



Food webs supporting fisheries production in estuaries with expanding coastal urbanisation

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ABSTRACT

The prospects that coastal urbanisation propagates in more fish production remains untested and thereby a fundamental question for managers challenged with approving urban expansion while also protecting and conserving habitat resources important for fish production. We tested this by collecting giant mud crabs (*Scylla serrata*) from highly urbanised waterways in south-east Queensland, Australia, and report that this crab not only occupy urban coastal waterways, but using a Bayesian stable isotope mixing model (MixSIAR) of the potential individual autotrophic sources, the range of feasible contributions for autotrophs was very broad, limiting the conclusions that could be made directly from the modelling. Patterns of contributions from pooled categories of autotrophs were clearer; at the site closest to seagrass, the pooled enriched autotroph sources contributed 69 to 87% of crab isotope signatures, while at all other sites (beyond approximately 500 m distance) it appears that crabs utilise a generalised pool of sources, either local or perhaps a mix of local transported sources. Using spatial analysis we reveal that the crab isotope values were not significantly related to the distance from any of the vegetated habitats (mangroves, seagrass and saltmarsh). The exception was two sites very close to seagrass (< 500 m distance), and not saltmarsh grass which has been reported elsewhere, where crabs had the most enriched C value. At all other sites (beyond approximately 500 m distance) it appears crabs utilise a generalised organic producer pool, either local or perhaps a mix of transported sources. Overall, this study provides evidence that in an era of coastal urbanisation expansion and loss of natural coastal vegetated areas, some fisheries species may have remarkable trophic plasticity to the new, engineered, habitat settings.

1. Introduction

Vegetated coastal habitats - mangroves, saltmarsh and seagrass - are critical in supporting the production of coastal fisheries (Bouillon et al., 2002; Layman, 2007; Baker et al., 2020; Plumlee et al., 2020). The determination of aquatic plant habitats, singly or in combination, that provide basal nutrition supporting aquatic food webs, continues to be a central research question for the objective of coastal habitat conservation and restoration (Connolly and Waltham, 2015; James et al., 2020; Loch et al., 2020; Park et al., 2021). This trophodynamic model is problematic however, because it has an underpinning that consumers, for example finfish and crustaceans, in estuaries are supported either from locally-derived sources or from spatially segregated sources, where water is the connecting vector of energy movement (Guest and Connolly, 2004; Ziegler et al., 2019; Plumlee et al., 2020; Lesser et al., 2021).

Resolving patterns and extent of movement of energy in coastal food webs is critical for managers challenged with approving more coastal urban and industrial development – this raises important decisions relating to choosing which tidal wetland/s to protect and conserve from those to be lost to development expansion (Swanson and Wilson, 2008; Bilkovic, 2011; Firth et al., 2020; Murray et al., 2022).

To maximise the financial prospects that residential real-estate with waterfrontage offers, developers excavate or reclaim areas of natural wetlands in many places to construct engineered urban waterways (Johnson and Williams, 1989; Maxted et al., 1997; Waltham and Sheaves, 2017). These artificial urban waterways massively extend the amount of available coastal habitat for aquatic species, with >4000 linear km in the world when last surveyed, with the highest proportion in Australia (Queensland), USA (Florida and New York), and UAE (Dubai) (Waltham and Connolly, 2011). This expansion has generated

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concerns about their ecological function and role as comparable fish habitat with adjacent natural coastal bays and estuaries (Sheaves et al., 2010; Olds et al., 2018; Gilby et al., 2021). Comparisons in the distribution and patterns of animals between natural and artificial waterways have been used to assess whether ecological processes differ between natural and artificial waterways (Baird et al., 1981; Morton, 1989; Waltham and Connolly, 2013). While these comparisons have shown that an almost complete overlap exists in the suite of fish species present (Morton, 1992; Rozas and Reed, 1994), they have neither elucidated the underlying ecological values and services artificial urban waterways provide, nor whether they differ from the natural habitats replaced, particularly given that artificial waterways lack the conspicuous macrophytes of natural vegetation habitats (Waltham and Connolly, 2007). While an early study in Florida concluded that food webs supporting production were similar across both natural and artificial habitat (Maxted et al., 1997), evidence elsewhere using carbon isotope analysis shows that some fish species rely on completely different plant-sources in artificial waterways compared to adjacent natural coastal areas, suggesting that coastal fisheries can have remarkable plasticity to urbanisation and habitat change (Waltham and Connolly, 2006). Beyond these small number of studies, little other data exists, which is concerning given the rate of coastal urban development expansion that continues to increase in many places around the globe (Airoldi et al., 2020).

The use of stable isotopes in food web studies is a widely used approach to resolve complex energy pathways from basal producers to higher order consumers (Lee, 2000; Mateo et al., 2008; Abrantes et al., 2015; Nelson et al., 2019; James et al., 2019, 2021). Carbon and nitrogen isotopes of potential basal food sources and of a predominantly carnivorous fisheries species, *Scylla serrata* (Forsk.) (giant mud crab), was examined here to further the knowledge for managers of the coastal estate, using spatially explicit isotope surveys to resolve a food web in highly urbanised waterways in south-east Queensland. *S. serrata* is widely distributed throughout the Indo-West Pacific, from the Middle East, south-east Asia to Japan, the western Pacific islands and northern Australia, and has been introduced to Hawaii. This species is exemplary for coastal food web studies for four reasons: (1) it lives on and can be caught over shallow to 2 m deep, unvegetated mudflats, which occur alongside the key vegetated coastal habitats of mangrove, saltmarsh and seagrass; (2) individuals do not move far on a daily basis (see Hill, 1978; Hyland et al., 1984), so their isotope signatures can show site specific variation; (3) individuals grow rapidly, and therefore reflect the isotope values of their diet quickly; and (4) its ecology is of broad interest due to its importance commercially - 175,000 t/yr globally, wild and aquaculture; and culturally and for subsistence fishing in southeast Asia and western Pacific islands (Connolly and Waltham, 2015). A previous isotope survey of giant mud crabs in natural environments in Queensland, Australia, used spatially explicit sampling and revealed that crabs had a food web supported by carbon (C) from seagrass (enriched C isotopes) when immediately adjacent to seagrass, and depleting C isotope values with increasing distance from seagrass (Connolly and Waltham, 2015). In a second study in Queensland that captured crabs in a partly urbanised estuary (Jinks et al., 2020), without seagrass meadows present, crabs were supported by saltmarsh vegetation, as has been found for other crustaceans on the east coast of Australia (Taylor et al., 2018). While *S. serrata* seems to occupy a broad range of coastal habitats ranging from natural to modified waterways, there remains a gap in knowledge relating to whether this species occupies the most urbanised areas with south-east Queensland, that make up a large part of the seascape extending >100 km from natural estuaries, and thereby no information on the food web supporting production of this species. Here we test the model that crabs also occupy highly urbanised waterways, and whether like natural and moderately urban systems (Connolly and Waltham, 2015; Jinks et al., 2020), are supported by local vegetation sources. The findings are important for managers challenged with approving more coastal development and engineering over protection

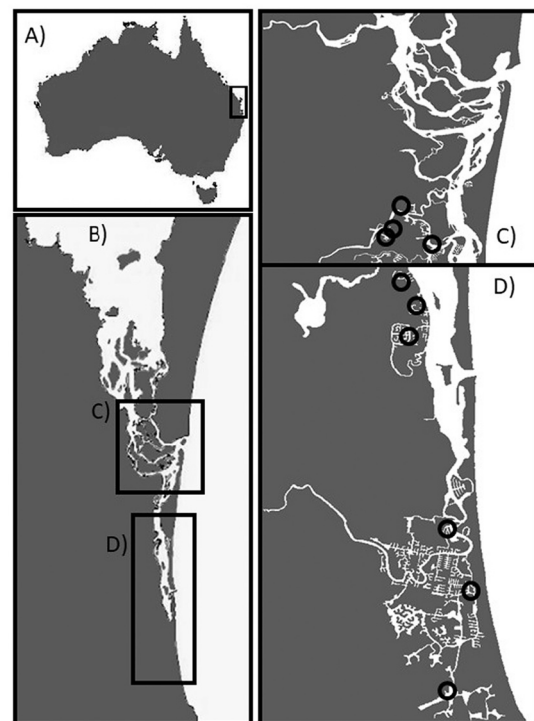


Fig. 1. Sampling locations in engineered, artificial waterways in Queensland, Australia: A) position in Australia; B) general location in southern Moreton Bay, C/D) inset of precise locations.

and conservation of natural vegetated resources in coastal waters.

2. Methods

2.1. Study area

Moreton Bay in Queensland, on the east coast of Australia, is a shallow, coastal embayment 1500 km² in area (Johnson, 2010). Human population growth in the region has been ~3% per year for decades (Leigh et al., 2013); which equates to 75 km² of forest and agricultural land being converted to housing estates annually. Natural wetland habitats fringing the bay have been cleared for urban development sprawl (Lovelock et al., 2019). While Moreton Bay supports a variety of commercial and recreational fish species, the trophic consequences of habitat loss is limited to only a few studies (Johnson and Williams, 1989; Pascoe et al., 2017). A comprehensive suite of finfish in Moreton Bay has been tested isotopically to determine basal autotrophic sources supporting productivity; for most fish species, the top three autotrophs were seagrass, epiphytic algae and saltmarsh grass, with a combined median C contribution of 60 to 90% (Melville and Connolly, 2005). Generally producers with enriched C isotope values are more important for production in Moreton Bay, and seagrass seems to be more important than saltmarsh grass (with a similar enriched C isotope signature) where it occurs, probably because saltmarsh occurs higher in the intertidal zone – more landward than mangroves in this region (Guest et al., 2004b).

2.2. Sample collection and processing

Adult giant mud crabs (3 individuals, all >100 mm carapace width – though at 5 sites only a single crab was captured despite best effort attempts to catch additional crabs) were collected for isotope analysis at each of 10 sites in urban, artificial tidal waterways in the austral summer (November) in southern Moreton Bay, Queensland, Australia (Fig. 1; 153°42'E, 27°93'S). Sites were positioned using coastal wetland maps

sourced from the Queensland Herbarium (Queensland Government) to represent different spatial distances from seagrass (*Zostera muelleri*), saltmarsh grass (*Sporobolus virginicus*), and mangroves (predominantly *Avicennia marina*). At all sites, distance (km) was measured as the most direct route, via water, to the nearest, substantial habitat patch.

As a proxy for carbon and nitrogen assimilation in the whole animal, muscle tissue was excised from the cheliped given that previous research has shown there is no measurable difference in the isotope values between cheliped and walking leg, nor is there a difference by *Scylla serrata* sex or size for adults (see Connolly and Waltham, 2015). Muscle tissue was dried to constant weight (60 °C), ground to a fine powder and analysed on an Isoprime Isotope Ratio Mass Spectrometer (Griffith University Stable Isotope Facility, Queensland, Australia). The ratios of $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ for *S. serrata* were calculated as the relative per mil (‰) difference between the sample and the recognised international standard. Analytical precision was determined from duplicate samples as being ± 0.5 .

2.3. Analysis of distances from autotrophs

A multiple stepwise regression was used initially to examine variability of $\delta^{13}\text{C}$ values of *S. serrata* among sites, using distance from seagrass, saltmarsh grass and mangroves as predictor variables for carbon and nitrogen isotopes separately. Akaike information criteria were used to examine model fit, and partial regressions were used to determine the amount of variation explained by individual habitats. Data were \log_x transformed to satisfy homogeneity of variances, although the assumption of linearity was still only partially fulfilled.

2.4. Modelling feasible source mixtures to explain crab nutrition

Mean isotope values of the dominant autotrophs in Moreton Bay were determined by pooling published literature (Guest et al., 2004a; Guest et al., 2004b; Melville and Connolly, 2005; Waltham and Connolly, 2006). Giant mud crab $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values collected at sites in this study and the autotroph values calculated from the literature were used in the Bayesian isotope mixing model framework (MixSIAR) was used to estimate the contribution of different food sources to assimilated carbon and nitrogen. MixSIAR estimates probability distribution of source contributions to consumer diets, whilst accounting for uncertainty in source isotope signatures and trophic fractionation (Parnell et al., 2010; Ramírez et al., 2014). The model examines all possible combinations of the potential contribution (0 to 100%) of each autotroph in small incremental adjustments (here 1%). Combinations of sources that resulted in an estimated *S. serrata* isotope values within 0.1‰ of the observed value were considered feasible solutions. We assumed a trophic enrichment factor (TEF) for the producers of $\delta^{13}\text{C} = 1.0 \pm 0.4$ and $\delta^{15}\text{N} = 3.1 \pm 1.3$. We also further adjusted the model by increasing both carbon and nitrogen by 1‰ and found it had no difference on the rank order and contribution for each producer - we are therefore confident that results are robust to the selected TEF (Connolly and Waltham, 2015; Jinks et al., 2020). The model reports results as the distribution of feasible solutions for each autotroph. When all possible primary producers were included, the breadth of distributions prevented clear conclusions about relative contributions, which is common in coastal estuaries when there are numerous primary producers available (Connolly and Waltham, 2015). Isotope values were therefore pooled for autotrophs with similar isotope values to provide greater resolution of contributions from three groups of autotrophs (enriched: seagrass, epiphytic algae, saltmarsh grass; depleted: mangrove, saltmarsh succulents; intermediate: microphytobenthos).

Table 1

Distance of sites from the three key habitats, and carbon and nitrogen isotope values (mean, SE) of giant mud crabs at each site (SE omitted where only $n = 1$ crab could be collected).

Site	Distance (km)			$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
	Seagrass	Saltmarsh	Mangrove		
1	11.3	17.0	15.0	-19.5 (0.5)	12.6 (1.3)
2	17.6	23.2	23.1	-21.7 (0.9)	12.4 (0.8)
3	9.5	1.6	0.4	-20.8 (0.8)	10.3 (0.8)
4	6.0	9.0	9.2	-20.7	10
5	4.8	0.3	0.3	-20.3 (0.3)	10.9 (1.5)
6	8.3	0.9	0.4	-21.5 (0.3)	9.9 (0.4)
7	0.4	1.8	0.5	-18.4	10
8	0.8	2.2	2.0	-20.1	10.6
9	0.3	1.6	0.5	-17.6	9.7
10	3.3	4.9	4.4	-22.0	8.9

Table 2

MixSIAR modelling results. Distributions of feasible contributions for each autotroph to giant mud crab nutrition in artificial habitat. Values are medians, with ranges in parenthesis: 5 and 95 percentiles. EPI: epiphytic algae, MAN: mangroves, MPB: microphytobenthos, SG: seagrass, SMG: saltmarsh grass, SMS: saltmarsh succulent.

	Autotroph contribution (%)					
	EPI	MAN	MPB	SG	SMG	SMS
4 (0-16)	2 (0-8)	83 (72-93)	6 (0-16)	2 (0-8)	2 (0-7)	

3. Results

3.1. Crab isotope values

The mean $\delta^{13}\text{C}$ values for *Scylla serrata* ranged from -17.6 to -22.0‰, and were generally within 1‰ for individuals at a site, while $\delta^{15}\text{N}$ values had a much smaller range, between 9.8 and 12.6‰ among sites (Table 1).

When modelling potential individual sources using carbon and nitrogen combined, the range of feasible contributions for autotrophs was very broad, limiting the conclusions that could be made directly from the modelling (Table 2). Patterns of contributions from pooled categories of autotrophs were clearer. At the site closest to seagrass (Table 1; site 9), the pooled enriched autotroph sources contributed most to crab carbon and nitrogen (Fig. 2a), while at all other sites (beyond approximately 500 m distance) it appears that crabs utilise a generalised C pool of sources, either local or perhaps a mix of local transported sources - for the site furthest from seagrass (Table 1; site 2) the enriched autotrophs contributed least, while MPB contributed the most to crab carbon and nitrogen (Fig. 2b). All model feasible distribution results are shown in the Supplementary.

The $\delta^{13}\text{C}$ isotope value of crabs was not significantly (multiple regression) related to the distance from any of the vegetated habitats (Fig. 3). While this is the case, the exception was two sites closest to seagrass (< 500 m distance) where crabs had the most enriched $\delta^{13}\text{C}$ values compared to all crabs caught further from seagrass and having more depleted values. The $\delta^{15}\text{N}$ isotope value of crabs was significantly (multiple regression) related to distance from vegetated habitats (see Supplementary), however, the relationship is probably not meaningful given the variability in the data around the regression lines.

3.2. Relationship with seagrass distance - comparing with crabs over natural estuaries

The seagrass proximity relationship is within the expected range of previous research, though is weaker in urban systems compared to natural sites (Fig. 4). These relationships are shown as a difference in slope between natural and artificial regression relationships of crab

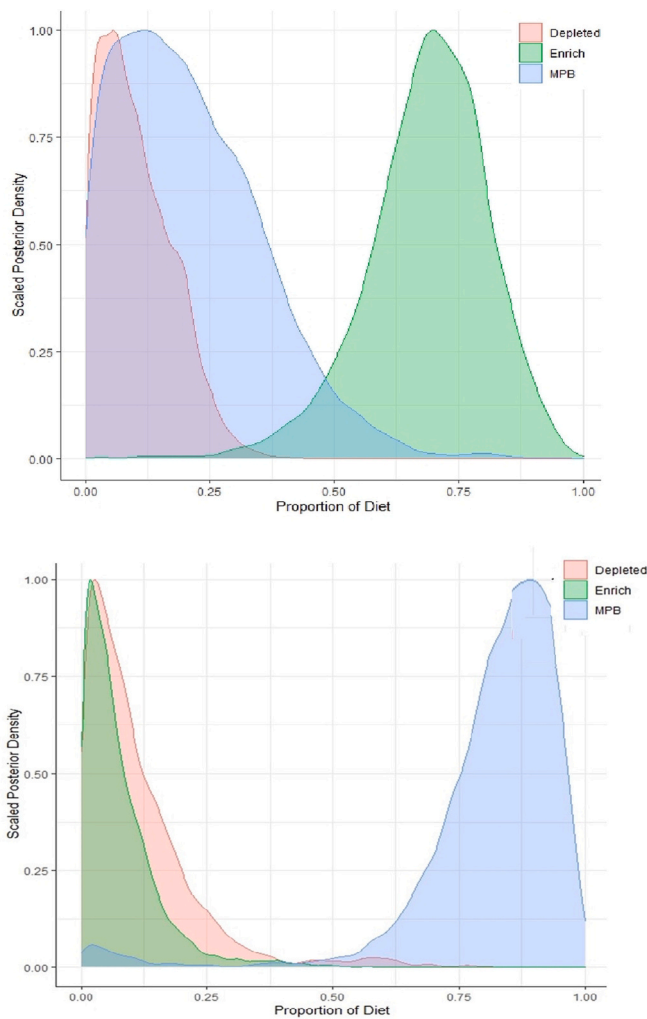


Fig. 2. Modelling the contributions of the 3 autotroph groups (depleted – mangrove and saltmarsh succulents; microphytobenthos algae; and enriched – seagrass, saltmarsh grass, and epiphytic algae) based on both carbon and nitrogen isotope results. A) the site close to seagrass (Table 1; site 9) – note that the second site closest to seagrass had a similar contribution and distribution of sources in the modelling; and B) modelling for the site furthest from seagrass (Table 1; site 2).

isotope values against seagrass distance (ANCOVA: interaction, $F_{1,20} = 9.92$, $P < 0.01$). This weaker relationship might be an artefact of absent or insubstantial seagrass meadows near to urban system openings, or simply a lack of data in artificial habitat within 300 m of seagrass. Beyond the first hundred metres the crab $\delta^{13}C$ value is more depleted and within the general range expected based on previous research.

4. Discussion

While the giant mud crab is found over natural areas across its range (Demopoulos et al., 2008), it can also occupy engineered waterways, providing evidence of remarkable plasticity to utilise created habitats in urbanising coastal areas. While this provides some suggestion that more urban waterways are simply an extension of natural areas, there is still data needed to decipher whether the stock numbers are disadvantaged with the new habitat – the sampling in this study was focused on food webs and further research is needed to quantify whether the new habitat supports fewer individuals or, indeed, habitat conditions are poorer which reduces their functional traits (Gilby et al., 2020).

Animals in estuaries that move and consume resources over the area they cover are considered to have contributions from sources that are

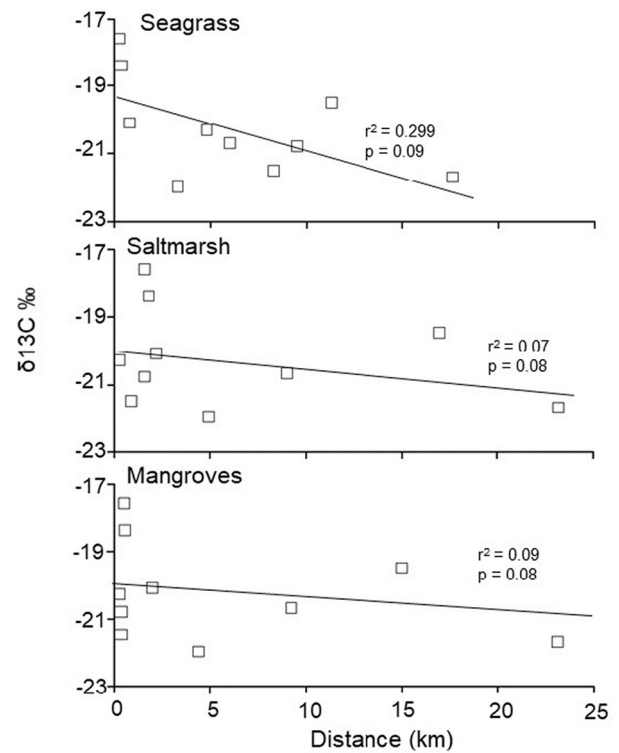


Fig. 3. Variation in $\delta^{13}C$ values of giant mud crabs in heavily urbanised waterways with distance from seagrass, saltmarsh grass, and mangroves. Values at each point are the site average.

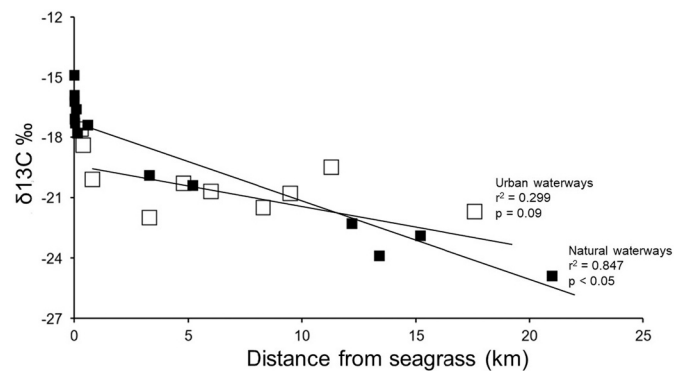


Fig. 4. Crabs at natural (closed symbols; Connolly and Waltham, 2015) and artificial sites (open symbols) shown here for mud crabs. Regression results also provided natural and artificial waterways.

not necessarily found where caught, but that was not the case here. Organic material from seagrass that is available in estuaries and known to support fisheries, is also true in some of the most extensively engineered coastal urban waterways, at least for the first 100 m. Beyond 100 m (which is the home range of *Scylla serrata*; Hill, 1978; Hyland et al., 1984) this study provides evidence that the nutrition of *S. serrata* appears to be supported by a generalised pool that would be a mix of local sources, such as benthic algae, and perhaps of sources transported from outside the artificial waterways. One major limitation of these engineered waterways is a distinct lack of vegetated habitats that are found in coastal estuaries (Greenwood and Morton, 1992; Morton, 1992), a consequence of the altered hydrology, lack of shallow water habitat, and at times poor water quality that is not conducive for aquatic plant growth.

Here a lack of spatial resolution of crabs captured in close proximity

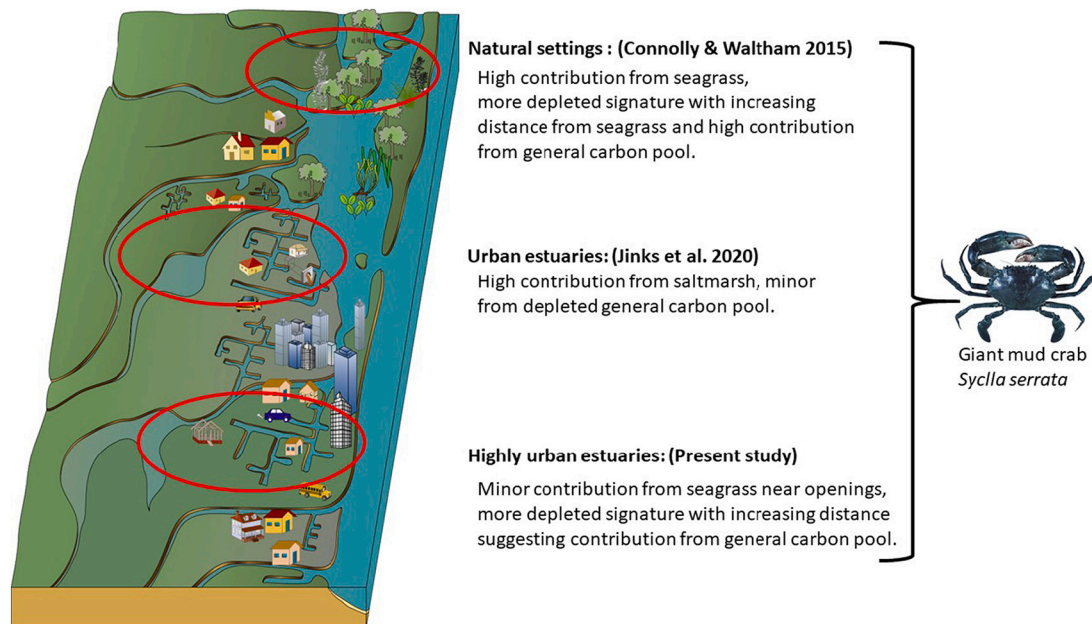


Fig. 5. Crabs are found across the continuum of natural areas, partly urbanised estuaries through to heavily urbanised artificial waterways, showing trophic plasticity. Crabs utilise local food sources, in natural areas nutrition is supported by seagrass with contribution reducing with increasing distance from patches, in semi-urban areas crabs are supported predominantly by saltmarsh, while in heavily urbanised seascapes there is minor seagrass contribution but nutrition is predominantly from the generalised, mixed carbon pool.

to seagrass turned out to be important in attempting to compare the pattern for crabs from natural sites in a previous study (Connolly and Waltham, 2015). Even in artificial waterways, there was a hint that organic matter from seagrass meadows is important, since crabs from the two sites nearest seagrass did in fact have carbon values more towards seagrass compared to mangroves (or terrestrial vegetation) end of the carbon range. With excess seagrass production available in natural habitat (Tomas et al., 2005; Duarte et al., 2013), it is conceivable that at least some of this allochthonous matter is transported into opening areas of artificial waterways. While possible, this trophic contribution is limited to the first few hundred metres, probably because of their narrow opening and restricted flow (Zigic et al., 2002), reducing the opportunity for tidal water with labile seagrass organic matter to ingress any further into the urban waterways. The results suggest that any transfer of seagrass nutrition via intermediate species that might have recently entered the urban waterways or are migrating between the natural areas and artificial waters also does not penetrate far into urban waterways. This evidence supports the idea that fisheries in these heavily urbanised waterways are supported by local sources, and probably not from nearby natural vegetation resources (Waltham and Connolly, 2006).

Terrestrial grass has an enriched carbon signature similar to seagrass, and while it would be washed into these systems during rainfall runoff, the chance of its contribution, and not seagrass, to be only in the vicinity of artificial openings seems unlikely, particularly given that crabs distant from openings had depleted carbon values despite that the grass grows as urban lawn adjacent to artificial waterways throughout their extent. In a diet study of the garfish *Arrhamphus sclerolepis* in artificial waterways (Connolly, 2003; Waltham and Connolly, 2006), a species known to be at least partly herbivorous (Tibbetts, 1997), there was no evidence in the stomach of fish, day or night, to suggest a feasible trophic importance of terrestrial grass.

Away from the urban waterway openings, C isotope values were depleted and within the narrow range more typical of animals in deeper waterways in the region (Melville and Connolly, 2003; Melville and Connolly, 2005; Waltham and Connolly, 2006). The design of these built waterways consists of deep channels to permit boating navigation,

bordered with fringes of sandy beaches or rock/concrete walls, meaning that they are not conducive to supporting marine plants found in natural parts of the bay. To this end, autotrophic production in artificial waterways is restricted to macroalgae, MPB, phytoplankton and terrestrial plants (Connolly, 2003; Waltham and Connolly, 2006). It is difficult to separately assess contributions among these isotopically similar sources, and further work is necessary to resolve their trophic role – for example, the use of sulfur isotopes might help resolve this uncertainty (Connolly et al., 2004; Szpak and Buckley, 2020). When considering the management of artificial waterways, then regardless of sources, these artificial waterways would seem to produce enough energy to support the mud crab species examined here.

In natural areas the range of C isotope values of giant mud crabs (−14 to −25‰) is wider than that reported for finfish over the same spatial scale (−16 to −19‰, Melville and Connolly (2005)). Factors affecting isotope values of marine animals, other than different local basal sources available among sites (Deegan and Garritt, 1997), have included size, sex or tissue type (Hobson et al., 1997; Camprasse et al., 2017; Louis et al., 2018), but none of these is particularly important for giant mud crabs (Connolly and Waltham, 2015). It is also possible that this among-site range was influenced by physiological processes, for example such as fractionation, which could be operating differently across the extent of artificial urban waterways included in this study (acknowledging that only a single crab individual was captured at some sites). Fractionation rates are known to vary depending on consumer size, growth rate and food quality (Adams and Sterner, 2000; Vander Zanden and Rasmussen, 2001), and any of these might contribute to differential fractionation rates among sites. We nevertheless consider that the low within-site variability in crab values reported here provides confidence that site differences reflect changes in source contributions. Importantly, for the purposes of this study, it indicates a relatively low level of dispersal of crabs among artificial sites and between natural and artificial waterways, as expected from previous tagging studies (Hill et al., 1982).

The model that urbanising coastal areas result in a reduced or, at worst, complete loss of essential habitat areas for fisheries production continues to be challenged, with the consensus that modified coastal

waters provide habitat for many of the same species found over natural areas of estuaries. There is emerging evidence that giant mud crabs, at least, can occupy the continuum from natural areas, to semi urban through to heavily urbanised artificial waterways (Fig. 5). This supports the model of plasticity that coastal fisheries show in adapting to newly created, engineered coastal habitat. This has been shown in other urban waterways, as well as for fauna attached to seawalls and piers, and nearby natural shores (Moreau et al., 2008; Loke and Todd, 2016; Lai et al., 2018). This evidence is becoming increasingly important for managers facing the challenge of approving more coastal sprawl while at the same time ensuring species conservation and protection (Johnston et al., 2015; Brook et al., 2018; Waltham et al., 2021).

Tidal urban waterways globally are mostly constructed as long, complex, narrow interconnecting channels that maximise the opportunity for residential properties with waterfrontage (Waltham and Connolly, 2011). An important engineering design consideration for these transitional waters is for a long residence time with limited exchange with natural estuarine waters. This engineering design is necessary for controlling the potential erosion and damage caused to infrastructure (e.g. road and bridge foundations) that strong currents can cause (Zigic et al., 2002). A longer residence time does increase susceptibility to contamination accumulation from sediment transport via runoff from surrounding urban and industrial centres (Moss, 1989; Lincoln-Smith et al., 1995; Maxted et al., 1997; Waltham et al., 2011).

This study adds to the evidence supporting the importance of organic material from seagrass meadows as the base for nutrition of a fisheries species in coastal areas. Spatial analysis showed a stronger pattern between seagrass proximity and *Scylla serrata* carbon isotope values, whereas no relationship existed for saltmarsh (or mangroves). The data here suggests that organic material derived from seagrass and/or epiphytic algae is important to fisheries production only in the immediate vicinity, beyond the first few hundred meters this contribution seems less important whereby crabs are then supported by a generalised pool of organic matter, likely of local origin. The study reinforces the need to conserve and protect seagrass meadows from adverse anthropogenic influences (Waltham and Sheaves, 2015), but indeed where seagrass is absent, coastal food webs are nevertheless supported by alternative sources.

Data accessibility statement

All data in this paper is available on request.

Declaration of Competing Interest

The authors declare no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.fooweb.2022.e00259>.

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