrate and fish species within the Cockburn Sound study region: the mantis shrimp (*Belosquilla laevis*) and western rock octopus (*Octopus djinda*).*

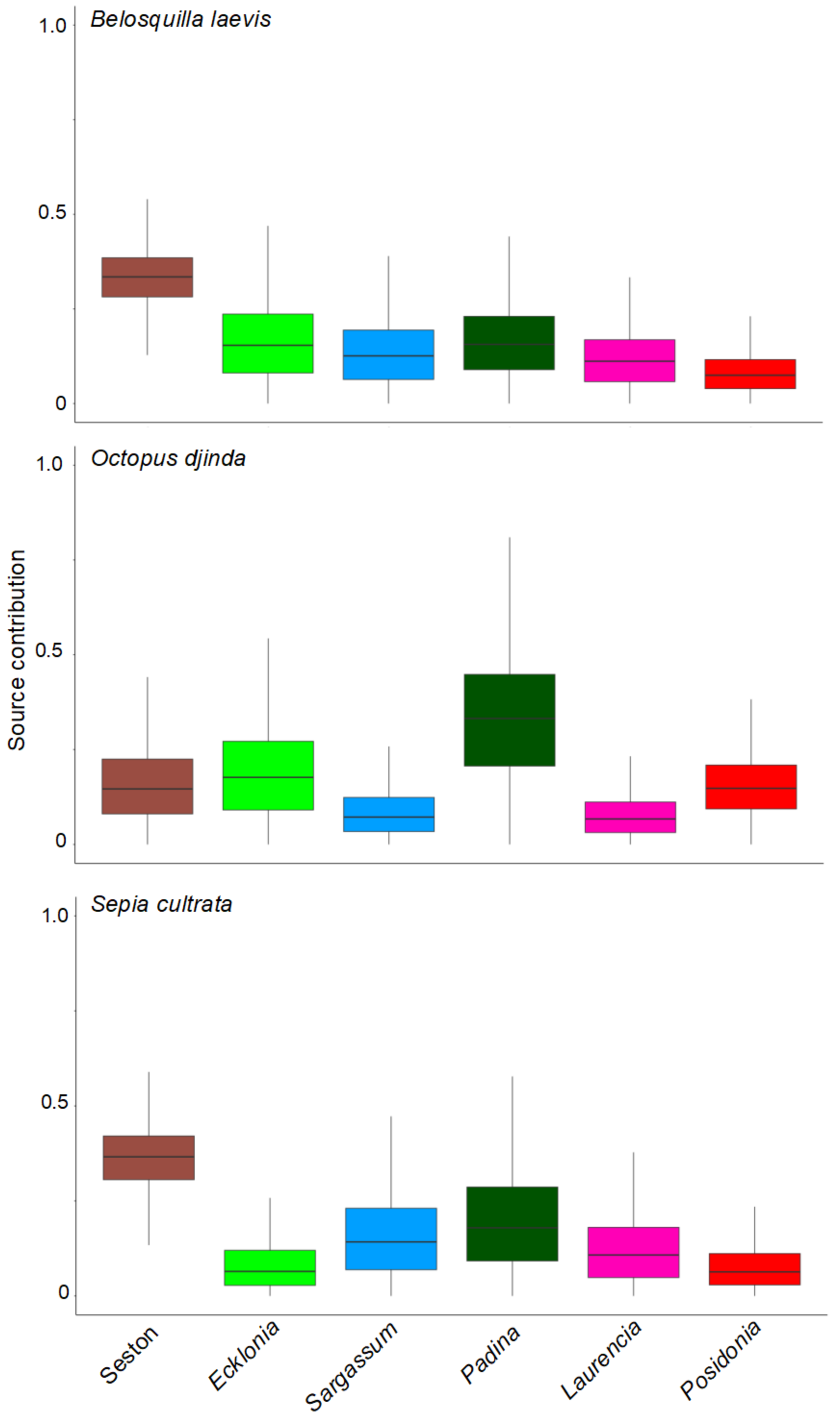


*Figure 91. Box-and-whisker plots showing distributions of source contributions determined by Mixing Models using ^{13}C and ^{15}N stable isotope ratios for the and benthic-carnivore invertebrate species the mantis Shrimp (*Belosquilla laevis*) and western rock octopus (*Octopus djinda*) and bentho-pelagic carnivore species southern squid (*Sepioteuthis australis*) collected across the Cockburn Sound study region. Box-and-whisker plots show indicate 2.5th, 25th, 50th (median), 75th, and 97.5th percentiles.*

*Figure 92. Bi-plots of δ^{13}C vs δ^{15}N and δ^{13}C vs δ^{34}S of sources, invertebrates and bentho-pelagic carnivorous invertebrate and fish species within the Cockburn Sound study region: southern squid (*Sepioteuthis australis*), cuttlefish (*Ascarosepion novaehollandiae *and* Ascarosepion cultratum*) and silver trevally (*Pseudocaranx georgianus*).*

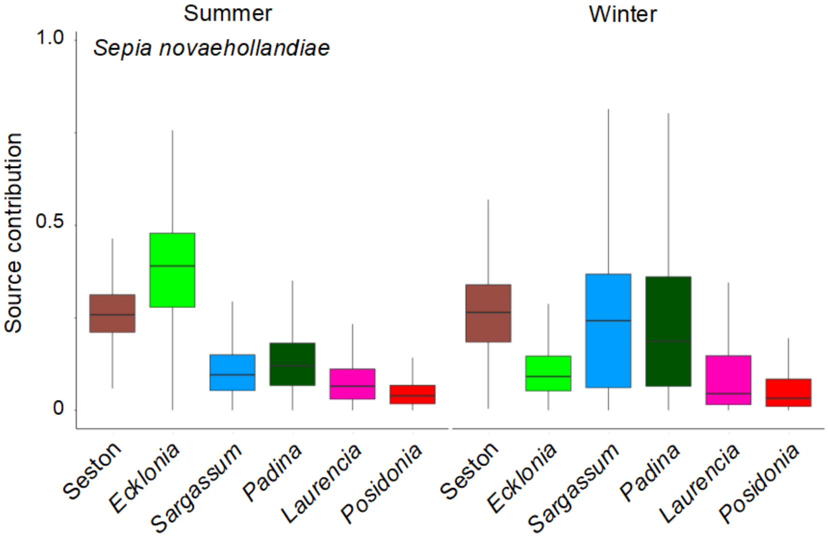


*Figure 93. Box-and-whisker plots showing distributions of source contributions determined by Mixing Models using ^{13}C and ^{15}N stable isotope ratios for the bentho-pelagic carnivorous cuttlefish (*Sepia novaehollandiae*) collected across the Cockburn Sound study region in summer and winter. Box-and-whisker plots show indicate 2.5th, 25th, 50th (median), 75th, and 97.5th percentiles.*

3.2.6. Finfish

The mean $\delta^{13}C$ values for the omnivorous fish species ranged between -18 and -16.5‰, and were within the range of macroalgae (Figure 94). The mean $\delta^{15}N$ value for this guild was enriched compared to the primary sources, and several guilds of invertebrates. The $\delta^{34}S$ values of this fish guild were similar to carnivorous benthic invertebrates and suspension-feeding invertebrates. The TLs for omnivorous fishes ranged between 2.9 and 3.6 (Table 13). The bridled leatherjacket had the lowest mean $\delta^{15}N$ (9.2‰) and TrL (2.9) compared to other omnivorous fishes (≥10 and 3.2, respectively).

The mean $\delta^{15}N$ values for benthic-invertivore fishes were typically greater than those of the omnivorous fishes and carnivorous benthic invertebrates (Figure 95), reflected by the higher TLs that ranged from 3.5 to 4.1 (Table 13). Snapper and western trumpeter whiting had the highest $\delta^{15}N$ (11.1‰) and TL (~4). Many species in this guild had mean $\delta^{13}C$ ranging between -19 and -17‰, which were typically depleted compared to most benthic invertebrates (Figure 95). In comparison, the mean $\delta^{13}C$ for the yellowfin whiting and the western shovelnose ray (*Aptychotrema vincentiana)* were more enriched (~-14 and -15‰, respectively) than other species in this guild as well as benthic invertebrates.

The benthic ambush carnivores flathead sandfish *,* rusty flathead*,* midget flathead and longspine flathead had similar mean $\delta^{13}C$ as benthic generalist invertebrates and omnivorous fishes (cf Figures 87 and 96). However, with the exception of soldier*,* their mean $\delta^{15}N$ values were slightly more enriched than those of benthic invertebrates, but similar to those of the benthic-invertivore fishes (cf Figures 87 and 96). Soldier had far lower $\delta^{15}N$ and TrL than the other benthic ambush carnivores (8.9 vs 10.6-12.2‰, 2.7 vs 3.6-4.2, respectively, Table 13). Compared to the other flathead species, longspine flathead had the highest $\delta^{15}N$ (12.2‰) and TrL (4.2).

The three benthic carnivorous elasmobranch species had varied mean $\delta^{13}C$ and $\delta^{15}N$ values to each other. The mean $\delta^{13}C$ value for Port Jackson shark (*Heterodontus portusjacksoni)* was more depleted than the other two species and similar to the base source kelp, whereas those for gummy shark (*Mustelus antarcticus)* and southern eagle ray (*M. tenuicaudatus)* lay within the range of macroalgae (Figure 97). In comparison, the gummy shark had the highest $\delta^{15}N$ value at ~12‰, while $\delta^{15}N$ for the other two was similar to a range of invertebrate guilds. As a consequence, the gummy shark had the highest TrL (4.3), while Port Jackson shark had the lowest (2.9) (Table 13).

The majority of the pelagic planktivorous fish species had depleted mean $\delta^{13}C$ values compared to benthic invertebrates, but similar values to those of the benthic-invertivore fishes (cf. Figures 95 and 98). Australian anchovy*,* scaly mackerel, yellowtail scad and Australian sardine had the most depleted mean $\delta^{13}C$ values, while those of the hardyhead were more enriched. The $\delta^{15}N$ values for this guild were similar to those of most species in other guilds, with TrLs ranging between 3.1 and 3.9 (Table 13).

The pelagic piscivores spinner shark (*Carcharhinus brevipinna)* and striped barracuda (*Sphyraena obtusata)* had a mean $\delta^{13}C$ value within the range of the pelagic planktivores, while their mean $\delta^{15}N$ values were slightly higher than those of the planktivores (Figure 99). Both species had TLs at ~4, which was similar to Indopacific Bottlenose Dolphins and Australian sealions but lower than little penguins (4.9) (Table 13). However, the mean $\delta^{13}C$ value for dolphins and Australian sealions was more enriched than these other species, but more similar to benthic invertebrates and ambush predators. The mean $\delta^{13}C$ value for little penguins was more depleted than most pelagic planktivores (Figure 99).

Figure 94. Bi-plots of δ^{13}*C vs* δ^{15}*N and* δ^{13}*C vs* δ^{34}*S of sources, invertebrates and omnivorous fish species within the Cockburn Sound study region: western smooth boxfish (*Anoplocapros amygdaloides*), bridled leatherjacket (*Acanthaluteres spilomelanurus*), southern garfish (*Hyporhamphus melanochir*), sea trumpeter (*Pelsartia humeralis*), and western striped grunter (*Helotes octolineatus*).*

Figure 95. Bi-plots of $\delta^{13}C$ *vs* $\delta^{15}N$ *and* $\delta^{13}C$ *vs* $\delta^{34}S$ *of sources, invertebrates and benthic-invertivore fish species within the Cockburn Sound study region: yelloweye mullet (*Aldrichetta forsteri*), western shovelnose ray (*Aptychotrema vincentiana*), snapper (*Chrysophrys auratus*), western gobbleguts (*Ostorhinchus rueppellii*), longspine dragonet (*Pseudocalliurichthys goodladi*), silverbelly (*Parequula melbournensis*), western butterfish (*Pentapodus vitta*), skipjack trevally (*Pseudocaranx wrighti*), large and small southern school whiting (*Sillago bassensis*), western trumpeter whiting (*Sillago burrus*), yellowfin whiting (*Sillago schomburgkii*) and Australian goatfish (*Upeneus australiae*).*

Figure 96. Bi-plots of $\delta^{13}C$ *vs* $\delta^{15}N$ *and* $\delta^{13}C$ *vs* $\delta^{34}S$ *of sources, invertebrates and benthic carnivorous ambush fish species within the Cockburn Sound study region: soldier (*Gymnapistes marmoratus*), rusty flathead (*Inegocia japonica*), midget flathead (*Onigocia spinosa*) and longspine flathead (*Platycephalus grandispinis*).*

Figure 97. Bi-plots of $\delta^{13}C$ *vs* $\delta^{15}N$ *and* $\delta^{13}C$ *vs* $\delta^{34}S$ *of sources, invertebrates and benthic carnivorous fish species within the Cockburn Sound study region: Port Jackson shark (*Heterodontus portusjacksoni*), gummy shark (*Mustelus antarcticus*) and southern eagle ray (*Myliobatis tenuicaudatus*). No* $\delta^{34}S$ *data are available for these species.*

*Figure 98. Bi-plots of δ^{13}C vs δ^{15}N and δ^{13}C vs δ^{34}S of sources, invertebrates and pelagic planktivorous fish species within the Cockburn Sound study region: common hardyhead (*Atherinomorus vaigiensis*), Australian anchovy (*Engraulis australis*), sandy sprat (*Hyperlophus vittatus*), blue sprat (*Spratelloides robustus*), Australian sardine (*Sardinops sagax*), scaly mackerel* (Sardinella lemuru*), and yellowtail scad (*Trachurus novaezelandiae*).*

Figure 99. Bi-plots of δ^{13}*C vs δ*^{15}*N and δ*^{13}*C vs δ*^{34}*S of sources, invertebrates and pelagic piscivorous and benthopelagic carnivorous species within the Cockburn Sound study region: spinner shark* (Carcharhinus brevipinna*) and striped barracuda (*Sphyraena obtusata*), little penguin (*Eudyptula minor*), Indo-Pacific bottlenose dolphin* (Tursiops aduncus*) and Australian sealion* (Neophoca cinerea)*.*

4. Discussion

This project has provided comprehensive analyses of the food web structure of Cockburn Sound using Gut Content (GCA) and Stable Isotope (SIA) analyses, which are increasingly being used as complementary tools in trophic studies (e.g. Hyndes & Lavery 2005, Crawley et al. 2009, Greenwell et al. 2019, Wu et al. 2019). GCA provides a snapshot in time of the last meal of consumers but at a fine taxonomic resolution (Lek et al. 2011, Maschette et al. 2020). In comparison, SIA provides information on the assimilation of nutrients from food sources over periods of weeks to months and have the capacity to determine the trophic levels of consumers and the primary source(s) of production that drive the food web (Vander Zanden et al. 2015). Combined, these tools allow us to determine the trophic structure of marine ecosystems and construct a food web model for Cockburn Sound (Figure 100).

Here, we firstly use the results of SIA to establish the primary base sources (primary producers) that contribute to the particulate organic matter (POM) in the sediment of Cockburn Sound. This is critical, since many invertebrates that form the primary consumers are macroinvertebrates that belong to detritivore or benthic generalist feeding guilds (Cronin-O'Reilly et al. submitted-b), and we show that these invertebrates form the food for many of higher-level consumers (invertebrates and fish). We then focus on the drivers of production for suspension feeders and detritivores, based on SIA only since GCA was not possible on these feeding guilds. Subsequently, we discuss the position of different feeding guilds, firstly invertebrates and then fishes, in the food web structure based on a combination of GCA, SIA and published data on the species or closely related species. Finally, we discuss the position of penguins and marine mammals in the food web based on SIA and published data on these species.

4.1. Primary sources of production and particulate organic matter

The primary producers analysed for stable isotopes in this study were intended to represent a range of primary producers that grow within or imported as detritus into the system and potentially form the primary sources that contribute directly or indirectly to the food web in the Cockburn Sound study region (i.e. including Owen Anchorage). As in many other studies on the lower west coast of Australia, $\delta^{13}C$ values for seagrasses, particularly *Posidonia* species, were higher and separated from macroalgae, but the $\delta^{13}C$ values across red and brown algae were less differentiated (Hyndes & Lavery 2005, Smit et al. 2005, Smit et al. 2006, Hyndes et al. 2013). In this study, the $\delta^{13}C$ values for the kelp *E. radiata* were far lower and distinct from other species of macroalgae. While samples of this kelp were collected from rocky substrata within the study region, sporophytes detach from a range of reefs in the region (Wernberg et al. 2006) and could be transported into Cockburn Sound by water movement and wind action. Since $\delta^{13}C$ can be highly variable across regions (Hyndes et al. 2013), variability in $\delta^{13}C$ of this and other macrophytes imported into the study region and contributing to the food web are likely to be greater.

The mean $\delta^{13}C$ value for seston (defined here as phytoplankton and suspended particulate organic matter collected by WWMSP Project "Zooplankton in Cockburn Sound") was far more depleted at - 23.5‰ than any of the macrophyte species but was also more depleted than seston sampled in other studies from the Cockburn Sound region (Hyndes & Lavery 2005, Smit et al. 2005, Smit et al. 2006). This likely reflects the focus of sampling exclusively in seagrass habitats in those earlier studies, with the $\delta^{13}C$ values likely reflecting resuspended particulate organic matter (POM) from within the seagrass meadows. Sampling of seston in the current study was carried out in more open water with less influence from detritus associated with benthic primary producers like seagrass and macroalgae. This may also explain the elevated $\delta^{13}C$ value of benthic microalgae (BMA, -14‰) in the study by Hyndes and Lavery (2005) who could only collect adequate samples of BMA at Mangles Bay. BMA in that study had a $\delta^{13}C$ value similar to that of the red alga *Laurencia* and the seagrass *Amphibolis*. Since BMA could not be collected in adequate quantities for SIA in the current study, knowledge on the role of BMA in the food web of Cockburn Sound remains a gap.

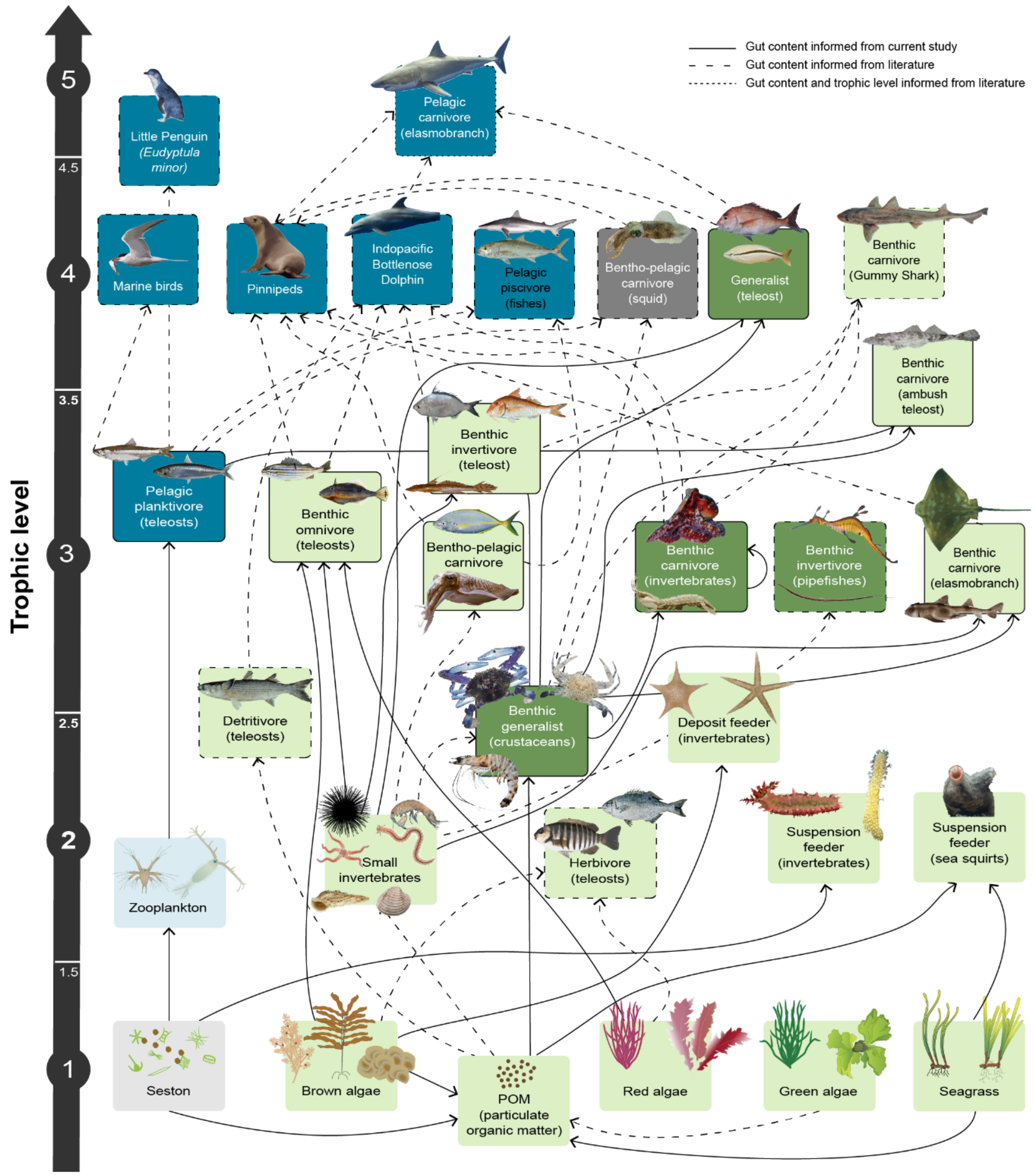


Figure 100. Conceptual food web for the Cockburn Sound region based on the results of the gut content analysis and stable isotope analysis from the current study and the literature (Appendix 4,5). Blue shading for a functional group indicates that it feeds primarily in the pelagic environment and green primarily on or near the benthic environment. Darker boxes indicate groups containing species of fisheries importance and/or conservation significance. Species in feeding guilds are given in Table 9. Species in other guilds include (i) Pelagic carnivore (elasmobranch), white shark (Carcharodon carcharias)*; (ii) Pinnipeds, Australian sea lion* (Neophoca cinerea)*, New Zealand sea lion* (Arctocephalus forsteri)*; (iii) Marine birds e.g. Australian fairy tern* (Sternula nereis nereis)* Australian pelican* (Pelecanus conspicillatus)*, Australian pied cormorant* (Phalacrocorax varius); *(iv) Pipefish e.g. weedy seadragon* (Phyllopteryx taeniolatus)*, spotted pipefish* (Stigmatopora argus) *and (v) Herbivore (teleost) e.g. zebrafish* (Girella zebra)*, silver drummer* (Kyphosus sydneyanus)*.*

Preliminary analyses of $\delta^{34}S$ for primary producers indicated further separation of taxa of primary producers, suggesting a strong potential to further delineate sources of production in the stable isotope mixing models. This stable isotope has been shown to allow clearer separation of sources in past studies (Connolly et al. 2004). However, analyses of consumers showed very high variation across species within functional groups, and more importantly, very high variation within species. The reasons for this high variation are unclear, but this led to an inability to use $\delta^{34}S$ in the mixing models. Conclusions on sources of production in this report and the construction of the food web (Figure 100) are therefore based on $\delta^{13}C$ and $\delta^{15}N$.

Mixing models using $\delta^{13}C$ and $\delta^{15}N$ for sedimentary POM revealed that a mixture of primary producers contributed to this detrital material, particularly in shallower regions (<10 m deep) of Cockburn Sound. In deeper regions (>10 m deep), the kelp *E. radiata* and, to a lesser extent, the seagrass *Posidonia* were predicted by the mixing models to make dominant contributions to the detritus in both Cockburn Sound and Owen Anchorage, most likely due to the accumulation of kelp thalli and seagrass leaves in the deeper waters after they have detached from reefs and meadows and have been transported into these depressions. Both these sources of detritus form major accumulations of wrack in beach systems and in subtidal areas in the study area, where kelp thalli and seagrass leaves regularly detach and are transported across habitats (Crawley et al. 2006, Wernberg et al. 2006, Ince et al. 2007). Ecopath modelling suggest that Cockburn Sound is dependent on a combination of internal and external sources of detritus (Lozano-Montes et al. 2024), which is supported by the cross-habitat movement of detritus seen outside Cockburn Sound. Seston appears to make greater contributions to the sedimentary POM in Owen Anchorage, particularly in the shallower areas. In addition, seagrass is likely to make a greater contribution to POM in areas dominated by seagrass (Smit et al. 2005, 2006). There was high variation in $\delta^{13}C$ of POM across the study region, but also within regions, suggesting a degree of spatial variability in the sources.

4.2. Invertebrates

Benthic invertebrates relied on a range of different primary sources for food, either directly or indirectly (Figure 100). While suspension (filter) feeders appear to derive their nutrients from a range of sources, they appear to select the suspended particles they ingest or assimilate. The solitary, suspension-feeding *Herdmania* (sea squirt) appears to gain its nutrients predominantly from *Posidonia*. *Herdmania* is abundant on the low-relief reefs within Cockburn Sound (Cronin-O'Reilly et al. submitted-b) and is a dominant suspension feeder in the broader Perth Metropolitan region (Bouvais 2016). It filters small organic particles from the water column via a mucus net and plays an important role in nitrogen cycling in southern Australia (Kelly et al. 2021). Little is known about the feeding habits of *Herdmania* in Australia, but the congeneric *H. pallida* ingests sediment along with organic particles, suggesting that *Herdmania* ingest particles resuspended into the water column from the sediment surface (Karthikeyan et al. 2009). Resuspended particulate *Posidonia* is therefore likely to contribute to the production of this suspension feeder. Given that a suite of primary producers contribute to the sediment POM, selective feeding likely accounts for the high contribution of *Posidonia* by this filter feeder. In comparison, the suspension-feeding spiny sea cucumber *C. quadrangularis* appears to gain nutrients from seston (or phytoplankton). This likely reflects different feeding mechanisms, with the sea cucumber known to climb seagrass leaves and rocky projections and raise its anterior (Woo et al. 2014) and thus select particles from the water column. However, the more enriched $\delta^{13}C$ for the red box sea cucumber (*C. anceps*) suggests that particulate macroalgae also contributes to the production of this suspension feeder. This is supported by a study from a seagrass bed in Malaysia where several sea cucumbers (including *C. quadrangularis*) had a lower $\delta^{15}C$ value than other echinoderms, i.e. echinoids and sea stars (Mukhttar et al. 2016). Both sea cucumber species were abundant within the study region during the current study (Cronin-O'Reilly et al. submitted-b) and in 2006-8 (Sampey et al. 2011).

The sea pen (*Cavernularia* sp.) had considerably higher δ^{15}N (>2‰) than the other three suspension-feeding invertebrates, placing it one trophic level higher than the other species. The trophic level of 2.85 in this study is not too dissimilar from the 2.5 for *Pennatula aculeata* in Newfoundland, which had a greater trophic level than other sea pens in the region, which was attributed to dietary supplemented with small invertebrates (Baillon et al. 2016). This is consistent with the assumption that these sea pens are suspension feeders that can ingest zooplankton or degraded fractions of POM (Edwards & Moore 2008, Sherwood et al. 2008). However, while this suggests that the species is consuming prey rather than seston or POM from other primary sources, *Cavernularia* belongs to the Order Pennatulacea (within Octocorals), a soft coral that has a symbiotic relationship with zooxanthellae (*Symbiodinium* dinoflagellates) that photosynthesise and provide dissolved organic nutrients to their host (Schubert et al. 2015). Soft corals, therefore, gain their nutrients from autotrophic and heterotrophic sources, with limited data on the relative proportions that these two pathways contribute to their productivity (Schubert et al. 2015). *Cavernularia* was one of the most common and abundant benthic invertebrate species in the study region (Sampey et al. 2011, Cronin-O’Reilly et al. submitted-b) and is likely to be an important species for filtering suspended POM, but little is known about its feeding ecology.

Our results suggest that Cockburn Sound is a detritus-driven system, with high abundances and diversity of benthic invertebrates belonging to detritivore or benthic generalist feeding guilds (Cronin-O’Reilly et al. submitted-b) that rely on detritus either solely or partially as a food source. The detritivore *S. inspinosus* (sea star), which prefers silty sand/mud sediments (Marsh & Fromont 2020) appeared to gain its nutrients from kelp (*E. radiata*). This likely reflects the greater proportions of kelp found in the sedimentary POM, particularly in the deeper areas of northern Cockburn Sound where this sea star species mainly occurs (Sampey et al. 2011). This species is a “mud ingester”, filling its stomach with sediment from which food is ingested (Gale et al. 2013, Mah 2018). The congeneric *Stellaster childreni* feeds in a similar manner and gastropods, bivalves, scaphopods, sponges, foraminiferans, seagrass and algae have been recorded in its stomach (Hassan et al. 2017). The more enriched δ^{13}C for the sea star *A. angulatus* suggests additional sources such as seagrasses are contributing to its diet, although these are likely to comprise a range of macrophytes that contribute to the sedimentary POM. This sea star prefers fine organic sediments in shallower waters near seagrass meadows, and, while its diet is unknown, the species has been observed extra-oral feeding (Lawrence et al. 2011, Marsh & Fromont 2020). Both species are abundant in the Cockburn Sound (Cronin-O’Reilly et al. submitted-b) and are likely to play a major role in the system as detritivores.

Benthic generalist invertebrates, including prawns and portunid (swimmer) crabs, gain their nutrients either directly or indirectly from a range of primary sources. Benthic generalist species mostly had trophic levels between 2 and 3, suggesting that they feed on both primary consumers and detrital sources. Although there is a lack of local information on the diet of penaeid prawns in temperate Western Australia, studies elsewhere indicate that species of *Panaeus* and *Metapenaeopsis* feed on benthic invertebrates and detritus (Rasheed & Bull 1992, Wassenberg & Hill 1993, Muralidharan et al. 2023). Mixing models suggest that detrital kelp and other brown algae likely form the primary sources, particularly for the western king prawn (*P. latisulcatus*). This is different from the high contribution made by seagrass, mangrove and/or salt marsh determined for penaeids in other coastal environments in Australia, but dietary sources of prawns vary across species, life stage and habitat (Loneragan et al. 1997, Hewitt et al. 2020). Reduced input of seagrass in prawns in this study may be due to the lower extent of seagrass habitat in Cockburn Sound. In comparison, portunid crabs feed on benthic macroinvertebrates and, to a lesser extent, detritus (this study; Williams 1982, Wu & Shin 1997). In the current study, the blue swimmer crab (*P. armatus*) consumed large proportions of small bivalves and urchins. The proportion of urchins in crab stomachs in the current study was far greater and those of crustaceans considerably lower than recorded in the deeper waters of Cockburn Sound several years earlier (Campbell et al. 2021). As portunid crabs are typically opportunistic in their feeding (Edgar 1990, Norman & Jones 1992), this may reflect the changes in the abundance of benthic invertebrate prey species. For example, crustaceans are regarded as being particularly sensitive to the effects of hypoxia

(Tweedley et al. 2012, 2016) and recent work have shown that severe conditions of low oxygen lasting 1 to 2 days occur periodically during late summer/early autumn in the deeper water of Cockburn Sound (Dalseno et al. 2024).

Stable isotope data could not be collected for macroinvertebrates that likely form the diets of blue swimmer crabs and other benthic generalist species due to the low biomass in benthic grab samples from WWMSP Project "Benthic Communities in Soft-sediment and Natural Hard Habitats". However, based on a mixing model for this species, their prey are likely to gain their nutrients from a mix of primary sources that reflect the detrital composition of the sediment. Mixing models suggest that blue swimmer crab and the pink swimmer crab (*T. rugosus)* ultimately gain their nutrients from a mix of sources, including detrital kelp and other brown algae as well as seston. This corresponds to the broad diet of meiofauna and small macroinvertebrates such as copepods, amphipods and polychaetes in shallow areas of Cockburn Sound that appear to rely on a broad suite of microalgae (benthic microalgae, BMA) and macroalgae including brown, red and green algae (Hyndes & Lavery 2005). However, since we were unable to collect BMA in this study, its contribution to the food web via these benthic feeders is still unknown and needs to be examined in the future. The EcoPath model for Cockburn Sound estimated that transfer efficiency was highest at TrL 2 suggesting that the transfer and recycling of energy is retained and accumulated in the lower (TrL <2.5) portion of the food web (Lozano-Montes et al. 2024). Emphasing, that organic matter recycling and detritivory by benthic invertebrates are important elements in enrichment and nutrient cycling of the Cockburn Sound food web.

Benthic and bentho-pelagic carnivores also form an important component of the invertebrate assemblage in the study region (Cronin-O'Reilly et al. submitted-b). Western rock octopus (*O. djinda)* and mantis shrimp (*B. laevis)* are benthic carnivores, as supported by their TrLs at ~3. This is further supported by GCA, which showed a high proportion of crustaceans in the diets of the octopus (35% volume and a 72% frequency of occurrence), with smaller volumes of teleosts and other cephalopods. This is similar to the preliminary results from Claybrook (2020) who recorded brachyurans, teleosts and non-cephalopod molluscs as the most frequently ingested prey from octopus in Cockburn Sound and the work of Greenwell et al. (2019) on the trophic role of octopus inhabiting an abalone ranch on the south coast of Western Australia. Compared to western rock octopus, the mantis shrimp had a more depleted $\delta^{13}C$ suggesting a slightly different food source. Mantis shrimp are known to feed on a range of benthic crustaceans, molluscs and fish (Bo et al. 2020), as well as zooplankton (deVries 2017). Thus, while mixing models suggested that a mix of benthic primary sources contributed indirectly to the productivity of both species, the higher contribution of seston for the mantis shrimp likely reflects the consumption of zooplankton.

The bentho-pelagic cuttlefishes *A. novaehollandiae* and *A. cultratum* (both formerly in the genus *Sepia*) had similar mean $\delta^{13}C$ and $\delta^{15}N$ values to those of the mantis shrimp, suggesting a similar diet. Indeed, mixing models for *A. novaehollandiae* suggested that the primary sources of production included both seston and macroalgae. *Sepia* spp. feed on a mix of fish and invertebrates (including other cephalopods) from the benthic and more pelagic habitats (Alves et al. 2006, Neves et al. 2009). Thus, this species, and possibly *A. cultratum*, likely feeds on both pelagic and benthic prey. The southern squid (*S. australis)* had a similar mean $\delta^{13}C$ to those of cuttlefish and mantis shrimp, suggesting a similar base source of food, but its higher mean $\delta^{15}N$ and TrL (~4 vs 3) suggests that this species feeds at a higher trophic level. For example, several studies on other species of loliginid squid, indicate they predate mainly on fish and cephalopods with some crustaceans and molluscs also being ingested (Valls et al. 2015, Islam et al. 2018, Larivain et al. 2024).

4.3. Fishes

The slightly enriched δ^{13}C and δ^{15}N of zooplankton compared to seston suggests, unsurprisingly, that zooplankton are feeding on seston (phytoplankton and suspended POM). The small filter-feeding Australian anchovy (*E. australis),* sandy sprat (*H. vittatus)* and blue sprat (*S. robustus)* had similar δ^{13}C values to each other, but these values were considerably more enriched than zooplankton, their expected food source. Their reliance on zooplankton is supported by GCA, which showed that the vast majority of the diet of sandy sprat and blue sprat comprised pelagic crustaceans. However, their diets also consisted of some small benthic invertebrates that would derive their nutrients from benthic sources, such as harpacticoid copepods and small gastropods and some sandy sprat did consume eggs, which may have been from other teleosts. Other studies of both these baitfish in shallow Perth Metropolitan waters have recorded the presence of harpacticoid, gastropods and teleost eggs (Goh 1992, Schafer et al. 2002). Thus, the enriched δ^{13}C values, along with higher than expected δ^{15}N values likely reflect greater ingestion of benthic prey and teleost eggs than shown in GCA, which could reflect the highly-schooling nature of these species and patchiness in prey abundance. The larger filter-feeding Australian sardine (*S. sagax*), scaly mackeral (*S. lemuru*) and yellowtail scad (*T. novaezelandiae*) had similar δ^{13}C and δ^{15}N values to smaller species in this feeding guild, suggesting that they feed on similar prey (Appendix 5). Scaly mackeral and yellowtail scad elsewhere have been shown to feed on a range of zooplankton, with adults of the former species also consuming phytoplankton (Metillo et al. 2018, Schilling et al. 2022).

The detritivorous sea mullet (*M. cephalus*) formed the lowest trophic guild for fish assemblages in the study region, as shown by the low TrL (2.7) and is similar to the value of 2.14 taken from the literature (Appendix 4). This reflects its focus on ingesting detritus (Whitfield et al. 2012, Krispyn et al. 2021) compared to omnivorous fish species, including the confamilal yelloweye mullet (TrL 3.6) which also ingests macroinvertebrates (Appendix 5; Platell et al. 2006). In addition, its more enriched mean δ^{13}C compared to the omnivores such as the yelloweye mullet and sea trumpeter (*Pelsartia humeralis*) suggests a contribution of seagrass detritus to its diet. This is supported by the δ^{13}C for this species being similar to samples collected near seagrass meadows in Cockburn Sound by Hyndes and Lavery (2005). Moreover, in a BRUV survey of various natural and man-made habitats in Cockburn Sound, sea trumpeter were found to have a strong association with seagrass habitats (Yeoh et al. submitted).

The meta-analysis identified that several of the species recorded in Cockburn Sound in Yeoh et al. (submitted) were herbivores (Appendix 5), for example, Gladius drummer (*Kyphosus gladius*), silver drummer (*Kyphosus sydneyanus*), McCulloch's scalyfin (*Parma mccullochi*), western scalyfin (*Parma occidentalis*) and herring cale (*Olisthops cyanomelas*) (Shepherd & Baker 2008, Vitelli et al. 2015, Turco 2017). However, as these were typically only recorded on baited remote underwater video (Yeoh et al. submitted), no physical specimens were able to be obtained of SIA.

Omnivores, including sea trumpeter (*P. humeralis)* and western striped grunter (*H. octolineatus),* had similar mean δ^{13}C to those of benthic generalist invertebrates (-16.5 to -18.4 vs - 15.2 to -17.3‰), suggesting that they gain nutrients from similar primary food sources. However, their trophic levels were higher, albeit with some overlap (2.8-3.6 vs 1.8-2.8). The western smooth boxfish (*A. amygdaloides)* ingested similar food items to that of snapper (*C. auratus*) and skipjack trevally (*P. wright*), i.e. crustaceans, molluscs, echinoderms, but in different relative proportions and with the addition of macrophytes, albeit in low volumes. The other omnivorous species have been shown to feed on a range of similar prey and plant material. For example, western striped grunter switch from small crustaceans to macrophytes as they increase in size and southern garfish (*H. melanochir*) consume macrophytes during daylight and small crustaceans at night (Earl et al. 2011, Poh et al. 2018, Whitfield et al. 2022). The bridled leatherjacket (*A. spilomelanurus*) had the lowest mean TrL (2.86) of all omnivores. This species is abundant in seagrass beds in Cockburn Sound (Hyndes et al. 2003, Yeoh et al. submitted) and macrophytes contribute a far larger proportion of its diet than the other omnivores (i.e. 86%; Appendix 5; see also Robertson & White 1986).

Benthic invertivores, including yelloweye mullet, snapper and skipjack trevally, displayed high overlap of mean $\delta^{13}C$ and $\delta^{15}N$ with those of omnivorous fish and benthic generalist invertebrates, again suggesting that they gain nutrients from a similar mix of primary food sources for several species. Modified Costello plot using gut content analysis showed that the latter two species western butterfish (*P. vitta*) and western trumpeter whiting (*S. burrus*) were very opportunistic in the diet. However, there was a wide range in mean $\delta^{13}C$ within this guild, with juvenile southern school whiting (*S. bassensis)* being the most depleted and yellowfin whiting (*S. schomburgkii)* being the most enriched in ^{13}C, suggesting a shift in base food sources between these two species. This likely reflects differences in habitat and food utilised by the different history stages and species (Hyndes et al. 1996, 1997). Among the fish in this group, snapper had the highest TrL, which likely reflects its greater consumption of teleost material (Table 5; French et al. 2012). The EcoPath model for Cockburn Sound highlighted that benthic invertebrates (e.g. western king prawn and blue swimmer crabs) and various fishes, including baitfish, mullets and a range of invertivores, comprised ~76% of the total biomass, showing the dominance of these benthic groups in the food web (Lozano-Montes et al. 2024). Such is the importance of these species that declines in their abundance have the potential to reduce the production of higher trophic levels consumers.

The benthic ambush predators rusty flathead (*I. japonica)* and midget flathead (*O. spinosa)* had similar mean $\delta^{13}C$ and $\delta^{15}N$ values to those of benthic and bentho-pelagic invertebrates (mantis shrimp and octopus, and squid and cuttlefish, respectively). Since mixing models suggested that mantis shrimp and octopus ultimately gain their nutrients from a mix of primary sources, but predominantly seston and kelp, these flathead species are likely to gain their nutrients from a similar mix of base sources. Analysis of their stomach contents showed that both these flathead species feed on a range of crustaceans, including amphipods, snapping shrimp, mantis shrimp and small crabs, and when larger also small fish. In comparison, the longspine flathead (*P. grandispinis)* had a higher mean $\delta^{15}N$ value, and therefore, a higher TrL (4.2 vs ~3.6). This likely reflects the greater consumption of fish by longspine flathead compared to the other flathead species. For example, in this study, 2% of the diet of midget flathead (max. size = 25 cm TL) was fish, whereas this value was 43% for the longspine Flathead (max. size = 38 cm TL; Appendix 4, Table 5). Similarly, Coulson et al. (2015) recorded that teleosts contributed 29% to the volume of longspine flathead's diet across south-western Australia. In contrast to these flathead species, soldier (*G. marmoratus*) had a far lower mean $\delta^{15}N$ value and TrL (2.7). Mean $\delta^{13}C$ and $\delta^{15}N$ values sit in the center of those for the different benthic invertebrates and likely reflect the high consumption of amphipods, many of which feed on detritus (Guerra-García et al. 2014).

The diets of many of the benthic invertivores (including blue swimmer crabs) and benthic ambush predators differed among the three regions, with the composition of prey consumed in Owen Anchorage typically being the most distinct. Prey categories that helped differentiate this region from North and South Cockburn Sound included greater volumes small gastropods, including retusids (blue swimmer crabs, longspine dragonets, western butterfish), ostracods (longspine dragonets), the bivalve *Solemya* sp. (longspine dragonets, western trumpeter whiting, skipjack travelly, snapper) and snapping shrimp (rusty flathead). In contrast, increased volumes of cumaceans (silver travelly, snapper) and polychaetes (western trumpeter whiting) in North and South Cockburn Sound. These dietary shifts reflect trends in the abundances of such taxa as determined by trawl and grab surveys in these regions (Cronin-O'Reilly et al. submitted-b). This indicates that, in addition to consuming a wide variety of prey, many fish predators appear to be opportunistic in their feeding seeming to target the most abundant and available prey. Moreover, that the prey resources in Owen Anchorage and Cockburn Sound differ likely due to the presence of seagrass, sediment composition (particularly grain size), water circulation and hypoxia (Kendrick et al. 2002, Sampey et al. 2011, Dalseno et al. 2024, Cronin-O'Reilly et al. submitted-b). It is worth noting, however, that many of the generalist species for which dietary information was obtained in the current study were associated with soft sediment, e.g. longspine dragonets and rusty flathead, or had no particular habitat preference, e.g. skipjack travelly and western butterfish (Yeoh et al. submitted). Thus, it is not clear whether such trends would also apply to more specialised seagrass-associated species, e.g. sygnathids (Kendrick & Hyndes 2005, Manning et al.

2019).

In terms of elasmobranchs, the southern eagle ray (*M. tenuicaudatus)* had mean δ^{13}C and δ^{15}N within the range of benthic-invertivore fish. Individuals examined in the current study consumed mainly crustaceans (portunid crabs), followed by polychaetes and molluscs, with only 3% of the volume comprising fish. The very small contribution of fish to the diet of southern eagle rays was also recorded in individuals found in marine waters further offshore and the Swan-Canning Estuary (Sommerville et al. 2011, Trayler et al. 2024). While the mean δ^{15}N for Port Jackson shark (*H. portusjacksoni)* was similar to that of the southern eagle ray, its mean δ^{13}C was more depleted and similar to the pelagic species, suggesting that seston indirectly makes a substantial contribution to the nutrients assimilated by this species. Port Jackson sharks are known to consume a wider variety of prey than southern eagle rays, including cephalopods and fish (Sommerville et al. 2011). The gummy shark (*M. antarcticus)* had the highest mean δ^{15}N and TrL (4.3) of all the finfish, indicating it has the highest trophic position of the species examined in the study. The diet of this shark mainly comprises fish, crabs and cephalopods, with these higher trophic-level taxa being consumed more frequently. Thus, while fish were found in 50% of the stomachs of gummy sharks, they were found in only 15.8% and 6.4% of Pork Jackson sharks and southern eagle rays, respectively, and a similar trend was found for cephalopods, i.e. 27.8 vs 8.5 and 1.4%, respectively (Simpfendorfer et al. 2001, Sommerville et al. 2011).

4.4. Birds and mammals

Little penguins (*E. minor)* had the highest mean δ^{15}N of all species examined, but greater than one trophic level above their expected food source of pelagic planktivores (Klomp & Wooller 1988). Their mean δ^{13}C was also more enriched than expected. This likely reflects an important food source that was missed within Cockburn Sound, or non-nesting penguins foraging in another region outside of Cockburn Sound prior to molting, and/or δ^{15}N from the feathers was enriched from the penguins' tissues (WWMSP Project "Determining the Diet, Causes of Mortality, Foraging Habitat and Home Range of Little Penguins"). In comparison, dolphins and sealions had similar mean δ^{15}N and TrL to those of a range of benthic carnivores including snapper, while their mean δ^{13}C was within the range of benthic invertebrates, suggesting a mix of base sources that contribute indirectly to their diet. Indo-Pacific dolphins in Cockburn Sound have a diet comprising a range of benthic and pelagic fish species, and octopus (WWMSP Project "Spatio-temporal distribution of key habitat-uses and key prey species for Indopacific bottlenose dolphins in Owen Anchorage and Cockburn Sound)". The lower TrL for dolphins than penguins may be due to some of the benthic fish they consume, e.g. sea mullet and estuary cobbler (D. Chabanne & K. Nicolson, Murdoch University, pers comm.), which have low trophic levels (see Table 13). The mean δ^{15}N for dolphins in Cockburn Sound (12.08) was greater than those that utilize the Peel-Harvey estuary (9.86) and similar to those in coastal waters directly south of Cockburn Sound (10.72-11.18; Nicholson et al. 2021). Similarly, the Australian sea lion consumes a range of fish, sharks and rays, cephalopods and crustaceans (McIntosh et al. 2006, Kirkwood & Goldsworthy 2013, Berry et al. 2017), with the consumption of lower tropic level fish and invertebrates species likely influencing the low TrL shown in Cockburn Sound.

More detailed analyses into the trophic ecology of penguins and dolphins in Cockburn Sound will be conducted in WWMSP Project "Determining the Diet, Causes of Mortality, Foraging Habitat and Home Range of Little Penguins)" and WWMSP Project "Spatio-temporal distribution of key habitat-uses and key prey species for Indopacific bottlenose dolphins in Owen Anchorage and Cockburn Sound)", respectively. However, modeling suggested that top predators such as large (white, tiger and spinner sharks) and small (e.g. Pork Jackson shark) sharks, dolphins, penguins and several sea birds had negative trophic impacts on small pelagic and invertivorous fish (Lozano-Montes et al. 2024). Thus, these predators were keystone species and exerted significant direct and indirect effects on the trophic structure in Cockburn Sound.

5. Conclusion and recommendations

Aquatic ecosystems are exposed to single and cumulative pressures acting simultaneously at multiple spatial and temporal scales. As food webs link major biotic and abiotic components, they allow for a quantification of the effects of environmental change on both the structure of biological diversity and ecosystem functioning (Mancinelli & Vizzini 2015, Alp & Cucherousset 2022). Using gut content and stable isotope approaches, this project aimed to produce a conceptual model and contemporary data on the diet of key fish and invertebrate species and food web structure for Cockburn Sound and Owen Anchorage. Such information is critical for ecosystem-based fisheries management and informing and validating the conceptual, qualitative and quantitative ecosystem models that were developed to characterise the trophic structure, ecosystem attributes and function of Cockburn Sound by Lozano-Montes et al. (2024). In addition to Cockburn Sound, Ecopath with Ecosim has also been used recently internationally to evaluate the impact of dredge spoil dumping (Raoux et al. 2020) and the deployment of artificial reefs (Zhang et al. 2022). During our study, the stomach contents of 2,117 individuals representing 16 fish and two invertebrate species were examined, and high-resolution data was generated, providing quantitative data on their last meal. These data were examined to determine the extent of dietary overlap and thus competition for food resources among species, and whether each species' diet changes through ontogeny and spatially and temporally. Stable isotope analysis was conducted on nine primary producers and 55 consumers (secondary consumers through to apex predators) to determine the main sources of production that drive secondary production and the flow of nutrients and energy through the food web. Data were extracted and synthesised from the scientific literature to provide trophic level and dietary composition data for ~200 fish species recorded in Cockburn Sound during the WWMSP. Based on our new understanding of the food web structure and trophic flows, the structure of the models developed by Lozano-Montes et al. (2024) and the dietary matrices created for the 73 functional groups in the Ecopath model need to be reviewed to allow simulations to be run and to evaluate future scenarios for Cockburn Sound.

Gut content analysis demonstrated that each species studied consumed a significantly different suite of prey and thus had a unique diet. Small pelagic baitfish species, blue sprat and sandy sprat, fed primarily on zooplankton, particularly planktonic crustaceans. Most other species studied fed on benthic or epibenthic prey. Blue swimmer crab and longspine dragonet consumed mainly bivalve and gastropod molluscs, while soldier, midget flathead and western rock octopus ingested predominantly crustaceans. Other species, such as skipjack trevally, western butterfish, snapper and western trumpeter whiting, had a broad diet consuming a range of taxa, including molluscs, polychaetes, crustaceans and echinoderms. Some of the larger flathead species consumed teleosts.

Blue swimmer crabs, western rock octopus, blue sprat and sandy sprat have a specialised diet, i.e. a particular dietary category was dominant in terms of the volume and frequency with which it was consumed. As such, these species are more at risk from future human disturbances that may shift the abundances and/or distributions of prey and thus reduce their abundance. There is some evidence that previous changes in food availability may have influenced the abundance of species in Cockburn Sound. For example, stocks of blue swimmer crabs declined significantly in the early 2000s and despite various management measures, the commercial and recreational fishery has been closed since 2014, with the lack of a recovery being linked to a decline in productivity in Cockburn Sound (Johnston et al. 2011, Marks et al. 2021). Moreover, Campbell et al. (2021) provided evidence that blue swimmer crabs in the nearby Peel-Harvey Estuary were consuming a lower calorie diet than in the past and ingested large quantities of mollusc shell fragments rather than living molluscs. As blue swimmer crabs and baitfish are secondary consumers, impacts on their food resources can affect higher trophic level fauna such as little penguins. Moreover, the Ecopath model developed for Cockburn Sound indicated that declines in benthic fishes have the potential to reduce the production of higher trophic levels consumers (Lozano-Montes et al. 2024).

Many of the other species studied, e.g. western butterfish, western trumpeter whiting, snapper, skipjack trevally, were trophic generalists. Thus, their diets may reflect the abundance of prey in proximity to where they were collected. Typically, these species would be considered more resilient to changes in the abundance and distribution of prey taxa, and co-occurring species often partition food resources to reduce the impacts of competition. Many of the species studied consumed small invertebrates, highlighting the importance of such taxa in the food web for Cockburn Sound (Figure 100). Decapod and stomatopods and bivalves were both identified as being particularly important for multiple species and likely a source of competition. There is very limited knowledge on the composition of the benthic macroinvertebrate fauna of Cockburn Sound, and the abundance of species other than those that have been or are currently fishery targets (e.g. blue swimmer crab and western king prawn), yet small portunids, various small crustaceans and molluscs are crucial food resources and a key link in the food web. Moreover, despite substantial research on seagrass meadows, their fish fauna and their restoration, there is almost no understanding of the invertebrate communities of these habitats (except for Brearley & Wells 1998).

Stable isotope analyses revealed a high degree of variability in the stable isotope signatures for sources of production (primary producers), invertebrates and fishes. Trophic levels varied up to nearly 5 (where a value of 1 reflects the base level of primary producers), indicating a high diversity of trophic guilds in the system. The high variability in $\delta^{13}C$ across consumer guilds and species indicates a diversity of sources contributing to the food web. Mixing models, based on $\delta^{13}C$ and $\delta^{15}N$, suggested that a range of primary producers contributed to the sedimentary detritus in the system, including benthic macrophytes (kelp and seagrass) and seston (phytoplankton and suspended POM). However, we could not collect adequate samples of BMA in the study, and this remains a gap in our understanding of benthic drivers of the food web in Cockburn Sound.

Benthic invertebrates and fishes gain their nutrients predominantly from a range of benthic primary producers, through either direct consumption of detritus or indirectly via their prey. Even some suspension feeders (sea squirt) are likely to gain their nutrients from the resuspension of sedimentary POM. This formed a clear benthic food web within the system, driven by sedimentary POM. In comparison, seston appeared to form the major base source for the pelagic food web, with planktivorous fishes forming the first consumer level. Slightly enriched $\delta^{13}C$ values suggest that benthic sources also contribute to this food web. Thus, the resuspension of benthic POM or the movement of consumers through the water column provides some coupling of these two food webs.

Development of the food web was inhibited by the lack of stable isotope data for the small invertebrates, which related to the small biomass obtained from samples collected in WWMSP Project "Benthic Communities in Soft-sediment and Natural Hard Habitats". Since GCA showed the importance of these invertebrates in Cockburn Sound, the absence of these consumers from our SIA and mixing models is clearly a gap in our ability to link these consumers to primary sources of production in the food web for Cockburn Sound. While there were considerable funding and efficiency benefits in utilising a coordinated sampling program across WWMSP projects, future programs should ensure adequate funding is assigned to individual projects to allow for contingency sampling and processing for these types of issues.

No dietary data are available for penaeid prawns (including the commercially important western king prawn), snapping shrimp, mantis shrimp and small crabs. This knowledge gap was also raised as a future research need by Lozano-Montes et al. (2024) in WWMSP Project "Using Conceptual, Qualitative and Quantitative Ecosystem Models to Characterise the Trophic Structure, Ecosystem Attributes and Functioning of Cockburn Sound". Future stable isotope analysis should also build on the data derived in this project and investigate food chain length, $\delta^{15}N$ range, $\delta^{15}N$–based trophic position and $\delta^{13}C$ range, isotopic niche size (i.e. trophic diversity) and the degree of trophic redundancy. Such metrics have proven useful in understanding the impacts of habitat degradation and land-use changes and changes in the abundance of both basal sources and predators (Alp & Cucherousset 2022) and would be useful in validating and/or revising the ecosystem models developed by Lozano-Montes et al. (2024).

Cockburn Sound has experienced significant widespread loss of seagrass (~80%) since the 1960s (Kendrick et al. 2002), and it has recently been suggested that the system has seen a phase shift from seagrass-driven to phytoplankton-driven system, with phytoplankton estimated to contribute over 70% of the primary production in the system (BMT 2018). However, there is no evidence that phytoplankton is driving the food web in Cockburn Sound. Firstly, seston (phytoplankton and suspended POM) contributed less to the sediment POM in Cockburn Sound compared to Owen Anchorage. Rather, macroalgae from within and outside the system contributed the most to the sedimentary POM. Secondly, the megabenthic and macrobenthic invertebrate communities were dominated by the detritivore and benthic generalist feeding guilds (Cronin-O'Reilly et al. submitted-b). Furthermore, the dominant invertebrates between the 1970s and 2021/22 were similar, i.e. swimmer crab species and megabenthic the western king prawn (Dybdahl 1979, Cronin-O'Reilly et al. submitted- b), while a direct comparison of trawl data between the 2000s and 2020s revealed declines in abundances of the suspension-feeding orange sea pen and sea cucumbers (as well as the western king prawn the swimmer crab *T. rugosus*, but increases in abundances of generalist benthic feeders such as the blue swimmer crab and mantis shrimp (Sampey et al. 2011, Cronin-O'Reilly et al. submitted- b). Thus, while we show that there is a clear pelagic path from phytoplankton to top-order consumers like the little penguin, the food web of Cockburn Sound is predominantly detritus-driven through predominantly macroalgae. Even suspension feeders like the ascidian (sea squirt) appear to rely on benthic production, in this case seagrass. There is a clear gap in our knowledge of primary production of macroalgae in Cockburn Sound as well as the inputs of macroalgal detritus from outside the embayment that likely drives secondary production. Also, as discussed earlier, there is need to better understand the role of BMA in the food web structure of Cockburn Sound.

Ecosim modelling has indicated that seagrass currently plays a modest role in the food web (Lozano-Montes et al. 2024), which is supported by our results. However, increases in seagrass biomass in Cockburn Sound over recent years, along with the projected increases from restoration projects, will increase benthic production both directly through the production of seagrass material and indirectly through the growth of epiphytic algae. Seagrasses in Owen Anchorage house vastly different fish and invertebrate communities than shallow or deep unvegetated habitats (Hyndes et al. 2003, Yeoh et al. submitted) and provide important food sources for those communities, particularly through epiphytes (Smit et al. 2005, 2006). While studies investigating the success of seagrass restoration in Cockburn Sound have focused on the seagrasses themselves and not the associated fauna, studies on *Zostera marina* beds in Europe and the USA have shown that restoration can have a positive impact on invertebrate communities (Sievers et al. , Orth et al. 2020, Gagnon et al. 2023). Increases in seagrasses will lead to increases in abundances of a range of feeding guilds, but particularly omnivorous species such as western striped grunter and the bridled leatherjacket, invertivores feeding on copepods such as pipefish, and the food web structure. It will also lead to the export of detritus from seagrass meadows to other shallow and deeper habitats of Cockburn Sound, leading to increased POM and production for detritivores and generalist feeding guilds.

The provision of additional hard substrate through the construction of breakwaters and/or the deployment of artificial reefs will influence the trophic environment of Cockburn Sound to some extent. The magnitude of the effects, however, will likely be influenced by factors such as the size of a reef and the degree of isolation of individual modules (Zalmon et al. 2014). A small-scale trial conducted in Cockburn Sound found that commonly used artificial reef substrates (i.e. limestone, steel and concrete) were colonised by tunicates, bryozoans, algae and barnacles (Cronin-O'Reilly et al. submitted-a). As hard substrates comprise only a small proportion of the habitat in Cockburn Sound, the additional provision of such a habitat would likely increase the filtering capacity of seston and resuspended sediment POM. The deployment of artificial structures could alter hydrodynamics, trap drift algal material and lead to increases in the input of biogenic material and leaching of contaminants from construction material, leading to changes in the benthic environment, particularly sediment particle sizes and organic content (Davis et al. 1982, Reeds et al. 2018). The impacts of artificial reefs on the surrounding infauna, which are prey to many fish species, are highly variable, with no changes detected in some studies, while others report increases or decreases in the species richness, abundance and biomass of infauna (Reeds et al. 2018). This indicates that the findings are context-dependent, i.e. influenced by the reef design, local environmental conditions, and habitat preferences of local species. However, there is a range of existing artificial reefs in south-western Australia where this phenomenon could be investigated (Florisson et al. 2018, Hammond et al. 2020). In terms of their fish faunas, existing rock walls in Cockburn Sound were found to support a different fish fauna to those in shallow, deeper and dredged areas of soft-sediment, i.e. habitat on to which breakwaters and artificial reefs would likely be deployed (Wakefield et al. 2013, Yeoh et al. submitted). Combined, the provision of additional hard substrate and associated sessile invertebrate fauna would likely benefit omnivorous species, e.g. western smooth boxfish (Maus et al. 2023) or generalist species, e.g. skipjack trevally and western butterfish (Yeoh et al. submitted).

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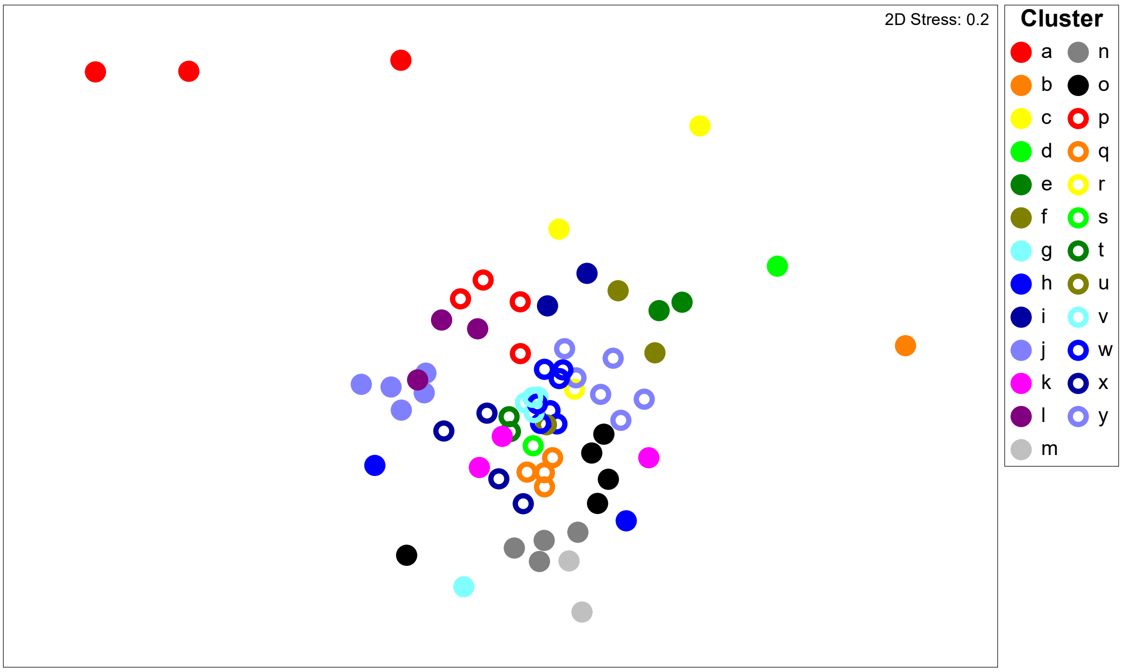
7. Appendices

Appendix 1. Common name, scientific name, family and cluster group to which each of the 72 fish species were allocated based on CLUSTER-SIMPROF analysis of the averaged values for 17 morpho-anatomical traits (Table 4). Shading denotes species for which dietary information was obtained during the current project.

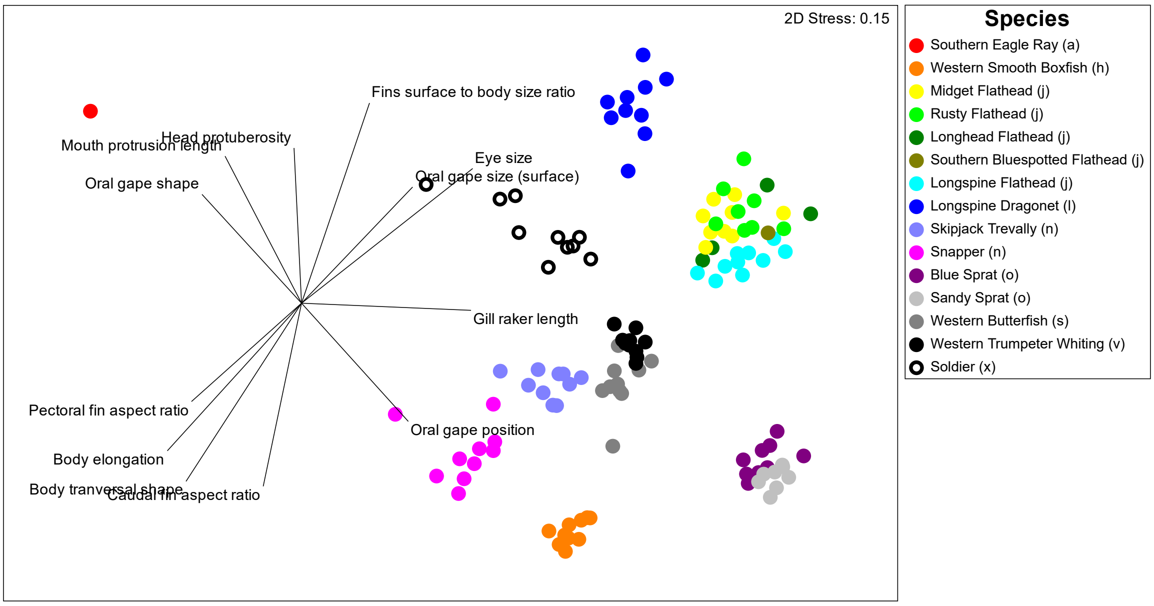
Common name	Species	Family	Cluster
Southern Eagle Ray	*Myliobatis tenuicaudatus*	Myliobatidae	*a*
Western Shovelnose Ray	*Aptychotrema vincentiana*	Trygonorrhinidae	*a*
Southern Fiddler Ray	*Trygonorrhina dumerilii*	Trygonorrhinidae	*a*
Smooth Pipefish	*Lissocampus caudalis*	Syngnathidae	*b*
Bearded Leatherjacket	*Anacanthus barbatus*	Monacanthidae	*c*
Tubemouth	*Siphonognathus argyrophanes*	Odacidae	*c*
Spotted Pipefish	*Stigmatopora argus*	Syngnathidae	*d*
Shorthead Seahorse	*Hippocampus breviceps*	Syngnathidae	*e*
West Australian Seahorse	*Hippocampus subelongatus*	Syngnathidae	*e*
Tiger Pipefish	*Filicampus tigris*	Syngnathidae	*f*
Longsnout Pipefish	*Vanacampus poecilolaemus*	Syngnathidae	*f*
Rough Bullseye	*Pempheris klunzingeri*	Pempherididae	*g*
Globefish	*Diodon nicthemerus*	Diodontidae	*h*
Western Smooth Boxfish	*Anoplocapros amygdaloides*	Ostraciidae	*h*
Spadenose Clingfish	*Cochleoceps spatula*	Gobiesocidae	*i*
Green Clingfish	*Cochleoceps viridis*	Gobiesocidae	*i*
Rusty Flathead	*Inegocia japonica*	Platycephalidae	*j*
Longhead Flathead	*Leviprora inops*	Platycephalidae	*j*
Midget Flathead	*Onigocia spinosa*	Platycephalidae	*j*
Longspine Flathead	*Platycephalus grandispinis*	Platycephalidae	*j*
Southern Bluespot Flathead	*Platycephalus speculator*	Platycephalidae	*j*
Common Hardyhead	*Atherinomorus vaigiensis*	Atherinidae	*k*
Southern Garfish	*Hyporhamphus melanochir*	Hemiramphidae	*k*
Yellowtail Barracuda	*Sphyraena obtusata*	Sphyraenidae	*k*
Longspine Dragonet	*Pseudocalliurichthys goodladi*	Callionymidae	*l*
Flathead Sandfish	*Lesueurina platycephala*	Leptoscopidae	*l*
Spiny Gurnard	*Lepidotrigla papilio*	Triglidae	*l*
Common Silverbiddy	*Gerres subfasciatus*	Gerreidae	*m*
Silverbelly	*Parequula melbournensis*	Gerreidae	*m*
Silver Trevally	*Pseudocaranx georgianus*	Carangidae	*n*
Skipjack Trevally	*Pseudocaranx wrighti*	Carangidae	*n*
Yellowtail Scad	*Trachurus novaezelandiae*	Carangidae	*n*
Snapper	*Chrysophrys auratus*	Sparidae	*n*
Sandy Sprat	*Hyperlophus vittatus*	Clupeidae	*o*
Scaly Mackerel	*Sardinella lemuru*	Clupeidae	*o*
Australian Sardine	*Sardinops sagax*	Clupeidae	*o*
Blue Sprat	*Spratelloides robustus*	Clupeidae	*o*
Australian Anchovy	*Engraulis australis*	Engraulidae	*o*
Port Jackson Shark	*Heterodontus portusjacksoni*	Heterodontidae	*p*
Estuary Cobbler	*Cnidoglanis macrocephalus*	Plotosidae	*p*
Whitelip Catfish	*Paraplotosus albilabris*	Plotosidae	*p*
Gummy Shark	*Mustelus antarcticus*	Triakidae	*p*
Australian Herring	*Arripis georgianus*	Arripidae	*q*
Yelloweye Mullet	*Aldrichetta forsteri*	Mugilidae	*q*
Sea Mullet	*Mugil cephalus*	Mugilidae	*q*
Tailor	*Pomatomus saltatrix*	Pomatomidae	*q*

Common name	Species	Family	Cluster
Blue Weed Whiting	*Haletta semifasciata*	Odacidae	*r*
Western Butterfish	*Pentapodus vitta*	Nemipteridae	*s*
Bluespotted Goatfish	*Upeneichthys vlamingii*	Mullidae	*t*
Australian Goatfish	*Upeneus australiae*	Mullidae	*t*
Western Striped Grunter	*Helotes octolineatus*	Terapontidae	*u*
King George Whiting	*Sillaginodes punctatus*	Sillaginidae	*v*
Southern School Whiting	*Sillago bassensis*	Sillaginidae	*v*
Western Trumpeter Whiting	*Sillago burrus*	Sillaginidae	*v*
Yellowfin Whiting	*Sillago schomburgkii*	Sillaginidae	*v*
Brownfield's Wrasse	*Halichoeres brownfieldi*	Labridae	*w*
Brownspotted Wrasse	*Notolabrus parilus*	Labridae	*w*
Spikey Bass	*Hypopterus macropterus*	Latidae	*w*
Rainbow Cale	*Heteroscarus acroptilus*	Odacidae	*w*
Little Weed Whiting	*Neoodax balteatus*	Odacidae	*w*
Longray Weed Whiting	*Siphonognathus radiatus*	Odacidae	*w*
Sea Trumpeter	*Pelsartia humeralis*	Terapontidae	*w*
Western Gobbleguts	*Ostorhinchus rueppellii*	Apogonidae	*x*
Old Wife	*Enoplosus armatus*	Enoplosidae	*x*
Little Gurnard Perch	*Maxillicosta scabriceps*	Neosebastidae	*x*
Soldier	*Gymnapistes marmoratus*	Tetrarogidae	*x*
Shorthead Sabretooth Blenny	*Petroscirtes breviceps*	Blenniidae	*y*
Southern Crested Weedfish	*Cristiceps australis*	Clinidae	*y*
Adelaide Weedfish	*Heteroclinus adelaidae*	Clinidae	*y*
Bridled Leatherjacket	*Acanthaluteres spilomelanurus*	Monacanthidae	*Y*
Toothbrush Leatherjacket	*Acanthaluteres vittiger*	Monacanthidae	*y*
Dusky Snake Blenny	*Ophiclinus antarcticus*	Ophiclinidae	*y*

Appendix 2. nMDS plot showing the relationships between each of the 72 fish species, based on their morpho-anatomical traits. Fish coded according to the cluster they belong (Appendix 1).



Appendix 3. nMDS plot based on the morpho-anatomical traits of individuals from 15 species where dietary data were available. The functional group to which each species belong (Figure 28) is listed in the key. Vectors are provided for species whose values for a trait change in a linear direction (Pearson correlation > 0.6) relative to the nMDS axes.



Appendix 4. Body shape, habitat, maximum size and estimated trophic level (TrL) and standard error (SE) of each of the 204 fish species recorded in Cockburn Sound by WWSMP Project "Spatial Distribution and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound" (Yeoh et al. submitted). Data obtained from Fishbase (Froese & Pauly 2024) and, where available, stable isotope data from the current project are provided (Table 9). D denotes, for the Fishbase data, how the trophic level was estimated i.e. 1, from an empirical study; 2, estimated from known dietary items; 3, estimated from a similar species. Maximum sizes based on TL, total length; SL, standard length; FL, fork length; DW, disk width; OT, other and values in italics were taken from Fishes of Australia (Bray & Gomon 2024).

Species	**Common name**	**Family**	**Fishbase data**							**Current study**				
			Body Shape	**Habitat**	**Size (cm)**		**TrL**	**SE**	**D**	**δ13C**	**δ15N**	**δ 34S**	**C:N**	**TrL**
Heterodontus portusjacksoni	Port Jackson Shark	Heterodontidae	Elongated	demersal	165	TL	3.45	0.48	2					
Carcharodon carcharias	White Shark	Lamnidae	fusiform / normal	pelagic-oceanic	640	TL	4.53	0.37	1					
Aulohalaelurus labiosus	Blackspotted Catshark	Scyliorhinidae	Elongated	demersal	*67*	*TL*	3.80	0.30	3					
Furgaleus macki	Whiskery Shark	Triakidae	Elongated	demersal	160	TL	3.75	0.41	1					
Mustelus antarcticus	Gummy Shark	Triakidae	Elongated	demersal	157	TL	4.10	0.45	1	-17.72	12.46		2.71	4.30
Carcharhinus brevipinna	Spinner Shark	Carcharhinidae	fusiform / normal	reef-associated	300	TL	4.20	0.64	1	-18.29	12.35		2.71	4.25
Rhynchobatus australiae	Whitespotted Guitarfish	Rhinidae	Elongated	demersal	124	TL	3.54	0.50	1					
Aptychotrema vincentiana	Western Shovelnose Ray	Trygonorrhinidae	Other	demersal	84	TL	3.60	0.60	3	-15.39	11.20		2.68	3.75
Trygonorrhina dumerilii	Southern Fiddler Ray	Trygonorrhinidae	Other	demersal	146	TL	3.70	0.60	3					
Hypnos monopterygius	Coffin Ray	Hypnidae	Other	reef-associated	70	TL	3.67	0.57	2					
Bathytoshia brevicaudata	Smooth Stingray	Dasyatidae	Other	demersal	430	TL	3.87	0.51	2	-19.52	9.24		2.74	2.90
Bathytoshia lata	Black Stingray	Dasyatidae	Other	demersal	260	DW	4.00	0.60	3					
Trygonoptera mucosa	Western Shovelnose Stingaree	Urolophidae	Other	demersal	44	TL	3.09	0.24	1					
Trygonoptera ovalis	Striped Stingaree	Urolophidae	Other	reef-associated	61	TL	3.60	0.50	3					
Trygonoptera personata	Masked Stingaree	Urolophidae	Other	demersal	47	TL	3.20	0.30	1					
Urolophus paucimaculatus	Sparsely-spotted Stingaree	Urolophidae	other	demersal	57	TL	3.70	0.59	2					
Myliobatis tenuicaudatus	Southern Eagle Ray	Myliobatidae	other	benthopelagic	150	DW	3.46	0.59	1	-16.53	10.16		2.70	3.30
Gymnothorax woodwardi	Woodward's Moray	Muraenidae	eel-like	reef-associated	*58*	*TL*	3.90	0.60	3					
Etrumeus jacksoniensis	Maray	Clupeidae	elongated	pelagic-neritic	*28*	*TL*	3.60	0.20	3					
Hyperlophus vittatus	Sandy Sprat	Clupeidae	elongated	pelagic-neritic	10	SL	3.40	0.45	2	-18.99	10.44	17.36	3.30	3.42
Nematalosa vlaminghi	Perth Herring	Clupeidae	fusiform / normal	pelagic-neritic	36	SL	3.40	0.45	2					
Sardinella lemuru	Scaly Mackerel	Clupeidae	fusiform / normal	pelagic-neritic	23	SL	2.48	0.00	2	-19.41	10.07		3.22	3.26
Sardinops sagax	Australian Sardine	Clupeidae	fusiform / normal	pelagic-neritic	40	SL	2.84	0.13	1	-19.85	9.65		3.30	3.08
Spratelloides robustus	Blue Sprat	Clupeidae	elongated	pelagic-neritic	12	SL	3.40	0.45	2	-18.82	10.63		3.44	3.51
Engraulis australis	Australian Anchovy	Engraulidae	elongated	pelagic-neritic	15	SL	3.00	0.00	2	-19.56	10.68	17.48	3.34	3.52
Trachinocephalus trachinus	Painted Grinner	Synodontidae	elongated	reef-associated	23	SL	4.20	0.70	3					
Gonorynchus greyi	Beaked Salmon	Gonorynchidae	elongated	demersal	50	TL	2.10	0.10	3					
Cnidoglanis macrocephalus	Estuary Cobbler	Plotosidae	elongated	demersal	91	SL	2.81	0.32	2					
Paraplotosus albilabris	Whitelip Catfish	Plotosidae	elongated	reef-associated	134	TL	3.44	0.54	2					
Plotosus lineatus	Striped Catfish	Plotosidae	fusiform / normal	reef-associated	32	TL	3.57	0.30	1					
Cochleoceps spatula	Spadenose Clingfish	Gobiesocidae	elongated	demersal	*7*	*TL*	3.20	0.30	3					
Cochleoceps viridis	Green Clingfish	Gobiesocidae	elongated	demersal	5	TL	3.20	0.30	3					
Euleptorhamphus viridis	Longfin Garfish	Hemiramphidae	eel-like	pelagic-oceanic	53	TL	3.40	0.45	2					
Hemiramphus robustus	Three-by-two Garfish	Hemiramphidae	elongated	pelagic-neritic	32	SL	3.40	0.50	3					
Hyporhamphus melanochir	Southern Garfish	Hemiramphidae	elongated	pelagic-neritic	52	SL	2.65	0.27	2	-18.38	10.08		3.26	3.26
Strongylura leiura	Slender Longtom	Belonidae	elongated	reef-associated	100	TL	3.94	0.64	2					
Atherinomorus vaigiensis	Common Hardyhead	Atherinidae	elongated	pelagic-neritic	17	TL	3.30	0.42	1	-18.08	11.43	17.64	3.20	3.85
Atherinosoma elongatum	Elongate Hardyhead	Atherinidae	elongated	pelagic-neritic	10	TL	3.30	0.40	3					

Species	Common name	Family	Fishbase data							Current study				
			Body Shape	Habitat	Size (cm)		TrL	SE	D	δ13C	δ15N	δ 34S	C:N	TrL
Craterocephalus mugiloides	Spotted Hardyhead	Atherinidae	elongated	pelagic-neritic	7	TL	2.84	0.36	2					
Leptatherina presbyteroides	Silver Fish	Atherinidae	elongated	pelagic-neritic	11	TL	3.30	0.40	3					
Metavelifer multiradiatus	Common Veilfin	Veliferidae	short and / or deep	benthopelagic	28	TL	3.70	0.60	3					
Fistularia commersonii	Smooth Flutemouth	Fistulariidae	elongated	reef-associated	160	TL	4.26	0.66	1					
Filicampus tigris	Tiger Pipefish	Syngnathidae	eel-like	demersal	30	SL	3.30	0.40	3					
Hippocampus breviceps	Shorthead Seahorse	Syngnathidae	other	demersal	15	TL	3.45	0.48	2					
Hippocampus subelongatus	West Australian Seahorse	Syngnathidae	other	demersal	20	OT	3.40	0.40	3					
Hippocampus tuberculatus	Knobby Seahorse	Syngnathidae	other	demersal			3.40	0.40	3					
Histiogamphelus cristatus	Rhino Pipefish	Syngnathidae	eel-like	demersal	27	SL	3.40	0.50	3					
Lissocampus caudalis	Smooth Pipefish	Syngnathidae	eel-like	demersal	10	SL	3.30	0.40	3					
Lissocampus fatiloquus	Prophet's Pipefish	Syngnathidae	eel-like	demersal	8	SL	3.20	0.40	3					
Mitotichthys meraculus	Western Crested Pipefish	Syngnathidae	eel-like	demersal	*23*	*SL*	3.40	0.40	3					
Pugnaso curtirostris	Pugnose Pipefish	Syngnathidae	eel-like	demersal	18	SL	3.30	0.40	3					
Stigmatopora argus	Spotted Pipefish	Syngnathidae	eel-like	demersal	25	TL	3.30	0.40	3					
Stigmatopora nigra	Widebody Pipefish	Syngnathidae	elongated	demersal	16	TL	3.30	0.40	3					
Vanacampus margaritifer	Mother-of-pearl Pipefish	Syngnathidae	eel-like	demersal	16	SL	3.40	0.40	3					
Vanacampus phillipi	Port Phillip Pipefish	Syngnathidae	eel-like	demersal	18	SL	2.90	0.18	1					
Vanacampus poecilolaemus	Longsnout Pipefish	Syngnathidae	eel-like	demersal	26	SL	3.30	0.40	3					
Maxillicosta scabriceps	Little Gurnard Perch	Neosebastidae	fusiform / normal	demersal	12	TL	3.37	0.26	1					
Scorpaena sumptuosa	Western Red Scorpionfish	Scorpaenidae	fusiform / normal	reef-associated	40	TL	3.80	0.20	3					
Centropogon latifrons	Western Fortescue	Tetrarogidae	short and / or deep	reef-associated	13	SL	3.20	0.30	3					
Gymnapistes marmoratus	Soldier	Tetrarogidae	fusiform / normal	demersal	23	SL	3.28	0.28	1	-16.08	8.85		3.33	2.73
Chelidonichthys kumu	Red Gurnard	Triglidae	elongated	demersal	60	TL	3.68	0.57	2					
Lepidotrigla papilio	Spiny Gurnard	Triglidae	elongated	demersal	20	SL	3.50	0.30	3					
Lepidotrigla spinosa	Shortfin Gurnard	Triglidae	Elongated	demersal	*12*	*TL*	3.50	0.30	3					
Acanthosphex leurynnis	Wasp-spine Velvetfish	Aploactinidae	short and / or deep	demersal	3	TL	3.10	0.40	3					
Aploactisoma milesii	Southern Velvetfish	Aploactinidae	elongated	benthopelagic	23	TL	3.70	0.50	3					
Erisphex aniarus	Darkfin Velvetfish	Aploactinidae	elongated	demersal	6	TL	3.30	0.50	3					
Kanekonia queenslandica	Deep Velvetfish	Aploactinidae	elongated	demersal	6	TL	3.30	0.50	3					
Paraploactis intonsa	Bearded Velvetfish	Aploactinidae	elongated	demersal	*16*	*TL*	3.40	0.50	3					
Inegocia japonica	Rusty Flathead	Platycephalidae	elongated	demersal	35	TL	3.69	0.40	1	-16.68	10.90	14.66	3.21	3.62
Leviprora inops	Longhead Flathead	Platycephalidae	Elongated	reef-associated	52	TL	4.00	0.70	3					
Onigocia spinosa	Midget Flathead	Platycephalidae	elongated	demersal	25	TL	3.70	0.60	3	-16.90	10.80	15.45	3.27	3.58
Platycephalus endrachtensis	Northern Sand Flathead	Platycephalidae	elongated	demersal	45	TL	4.40	0.73	1					
Platycephalus grandispinis	Longspine Flathead	Platycephalidae	elongated	demersal	38	TL	3.83	0.35	1	-16.98	12.24		3.22	4.20
Platycephalus laevigatus	Rock Flathead	Platycephalidae	elongated	demersal	50	TL	3.83	0.47	1					
Platycephalus speculator	Southern Bluespot Flathead	Platycephalidae	elongated	demersal	90	TL	4.00	0.39	1					
Platycephalus westraliae	Yellowtail Flathead	Platycephalidae	Elongated	demersal	55	SL	3.90	0.50	3					
Pegasus volitans	Slender Seamoth	Pegasidae	other	demersal	20	TL	3.50	0.37	2					
Hypopterus macropterus	Spikey Bass	Latidae	fusiform / normal	demersal	14	SL	3.70	0.60	3					
Caesioscorpis theagenes	Blowhole Perch	Serranidae	fusiform / normal	reef-associated	*18*	*TL*	3.60	0.60	3					
Hypoplectrodes nigroruber	Banded Seaperch	Serranidae	fusiform / normal	reef-associated	30	TL	3.97	0.65	2					
Amniataba caudavittata	Yellowtail Grunter	Terapontidae	fusiform / normal	benthopelagic	30	TL	3.17	0.14	1					
Helotes octolineatus	Western Striped Grunter	Terapontidae	elongated	demersal	28	TL	2.00	0.00	2	-17.01	10.92	17.25	3.41	3.63
Pelsartia humeralis	Sea Trumpeter	Terapontidae	fusiform / normal	benthopelagic	38	TL	2.90	0.40	3	-16.47	9.98		3.30	3.22
Ostorhinchus rueppellii	Western Gobbleguts	Apogonidae	short and / or deep	reef-associated	12	TL	3.50	0.50	2	-17.42	10.86		3.26	3.60
Ostorhinchus victoriae	Western Striped Cardinalfish	Apogonidae	fusiform / normal	reef-associated	8	TL	3.50	0.50	2					
Siphamia cephalotes	Wood's Siphonfish	Apogonidae	short and / or deep	benthopelagic	5	SL	3.40	0.50	3					
Siphamia cuneiceps	Wedgehead Siphonfish	Apogonidae	short and / or deep	benthopelagic	*4*	*SL*	3.20	0.50	3					
Vincentia punctata	Orange Cardinalfish	Apogonidae	fusiform / normal	reef-associated	15	TL	3.60	0.50	3					

Species	Common name	Family	Fishbase data							Current study				
			Body Shape	Habitat	Size (cm)		TrL	SE	D	δ13C	δ15N	δ 34S	C:N	TrL
Sillaginodes punctatus	King George Whiting	Sillaginidae	elongated	demersal	72	TL	3.28	0.30	1					
Sillago bassensis	Southern School Whiting	Sillaginidae	fusiform / normal	demersal	33	SL	3.31	0.47	2	-17.91	11.17	10.06	3.27	3.74
Sillago burrus	Western Trumpeter Whiting	Sillaginidae	fusiform / normal	demersal	36	SL	3.31	0.20	1	-17.74	11.72	6.15	3.28	3.98
Sillago robusta	Stout Whiting	Sillaginidae	fusiform / normal	demersal	30	TL	3.25	0.14	1					
Sillago schomburgkii	Yellowfin Whiting	Sillaginidae	elongated	demersal	42	TL	3.22	0.24	1	-14.41	11.63		3.24	3.94
Sillago vittate	Western School Whiting	Sillaginidae	fusiform / normal	demersal	30	SL	3.46	0.22	1					
Pomatomus saltatrix	Tailor	Pomatomidae	fusiform / normal	pelagic-oceanic	130	TL	4.53	0.30	1					
Echeneis naucrates	Sharksucker	Echeneidae	elongated	reef-associated	110	TL	3.68	0.26	1					
Pseudocaranx georgianus	Silver Trevally	Carangidae	fusiform / normal	reef-associated	*94*	*TL*	3.92	0.56	1	-18.12	10.88		3.25	3.61
Pseudocaranx wrighti	Skipjack Trevally	Carangidae	fusiform / normal	pelagic-neritic	70	SL	3.42	0.32	1	-18.38	11.61	15.18	3.34	3.93
Seriola dumerili	Amberjack	Carangidae	fusiform / normal	reef-associated	190	TL	4.50	0.73	1					
Seriola hippos	Samsonfish	Carangidae	fusiform / normal	pelagic-neritic	150	TL	4.60	0.53	2					
Trachurus declivis	Common Jack Mackerel	Carangidae	fusiform / normal	benthopelagic	64	SL	3.93	0.61	2					
Trachurus novaezelandiae	Yellowtail Scad	Carangidae	fusiform / normal	pelagic-oceanic	50	SL	3.22	0.40	2	-19.54	11.64	18.25	3.33	3.94
Arripis georgianus	Australian Herring	Arripidae	fusiform / normal	pelagic-neritic	41	FL	4.31	0.76	2					
Pentapodus vitta	Western Butterfish	Nemipteridae	fusiform / normal	reef-associated	26	TL	3.60	0.50	3	-17.25	11.30	9.65	3.38	3.80
Gerres subfasciatus	Common Silverbiddy	Gerreidae	fusiform / normal	demersal	20	TL	3.30	0.30	3					
Parequula melbournensis	Silverbelly	Gerreidae	short and / or deep	demersal	22	TL	3.46	0.20	1	-18.71	10.86	17.01	3.29	3.60
Plectorhinchus flavomaculatus	Goldspotted Sweetlips	Haemulidae	fusiform / normal	reef-associated	60	TL	3.99	0.66	2					
Chrysophrys auratus	Snapper	Sparidae	short and / or deep	reef-associated	130	TL	3.59	0.22	1	-17.86	12.02	16.79	3.26	4.11
Rhabdosargus sarba	Tarwhine	Sparidae	short and / or deep	reef-associated	80	TL	3.37	0.58	1					
Parupeneus chrysopleuron	Rosy Goatfish	Mullidae	fusiform / normal	demersal	55	TL	3.50	0.37	2					
Parupeneus spilurus	Blacksaddle Goatfish	Mullidae	fusiform / normal	reef-associated	50	TL	3.51	0.20	1			3.41		
Upeneichthys vlamingii	Bluespotted Goatfish	Mullidae	fusiform / normal	demersal	35	TL	3.50	0.50	3					
Upeneus australiae	Australian Goatfish	Mullidae	fusiform / normal	demersal	16	SL	3.39	0.00	1	-17.66	10.81		3.48	3.58
Upeneus tragula	Bartail Goatfish	Mullidae	fusiform / normal	reef-associated	25	TL	3.59	0.48	1					
Parapriacanthus elongatus	Elongate Bullseye	Pempherididae	fusiform / normal	demersal	14	TL	3.40	0.40	3					
Pempheris klunzingeri	Rough Bullseye	Pempherididae	short and / or deep	demersal	18	TL	3.40	0.50	3					
Kyphosus gladius	Gladius Drummer	Kyphosidae	elongated	pelagic-neritic	46	SL	2.00	0.50	3					
Kyphosus sydneyanus	Silver Drummer	Kyphosidae	short and / or deep	demersal	80	TL	2.00	0.00	1					
Microcanthus strigatus	Stripey	Scorpididae	short and / or deep	reef-associated	16	TL	3.00	0.35	2					
Scorpis aequipinnis	Sea Sweep	Scorpididae	short and / or deep	demersal	40	TL	3.26	0.30	1					
Chelmonops curiosus	Western Talma	Chaetodontidae	short and / or deep	reef-associated	26	TL	3.29	0.40	2					
Enoplosus armatus	Old Wife	Enoplosidae	elongated	reef-associated	50	TL	3.36	0.44	1					
Parma mccullochi	McCulloch's Scalyfin	Pomacentridae	short and / or deep	reef-associated	20	SL	2.79	0.26	2					
Parma occidentalis	Western Scalyfin	Pomacentridae	short and / or deep	reef-associated	13	SL	2.74	0.25	2					
Goniistius gibbosus	Magpie Morwong	Cheilodactylidae	fusiform / normal	reef-associated	30	TL	2.78	0.25	2					
Nemadactylus valenciennesi	Blue Morwong	Cheilodactylidae	fusiform / normal	demersal	90	TL	3.40	0.30	3					
Aldrichetta forsteri	Yelloweye Mullet	Mugilidae	fusiform / normal	demersal	50	SL	2.51	0.26	2	-17.53	10.72	12.19	3.30	3.55
Mugil cephalus	Sea Mullet	Mugilidae	fusiform / normal	benthopelagic	100	SL	2.14	0.18	1	-13.83	8.78		3.41	2.70
Sphyraena novaehollandiae	Snook	Sphyraenidae	elongated	pelagic-neritic	100	TL	4.50	0.80	2	-16.82	9.19	15.54	3.33	2.88
Sphyraena obtusata	Yellowtail Barracuda	Sphyraenidae	elongated	reef-associated	55	TL	4.50	0.35	1	-19.21	11.69	19.60	3.26	3.97
Sphyraena pinguis	Striped Barracuda	Sphyraenidae	elongated	pelagic-neritic	50	TL	4.49	0.80	1					
Austrolabrus maculatus	Blackspotted Wrasse	Labridae	short and / or deep	reef-associated	13	SL	3.40	0.40	3					
Choerodon rubescens	Baldchin Groper	Labridae	short and / or deep	reef-associated	90	TL	3.60	0.50	3					
Coris auricularis	Western King Wrasse	Labridae	fusiform / normal	reef-associated	40	TL	3.50	0.30	3					
Haletta semifasciata	Blue Weed Whiting	Labridae	fusiform / normal	demersal	29	SL	3.19	0.49	2					
Halichoeres brownfieldi	Brownfield's Wrasse	Labridae	fusiform / normal	reef-associated	15	TL	3.40	0.50	3					
Heteroscarus acroptilus	Rainbow Cale	Labridae	fusiform / normal	reef-associated	24	SL	2.92	0.27	1					

Species	Common name	Family	Fishbase data							Current study				
			Body Shape	Habitat	Size (cm)		TrL	SE	D	δ13C	δ15N	δ 34S	C:N	TrL
Neoodax balteatus	Little Weed Whiting	Labridae	elongated	demersal	14	SL	2.80	0.20	3					
Notolabrus parilus	Brownspotted Wrasse	Labridae	fusiform / normal	reef-associated	*49*	*TL*	3.60	0.50	3					
Olisthops cyanomelas	Herring Cale	Labridae	fusiform / normal	pelagic-neritic	35	SL	2.70	0.20	3					
Ophthalmolepis lineolata	Southern Maori Wrasse	Labridae	elongated	benthopelagic	40	TL	3.50	0.37	2					
Pseudolabrus biserialis	Redband Wrasse	Labridae	short and / or deep	reef-associated	17	SL	3.50	0.37	2					
Siphonognathus argyrophanes	Tubemouth	Labridae	elongated	demersal	40	SL	2.60	0.20	3					
Siphonognathus caninis	Sharpnose Weed Whiting	Labridae	elongated	demersal	10	SL	2.80	0.20	3					
Siphonognathus radiatus	Longray Weed Whiting	Labridae	elongated	reef-associated	18	SL	2.70	0.20	3					
Suezichthys cyanolaemus	Bluethroat Rainbow Wrasse	Labridae	elongated	demersal	10	SL	3.50	0.50	3					
Parapercis haackei	Wavy Grubfish	Pinguipedidae	elongated	reef-associated	10	TL	3.40	0.40	3					
Crapatalus munroi	Pink Sandfish	Leptoscopidae	elongated	demersal	12	TL	3.40	0.50	3					
Lesueurina platycephala	Flathead Sandfish	Leptoscopidae	elongated	demersal	11	SL	3.03	0.10	1	-17.60	10.63		3.37	3.50
Petroscirtes breviceps	Shorthead Sabretooth Blenny	Blenniidae	elongated	reef-associated	11	SL	2.06	0.22	1					
Ophiclinus antarcticus	Dusky Snake Blenny	Ophiclinidae	elongated	benthopelagic	14	TL	3.40	0.40	3					
Helcogramma decurrens	Blackthroat Threefin	Tripterygiidae	elongated	benthopelagic	5	SL	3.10	0.30	3					
Cristiceps australis	Southern Crested Weedfish	Clinidae	elongated	benthopelagic	18	TL	3.90	0.64	1					
Heteroclinus adelaidae	Adelaide Weedfish	Clinidae	elongated	benthopelagic	9	TL	3.49	0.30	1					
Heteroclinus heptaeolus	Ogilby's Weedfish	Clinidae	elongated	benthopelagic	10	TL	3.50	0.50	3					
Heteroclinus roseus	Rosy Weedfish	Clinidae	elongated	benthopelagic	15	TL	3.60	0.50	3					
Dactylopus dactylopus	Finger Dragonet	Callionymidae	elongated	reef-associated	30	TL	3.40	0.40	3					
Eocallionymus papilio	Painted Stinkfish	Callionymidae	fusiform / normal	reef-associated	10	TL	3.20	0.40	3					
Pseudocalliurichthys goodladi	Longspine Dragonet	Callionymidae	elongated	demersal	22	TL	3.30	0.40	3	-17.22	10.09		3.25	3.27
Acentrogobius pflaumii	Striped Sandgoby	Gobiidae	elongated	demersal	12	TL	3.07	0.17	1					
Amblygobius phalaena	Whitebarred Goby	Gobiidae	elongated	reef-associated	15	TL	3.63	0.38	1					
Arenigobius bifrenatus	Bridled Goby	Gobiidae	elongated	demersal	8	SL	3.30	0.40	3					
Bathygobius fuscus	Dusky Frillgoby	Gobiidae	fusiform / normal	reef-associated	12	TL	3.42	0.56	1					
Callogobius mucosus	Sculptured Goby	Gobiidae	Elongated	reef-associated	11	TL	3.30	0.40	3					
Favonigobius lateralis	Southern Longfin Goby	Gobiidae	elongated	demersal	9	TL	3.50	0.40	3					
Nesogobius pulchellus	Sailfin Goby	Gobiidae	Elongated	demersal	7	TL	3.30	0.40	3					
Priolepis nuchifasciata	Threadfin Reefgoby	Gobiidae	fusiform / normal	reef-associated	4	TL	3.10	0.30	3					
Siganus fuscescens	Black Rabbitfish	Siganidae	short and / or deep	reef-associated	40	TL	2.03	0.06	1					
Scomber australasicus	Blue Mackerel	Scombridae	fusiform / normal	pelagic-neritic	44	FL	4.23	0.49	1					
Pseudorhombus jenynsii	Smalltooth Flounder	Paralichthyidae	short and / or deep	demersal	34	TL	3.50	0.37	2					
Engyprosopon grandisquama	Spot-tail Wide-eye Flounder	Bothidae	short and / or deep	reef-associated	15	TL	3.13	0.00	1					
Ammotretis elongatus	Elongate Flounder	Pleuronectidae	short and / or deep	demersal	22	TL	3.01	0.00	1					
Aseraggodes haackeanus	Southern Sole	Soleidae	short and / or deep	demersal	14	TL	3.60	0.50	3					
Zebrias cancellatus	Harrowed Sole	Soleidae	short and / or deep	demersal	27	TL	3.60	0.50	3					
Cynoglossus broadhursti	Southern Tongue Sole	Cynoglossidae	elongated	demersal	25	TL	3.40	0.40	3					
Cynoglossus maculipinnis	Spotfin Tongue Sole	Cynoglossidae	short and / or deep	demersal	15	TL	3.40	0.40	3					
Paraplagusia bilineata	Lemon Tongue Sole	Cynoglossidae	short and / or deep	demersal	32	TL	3.50	0.40	3					
Acanthaluteres brownii	Spinytail Leatherjacket	Monacanthidae	short and / or deep	reef-associated	55	TL	2.80	0.40	3					
Acanthaluteres spilomelanurus	Bridled Leatherjacket	Monacanthidae	short and / or deep	demersal	14	TL	2.90	0.40	3	-17.61	9.16	17.99	3.31	2.86
Acanthaluteres vittiger	Toothbrush Leatherjacket	Monacanthidae	short and / or deep	demersal	35	TL	2.00	0.00	2					
Anacanthus barbatus	Bearded Leatherjacket	Monacanthidae	elongated	reef-associated	35	TL	2.80	0.40	3					
Brachaluteres jacksonianus	Southern Pygmy Leatherjacket	Monacanthidae	short and / or deep	reef-associated	10	TL	2.90	0.40	3					
Chaetodermis penicilligerus	Tasselled Leatherjacket	Monacanthidae	short and / or deep	reef-associated	31	TL	2.80	0.40	3					
Eubalichthys caeruleoguttatus	Bluespotted Leatherjacket	Monacanthidae	short and / or deep	demersal	38	TL	2.80	0.40	3					
Eubalichthys mosaicus	Mosaic Leatherjacket	Monacanthidae	short and / or deep	reef-associated	60	TL	2.80	0.40	3					
Meuschenia freycineti	Sixspine Leatherjacket	Monacanthidae	short and / or deep	demersal	60	TL	2.34	0.25	1					

Species	Common name	Family	Fishbase data							Current study				
			Body Shape	Habitat	Size (cm)		TrL	SE	D	δ13C	δ15N	δ 34S	C:N	TrL
Meuschenia hippocrepis	Horseshoe Leatherjacket	Monacanthidae	short and / or deep	demersal	51	TL	2.80	0.40	3					
Monacanthus chinensis	Fanbelly Leatherjacket	Monacanthidae	short and / or deep	reef-associated	38	TL	2.36	0.14	1					
Nelusetta ayraud	Ocean Jacket	Monacanthidae	short and / or deep	demersal	100	TL	3.71	0.60	2					
Scobinichthys granulatus	Rough Leatherjacket	Monacanthidae	short and / or deep	reef-associated	30	TL	2.80	0.40	3					
Anoplocapros amygdaloides	Western Smooth Boxfish	Ostraciidae	short and / or deep	demersal	30	TL	3.40	0.50	3	-17.28	10.48		3.29	3.44
Aracana aurita	Shaw's Cowfish	Ostraciidae	short and / or deep	demersal	20	TL	3.30	0.50	3					
Ostracion cubicus	Yellow Boxfish	Ostraciidae	short and / or deep	reef-associated	45	TL	3.40	0.48	3					
Tetrosomus reipublicae	Smallspine Turretfish	Ostraciidae	short and / or deep	demersal	30	TL	3.50	0.37	2					
Arothron hispidus	Stars-and-stripes Puffer	Tetraodontidae	short and / or deep	reef-associated	50	TL	3.24	0.20	1					
Contusus brevicaudus	Prickly Toadfish	Tetraodontidae	short and / or deep	demersal	25	TL	3.40	0.20	3					
Lagocephalus sceleratus	Silver Toadfish	Tetraodontidae	fusiform / normal	reef-associated	110	TL	3.70	0.36	1					
Omegophora armilla	Ringed Toadfish	Tetraodontidae	short and / or deep	demersal	25	TL	3.40	0.20	3					
Polyspina piosae	Orangebarred Puffer	Tetraodontidae	short and / or deep	benthopelagic			3.40	0.20	3					
Torquigener hicksi	Hicks' Toadfish	Tetraodontidae	fusiform / normal	demersal	13	TL	3.30	0.20	3					
Torquigener pallimaculatus	Rusty-spotted Toadfish	Tetraodontidae	fusiform / normal	demersal	18	SL	3.40	0.20	3					
Torquigener pleurogramma	Weeping Toadfish	Tetraodontidae	fusiform / normal	demersal	21	TL	3.40	0.20	3					
Torquigener vicinus	Orangespotted Puffer	Tetraodontidae	short and / or deep	demersal			3.30	0.20	3					
Diodon nicthemerus	Globefish	Diodontidae	short and / or deep	reef-associated	40	TL	3.80	0.20	3					

Appendix 5. Dietary composition (%) of each of the 204 fish species recorded in Cockburn Sound by WWSMP Project "Spatial Distribution and Temporal Variability in Life Stages of Key Fish Species in Cockburn Sound" by Yeoh et al. (submitted) derived from the peer-reviewed literature (no shading) and/or the current study (grey shading). M; macrophytes; PP, phytoplankton; Fo, foraminiferans, Po, poriferans; Cn, benthic cnidarians; Lo, lophophorates (i.e. bryozoans and entoprocts); Tun, benthic tunicates; USI, unidentified sessile "invertebrates" (including tunicates); An, annelids; Ne, nemerteans; Nem, nematodes; ZP, zooplankton (i.e. planktonic crustaceans, pelagic tunicates, pelagic eggs/larvae and chaetognaths); SC, small benthic crustaceans (e.g. harpacticoid copepods. amphipods, isopods and tanaids); LC, large benthic crustaceans (e.g. stomatopods and decapods); UC, unidentified crustaceans; H/C, hexapods and chelicerates; SM, shelled molluscs (e.g. gastropods and bivalves); C, cephalopods; UM, unidentified molluscs; Ec, echinoderms; Cc, cephalochordates; T, teleosts; E, elasmobranchs, Av, aves; R, marine reptiles; Mm, aquatic mammals; SSM, fish scales, skin and mucus; S/D, sediment and detritus. The metadata for each fish species are given in Appendix 6 and taxonomic information in Appendix 4.

Species	M	PP	Fo	Po	Cn	Lo	Tun	USI	An	Ne	Nem	ZP	SC	LC	UC	H/C	SM	C	UM	Ec	Cc	T	El	Av	R	Mm	SSM	S/D
H. portusjacksoni					0.9				10.2	3.4			0.3	9.2	0.8		24.2	8.9	3.1	16.9		22.0						
C. carcharias																	0.4	3.7				36.3	36.5	1.1	0.4	21.6		
A. labiosus									3.2					25.8				2.0				69.0						
F. macki														0.8				94.4				4.8						
M. antarcticus									1.0						42.7			44.7				11.7						
C. brevipinna	1.0													2.0				5.9				90.6	0.5					
R. australiae														16.0				0.6				83.4						
A. vincentiana	1.7								1.1				8.1	47.9	5.5			1.8				33.8						
T. dumerilii	0.8								5.3				8.5	55.1	9.6			2.8				17.3	0.6					
H. monopterygius														3.6				58.0				38.4						
B. brevicaudata									5.9					85.4			0.0					8.7						
B. lata									1.5					84.2								14.3						
T. mucosa	0.5								89.3				6.1	3.4			0.4			0.2		0.1						
T. ovalis									77.8				2.2	10.3			0.5				3.0	6.2						
T. personata	0.1								57.8				28.0	13.6			0.3			0.1								0.1
U. paucimaculatus	0.1								14.4			0.1	52.5	31.7			0.4	0.6		0.1		0.1						
M. tenuicaudatus	1.9								22.1	0.5			9.4	14.5	5.3		39.3	1.4	0.6	2.1		3.0						
	0.1						0.8		29.4					49.5			11.7			0.6		3.9						4.0
G. woodwardi									2.9					83.3				2.7				11.3						
E. jacksoniensis												98.3	1.7				0.0	0.0										
H. vittatus									4.4		1.5	5.0	85.2		3.9													
												95.1	4.3				0.6											
N. vlaminghi																												100.0
S. lemuru												100.0																
S. sagax		2.4					22.5					72.4						0.3				2.4						
S. robustus					0.9				0.3			73.4	1.2		23.8		0.3											0.1
			0.2									89.4	5.6				4.2											0.6
E. australis												74.1	25.9															
T. trachinus									3.9				3.9	55.0								37.2						
G. greyi									16.7				38.9				44.4											
C. macrocephalus									2.8				0.3	4.9			46.2					0.8						45.0
P. albilabris													P	P			P											
P. lineatus													33.5	51.5			7.9					7.1						
C. spatula													8.3							91.7								
C. viridis									1.7				96.1			2.2												
E. viridis												100.0																

Species	M	PP	Fo	Po	Cn	Lo	Tun	USI	An	Ne	Nem	ZP	SC	LC	UC	H/C	SM	C	UM	Ec	Cc	T	El	Av	R	Mm	SSM	S/D
H. robustus	17.9											24.5	35.1				6.2					16.3						
H. melanochir	57.5								13.4				29.0			0.2												
S. leiura									0.5				0.5	8.0		5.0						86.0						
A. vaigiensis	1.1		2.7		0.3				4.9		0.3	32.5	43.6	0.6	2.1	8.9			2.9			0.1						
A. elongatum	3.9											5.5	5.5		31.7		0.2					35.0						18.1
C. mugiloides												3.5	6.1	44.2	25.1	2.0												19.1
L. presbyteroides													35.0	35.0														30.1
M. multiradiatus												100.0																
F. commersonii	0.3											11.2	4.6	0.8								83.1						
F. tigris	1.4												88.1	4.8														5.7
H. breviceps	1.6		1.0						0.4			1.4	89.8			0.6	2.3											2.9
H. subelongatus	2.7												61.7	30.3			0.9											4.4
H. tuberculatus									0.4			1.4	46.5	43.7								3.0						5.1
H. cristatus	1.4											4.3	84.0	1.0		0.3	1.3											7.7
Lissocampus caudalis												13.1	83.9				0.4											2.6
L. fatiloquus												74.0	22.0		4.0													
M. meraculus													91.1															8.9
P. curtirostris	0.3		0.3						0.4			2.5	85.5	3.3			2.1											5.6
S. argus												90.0	9.8	0.1			0.1											
S. nigra												91.0	8.8	0.1														0.1
V, margaritifer												73.5	24.0		2.5													
V. phillipi	5.2		0.4						1.7			4.6	72.1	2.3			2.2											11.5
V. poecilolaemus	1.2		0.1									0.7	73.6	22.0														2.4
M. scabriceps									7.4				44.5	42.2	5.0		0.9											
S. sumptuosa												2.4		4.9	48.7							44.0						
C. latifrons	2.4								4.4				14.6	51.3	24.4		2.9											
G. marmoratus									1.6				4.0	84.8			4.0					5.6						
	0.1								5.8				36.3	56.9			0.8											0.0
C. kumu	0.1								3.8				16.6	37.0	26.4		0.6	0.5				12.2						2.8
L. papilio									0.6				72.7	20.8			2.5											3.4
L. spinosa													16.7	73.3	10.0													
A. leurynnis																												
A. milesii	0.5								2.1				94.6	1.6	0.4		0.6					0.2						
E. aniarus																												
K. queenslandica															100.0													
P. intonsa																												
I. japonica													0.4	84.2	0.4							15.0						
	0.5								3.6		0.0		2.7	53.6			0.4			0.1		37.8						1.3
L. inops														5.6	1.4			1.4				91.6						
	1.4													77.4			1.4	1.8				17.8						0.2
O. spinosa	0.2								4.0				14.9	77.7								2.5						0.8
P. endrachtensis														8.7	5.1				4.2			82.0						
P. grandispinis									4.6				24.7	36.3	1.8		2.2	1.4				29.0						
	0.4								11.7				1.9	29.6			1.8					52.3						2.2
P. laevigatus													0.4	29.2	2.6		2.0	3.2				62.6						
P. speculator									1.4			0.1	1.7	62.9			1.1					32.8						
	10.0													15.0								75.0						
P. westraliae									0.9				3.5	14.7	5.1		1.2					74.6						
														6.5								90.3						3.2
P. volitans															100.0													
H. macropterus	1.6								0.4				1.9	86.8	0.6		0.6					8.1						

Species	M	PP	Fo	Po	Cn	Lo	Tun	USI	An	Ne	Nem	ZP	SC	LC	UC	H/C	SM	C	UM	Ec	Cc	T	El	Av	R	Mm	SSM	S/D
C. theagenes									0.4			97.5	2.1															
H. nigroruber													2.0	36.0			2.0			2.0		58.0						
A, caudavittata	21.3					0.9			2.0				62.5	0.7	0.1		3.3		1.1			1.8						6.2
H. octolineatus	68.2								0.7				13.1		2.5		2.5		0.1								2.5	10.5
P. humeralis	0.5												99.5															
O. rueppellii	1.9								1.2				75.2	10.4					0.7			3.9						6.7
O. victoriae	0.7								10.3				25.6	49.9	6.0		3.9					3.5						
S. cephalotes													100.0															
S. cuneiceps									6.4			28.1	24.4	41.1														
V. punctata									6.8				86.4		6.8													
S. punctatus	4.2								38.9				44.1	11.6						0.1		1.0						
S. bassensis	1.0								24.5			0.5	36.4	7.3			9.8			16.1		4.4						
S. burrus	0.4								48.8				25.7	6.0			11.9			7.2								
	0.1		0.2						31.0			0.3	1.2	23.5			29.5			11.1								3.0
S. robusta	0.2								13.5			4.7	48.5	20.2			3.3	1.4		6.9		1.4						
S. schomburgkii	3.2								48.6			1.6	34.1	6.2			6.3											
S. vittata	1.0						0.1		28.6			0.1	38.2	2.1			13.9			13.6		2.4						
P. saltatrix																		31.5				68.5						
E. naucrates													1.4		40.9		7.8			12.1		37.8						
P. georgianus									2.0				10.9	26.6			27.2	5.6		8.1		19.7						
P. wrighti	0.2				0.1				8.1			11.3	16.7	10.0	24.6		12.4			3.3		0.8						12.7
	0.3		1.5			0.1			10.5			2.8	8.8	15.8			40.1			9.8								10.3
S. dumerili																		29.0				71.0						
S. hippos																		8.0				92.0						
T. declivis												9.6	0.2		0.5		2.0	0.1				87.6						
T. novaezelandiae												100.0																
A. georgianus	0.7								9.4				7.7	45.4		3.3	0.1					33.1						0.2
P. vitta									6.5					51.3	27.8			5.3	0.1			9.0						
	0.5		0.1						12.1				1.3	22.6			25.7	1.2		24.5		1.5						10.5
G. subfasciatus	1.6								61.5			19.4	8.9	1.0	0.5		7.0											
P. melbournensis	1.5								45.4			7.4	8.1	8.6	5.1		13.2			8.0								2.6
P. flavomaculatus	8.0								3.0					73.0			2.0		3.0	7.0		4.0						
C. auratus	2.1				0.1				2.6				2.9	15.4	0.6		9.9	1.9		45.0		19.5						
	0.3		0.2	0.2			1.1		3.3				6.6	39.4			33.0			10.3		2.3						3.3
R. sarba	14.9				0.1	0.1			3.8				12.7	14.7	1.9	0.1	16.7		0.1	1.7		0.7						32.6
P. chrysopleuron												4.5	10.0	57.5	0.5							27.5						
P. spilurus												6.0	20.0	60.0	1.0							13.0						
U. vlamingii									17.5				19.2	61.9								1.5						
U. australiae									0.2				0.2	93.9			0.3					5.4						
U. tragula	0.6								17.3				55.0	17.3	7.0		2.8											
P. elongatus									12.8			0.9	79.0	6.7								0.6						
P. klunzingeri									21.1			0.2	59.6	12.7			4.3	0.3				1.5						0.3
K. gladius	100.0																											
K. sydneyanus	100.0																											
M. strigatus	10.4			0.2					0.1			85.7	2.6		0.6		0.4											
S. aequipinnis	68.7				0.1				0.7		0.2	24.9	4.1		0.1	0.4	0.4					0.4						
C. curiosus					0.2				49.9						49.9													
E. armatus												34.0			66.0													
P. mccullochi	100.0																											
P. occidentalis	100.0																											

Species	M	PP	Fo	Po	Cn	Lo	Tun	USI	An	Ne	Nem	ZP	SC	LC	UC	H/C	SM	C	UM	Ec	Cc	T	El	Av	R	Mm	SSM	S/D
G. gibbosus				4.5					2.1				71.0	19.6			1.9			0.4								0.4
N. valenciennesi	6.2								19.4				16.5	5.0			5.2			29.9	16.4	1.4						
A. forsteri	3.0	3.0							22.4	0.1		1.0	3.9	24.9		11.3	7.0					0.6						22.8
M. cephalus	1.2																2.0											96.9
S. novaehollandiae															15.4			1.1				83.4						
S. obtusata																						100.0						
S. pinguis														0.8				0.7				98.5						
A. maculatus	1.1				0.1		0.7		5.1				28.2	17.7			45.3			1.2		0.5						
C. rubescens									0.1	1.5			0.8	14.2	3.8		50.9			27.5		0.9	0.3					
C. auricularis	3.8		0.4	0.5	0.1	0.2			8.0	0.2			25.2	12.1	10.5	0.2	22.7	0.3		6.7		4.3						4.8
H. semifasciata	20.1					0.2			12.1				13.2	8.7	5.5	0.1	20.3			1.6								18.3
H. brownfieldi													95.0						5.0									
H. acroptilus	58.6		0.1	0.5	1.7	10.2	4.5		1.3				2.7	0.1	0.5	0.2	11.0			0.7								7.8
N. balteatus	4.5		2.2										29.0	5.4	9.7	0.1	47.1											2.0
N. parilus	9.7					0.6	1.9		3.1				17.6	14.9	6.1	1.5	32.7			2.1		1.4						8.4
O. cyanomelas	100.0																											
O. lineolata	1.9			0.7			0.8		7.2	1.1			4.8	23.1	10.2	0.4	27.7			13.7		6.8						1.6
P. biserialis					0.1	0.6			0.3				4.6	60.9			29.2			4.4								
S. argyrophanes																												
S. caninis																												
S. radiatus	1.5		0.3		0.0	0.6			1.2			0.4	43.9	5.5	25.3	2.2	16.3			0.2		0.2						2.4
S. cyanolaemus																												
P. haackei									15.7				77.4				7.0											
C. munroi									P				P	P			P					P						
L. platycephala	2.5		0.2						25.7		0.2	0.2	46.8	3.1	9.2		1.5		0.2			10.2						
P. breviceps	48.8												51.2															
O. antarcticus																												
H. decurrens									16.6			1.8	60.6	7.9	2.7		9.1			1.3								
C. australis															59.6							40.4						
H. adelaidae									2.0						98.0													
H. heptaeolus									11.0						88.9							0.1						
H. roseus															25.0							75.0						
D. dactylopus									19.0			7.0	61.0				9.0											4.0
E. papilio	6.9				2.3	3.5			13.6			28.1	11.5		9.5		24.6											
P. goodladi									29.0				1.0	32.0			33.0	1.0		4.0								
	7.8		2.3						2.0		0.1	0.1	5.2	1.1			36.0			9.2		0.0						36.1
A. pflaumii									7.1				71.5	7.2														14.2
A. phalaena	75.0								1.0				17.0		4.0													3.0
A. bifrenatus	1.1								4.4	10.9			83.7															
B. fuscus	0.2								6.8				47.6	3.2		9.7	32.4											
C. mucosus												1.2	28.4	24.7	6.2		11.1											28.4
F. lateralis									50.6				39.3															10.1
N. pulchellus									10.0						76.0				14.0									
P. nuchifasciata			3.9						1.4			32.5	54.6		7.6													
S. fuscescens	97.4				0.3						2.2				0.1				0.1									
S. australasicus												40.0			22.0							38.0						
P. jenynsii	0.1		0.1						8.9				27.0	28.4	7.9							24.1						3.4
E. grandisquama									13.7						23.5				27.5			35.3						
A. elongatus	0.9		1.3						20.0		0.3		74.6	2.6					0.3									
A. haackeanus		1.1							38.9			55.6	1.1															3.3

Species	M	PP	Fo	Po	Cn	Lo	Tun	USI	An	Ne	Nem	ZP	SC	LC	UC	H/C	SM	C	UM	Ec	Cc	T	El	Av	R	Mm	SSM	S/D
Z. cancellatus									24.5				1.5	35.1								38.9						
C. broadhursti									17.7				3.5	58.8	20.0													
C. maculipinnis	0.0				0.1				11.7	0.0			2.0	26.7			12.9			46.7		0.0						
P. bilineata									5.1			8.6	42.3	44.0														
A. brownii	10.0							10.0	20.0						60.0													
A. spilomelanurus	86.8					2.3			1.0				6.7	0.3		1.9	1.0											
A. vittiger	10.0							15.0	15.0						50.0				10.0									
A. barbatus																												
B. jacksonianus									10.0						70.0				20.0									
C. penicilligerus	42.7											6.1	24.4				26.8											
E. caeruleoguttatus	16.7			33.3	16.7				33.3																			
E. mosaicus	23.8			47.8	8.5	7.2	12.1										0.5											
M. freycineti	78.9				12.2		0.4		0.4					1.8			1.6	4.8										
M. hippocrepis	11.6			74.2	0.0	1.0	1.7		7.4		0.1		0.1				0.3	3.1				0.5						
M. chinensis	64.9				1.4		0.5		11.8				5.2	1.9	1.3		12.7											0.2
N. ayraud															1.4			98.6										
S. granulatus	33.8			6.6	10.7	6.3	5.9		3.5				1.7	3.4	3.4	0.2	8.6			15.9								
A. amygdaloides	8.2						2.9		5.7				0.5	37.7			8.3			34.0								2.8
A. aurita	5.5					3.0			64.1				15.6	3.3	5.1		0.9		1.1	1.5								
O. cubicus	5.9						59.2		1.0			28.3	0.1	1.0			1.0											3.6
T. reipublicae	P				P				P				P				P											
A. hispidus	0.2			22.9	1.5		17.2							4.8			28.1			25.4								
C. brevicaudus													53.9	1.2			20.4			24.5								
L. sceleratus	1.0													63.3	4.5		0.5		1.0	7.0		22.8						
O. armilla																	100.0											
P. piosae													23.8	38.1	38.1													
T. hicksi														82.8			10.1											7.1
T. pallimaculatus						4.0			3.0				26.0	35.0			25.0				4.0	3.0						
T. pleurogramma	12.6					0.1			1.0				27.4	3.9		15.0	26.6					5.3						8.1
T. vicinus									9.4				7.3	75.1	8.2													
D. nicthemerus	1.7								1.6				1.4	18.7	0.3		70.7			5.5								

Appendix 6. Metadata for the dietary composition of the 204 fish species found in Cockburn Sound during the WAMSI Westport Marine Science Program provided in Appendix 5. Data include whether a surrogate species was used and the location of the sampling, sample size (n), type of data, maximum size of fish examined in the study and the reference for the study. %V, percentage volume; %W, percentage weight; %N, percentage number; %O percentage frequency of occurrence; %IRI, percentage index of relative importance; PA, presence/absence. Current = current study and – denotes that no data were available. Full species names given in Appendix 4.

Species	Surrogate species	Location	*n*	Data	Size (cm)	Source
H. portusjacksoni		SW Australia	260	%V	165	1
C. carcharias		Global	259	%IRI	-	2
A. labiosus	*Scyliorhinus capensis* & *Poroderma africanum*	Global	97	%V	67	2
F. macki		SW Australia	372	%F	-	3
M. antarcticus		SE Australia	7	%W	-	4
C. brevipinna		Global	189	%IRI	-	2
R. australiae	*Rhynchobatus laevis*	Arabian Sea	100	%IRI	-	5
A. vincentiana		SW Australia	-	%V	-	1
T. dumerilii		Rottnest Island-Comet Bay, WA	261	%V	126	6
H. monopterygius		Ballina, NSW	82	%V	70	7
B. brevicaudata		Port Phillip Bay, Victoria	7	%W	-	8
B. lata		Kāne'ohe Bay, Hawaii	40	%W	95 DW	9
T. mucosa		SW Australia	140	%V	37	10
T. ovalis	*Trygonoptera testacea*	-	187	%V	-	11
T. personata		SW Australia	150	%V	47	10
U. paucimaculatus		SW Australia	190	%V	57	10
M. tenuicaudatus		SW Australia	173	%V	120	1
		Cockburn Sound	-	%V	-	Current
G. woodwardi	*Gymnothorax prasinus* & *Gymnothorax undulatus*	Madagascar; New Zealand	156	%V	NA	12,13
E. jacksoniensis	*Etrumeus teres*	Mediterranean	240	%W	-	14
H. vittatus		Murray River, SA	190	%N	10	15
		Cockburn Sound	-	%V	-	Current
N. vlaminghi		Swan-Canning Estuary, WA	2	%V	-	16
S. lemuru		Sulu Sea, The Philippines	190	%V	-	17
S. sagax		Peru	94	%V	39.5	18
S. robustus		south-western Australia	-	%V	-	19
		Cockburn Sound	-	%V	-	Current
E. australis		Spencer Gulf, South Australia	4	%W	-	20
T. trachinus		Kuchierabu-jima Island, Japan	21	%F	23	21
G. greyi		Spencer Gulf, South Australia	2	%W	-	20
C. macrocephalus		Wilson Inlet	-	%V	-	22
P. albilabris		Indo-Pacific	-	PA	-	23
P. lineatus		Miura Peninsula, Japan	57	%V	32	24
C. spatula		New Zealand	3	%V	7	13
C viridis		Mediterranean	80	%N	-	25
E. viridis		Indo-Pacific	-	%V	-	26
H. robustus		Karachi coast, Pakistan	225	%N	-	27
H. melanochir		Gulf St Vincent, SA	300	%V	52	28
S. leiura		Veracruz, México	43	%IRI	-	29
A. vaigiensis		lower west coast of Australia	244	%V	17	30
A. elongatum		Swan-Canning Estuary, WA	78	%V	-	16
C. mugiloides		Swan-Canning Estuary, WA	57	%V	-	16
L. presbyteroides		Perth, WA	97	%V	11	16
M. multiradiatus		Mediterranean	-	N/A	-	31
F. commersonii		Lebanon	243	%N	160	32
F. tigris		Fremantle, Western Australia	10	%V	-	33
H. breviceps		Fremantle, Western Australia	67	%V	-	33
H. subelongatus		Fremantle, Western Australia	22	%V	-	33
H. tuberculatus		Wellington Harbour	59	%V	-	34
H. cristatus		Fremantle, Western Australia	58	%V	-	33
L. caudalis		Fremantle, Western Australia	8	%V	-	33
L. fatiloquus		Western Port, VIC	17	%V	-	35
M. meraculus		Fremantle, Western Australia	19	%V	-	33
P. curtirostris		Fremantle, Western Australia	39	%V	-	33
S. argus		Fremantle, Western Australia	165	%V	-	33

Species	Surrogate species	Location	*n*	Data	Size (cm)	Source
S. nigra		Fremantle, Western Australia	144	%V	-	33
V. margaritifer		Western Port, VIC	17	%V	-	35
V. phillipi		Fremantle, Western Australia	26	%V	-	33
V. poecilolaemus		Fremantle, Western Australia	67	%V	-	33
M. scabriceps		Perth-Geographe Bay, WA	159	%V	12	36
S. sumptuosa		Port Albert, VIC	43	%W	40	37
C. latifrons		Port Hacking, New South Wales	90	%V	-	38
G. marmoratus		Tasmania	-	%N	-	39
		-	-	%V	-	Current
C. kumu		Tasmania	135	%V	-	40
L. papilio		south-western Australia	-	%V	-	41
L. spinosa		Spencer Gulf, South Australia	8	%W	-	20
A. leurynnis		-	-	-	-	-
A. milesii		Aburatsubo Bay, Japan	142	%N	-	42
E. aniarus		-	-	-	-	-
K. queenslandica		Spencer Gulf, South Australia	1	%W	-	20
P. intonsa		-	-	-	-	-
I. japonica		-	-	%W	-	43
		-	-	%V	-	Current
L. inops		Albany, WA	98	%V	29	44
		-	-	%V	-	Current
O. spinosa		-	-	%V	-	Current
P. endrachtensis		Embley Estuary, Queensland	9	%W	-	45
P. grandispinis		-	304	%V	-	44
		-	-	%V	-	Current
P. laevigatus		South Western Australia	-	%V	-	44
P. speculator		South Western Australia	-	%V	-	44
		-	-	%V	-	Current
P. westraliae		South Western Australia	-	%V	-	44
		-	-	%V	-	Current
P. volitans		Spencer Gulf, South Australia	7	%W	-	20
H. macropterus		Shark Bay, WA	113	%V	47	46
C. theagenes		New Zealand	26	%V	16	13
H. nigroruber		Goat Island, NZ	7	%V	30	13
A. caudavittata		Swan-Canning Estuary, WA	94	%V	-	16
H. octolineatus		Swan Estuary, Shark Bay, WA	113	%V	28	16
P. humeralis		Perth, WA	21	%V	38	47
O. rueppellii		Swan Estuary, WA	129	%V	12	16
O. victoriae		Shark Bay, WA	382	%V	8	46
S. cephalotes		Western Port, VIC	27	%V	5	48
S. cuneiceps	*Siphamia tubifer*	Okinawa, Japan	25	%V	-	49
V. punctata	*Vincentia badia*	Spencer Gulf, SA	13	%W	15	20
S. punctatus		Shoalwater, WA	59	%V	72	50
S. bassensis		lower west coast of Australia	-	%V	-	50
S. burrus		lower west coast of Australia	-	%V	-	50
		Cockburn Sound	-	%V	-	Current
S. robusta		lower west coast of Australia	-	%V	-	50
S. schomburgkii		lower west coast of Australia	-	%V	-	50
S. vittata		lower west coast of Australia	-	%V	-	50
P. saltatrix		Western/Eastern Capes, South Africa	77	%V	130	51;52
E. naucrates		Florida, USA	46	%W	-	53
P. georgianus		Mid and south western Australia	243	%V	55	54
P. wrighti		south-western Australia	189	%V	70	55
		-	-	%V	-	Current
S. dumerili		Mediterranean Sea	308	%W	-	56
S. hippos	*Seriola lalandi*	NZ, Mexico	34	%V	150	13,57
T. declivis		Maria Island, Tasmania	169	%E	64	58
T. novaezelandiae		Sydney, NSW	24	%N	50	59
A. georgianus		Wilson Inlet	238	%V	-	22
P. vitta	*Nemipterus peronii*	Gulf of Carpentaria, NT	123	%V	26	60
		-	-	%V	-	Current
G. subfasciatus		Shark Bay	-	%V	-	46
P. melbournensis		south-western Australia	433	%V	22	55
P. flavomaculatus	*Plectorhinchus obscurus*	New Caledonia	18	%V	60	61
C. auratus		lower west coast of Australia	-	%V	-	54
		-	-	%V	-	Current
R. sarba		Mid and SW Australia	-	%V	-	62

Species	Surrogate species	Location	*n*	Data	Size (cm)	Source
P. chrysopleuron	*Plectorhinchus cyclostomus & Plectorhinchus spilurus*	Okinawa, Japan	24	%V	55	63
P. spilurus		Okinawa, Japan	23	%V	36	63
U. vlamingii		Spencer Gulf, SA	55	%W	35	20
U. australiae		Veracruz, Mexico	429	%W	-	64
U. tragula		Shark Bay, WA	69	%V	30	46
P. elongatus		Perth-Geographe Bay, WA	158	%V	14	41
P. klunzingeri		Perth-Geographe Bay, WA	178	%V	18	41
K. gladius		Perth, WA	25	%W	52	65
K. sydneyanus		Perth, WA	20	%W	80	65,66
M. strigatus	*Trachinocephalus myops*	Botany Bay, NSW	42	%A	16	67
S. aequipinnis		Portland-Peterborough, VIC	215	%W	40	68
C. curiosus		Lizard Island, GBR	32	%F	26	69
E. armatus		Port Philip Bay, SA	5	%W	50	70
P. mccullochi		Marmion, WA	80	%V	20	71
P. occidentalis	*Dellichthys morelandi*	VIC, SA	48	%V	20	72
G. gibbosus	*Opeatogenys gracilis*	Miyake-jima, Japan	8	%W	-	73
N. valenciennesi	*Euleptorhamphus velox*	Spencer Gulf, SA	7	%W	90	13
A. forsteri	*Hemiramphus far*	Wilson Inlet, WA	262	%V	50	22
M. cephalus		Wilson Inlet, WA	262	%V	-	22
S. novaehollandiae	*Strongylura marina*	South Australia	318	%W	-	74
S. obtusata		Solomon Islands	15	%W	55	75
S. pinguis		Gadeok-do, Korea	-	%W	-	76
A. maculatus		New Castle-Gosford, NSW	86	%V	13	77
C. rubescens		Abrolhos Islands, WA	237	%V	90	78
C. auricularis	*Veliferidae*	Jurien-Perth, WA	490	%V	40	79
H. semifasciata		Fremantle< WA	55	%V	29	80
H. brownfieldi		Western Port, VIC	10	%V	15	81
H. acroptilus		Fremantle, WA	111	%V	29	80
N. balteatus		Fremantle, WA	47	%V	14	80
N. parilus	*Hippocampus abdominalis*	Owen Anchorage region	-	%V	-	80
O. cyanomelas		Mooring Bay, SA	26	%V	51	82
O. lineolata		Jurien-Perth, WA	331	%V	41	79
P. biserialis	*Urocampus carinirostris*	New Zealand	42	%V	17	13
S. argyrophanes		Spencer Gulf, South Australia	-	%W	-	20
S. caninis		Spencer Gulf, South Australia	-	%W	-	20
S. radiatus		Fremantle, WA	120	%V	-	80
S. cyanolaemus		-	-	-	-	-
P. haackei	*Vanacarnpus phillipi*	Spencer Gulf, SA	4	%W	10	20
C. munroi		New Zealand	-	PA	-	83
L. platycephala		lower west coast of Australia	-	%V	-	30
P. breviceps		Kwangyang Bay, Korea	267	%W	11	84
O. antarcticus	*Scorpaena papilosa*	-	-	-	-	-
H. decurrens	*Centropogon australis*	Central Chile	94	%W	5	85
C. australis		Port Phillip Bay, Victoria	14	%W	18	70
H. adelaidae		Port Phillip Bay, Victoria	15	%W	-	70
H. heptaeolus		Port Phillip Bay, Victoria	36	%W	-	70
H. roseus		Port Phillip Bay, Victoria	5	%W	-	70
D. dactylopus		Okinawa, Japan	8	%V	30	63
E. papilio		Spencer Gulf, SA	13	%V	10	20
P. goodladi	*Hypodytes rubripinnis*	Moreton Bay, QLD	200	%V	22	86
		-	-	%V	-	Current
A. pflaumii		-	15	%V	-	87
A. phalaena		Orpheus Island, QLD	28	%W	15	88
A. bifrenatus		Port Hacking, NSW	8	%V	-	89
B. fuscus		Chowder Bay, New South Wales	67	%V	-	90
C. mucosus		Okinawa, Japan	5	%V	11	63
F. lateralis		Swan River, WA	80	%V	9	91
N. pulchellus		Western Port, Victoria	22	%W	-	92
P. nuchifasciata		-	54	%V	-	93
S. fuscescens		Marmion, Cockburn Sound, WA	40	%V	40	94
S. australasicus		South-eastern Australian shelf	48	%W	-	4
P. jenynsii		south-western Australia	-	%V	-	19
E. grandisquama		Tamilnadu, India	48	%V	-	95
A. elongatus		lower west coast of Australia	-	%V	-	30
A. haackeanus		Logan-Albert estuary, QLD	206	%V	-	96
Z. cancellatus		Bohai Sea, China	61	%W	-	97
C. broadhursti	*Pegasus lancifer*	Spencer Gulf, South Australia	7	%W	-	20

Species	Surrogate species	Location	*n*	Data	Size (cm)	Source
C. maculipinnis	*Psammoperca waigiensis*	Seto Inland Sea, Japan	179	%W	-	98
P. bilineata	*Caesioscorpis lepidoptera*	Sanrimatsubara, Japan	39	%V	14	99
Acanthaluteres brownii	*Hypoplectrodes huntii*	Western Port, VIC	11	%V	55	81
A. spilomelanurus		Tasmania	73	%V	14	81
A. vittiger		Western Port, VIC	31	%V	35	8
A. barbatus		-	-	-	-	-
B. jacksonianus		Western Port, VIC	12	%V	10	48
C. penicilligerus	*Acreichthys tomentosus*	Bolinao, Philippines	18	%V	31	100
E. caeruleoguttatus	*Eubalichthys gunnii*	Spencer Gulf, SA	1	%W	60	20
E. mosaicus		Spencer Gulf, SA	7	%W	60	20
M. freycineti		Port Hacking, NSW	45	%V	60	101
M. hippocrepis		SA	102	%W	51	102
M. chinensis		Port Hacking, NSW	148	%V	38	101
N. ayraud		Spencer Gulf, SA	3	%W	-	20
S. granulatus		Spencer Gulf, SA	35	%W	30	20
A. amygdaloides		-	-	%V	-	Current
A. aurita		Spencer Gulf, SA	7	%W	20	20
O. cubicus	*Ostracion meleagris*	Kuchierabu-jima/Yakushima Islands, japan	16	%W	45	103
T. reipublicae	*Tetrosomus gibbosus*	Mediterranean	-	PA	-	104
A. hispidus		New Caledonia, Hawaii	15	%V	50	61
C. brevicaudus		Spencer Gulf, SA	7	%W	NA	20
L. sceleratus		New Caledonia, Med Sea	109	%V	110	61
O. armilla		Spencer Gulf, SA	1	%W	25	20
P. piosae		Spencer Gulf, SA	5	%W	NA	20
T. hicksi	*Torquigener hamilton*	Morton Bay, Queensland	43	%V	-	105
T. pallimaculatus	*Torquigener hamilton*	Port Hacking, NSW	43	%V	-	89
T. pleurogramma		Swan Estuary, WA	1.7	%V	21	16
T. vicinus	*Torquigener glaber*	Western Port, Victoria	548	%V	-	106
D. nicthemerus		Spencer Gulf, SA	17	%W	40	20

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