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Southern range extensions for twelve heterobranch sea slugs (Gastropoda: Heterobranchia) on the eastern coast of Australia

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Abstract

Port Stephens, on the central New South Wales coast, provides ideal oceanographic and benthic conditions for the settlement and growth of larvae of tropical species delivered from the north by the East Australian Current. The popularity of the bay for recreational and scientific diving has facilitated extensive documentation of the biota over several decades, confirming its high biodiversity. Of the 313 species of heterobranch sea slugs recorded from Port Stephens to date, 30 are not known to occur further south. Our observations increase the number of taxa with a southern distribution limit at Port Stephens by 12 species and add to a growing list of marine taxa that are progressively extending their southern range, potentially as a result of climate change.

Keywords: Port Stephens, Opisthobranchs, Nudibranchs, Climate change, Citizen science

Introduction

Heterobranch sea slugs (hereafter simply sea slugs) are predominantly tropical marine animals that, on the eastern Australian coast, exhibit a latitudinal gradient with rapid attenuation of species diversity from more than 1,000 species in the northern Great Barrier Reef (GBR) to approximately 500 in central New South Wales (NSW) (Rudman & Willan, 1998). The southward flow of the East Australian Current (EAC) brings warm water from tropical latitudes to the Tasman Sea (Booth et al., 2007; Malcolm et al., 2010) and with it planktonic larvae (Booth et al., 2007; Malcolm et al., 2010). With increasing latitude, the current moves offshore and generates eddies (mostly in summer) that deliver an intermittent supply of these tropical larvae to the central and southern NSW coast (Burn, 2006).

South-eastern Australia is a recognised climate change 'hot-spot' (Hobday & Lough, 2011) where strengthening of the EAC and increasing water temperature may facilitate the arrival and establishment of novel species that may alter species interactions (Underwood & Chapman, 2007). In this area, southward shifts in distribution are anticipated for many marine organisms (Przeslawski et al., 2008), with range extensions already documented for some species of fishes (Figueira & Booth, 2010; Harasti, 2015), scleractinian corals (Baird et al., 2012), sea slugs (Nimbs et al., 2015), and host anemones and their complement of commensal crustaceans (Scott et al., 2015). New species records will come about through greater intensity of observations (sea slugs are inherently rare in time and space - Marshall & Willan, 1999) and as a result of range shifts due to warming conditions. Those changes resulting from warming seas have important implications for marine conservation management particularly for species with a very restricted range (O'Hara 1995).

Comprehensive data on the occurrence of a range of marine organisms tend to be confined to locations near major population centres due primarily to the proximity of research facilities (Smith 2005, 2008a, b; Burn, 2006). For this reason, species lists for the central NSW coast, especially adjacent to Sydney, are comprehensive,

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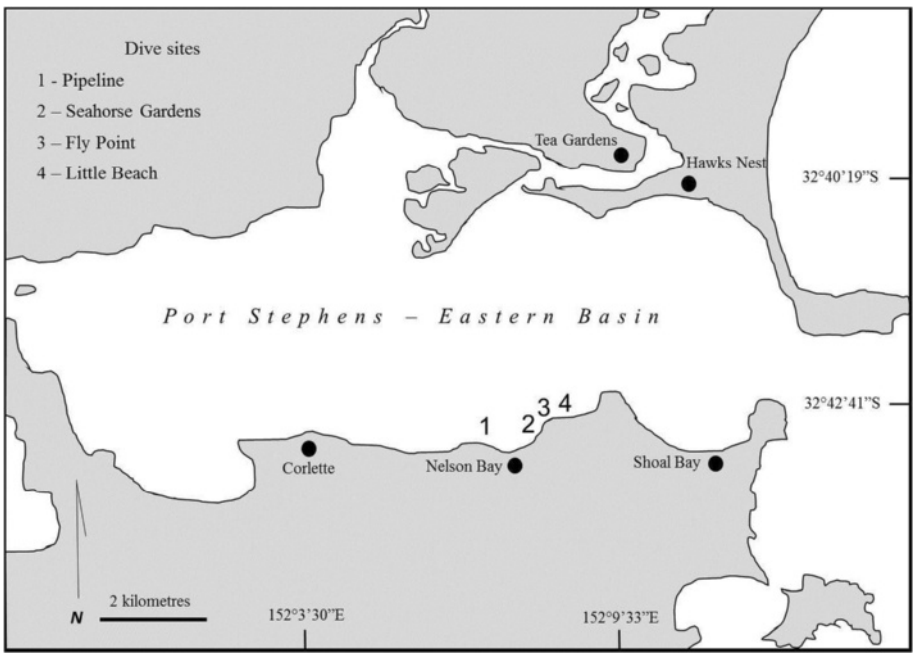

Fig. 1 Map of Port Stephens eastern basin with dive sites indicated. Shading represents land

particularly for fishes (Gladstone, 2007; Morton & Gladstone, 2011; Harasti et al., 2015). The occurrence and distribution of sea slugs is also well known, however to record range extensions reliably, it is imperative that observations of any taxa not previously recorded in an area are thoroughly documented.

The Port Stephens–Great Lakes Marine Park encompasses 98,000 ha of coastal and shelf waters between Cape Hawke and Birubi Beach, incorporating the extensive Port Stephens embayment (Fig. 1). Within the marine park, varying oceanographic conditions, sea bed topography and sessile assemblages contribute to a high species diversity that is a mixture of tropical, subtropical and temperate flora and fauna (DECCW, 2010, Smith et al., 2010). Being close to Newcastle, the second largest city in NSW, and with easy access for SCUBA divers and watercraft, the biotic and abiotic aspects of Port Stephens have been well studied (e.g. Harasti et al., 2014; Poulos et al., 2015; Davis et al., 2015).

Many sea slug species of tropical origin are regularly observed in Port Stephens where conditions are conducive for the settlement of veliger larvae that may have travelled considerable distance on the EAC. In this paper, observations of 12 sea slug species are recorded at significant distances (at least 300 km) south of their previously reported southern limit. Coastal lagoons and estuaries provide sheltered locations for successful settlement and growth of more tropically adapted marine organisms (Willan et al., 1979) and accessible, safe diving conditions. These factors, combined with the increasing popularity of diving-based citizen science activities in the region (e.g. Smith & Edgar, 2014 and the current *Sea Slug Census* program) increase the likelihood that additional species will not only occur in the region, but also that they have a reasonable probability of being found.

Table 1 Selected records of *Philinopsis orientalis* from Australian waters

Location	Record coordinates	Year	Reference
Lizard Island, QLD	14°40′30″S 145°26′26″E	1982	Pers. obs. (R. C. Willan)
Coates Reef, QLD	17°10′53″S 146°22′10″E	1997	Pers. obs. (R. C. Willan)
Rottnest Island, WA	31°59′19″S 115°30′10″E	1990–2000	(Wells & Bryce 2000, p. 31–32)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2015	This paper

Materials and methods

Port Stephens is a large, drowned river valley fed by two major, eastward-flowing rivers, the Karuah and the Myall, and comprises two basins that exhibit differences in substrate and hydrodynamics. The marine-influenced eastern basin is characterised by a complex of channels and shoals formed by the influence of strong tidal flows (Vila-Concejo et al., 2007) with a diverse range of marine habitats (Davis et al., 2015). A narrow entrance and elevated shoreline to the south-east provide considerable

Fig. 2 **a**. *Philinopsis orientalis*. Fly Point, 14 February, 2015. **b**. *Jorunna ramicola*. Pipeline, 30 November, 2013. **c**. *Thordisa tahala*. Little Beach, 15 January, 2015. **d**. *Marionia pustulosa*. Seahorse Gardens, 7 March, 2015. Photos: **a**, Matt Doyle; **b**, **c**, Tom Davis; **d**, Kristine O'Keefe

protection from the effects of strong southerly winds and large ocean swells. The tidal range in the sheltered port is approximately 1.4 m (Creese & Wales, 2009) and the average depth is 14 m (Poulos et al., 2015).

Organic input from rivers and tidal flow contribute considerable volumes of food to support suspension-feeding organisms such as sponges, ascidians, octocorals and hydroids (Smith 2008a, b; Smith et al., 2010). These organisms, in turn, provide food and habitat for a diverse assemblage of sea slugs. Several popular shore-dive sites, noted for their diverse invertebrate life and opportunities for macro-photography, are located on the southern shoreline of the eastern basin, centered around Nelson Bay (32°42′54″S 152°9′01″E) (Fig. 1).

The 'Pipeline' supports a mixed habitat comprising rocky reef with large macrophytes and sandy sediments with seagrasses, sponges and octocorals (Harasti & Gladstone, 2013). 'Seahorse Gardens' is 900 m east of the 'Pipeline' and supports octocoral colonies situated in sandy substrate with sponges located in deeper areas (Harasti et al., 2014). 'Fly Point' lies to the east of 'Seahorse Gardens' within a sanctuary (no take) zone that has been protected since 1983. Situated on a prominent point, this site has complex topography including a series of substantial ledges at various depths. While many habitats are similar to those at 'Pipeline', there are extensive areas of large sponges in the deeper sections (to 24 m) (Coleman and Marsh 1997). 'Little Beach' is 450 m east of 'Fly Point' and comprises sandy substrate interspersed with seagrasses, sponges and gorgonians (Harasti et al., 2014).

Observations of sea slugs were made between 2009 and 2015 using SCUBA at the four dive sites. Many observations were made during recreational diving activities, as incidental sightings whilst undertaking other research or as part of broader research projects carried out by TRD and ML. Other observations were made as part of a Southern Cross University (SCU)/Combined Hunter Underwater Research Group (CHUG) citizen-science project to document the diversity of sea slugs at three-monthly intervals over a two-year period (the *Sea Slug Census*).

Records of all species of sea slugs were collated from the authors' databases as well as from extensive

Table 2 Records of *Jorunna ramicola* from Australian waters

Location	Record coordinates	Year	Reference
Alexandra Headland, QLD	26°40′20″S 153°06′49″E	2004	Cobb & Mullins (2009a)
Gold Coast, QLD	27°56′09″S 153°25′34″E	2011	Aston (2011a)
Hastings Point, NSW	28°21′37″S 153°34′45″E	2006–2011	Riek (2013a)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2013	This paper

Table 3 Records of *Thordisa tahala* from Australian waters

Location	Record coordinates	Year	Reference
Gneering Shoals, QLD	26°38′54″S 153°10′58″E	2014	Cobb & Mullins (2009d)
Gold Coast Seaway, QLD	27°56′09″S 153°25′34″E	2013	Aston (2011b), Good (2015)
Brunswick River, NSW	28°32′10″S 153°33′03″E	2004–2014	Riek (2013b)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2015	This paper

Table 4 Records of *Marionia pustulosa* from Australian waters

Location	Record coordinates	Year	Reference
Dampier, WA	20°39′29″S 116°41′59″E	1990	(Coleman 2008, p. 399)
Port Curtis, QLD	23°49′00″S 151°16′25″E	1929	Odhner (1936)
Noosa, QLD	26°22′39″S 153°06′05″E	2000	(Coleman 2008, p. 399)
Mooloolaba, QLD	26°40′34″S 153°07′09″E	1997	(Coleman 2008, p. 399)
Flinders Reef, QLD	26°58′47″S 153°29′06″E	2009	Cobb & Mullins (2009b)
Mud Island, QLD	27°20′32″S 153°14′15″E	1972	Thompson (1972)
North Solitary Island, NSW	29°55′18″S 153°23′14″E	1989	Australian Museum (1989)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	1988, 1996, 2015	Carol Buchanan, this paper.

photographic material from key underwater photographers. Species observations that had been reported online (in Nudi Pixel or the Sea Slug Forum) were considered as published observations.

Results

Systematics

Order CEPHALASPIDEA Fischer, 1887
Family AGLAJIDAE Pilsbry, 1895 (1847)
Genus *Philinopsis* Pease, 1860
Philinopsis orientalis (Baba, 1949)
Synonym: *Aglaja orientalis* Baba, 1949

This distinctive aglajid was originally named *Aglaja orientalis* by Baba (1949) from specimens found off Kurosaki and Hayama in Sagami Bay, Japan. Baba expressed doubts about that generic location in correspondence with RCW. It was recently transferred into the genus *Philinopsis* (Camacho-García et al. 2013). Since then, it has been found at several locations throughout the Indo-Pacific including La Reunion and New Caledonia (Rudman, 2003f). It is distinguished by the presence of numerous scattered white spots and areas of opaque white marks containing smaller yellow lines and spots that form a line across the head and transversely across the mid-notum, and a patch on the tail (Gosliner et al., 2008, p. 42). In Australian waters, there are published records of *P. orientalis* from Rottnest Island, WA (Wells & Bryce, 2000, p. 31–32) and from the (northern) GBR (Marshall & Willan, 1999, p. 171) (Table 1). An observation of a 15 mm specimen at 8 m depth on 14 February, 2015 at 'Fly Point' (Fig. 2a) extends the east coast range for this species by 2,246 km to central NSW.

Table 5 Records of *Trinchesia ornata* from Australian waters

Location	Record coordinates	Year	Reference
Heron Island, QLD	23°27′04″S 151°55′17″E	1998–1994	(Marshall & Willan 1999, p. 141)
Heron Island, QLD	23°27′04″S 151°55′17″E	1994	Museum Victoria (1980)
Gneering Shoals, QLD	26°38′54″S 153°10′58″E	2004	MAGNT 2011)
Alexandra Headland, QLD	26°40′20″S 153°06′49″E	2004	(Coleman 2008, p. 379)
Byron Bay, NSW	28°36′41″S 153°37′46″E	1992	(Coleman 2008, p. 379)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2013	This paper

Table 6 Records of *Trinchesia puellula* from Australian waters

Location	Record coordinates	Year	Reference
Gneering Shoals, QLD	26°38′54″S 153°10′ 58″E	2008	Cobb & Mullins (2008)
Nelson Bay, NSW	32°43′13″S 152°08′ 39″E	2013	This paper

Order NUDIBRANCHIA Cuvier, 1817
Family DISCODORIDIDAE Bergh, 1891
Genus *Jorunna* Bergh, 1876
Jorunna ramicola M. C. Miller, 1996

Jorunna ramicola was described first from New Zealand (Miller, 1996); however, it has subsequently been found widely in the Indo-Pacific Ocean with a distribution that includes Madagascar, Japan, Philippines and Papua New Guinea (Camacho-García & Gosliner, 2008; Gosliner et al. 2008) (Note that this assumption of a single species has not been tested genetically and species of *Jorunna* are notoriously difficult to identify morphologically). As with many discodorids, this species exhibits protective resemblance (Behrens et al., 2005) by mimicking the surface pattern and colour of its host sponge (*Callyspongia*) and is thus well camouflaged. In Australia, this

Table 7 Records of *Facelina rhodopos* from Australian waters

Location	Record coordinates	Year	Reference
Lizard Island, QLD	14°40′43″S 145°88′ 13″E	2002	Australian Museum (2002)
Hastings Point, NSW	28°21′37″S 153°34′ 45″E	2005	Riek (2013c)
Sandy Beach, NSW	30°08′44″S 153°12′ 08″E	2014	Pers. obs. (M. Nimbs)
Nelson Bay, NSW	32°43′13″S 152°08′ 39″E	2014	This paper

Table 8 Records of *Sakuraeolis nungunoides* from Australian waters

Location	Record coordinates	Year	Reference
Mudjimba Island, QLD	26°36′52″S 153°06′53″E	2012	Cobb & Mullins (2012b)
Gold Coast, QLD	27°56′09″S 153°25′34″E	2012	Good (2012)
Brunswick River, NSW	28°32′10″S 153°33′03″E	2004	Riek (2013d)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2013–2015	This paper

species has been recorded several times from subtropical QLD and northern NSW (Table 2). Prior to our observation of a 12 mm individual at 6 m depth from the 'Pipeline' on 30 November, 2013 (Fig. 2b), the southernmost record of *J. ramicola* was at Hastings Point, NSW, on 27 April, 2010 (Riek, 2013a). The Nelson Bay record extends the range south by 500 km.

Genus *Thordisa* Bergh, 1877
Thordisa tahala Chan & Gosliner, 2007

The original description of *Thordisa tahala* was based on descriptions from preserved specimens from Madagascar, Indonesia and the Marshall Islands (Chan & Gosliner, 2007), indicating a wide Indo-Pacific distribution (Gosliner et al., 2008). The specific name was derived from Malagasy (tahala = ridge) for the network of raised ridges on the dorsum and, in conjunction with its colour, the network pattern distinguishes *T. tahala* from any other species within the genus (Chan & Gosliner, 2007). The previously known range of *T. tahala* in Australian waters was a 210 km section of coast from the Gneering Shoals in southern QLD to the Brunswick River, NSW (Table 3). This observation on 22 January, 2015 of a 60 mm specimen (Fig. 2c) at 8 m depth, at night, from 'Little Beach' extends the east coast range for this species by 480 km.

Family TRITONIIDAE Lamarck, 1809
Genus *Marionia* Vayssière, 1877
Marionia pustulosa Odhner, 1936

Marionia pustulosa is a moderately large sea slug which, when amongst its host octocoral, is camouflaged using a complex pattern of reticulated lines, various muted colours and many elevated papillae on its dorsum, oral veil and rhinophoral sheaths. This dendronotid nudibranch appears endemic to Australia and was first described by Odhner from a specimen sourced from Port Curtis, QLD, in 1929 and later redescribed by Thompson (1972) using a live specimen found in Moreton Bay, QLD, in 1972. It has been recorded from Dampier, WA, Noosa, QLD (Coleman, 2008), and North Solitary Island, NSW (Australian Museum, 1989), amongst other locations (Table 4). This species was photographed by Carol Buchanan in Nelson Bay in March 1988 and again in March 1996; however, these observations remained unpublished. Those earlier observations, and another of a 35 mm specimen (Fig. 2d) in 6 m of water at 'Seahorse Gardens' on 7 March, 2015 increase the southern range of *M. pustulosa* by 332 km.

Family TERGEPEDIDAE Bergh, 1889
Genus *Trinchesia* Ihering, 1879

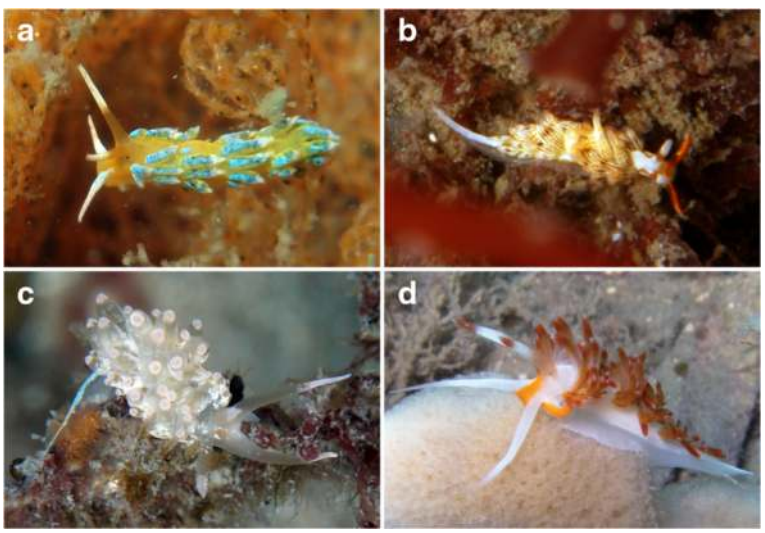

Fig. 3 **a**. *Trinchesia ornata*. Little Beach, 8 December, 2013. **b**. *Trinchesia puellula*. Little Beach, 11 September, 2013. **c**. *Facelina rhodopos*. Little Beach, 15 December, 2014. **d**. *Sakuraeolis nungunoides*. Fly Point, 23 August, 2013. Photos: **a**, **b**, **c**, Tom Davis; **d**, Nicola Davis

Table 9 Records of *Kaloplocamus peludo* from Australian waters

Location	Record coordinates	Year	Reference
Heron Island, QLD	23°27′04″S 151°55′ 17″E	2007	Rudman (2007)
Currimundi Reef, QLD	26°46′02″S 153°09′ 34″E	2014	Cobb & Mullins (2012a)
Nelson Bay, NSW	32°43′13″S 152°08′ 39″E	2014	This paper

Trinchesia ornata (Baba, 1937)
Synonyms: *Catriona ornata* (Baba, 1937), *Cuthona ornata* Baba, 1937

Trinchesia ornata is recognised by its orange body with blue and yellow cerata (Gosliner et al., 2008) and by its obligate predation of thecate hydroids (Gosliner, 1987; Marshall & Willan, 1999). Although originally described from Tomioka in Japan (Baba, 1937), its range extends from South Africa (Gosliner, 1987, pp. 20, 116), La Réunion (Nudi Pixel, 2011d) to Japan, Hong Kong (Gosliner et al., 2008), Indonesia, Thailand, Philippines, Palau (Nudi Pixel, 2011e) and Australia (Marshall & Willan, 1999; Coleman, 2008). In Australia, *T. ornata* has previously been recorded from various locations from Heron Island in the southern GBR to Byron Bay, NSW (Table 5). It is rather difficult to see underwater, but is assumed to be quite common. On 8 December, 2013 a 5 mm specimen was observed at 'Little Beach' on rocky reef at 8 m deep (Fig. 3a), 475 km south of its previously reported southernmost distributional limit.

Trinchesia puellula Baba, 1955
Synonyms: *Cratena puellula* Baba, 1955, *Catriona puellula* (Baba, 1955), *Cuthona puellula* (Baba, 1955)

Baba (1955) described this species from a single 10 mm animal from Hayama, Sagami Bay, Japan. It is characterised by the presence of orange markings on both the rhinophores and oral tentacles, vertical white lines on the cerata, and the black speckled appearance of the digestive gland within the cerata (Rudman, 2002d). It was later reported from California (Marcus, Er. 1961) and then from Australia in 2008 at Gneering Shoals, QLD (Table 6), implying a broad distribution across the Pacific Ocean, most likely facilitated by shipping. Little is known of the biology and ecology of this species with few observations recorded outside Japanese waters. Our recent observation of a 5 mm specimen on sand at 'Little Beach' on 11 September, 2013 at 7 m depth constitutes a southward range extension of 680 km (Fig. 3b).

Family FACELINIDAE Alder & Hancock, 1855
Genus *Facelina* Alder & Hancock, 1855
Facelina rhodopos Yonow, 2000
Synonym: *Pruvotfolia rhodopos* (Yonow, 2000)

This aeolid has an Indo-Pacific distribution from the Red Sea (Yonow, 2000), through La Réunion (Bidgrain, 2006), Kenya, Philippines, Indonesia (Nudi Pixel, 2011a) and Malaysia (Rudman, 2002a) to Australia. *Facelina rhodopos* bears clusters of cerata tipped with pink/peach rings and an opaque longitudinal metapodial line which are diagnostic of the species (Yonow, 2000). In Australian waters, it has been found in the northern GBR at Lizard Island, QLD, and in northern NSW from Hastings Point

Fig. 4 a. *Kaloplocamus peludo*. Fly Point, 11 September, 2014. **b**. *Tambja victoriae*. Fly Point, 20 February, 2010. **c**. *Polycera risbeci*. Pipeline, 23 November, 2014. **d**. *Thecacera pacifica*. Fly Point, 6 December, 2014. Photos: **a**, Tom Davis; **b**, Roxanne Streatfeild; **c**, David Harasti; **d**, Meryl Larkin

Table 10 Records of *Tambja victoriae* from Australian waters

Location	Record coordinates	Year	Reference
Hibernia Passage, QLD	12°47′54″S 143°48′47″E	1981	Australian Museum (1981)
Swain Reefs, QLD	21°14′22″S 151°50′48″E	1985	Australian Museum (1985)
North West Reef, QLD	23°14′54″S 151°46′41″E	1983	Australian Museum (1983)
Heron Island, QLD	23°27′04″S 151°55′17″E	1973–2008	Nudi Pixel (2003); Rudman (2005); (Coleman 2008, p. 369); Nudi Pixel (2008d)
Mooloolaba, QLD	26°39′37″S 153°08′08″E	2003	Cobb & Mullins (2003)
Gold Coast Seaway, QLD	27°56′09″S 153°25′34″E	2014	Aston (2014)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2010	This paper

and Sandy Beach (Table 7). On 15 December, 2014 at 'Little Beach', we observed a 15 mm specimen at 7 m depth on a rocky reef (Fig. 3c) at night. This record extends the east coast range southward by 300 km.

Genus *Sakuraeolis* Baba, 1965
Sakuraeolis nungunoides Rudman, 1980

Sakuraeolis nungunoides was originally described from Tanzania in tropical eastern Africa. Its range has subsequently been found to extend into the Indo-Pacific reaching Malaysia, the Philippines, New Caledonia and Australia (Rudman, 2003d). This species bears long, transparent cerata which are frequently held erect; each has a subapical orange band. A median orange band extends between the base of the rhinophores and the oral tentacles. The rhinophores are long, tapering, translucent and tipped in orange (Rudman, 2003d). When irritated, *S. nungunoides* straightens and 'bristles' each ceras which, according to Rudman, is similar to the behaviour of a porcupine (Swahili = *Nungunungu*), for which this species is named. In Australia, *S. nungunoides* has been recorded from the Sunshine Coast (Mudjimba Island), QLD, to the Brunswick River, NSW (Table 8). The observation of a 35 mm specimen at 'Fly Point' on 23 August, 2013 at 14 m, and two additional individuals 'Little Beach' at 11 m deep on 2 February, 2015 (Fig. 3d) extend its southern range by 475 km.

Table 11 Records of *Polycera risbeci* from Australian waters

Location	Record coordinates	Year	Reference
Heron Island, QLD	23°27′04″S 151°55′17″E	1981–1994	(Marshall & Willan 1999, p. 53)
Mooloolaba, QLD	26°40′34″S 153°07′09″E	2009	Cobb & Mullins (2009c)
Hastings Point, NSW	28°21′37″S 153°34′45″E	2006, 2013	Riek (2013e)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2014	This paper

Family POLYCERIDAE Alder & Hancock, 1845
Genus *Kaloplocamus* Bergh, 1880
Kaloplocamus peludo Vallès & Gosliner, 2006

This polycerid feeds on arborescent bryozoans and possesses numerous dorsal papillae (Gosliner & Vallès, 2006) that afford it a strong resemblance to its prey (Gosliner et al., 2008, p. 105). *Kaloplocamus peludo* has a wide Indo-Pacific distribution and, in Australia, has been recorded at Heron Island, QLD, in 2007, and more recently at Currimundi Reef, QLD in 2014 (Table 9). This observation of a 10 mm specimen at 'Fly Point' on 11 September 2014 at 7 m depth represents a 640 km southward range extension (Fig. 4a).

Genus *Tambja* Burn, 1962
Tambja victoriae Pola, Cervera & Gosliner, 2005

This species is distinguished from other *Tambja* species by the presence of dark blue rhinophores surrounded by dark blue rhinophoral sheaths edged in yellow (Gosliner et al., 2008, p. 118) and is known to feed on arborescent bryozoans. Its distribution is

Table 12 Records of *Thecacera pacifica* from Australian waters

Location	Record coordinates	Year	Reference
Christmas Island	10°30′08″S 105°40′59″E	1987	Rudman (2002c)
Bynoe Harbour, NT	13°39′51″S 130°32′12″E	2003	MAGNT (2003)
Kendrew Island, WA	20°28′41″S 116°32′23″E	1972	Museum Victoria (1975a)
Tweed River, NSW	28°10′18″S 153°32′57″E	2013	Aston (2013)
Rottnest Island, WA	31°59′19″S 115°30′10″E	2011	Nudi Pixel (2011c)
Nelson Bay, NSW	32°43′13″S 152°08′39″E	2014	This paper
Esperance, WA	33°21′00″S 121°53′00″E	1985	Clay Bryce, this paper
Albany, WA	35°04′43″S 117°57′03″E	2010	Nudi Pixel (2010d)

Table 13 Sea slug species with a southern distribution limit on the eastern Australian coast at Port Stephens, NSW

Order	Species	Published record	Reference
Cephalaspidea	*Philinopsis reticulata*	2004	NudiPixel (2004)
	Haminoea cymbalum	1980	Australian Museum (1980)
Sacoglossa	*Lobiger viridis*	2009	Rudman (2009)
	Polybranchia orientalis	1999	Rudman (1999e)
Pleurobranchomorpha	*Pleurobranchus forskalii*	2012	Nudi Pixel (2012)
Nudibranchia	*Nembrotha purpureolineata*	1999	Rudman (1999b)
	Nembrotha rosannulata	2004	Rudman (2008)
	Polycera melanosticta	2014	MAGNT (2014)
	Okenia hallucigenia	1986	Australian Museum (1986)
	Okenia harastii	2013	Pola et al., 2014
	Okenia purpurata	2000	Rudman (2006b)
	Okenia vena	2000	Rudman (2006c)
	Aegires incusus	2009	Nudi Pixel (2009a)
	Ceratosoma tenue	2008	Nudi Pixel (2008a)
	Chromodoris striatella	2000	Rudman (2000a)
	Goniobranchus albonares	1998	Rudman (1998a)
	Goniobranchus verrieri	2003	Rudman (2003a)
	Hypselodoris tryoni	2010	Nudi Pixel (2010c)
	Noumea laboutei	2008	Nudi Pixel (2008c)
	Noumea varians	1999	Rudman (1999d)
	Thorunna florens	2002	Rudman (2003e)
	Platydoris ellioti	2010	Nudi Pixel (2010b)
	Sebadoris fragilis	1997	Rudman (1998b)
	Dermatobranchus dendronephthyphagus	2004	Rudman (2004a)
	Crosslandia viridis	1999	Rudman (1999a)
	Notobryon wardi	1999	Rudman (1999c)
	Eubranchus ocellatus	2010	Nudi Pixel (2010a)
	Cuthona yamasui	2008	Nudi Pixel (2009b)
	Trinchesia sibogae	1999	Rudman (2003b)
	Cerberilla ambonensis	2010	Rudman (2010)

thought to be restricted to the western Pacific Ocean, extending from the Philippines to Papua New Guinea and eastern Australia (Rudman, 2005; Gosliner et al., 2008). However, this has not been tested genetically. Australian records indicate a distribution spanning the northern GBR to the Gold Coast in southeastern QLD (Table 10). The observation of a 30 mm individual at 'Fly Point', on 20 February, 2010 at 7 m depth constitutes a southward range extension of 700 km (Fig. 4b).

Genus *Polycera* Cuvier, 1816
Polycera risbeci Odhner, 1941

This small polycerid is distinguished by the presence of several transverse, broken, brown lines across the body (Marshall & Willan 1999, p. 53; Gosliner et al., 2008, p. 102). The gills are pale yellow and the rhinophores are large. *Polycera risbeci* occurs in the tropical Indian and western Pacific Oceans (Gosliner et al., 2008, p. 102) with an Australian distribution extending from Heron Island, QLD, to northern NSW (Table 11). On 23 November, 2014 an individual measuring approximately 4 mm was observed at the 'Pipeline' at 5 m (Fig. 4c) extending its southern range by 665 km.

Genus *Thecacera* Fleming, 1828
Thecacera pacifica (Bergh, 1884)
Synonyms: *Ohola pacifica* Bergh, 1884, *Thecacera inhacae* MacNae, 1958

Thecacera pacifica has an orange body with black, blue and white tips to the tail and both the extra-

rhinophoral and extra-branchial appendages (Gosliner et al., 2008, p. 109). This well-known species has become colloquially known as the *Pikachu* sea slug in Japan and on social media after its similarity to a popular Pokémon toy (Rudman, 2003c; Simonitch, 2012). It has a wide distribution from southern Africa, the Red Sea, Japan, Australia, Hawai'i and the Gulf of Mexico (Gosliner et al., 2008, p. 109), though this has not been tested genetically. The extension of this species into the Gulf of Mexico may be the result of dispersal via shipping as is the case for its congener *T. pennigera* (Willan, 1976). Although *T. pacifica* has been found several times in WA, including observations as far south as Esperance in 1985 and Albany in 2010, it has been recorded only once on the east coast at the Tweed River, NSW, in 2013 (Table 12). An observation of a 30 mm individual at 'Fly Point' at 7 m depth on 6 December, 2014 extends its southern range by 685 km (Fig. 4d).

Discussion

Preliminary results from a biogeographic study of sea slug distribution on the NSW coast (by MN) record 313 species for Port Stephens. Of those, 30 species have not been found further south on the east coast (Table 13).

As a well-studied sea slug 'hot spot', there are extensive records for Port Stephens that clearly indicate a sustained high species richness. These observations of 12 heterobranch sea slugs substantially (i.e., by distances greater than 300 km) south of their previously reported range provide support for other observations of range extensions of other taxa during the last decade. For example, the tropical stichodactylid actinian *Stichodactyla haddoni* (Saville-Kent, 1893), host for three species of tropical commensal shrimps, was recently reported from Port Stephens and Sydney Harbour (Scott et al., 2015). Other documented range extensions on Australia's eastern coast include four heterobranch sea slugs on the mid-north coast of NSW (Nimbs *et al*. 2015) and a number of intertidal mollusc species in eastern Tasmania (Pitt et al., 2010).

There are two important additional points to make about the range extensions to Port Stephens that have been documented here. Firstly, almost half of the species were found only as juveniles suggesting that, whilst they may recruit to the Port, they may not survive to adulthood or to form breeding populations there. Indeed, the fate of juveniles found at the limit of their geographic range is a topic requiring further study. Secondly, whilst our primary hypothesis is that the range extensions result from climate change related processes, the alternate hypothesis of greater sampling effort needs to be considered. Port Stephens is progressively attracting greater attention from scientists and also from citizen scientists who are becoming more experienced in differentiating between similar heterobranch taxa, particularly the smaller species. Citizen science participation has expanded substantially over the past few years through programs such as the *Sea Slug Census* and the *Nelson Bay Nudi Festival*. Therefore, it is likely that at least some of the range extensions reported here may be of species that were overlooked in the past.

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Authors' contributions

MN collated occurrence records and with RCW and SDAS wrote the manuscript. ML, TD, DH and SDAS carried out fieldwork and documented species occurrence. RCW identified the animals from photographs. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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