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Recognising the importance of shellfish to First Nations peoples, Indigenous and Traditional Ecological Knowledge in aquaculture and coastal management in Australia

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ABSTRACT

Throughout the world, there is a growing recognition of the importance and need for incorporation of Indigenous and Traditional Ecological Knowledge (TEK) of First Nations peoples in shellfish aquaculture and coastal management. In Australia, however, the incorporation of First Nations TEK of shellfish aquaculture and coastal management is in its infancy. This is a concern because the combined perspectives of Indigenous knowledge and Western Science are needed to restore culturally and economically significant shellfish and create successful, respectful and sustainable outcomes. The aims of this perspective piece are first to describe the evidence for the importance of shellfish aquaculture and management to First Nations peoples of Australia and second to highlight the opportunity to incorporate First Nations TEK in shellfish restoration and aquaculture in Australia. Already, models of successful incorporation of TEK of shellfish exist in Aotearoa, which provide an example for incorporation of TEK of shellfish in Australia. First Nations peoples of Australia hold a deep cultural connection with shellfish and Sea Country that has persisted for millennia. If we are to appropriately sustain and restore shellfish and manage our coasts, we must incorporate First Nations TEK and views, and respect and protect their ongoing connections to Sea Country.

Keywords: biodiversity, climate change, ecology, estuarine, Indigenous, Indigenous ecology, Indigenous restoration, invertebrates, mangroves, marine, molluscs, ocean acidification, restoration, salinity, salt marshes, wetlands.

Introduction

First Nations peoples possess important and valuable Indigenous and Traditional Ecological Knowledge (TEK) on shellfish aquaculture and coastal management (Reeder-Myers *et al.* 2022). It is now increasingly recognised that Indigenous knowledge and TEK combined with Western Science may provide the best solution to sustain, improve and restore shellfish populations, and importantly, give respect to First Nations custodianship of Sea Country (Kutay *et al.* 2021). Since Australia's colonisation, the management of Sea Country resources have predominantly been based on Western Science and an exploitative mindset (Gibbs *et al.* 2023; Stelling-Wood *et al.* 2023). Only in the last decade has the essential need to incorporate Indigenous knowledge and TEK with Western Science been gaining momentum (Bartlett *et al.* 2012).

The aims of this perspectives piece are to firstly describe the importance of shellfish to First Nations peoples of Australia and the value of TEK in shellfish aquaculture and management, and secondly to highlight the opportunity to incorporate First Nations TEK in shellfish restoration and aquaculture in Australia. We also provide examples whereby incorporating First Nations TEK of shellfish and coastal management in Aotearoa (New Zealand) has led to more sustainable outcomes. Recognising TEK of shellfish is important given the challenges for shellfish at a time where less than 1% of shellfish reefs remain nationally and globally and there are multiple anthropogenic impacts on coastal

Collection: Science in Sea Country

management (Beck *et al.* 2011; Clark and Johnston 2017; Bolotov *et al.* 2018). If we are to improve our aquatic ecosystems, we need to restore iconic shellfish reefs that are in crisis and understand and respect traditional Sea Country management strategies of First Nations peoples of Australia, then we need to incorporate TEK with Western Science approaches.

The importance of shellfish to First Nations peoples of Australia

Shellfish have been an important source of food, trade and culture to First Nations people around the globe for thousands of years (Reeder-Myers *et al.* 2022). Archaeological evidence suggests that pre-colonial shellfish ecosystems were not 'wild', but rather a cultivated resource successfully managed by First Nations peoples over millennia (Fletcher *et al.* 2021; Reeder-Myers *et al.* 2022). The management and consumption of shellfish was part of a broader socio-ecological system that was disrupted by colonialism (Reeder-Myers *et al.* 2022). For First Nations peoples of Australia, shellfish provide an unbroken cultural connection to Sea Country. Evidence of the importance of shellfish as a sustainable food source for First Nations peoples of Australia has been found in studies of middens around Australia (Gillespie and Temple 1977; Cann *et al.* 1991; Frankel 1991; Clune and Harrison 2009; Tables 1 and 2).

Middens provide a wealth of archaeological knowledge on the age, species and quantities of shellfish present (Table 1). Such knowledge provides insights into the diet of First Nations peoples of Australia, how it changed with the environment over time and how the abundance of shellfish varied among locations and timeframes. For example, Cann *et al.* (1991) found the lower levels of middens in the Robe Range within Little Dip Conservation Park in South Australia consisted of cockle (*Katelysia*) shells with radiocarbon dates of ~7910 years old and the upper levels consisted of *Turbo* shells with a radiocarbon date of 470 years old. Godfrey (1988, 1989) also used oxygen isotope analysis and radiocarbon dating of middens and found that pipis (*Donax deltoides*) had been fished for over 10 000 years in Discovery Bay, south-western Victoria, Australia, and were harvested at certain times of the year, particularly late winter. Middens also provide knowledge on how dietary patterns have changed over millennia (Luebbers 1978; Godfrey 1988, 1989; Cann *et al.* 1991). A midden site in South Australia identified two horizons. The first horizon being between 10 000 and 6000 years old and containing shellfish that were collected from the intertidal habitats indicated consumption largely of intertidal gastropods. The second horizon indicated that pipis and mussels were taken at that time, from the inter- and subtidal habitats (Luebbers 1978).

Other middens have been found to contain mostly oysters. In Great Oyster Bay, Tasmania, Australia, the middens were dominated by flat oysters (*Ostrea angasi*) and mussels (*Mytilus planulatus*) (Lourandos 1968). However, dietary patterns were not consistent even within locations in close proximity. Just ~130 km from Great Oyster Bay in Eddystone Point the dominant species in the middens were abalone (*Haliotis rubra*) and turbo snails (*Lunella undulata*) (Lourandos 1968).

Today, Australia's most popular choice of oyster is the Sydney rock oyster (*Saccostrea glomerata*). The Sydney rock oysters' popularity extends back to First Nations peoples of Australia, far longer in time than European modern oyster aquacultural practices. For example, Sydney rock oysters have been found extensively in middens such as those on the Richmond River (New South Wales, Australia) where 98% of all molluscan shells were Sydney rock oysters (Bailey 1975). An in-depth study of middens along the central coast of New South Wales, Australia, also provides evidence of the importance of the Sydney rock oyster (*S. glomerata*), the flat oyster (*O. angasi*) and 28 other molluscs for First Nations peoples of Australia (Stockton 1977). Further, in south-east Queensland, investigations into the Toulkerrie midden resulted in the identification of 6 species of molluscs, including the Sydney rock oyster, and 10 species of fish (Hall and Bowen 1989). Overall, these archaeological studies of middens have a wealth of knowledge regarding the type and quantities of shellfish harvested and the importance of shellfish to First Nations peoples of Australia (Table 1). Table 1 provides a snapshot of archaeological studies that have identified an enormous range of edible molluscs, shellfish and invertebrates consumed by First Nations peoples of Australia across thousands of years, including prominently the Sydney rock oyster.

Middens also had an important role in communicating to other clans who travelled as part of seasonal practices, through the record of recently eaten species, the available shellfish resources and other marine animals, ensuring overharvesting did not occur and sustaining shellfish availability (Rowland 1994; Korff 2021; Table 2). Further, middens were a site of spiritual and sacred places for teaching and learning for First Nations peoples containing human remains and artefacts. Middens were also places where the next generation were taught how to read the seasons, how to understand which organisms to harvest and what practices were need to help the environment remain in balance.

Traditional Ecological Knowledge (TEK) and First Nations knowledge

Archaeological research from middens has highlighted the importance of shellfish to First Nations peoples of Australia. Shellfish reefs were also essential in building colonial settlements. Shellfish are also important today with oyster farming alone in Australia forming a A$138 000 000 year^{-1} industry (cf. Australian Bureau of Agricultural and Resource Economics and Sciences, see https://www.agriculture.gov.au/abares). Despite the importance of shellfish to all Australians,

Table 1. Molluscs found commonly in middens in Australia.

Author of study	Geologic era and time	Location	Common name	Scientific name
Campbell (1972) (NSW)	4220 years BP	Clybucca	Sydney Cockle	*Anadara trapezia*
			Sydney Rock Oysters	*Saccostrea glomerata*
	4850 years BP	Connection Creek	Sydney Rock Oysters	*Saccostrea glomerata*
Bowdler (1976) (NSW)	2975 years BP	Bass Point	Mussel	*Mytilus edulis*
			Spengler's Trumpet	*Cabestana spengleri*
			Twisted Necklace	*Ninella torquata*
			Cart-rut Shell	*Dicathias orbita*
Stockton (1977) (NSW)	6000 years BP	Pinney Beach	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Sydney Cockle	*Anadara trapezia*
			Variegated Limpet	*Cellana tramoserica*
			Scaly Limpet	*Patellanax peronii*
			Black Elephant Snail	*Scutus antipodes*
		Bouddi National Park Midden 1	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Cart-rut Shell	*Dicathais orbita*
			Black Nerita	*Nerita atramentosa*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Variegated Limpet	*Cellana tramoserica*
			Tall-ribbed Limpet	*Patelloida alticostata*
			Chiton	*Chiton* sp.
			Black Elephant Snail	*Scutus antipodes*
		Bouddi National Park Midden 2	Spengler's Triton	*Cabestana spengleri*
			Small Turban Snail	*Lunella undulata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Cart-rut Shell	*Dicathais orbita*
			Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Sydney Cockle	*Anadara trapezia*
			Common Mussel	*Mytulis planulatus*
			Variegated Limpet	*Cellana tramoserica*
			Tall-ribbed Limpet	*Patelloida alticostata*
			Chiton	*Chiton* sp.
			Black Elephant Snail	*Scutus antipodes*
			Lined Periwinkle	*Austrocochlea constricta*
			Circular Tapestry Shell	*Circe scripta*
		Milligans Cave	Large Turban Snail	*Turbo torquata*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Mud Oyster	*Ostrea angasi*
			Sydney Cockle	*Anadara trapezia*
			Hairy Mussel	*Trichomya hirsuta*
			Common Mussel	*Mytulis planulatus*

(*Continued on next page*)

Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
			Hercules Club Whelk	*Pyrazus ebeninus*
			Mud Whelk	*Batillaria australis*
			Chama	*Chama* sp.
			Pipi	*Plebidonax deltoides*
			Circular Tapestry Shell	*Circe scripta*
		Newport	Spengler's Triton	*Cabestana spengleri*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Mud Oyster	*Ostrea angasi*
			Sydney Cockle	*Anadara trapezia*
			Hairy Mussel	*Trichomya hirsuta*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Mud Whelk	*Batillaria australis*
		Spring Cove	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Small Turban Snail	*Turbo undulata*
			Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Variegated Limpet	*Cellana tramoserica*
			Air-breathing Limpet	*Siphonaria* sp.
		Reef Beach	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Small Turban Snail	*Turbo undulata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Cart-rut Shell	*Dicathais orbita*
			Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Sydney Cockle	*Anadara trapezia*
			Hairy Mussel	*Trichomya hirsuta*
			Variegated Limpet	*Cellana tramoserica*
			Tall-ribbed Limpet	*Patelloida alticostada*
			Cap-shaped Limpet	*Monfortula rugosa*
			Air-breathing Limpet	*Siphonaria* sp.
			Chiton	*Chiton* sp.
			Chama	*Chama* sp.
			Lined Periwinkle	*Austrocochlea constricta*
			Circular Tapestry Shell	*Circe scripta*
		Balls Head	Sydney Rock Oyster	*Saccostrea glomerata*
			Mud Oyster	*Ostrea angasi*
			Sydney Cockle	*Anadara trapezia*
			Hairy Mussel	*Trichomya hirsuta*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Mud Whelk	*Batillaria australis*
			Air-breathing Limpet	*Siphonaria* sp.

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Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
			Limpet	*Notoacmea* sp.
			Chiton	*Chiton* sp.
			Chama	*Chama* sp.
			Periwinkle	*Austrocochlea concamerata*
		Gymea Bay	Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Mud Oyster	*Ostrea angasi*
			Sydney Cockle	*Anadara trapezia*
			Hairy Mussel	*Trichomya hirsuta*
			Mud Whelk	*Batillaria australis*
			Chama	*Chama* sp.
			Lined Periwinkle	*Austrocochlea constricta*
			Circular Tapestry Shell	*Circe scripta*
		Wattamolla	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Small Turban Snail	*Turbo undulata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Cart-rut Shell	*Dicathais orbita*
			Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Sydney Cockle	*Anadara trapezia*
			Hairy Mussel	*Trichomya hirsuta*
			Common Mussel	*Mytulis planulatus*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Mud Whelk	*Batillaria australis*
			Variegated Limpet	*Cellana tramoserica*
			Scaly Limpet	*Patellanax peronii*
			Tall-ribbed Limpet	*Patelloida alticostata*
			Cap-shaped Limpet	*Monfortula rugosa*
			Chiton	*Chiton* sp.
			Black Elephant Snail	*Scutus antipodes*
			Lined Periwinkle	*Austrocochlea constricta*
			Pipi	*Plebidonax deltoides*
		Bass Point	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Cart-rut Shell	*Dicathais orbita*
			Common Mussel	*Mytulis planulatus*
		Currarong	Spengler's Triton	*Cabestana spengleri*
			Large Turban Snail	*Turbo torquata*
			Small Turban Snail	*Turbo undulata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Cart-rut Shell	*Thais orbita*
			Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*

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Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
			Hairy Mussel	*Trichomya hirsuta*
			Common Mussel	*Mytulis planulatus*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Chiton	*Chiton* sp.
			Lined Periwinkle	*Austrocochlea constricta*
			Pipi	*Plebidonax deltoides*
		Durras North	Triton	*Charonia rubicunda*
			Large Turban Snail	*Turbo torquata*
			Small Turban Snail	*Turbo undulata*
			Abalone–Mutton Fish	*Haliotis rubra*
			Cart-rut Shell	*Dicathais orbita*
			Black Nerite	*Nerita atramentosa*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Sydney Cockle	*Anadara trapezia*
			Common Mussel	*Mytulis planulatus*
			Variegated Limpet	*Cellana tramoserica*
			Scaly Limpet	*Patellanax peronii*
			Chiton	*Chiton* sp.
			Black Elephant Snail	*Scutus antipodes*
			Lined Periwinkle	*Austrocochlea constricta*
			Pipi	*Plebidonax deltoides*
Luebbers (1978) (SA)	1470 years BP	Cape Northumberland	Limpets	*Cellana*
			Snails	*Subninella*
	1134 years BP	Canunda Rock	Limpets	*Cellana*
			Sea Snails	*Dicathias*
			Turbo Snails	*Subninella*
	2990 years BP		Mussels	*Brachidontes*
	3800 years BP		Pipi	*Plebidonax*
	1020 years BP	Mount Burr	Mussels	*Brachidontes*
			Abalone	*Haliotis*
	8600 years BP		Mussels	*Brachidontes*
	760 years BP	Bevilaqua Cliffs	Snails	*Subninella*
	8250 years BP		Pipis	*Plebidonax*
	1020 years BP	Mount Burr	Mussels	*Brachidontes*
			Abalone	*Haliotis*
	8600 years BP		Mussels	*Brachidontes*
	8700 years BP	Cape Martin	Mussels	*Mytulis*
			Cockles	*Katelysia*
Sullivan (1982) (NSW)	500 years BP	Durras North	Mussels	*Mytilus planulatus*
	800 years BP	Birubi	Mussels	*Mytilus planulatus*
	1000 years BP	Bowen Island	Mussels	*Mytilus planulatus*
	1100 years BP	Batemans Bay (North Head)	Mussels	*Mytilus planulatus*
	1200 years BP	Cemetery Point	Mussels	*Mytilus planulatus*
	1500 years BP	Gymea Bay	Mussels	*Mytilus planulatus*

(*Continued on next page*)

Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
	1900 years BP	Wattamolla	Mussels	*Mytilus planulatus*
	2000 years BP	Nundera Point	Mussels	*Mytilus planulatus*
	2800 years BP	Daleys Point	Mussels	*Mytilus planulatus*
	2800 years BP	Pambula Lake	Mussels	*Mytilus planulatus*
	2800 years BP	Newport	Mussels	*Mytilus planulatus*
	2800 years BP	Yowie Bay	Mussels	*Mytilus planulatus*
	2800 years BP	Curracurrong	Mussels	*Mytilus planulatus*
	2800 years BP	Bass Point	Mussels	*Mytilus planulatus*
Hall and Bowen (1989) (SE Queensland)	1600 years BP	The Toulkerrie midden	Pippi	*Donax deltoides*
			Oyster	*Saccostrea commercialis*
			Cockle	*Anadara trapezia*
			Sand Snail	*Polinices sordidus*
			Mud Whelk	*Pvrazus ebeninus*
			Hairy Mussel	*Trichomva hirsuta*
Cann *et al.* (1991) (SA)	840 years BP	Robe Midden	Turbo Snails	*Subninella*
	7910 years BP		Cockles	*Katelysia* spp.
Attenbrow (2010) (NSW)	4000–6000 years BP	Abbortsford	Sydney Cockle	*Anadara trapezia*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Gold-mouthed Conniwink	*Bembicium auratum*
			Mud Oyster	*Ostrea angasi*
			Mud Whelk	*Batillaria australis*
			Limpet	Limpet sp. unidentified
			Lined Periwinkle	*Austrocochlea constricta*
			Bearded Ark Clam	*Barbatia pistachia*
				Bittium lacertinum
				Circe trigone
			Keyhole Limpet	*Clypidina rugosa*
			Boring Venus Shell	*Irus crenatus*
				Laternula craccina
				Prothalotia comtessei
		Balls Head	Sydney Cockle	*Anadara trapezia*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
				Chama fibula
			Mud Oyster	*Ostrea angasi*
			Mud Whelk	*Batillaria australis*
			Periwinkle	*Austrocochlea concamerata*
			Common Conniwink	*Bembicium melanostoma*
				Bittium lacertinum
			Boring Venus Shell	*Irus crenatus*

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Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
				Prothalotia comtessei
				Pyrene sp.
			Air-breathing Limpet	*Siphonaria* sp.
			Heart Venerid	*Timoclea cardioides*
		Bantry Bay	Sydney Cockle	*Anadara trapezia*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Mud Oyster	*Ostrea angasi*
			Limpet	Limpet sp. unidentified
		Moore's Wharf	Sydney Cockle	*Anadara trapezia*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Mud Oyster	*Ostrea angasi*
		Milk Beach	Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Spengler's Trumpet	*Cabestana spengleri*
				Chama fibula
			Black Nerite	*Nerita atramentosa*
			Limpet	Limpet sp. unidentified
			Sea Snail	*Austrocochlea* sp.
			Mulberry Whelk	*Morula marginalba*
				Mitra badia
		Mount Trefle	Sydney Cockle	*Anadara trapezia*
			Hercules Club Whelk	*Pyrazus ebeninus*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Spengler's Trumpet	*Cabestana spengleri*
			Variegated Limpet	*Cellana tramoserica*
				Chama fibula
			Cart-rut Shell	*Dicathais orbita*
			Black Nerite	*Nerita atramentosa*
			Mud Oyster	*Ostrea angasi*
			Large Turbo Snail	*Turbo torquata*
			Mud Whelk	*Batillaria australis*
			Lined Periwinkle	*Austrocochlea constricta*
			Periwinkle	*Austrocochlea concamerata*
			Sea Snail	*Austrocochlea* sp.
			Oyster Drill	*Bedeva hanleyi*
			Striped Mouth Conniwink	*Bembicium nanum*
			Marine Snail	*Bembicium* sp.
			Whelk	*Cabestana* sp.
				Cardita excavata
			Circular Tapestry Shell	*Circe scripta*

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Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
			Ridged Lucine	*Codakia rugifera*
			Dirty Sand Snail	*Conuber sordidum*
			Prickly Slipper Limpet	*Crepidula aculeata*
			Pipi	*Plebidonax deltoides*
			Yellow Coated Clusterwink	*Hinea brasiliana*
			Boring Venus Shell	*Irus crenatus*
				Mitra badia
			Common Mussel	*Mytulis planulatus*
			Little Blue Periwinkle	*Nodilittorina unifascata*
			Tenison Woods	*Patelia chapmani*
			Doughboy Scallop	*Pecten furnatus*
			Black Elephant Snail	*Scutus antipodes*
			Denticulate Siphon Shell	*Siphonaria denticulata*
			Small Keyhole Limpet	*Tugali parmaphoidea*
			Small Turbo Snail	*Turbo undulata*
			Venus Clams	*Veneridea (fam)*
			Little Brown Mussel	*Xenostrobus securis*
		Reef Beach	Sydney Cockle	*Anadara trapezia*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Hairy Mussel	*Trichomya hirsuta*
			Spengler's Trumpet	*Cabestana spengleri*
			Variegated Limpet	*Cellana tramoserica*
				Chama fibula
			Cart-rut Shell	*Dicathais orbita*
			Black Nerite	*Nerita atramentosa*
			Large Turbo Snail	*Turbo torquata*
			Black Keyhole Limpet	*Amblychilepas nigrita*
			Lined Periwinkle	*Austrocochlea constricta*
			Periwinkle	*Austrocochlea concamerata*
			Oyster Drill	*Bedeva hanleyi*
			Striped Mouth Conniwink	*Bembicium nanum*
			Circular Tapestry Shell	*Circe scripta*
			Keyhole Limpet	*Clypidina rugosa*
			Abalone/Muttonfish	*Haliotis rubra*
			Yellow Coated Clusterwink	*Hinea brasiliana*
			Boring Venus Shell	*Irus crenatus*
			Common Mussel	*Mytulis planulatus*
			Oysters	Family Ostreidae
			Tall-ribbed limpet	*Patelloida alticostata*
			Triton Shells	Family Ranellidae
			Denticulate Siphon Shell	*Siphonaria denticulata*

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Table 1. (*Continued*).

Author of study	Geologic era and time	Location	Common name	Scientific name
			Air-breathing limpet	*Siphonaria* sp.
			Chinaman's Fingernail	*Solen correctus*
			Small Turbo Snail	*Turbo undulata*
Colley (1997) (NSW)	6900 years BP	Disaster Bay	Common Edible Mussel	*Mytilus edulis planulatus*
			Triton	*Cabes tana spengleri*
			Beaked Mussel	*Austromytilus rostratus*
			Wavy Turban Shell	*Turbo undulatus*
			Chitons	*Class Polyplacophora*
			Cartrut Shell	*Dicathias orbita*
			Sydney Rock Oyster	*Saccostrea glomerata*
			Worm Shells	Family Venetidae
			Limpets	Family Patellidae
			Rock Barnacles	Crustacea
			Mud Ark	*Anadara trapezia*
			Large Turban Shell	*Turbo torquata*
			Black Periwinkle	*Nerita atramentosa*
			Abalone	*Haliotis* sp.
			Venus Shell	Family Veneridae
			Wavy Top Shell	*Austrocochlea concamerata*
			Club Mud Whelk	*Pyrazus ebeninus*
			Mussels	Family Mytilidae
			Mud Oyster	*Ostrea agnasi*
			Southern Mud Whelk	*Batillaria australis*
			Periwinkles	Family Littorinidae
			Elephant Snail	*Scutus antipodes*
			Hairy Mussel	*Trichomya hirsuta*
			Scallops	Family Pectinidae
			Banded Kelp Shell	*Bankivia* sp.
			Whelks	Family Buccinidae
			Nassarius	Family Nassariidae
			Creepers	Family Cerithiidae
			Bailey's Dog Winkle	*Dicathais baileyana*
			Tenison's False Dog Cockle	*Limpopsis tenisoni*
			Ribbed Top Shell	*Austrocochlea constricta*
				Bernbiciurn sp.
			Dog Whelks	Family Nassidae

Mutton Fish is an Indigenous name for abalone.

very few studies have attempted to describe the TEK of shellfish aquaculture and coastal management of marine resources (Bowdler 1976; Attenbrow 2010). TEK is a subset of Indigenous knowledge and is defined as 'a cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment' (Berkes *et al.* 2000, p. 1252). TEK has advantages over Western Science because it can provide local, long-term information on species, including their spatial and temporal distributions, life-history stages, behaviours, trends and responses to disturbances (both natural and human-induced). TEK also gives insight into the customary tools, practices and management systems used to cultivate,

Table 2. Invertebrates found in middens along the New South Wales coast (Schnierer and Egan 2016).

Class	Common name	Scientific name
Polychaeta	Beach Worm	*F. onuphidea*
Polyplacophora	Chiton	*Ischnochiton australis*
	Unidentified sp.	
	Albida Chiton	*Plaxiphora albida*
Bivalvia	Ark Shell	*Barbatia bistachia*
	Beaked Mussel	*Austromylitus rostratus*
	Bivalve	*Callista* sp.
	Blue Sea Mussel	*Mytulis planulatus*
	Cobra	*Teredo navalis*
	Commercial Scallop	*Pecten fumatus*
	Freshwater Mussel	*Hyridella* sp.
	Hairy Mussel	*Trichomya hirsuta*
	Heart Cockle	*Cardium racketti*
	Jewel Box	*Chama fibula*
	Mud Oyster	*Ostrea angasi*
	Pacific Oyster	*Crassostrea gigas*
	Pipi	*Plebidonax deltoides*
	Razor Clam	*Pinna* sp.
	Scallop	*Scaeochlamys peroniana*
	Sydney Cockle	*Anadara trapezia*
	Sydney Rock Oyster	*Saccostrea glomerata*
	Tapestry Cockle	*Tapes watlingi*
	Tenison's False Dog Cockle	*Limopsis tenisoni*
Gastropoda	Australian Mud Whelk	*Velacumantis australis*
	Banded Kelp Shell	*Bankivia* sp.
	Black Lip Abalone	*Haliotis rubra*
	Bonnet Shell	*Phalium* sp.
	Cart-rut Shell	*Dicathais orbita*
	Chapmans Limpet	*Patella chapmani*
	Common Periwinkle	*Austrocochlea constricta*
	Common Tent shell	*Australium tentoriiformis*
	Cone Shell	*Conus papilliferus*
	Dog Whelk	*Nassarius jonasii*
	Elephant Snail	*Scutus antipodes*
	False Baler Shell	*Livonia mamilla*
	Frasers Banded Snails	*Sphaerospira fraseri*
	Giant Triton	*Monoplex australasiae*
	Gold-mouthed Conniwink	*Bembicium auratum*
	Knobbed Triton	*Charonia rubicunda*
	Limpet	*Patelloida mimula*
	Margin Shells	*Marginellid* sp.
	Mitre Shell	*Mitra contermina*
	Moon Snail	*Polinices melastomus*
	Mud Whelk	*Pyrazus ebeninus*
	Nerite	*Nerita atramontosa*
	Peron's Limpet	*Patella peroni*
	Ribbed Limpet	*Patelloida alticostata*
	Ribbed Limpet	*Patelloida complanata*
	Spengler's Trumpet	*Cabestana spengleri*
	Topsnail	*Clanculus* sp.
	Turban Snail	*Turbo* spp.
	Variegated Limpet	*Cellana* sp.
Cephalopoda	Octopus	*Octopus* sp.
	Cuttlefish	*Sepia* sp.
	Squid	*Nototodarus* sp.
Malacostraca	Bait Yabby	*Callianassa australiensis*
	Bay Prawn	*Metapenaeus bennettae*
	Blue Swimmer Crab	*Portunus pelagicus*
	Cleft-fronted Shore Crab	*Plagusia chabrus*
	Eastern King Prawn	*Merlicertus plebejus*
	Eastern Rock Lobster	*Sagmariasus verreauxi*
	Freshwater Shrimp	*Macrobrachium* sp.
	Freshwater Yabby	*Cherax destructor*
	Mud Crab	*Scylla serrata*
	Reef Crab	*Ozius truncatus*
	School Prawn	*Metapenaeus macleayi*
	Shore Crab	*Plagusia glabra*
	Spanner Crab	*Ranina ranina*
	Swift-foot Shore Crab	*Leptograpsus variegatus*
Echinoidea	Unidentified Sea Urchin	
Ascidiacea	Cunjevoi	*Pyura stolonifera*

harvest and sustain species (Berkes *et al.* 1995; Johannes *et al.* 2000; Dulvy and Polunin 2004; Haggan *et al.* 2007; Johannes and Neis 2007; Moreira Moura and Sant'Ana Diegues 2009). Combined, Indigenous knowledge and Western Science has been described as 'two-eyed seeing' (Bartlett *et al.* 2012). Two-eyed seeing, first described in Canada, is a metaphor for when a person is familiar with both Indigenous knowledge and Western knowledge systems (McAllister *et al.* 2020) and is more ably prepared to meet a challenge or task at hand.

The recognition of the importance and incorporation of TEK in shellfish aquaculture and coastal management is particularly well developed in Canada (Treseder and Krogman 1999; Mascarenhas 2007; Beckford *et al.* 2010; Tsuji *et al.* 2020; Chan *et al.* 2021), Aotearoa–New Zealand (Wehi *et al.* 2013; Paul-Burke *et al.* 2018; Whaanga *et al.* 2018; Maxwell *et al.* 2020) and to a lesser extent in Kenya, Peru, Colombia, and Panama (Zimmerer 2012; Ulloa 2017; Weber and Tascón 2020). In Australia; however, TEK of shellfish aquaculture and coastal management is under studied and under incorporated. The lack of understanding and incorporation of TEK in shellfish aquaculture and coastal management is surprising given that First Nations peoples of Australia are the world's oldest living culture, encompassing knowledge over 65 000 years and inhabiting a land with 34 000 km of mainland coastline. Among other reasons discussed later in this article, the lack of the incorporation of TEK in shellfish aquaculture and coastal management in Australia maybe because Western Science privileges written knowledge, and Indigenous knowledge was and is predominantly oral and lived, communicated intergenerationally through cultural stories, songs and dance (Benjamin *et al.* 2020; Veth *et al.* 2020; Hale *et al.* 2021; Wiseman *et al.* 2021). There are also examples of stories on social media platforms, including even YouTube.

Although limited, there is some information available on the TEK surrounding cultivation, harvest and management of shellfish from the Quandamooka people in Moreton Bay, Southern Queensland, Australia (Ross 1996). Shellfish were described as a key resource to the Quandamooka oyster farmers who created artificial oyster reefs within the bay, identifying natural high points in the water as a location to place dead shells for oyster spat to recruit. These artificial reefs were found on the west coast of North Stradbroke Island and played a fundamental role in maintaining water quality in the region (Ross 1996; Thurstan *et al.* 2019). To ensure that oysters were available throughout the year and that overharvesting did not occur, oyster beds were continuously monitored and in the event of a depletion of oysters in one bed, oysters from another bed were transferred to replace oysters that had died. Prior to European colonisation, the coastline of Morton Bay on Quandamooka Country was abundantly populated with reef-forming shellfish species (O'Rourke 2013). Over the last 125 years, however, overharvesting, hyposalinity and disease have led to a severe decline of shellfish populations (Diggles 2013). In response to this, the Moreton Bay region is now a site of shellfish reef restoration. The incorporation of some TEK of shellfish culture, harvest and management from the Quandamooka people (e.g. which substrate to use), the appropriate selection of restoration sites, and how to best monitor and manage restored reefs into the future has improved the outcomes of shellfish reef restoration projects. However, the continual monitoring and management practices of shellfish restoration of First Nations peoples have not been as well incorporated. Instead Western management models of shellfish restoration, primarily being to 'lock away' and 'keep people out', have been used. Debates continue today about which type of management practices should be used in the future. In other areas such as fire management, co-led design of projects with the Quandamooka people and stakeholders is creating respect, recognition, relatedness and reciprocity, which is actively bringing Quandamooka culture to the forefront of restoration (Fischer *et al.* 2019).

In contrast to the lack of recognition of TEK on shellfish and coastal management of First Nations peoples of Australia, there is a long history of recognition for their highly developed fishing skills. Examples of fishing skills include strategies used to attract dolphins, which in turn would scare fish into the shallow waters to be speared or caught in nets (Hall 1984). Other examples of fishing include poison on bark to stun fish, the use of lines and hooks (Bowdler 1976) and fire to attract fish at night that were then speared or caught in a net. There was even the mimicking of seagulls to scare fish into traps (Mountford 1939). These fishing skills were admired by early European settlers and records indicate a vibrant industry trading in shellfish and fish between European settlers and First Nations peoples of Australia (Kerkhove 2013, 2018).

The importance of First Nations knowledge of shellfish in Aotearoa

The lack of incorporation of First Nations TEK in Australia contrasts with the considerable incorporation of shellfish and coastal management TEK of the First Nations peoples of Aotearoa (New Zealand). Over the last decade, the Māori TEK on shellfish and shellfish cultivation, information on historical abundance, contemporary ecology and conservation of species in Aotearoa has been incorporated into management of coastal ecosystems (Geary *et al.* 2019).

For example, First Nations Aotearoa knowledge and practices have been used to revitalise fisheries, such as scampi (*Metanephrops challengeri*) (Ogilvie *et al.* 2018) and Koura (freshwater crayfish, *Paranephrops planifrons* or *P. zealandicus*) (Kusabs *et al.* 2018). One example from Aotearoa demonstrates the transition from 'how to catch more' to 'how to reduce the impact of fishing on the environment' by understanding First Nation knowledges regarding scampi that is grounded in First Nations TEK frameworks (Ogilvie *et al.* 2018). Kusabs *et al.* (2015) and Kusabs and Quinn (2009) also highlighted effective methods for harvesting Koura, a freshwater crayfish that is endemic to Aotearoa. There are two species of Koura: *P. planifrons* found on the North Island and in the north-west of the South Island, and *P. zealandicus* that is distributed along the eastern side of the South Island and on Stewart Island. Kusabs *et al.* (2018) explored First Nations methods of harvesting and cultivating Koura and showed that the method of using whakaweku (artificial habitats made from fronds of bracken ferns) resulted in higher catch rates of Koura and lower catch rates of bycatch compared to other techniques.

Further, Paul-Burke *et al.* (2018) illustrated the power of First Nations knowledge as a foundation for improving, enhancing and safeguarding mussel (*Perna canaliculus*) populations in Ōhiwa harbour. The outcome of this has become an incorporation of local *Iwi* (tribe) and government partnering in the creation of a Mussel Management Action Plan (MMAP), which has been grounded in the principles of First Nations ecological knowledge practices and their cultural relationships with the area. This plan also established a monitoring regime and a restoration plan for the mussel population in the Ōhiwa harbour area. In 2016, before the implementation of this action plan there had been a significant decline in the abundance of mussels; however, since 2018, there has been a steady increase in the abundance of mussels based on First Nations ecological practices (Radio New Zealand 2021). Interestingly, in an interview, Paul-Burke *et al.* (2018) stated that because of First Nations knowledge and practices of the local *Iwi* (tribe), shellfish beds were located using cultural landmarks that had previously been missed. Another benefit of the use of First Nations practices is based on natural substrata rather than plastics used commonly used in Western aquaculture. The use of TEK has led to the revitalisation of culture and also both reduced plastic pollution and increased the densities of mussel populations (Paul-Burke *et al.* 2018).

Like First Nations peoples of Australia, the importance of shellfish for First Nations Māori is also found in cultural oral traditions including the ancestral sayings or *whakataukī* described by Wehi *et al.* (2013) and Whaanga *et al.* (2018). *Whakataukī* provides an example of shellfish in everyday life. Ancestral sayings were used to describe the many physical features of fish and shellfish and the location of these species and how these changed over time. Wehi *et al.* (2009, 2013) described both the complexity of oral traditions of *whakataukī* (ancestral sayings) and separated these from *pūrākau* and *kōrero* (myths and stories), *karakia* (prayer), and *waiata* (song) about shellfish, and these were incorporated into understanding time and culture. Wehi *et al.* (2009, 2013) also explained that the names of organisms can be misunderstood using Western labels. In contrast to Western names, the name of shellfish in the language of First Nations peoples of Aotearoa is related to culture and creates meaning about the way it moves, or the way it eats, what it eats, where it lives and what it looks like. Understanding the shellfish name provides much more information than the name used in the western world. For example, ***Ngā kai a Tamatāhei ki a koe! Ehara tēnā, kei tua o Kapenga e haere ana***, translates to 'See the food of Tamatāhei for you!', to which the reply would be 'Never! It has passed on the other side of Kapenga.' Within these phrases are references to Tamatāhei, which is the name of a place that is famous for the Manuka trees, which have traditionally been used for tool making, and Kapenga, the name of a large flax swamp tree from which is the flax of the garment has come from. This illustrates three very important features: (1) locations of importance; (2) the resources associated with specific locations; and (3) the use of the resources from these locations.

The incorporation of First Nations Aotearoa TEK has led to a reinvigoration of practices with embedded cultural values, highlighting the in-depth knowledge held by First Nations knowledge holders. Moller (2009), Moller *et al.* (2009*a*) and Taiepa *et al.* (1997) described the value of First Nations TEK or *mātauranga Māori* (Māori knowledge) as extensive and in-depth. Moller (2009) and Moller *et al.* (2000, 2004, 2009*b*, 2009*c*) also highlighted the importance of TEK for the sustainability and cultural practices and improved health of ecosystems. Clapcott *et al.* (2018) too argued for the importance of First Nation practices to assess aquatic environments, a notion that has now been supported by other studies (Crow *et al.* 2018; Hikuroa *et al.* 2018; Hopkins 2018). Crow *et al.* (2018) stated that Māori TEK can better inform the assessment of natural waterways and TEK combined with Western technology can be of great benefit to new fisheries practices.

Differences between First Nations knowledge in Australia and Aotearoa

Reasons for the differences between the more developed incorporation of TEK on shellfish in Aotearoa compared to the lack of incorporation of TEK in Australia in part may reflect the importance of shellfish to Māori culture and perhaps also stem from the signing of the treaty of Te Tiriti o Waitangi in 1840 and the dual absence of a treaty and voice for First Nations peoples of Australia. The Te Tiriti o Waitangi treaty demonstrated respect for the Māori people and the treaty symbolised and described the relationship between two cultures and two systems of law and morality. Te Tiriti affirmed and promised to uphold the mana (customary authority), tino rangatiratanga (leadership) and tikanga (law) of Māori, and commits to a relationship of equal partnership between Māori chiefs and the British Crown (Armstrong *et al.* 2019; Taylor *et al.* 2020).

The treaty cemented the intrinsic value of Māori culture in Aotearoa, which has been recognised by the New Zealand government for over 150 years. No such treaty or recognition in the constitution has occurred for First Nations peoples of Australia, although the Uluru Statement from the Heart recognises that 'Aboriginal and Torres Strait Islander tribes were the first sovereign Nations of the Australian continent and its adjacent islands and possessed it under our own laws and customs'. The absence of rectification in treaty or through the constitution has led to fragmented government programs designed to assimilate and eliminate First Nations Australian culture and language, and with it, TEK of shellfish and shellfish management (Zuckermann *et al.* 2014). TEK was replaced with a colonial mindset of resource exploitation that has led Australia to losing 92% of Sydney Rock oyster (*S. glomerata*) and over 99% of flat oyster (*O. angasi*) reef systems (Gillies *et al.* 2018). Such cultural and environmental damage has only recently begun to be repaired. There are lessons to be learned from First Nations peoples of Australia. Concerted effort needs to be made to restore and recover the TEK of shellfish and coastal management that remains.

Recommendations and conclusions

Across the globe, many shellfish, shellfish reefs and coastal ecosystems are in ecological crisis (Beck *et al.* 2011). Continued anthropogenic pressure from habitat destruction and climate change continue to threaten shellfish and their habitats and create doubt about their resilience to persist (Parker *et al.* 2013; Scanes *et al.* 2020; Gibbs *et al.* 2021; Ross *et al.* 2023). If we are to appropriately restore shellfish resources including oysters, mussels, pipis, scallops (Pawley and Smith 2012; Howarth *et al.* 2015; Talman 2017) and abalone (Hobday *et al.* 2000; Shepherd *et al.* 2001; Jenkins 2004), and the valuable ecosystem services and aquaculture industries they provide, worth billions of dollars per annum (Food and Agriculture Organization of the United Nations 2016, 2020), then we need to understand and incorporate TEK of First Nations peoples of Australia before both TEK and shellfish are lost. We have seen the benefits of incorporating traditional TEK for Koura and mussel fisheries in Aotearoa and the use of fire management by the Quandamookas. Moving forward, our strongest option to sustain and restore shellfish and shellfish reefs and ultimately estuarine ecosystem health in Australia is to combine Western Science management and decision-making grounded in TEK. This requires partnerships built on respect, recognition, relatedness and reciprocity where Traditional Owners are the co-designers or lead-designers and where intellectual property rights are understood and protected (Gibbs *et al.* 2023). First Nations peoples of Australia have a culture that is centred around caring and protecting Land, Sea and Sky Country. This culture has largely been pushed to the background by government and other organisations. TEK and First Nations management practices create an opportunity to strengthen and resurrect connections of First Nations peoples of Australia to Sea Country (Gibbs *et al.* 2023). For modern society to restore and secure the future, we need to understand the past of the oldest living culture in the world and incorporate it into our future.

Optimistically, there have been changes to legislation that recognise Indigenous knowledge and TEK. For example, amendments were made in 2010 to the New South Wales *Fisheries Management Act* 1994 (NSW FMA), which highlights the economic and social importance of traditional aquatic resources for First Nations peoples of Australia and their cultural and spiritual significance (Schnierer 2011). The amendments to the NSW FMA in 2010 established the New South Wales Aboriginal Fishing Advisory Council (NSW AFAC) to advise the Minister and New South Wales Department of Primary Industries (NSW DPI) of culturally appropriate management protocols. However, it is clear that legislation alone will not lead to the development of culturally appropriate management practices. So far, legislation has made very little difference to the incorporation of Indigenous cultural practices into shellfish restoration projects, and more is required (Gibbs *et al.* 2023).

We are only just at the beginning of a journey in Australia to understand the importance of shellfish, and to document and incorporate TEK held by First Nations peoples of Australia, to sustain shellfish, restore shellfish reefs, and respect views of First Nations peoples of Australia in shellfish aquaculture and value their coastal and cultural management strategies. If we are to successfully combine Western Science and TEK to appropriately manage and restore our coasts, then we need to create bonds of trust with Nations Australians TEK, identify and understand their viewpoints on restoration, shellfish aquaculture and coastal management, and finally respect and protect their connections to Sea Country.

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