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Keywords

deep-sea; range extension; *Somniosus*; western Pacific Ocean

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Abstract

Technological advances have enabled the expansion of ocean exploration to include the deep ocean, providing new species observations. Here, the authors present two new observations, captured by deep-sea cameras, of the sleeper shark *Somniosus cf. pacificus* from the Solomon Islands and Palau. This presents the first observation of *S. cf. pacificus* in the western Pacific tropics and extends its range about 2000 nautical miles south. The observations presented here provide much-needed information on the range of this species which can help guide future management and conservation actions.

KEYWORDS

deep-sea, range extension, *Somniosus*, western Pacific Ocean

The understanding of deep-sea species ranges is limited owing to sampling limitations and the sheer difficulty of consistently sampling across great depths and extensive areas (Levin *et al.*, 2019). Most range estimates of deep-sea species are, thus, based on opportunistic observations and best guess estimates (McClain & Hardy, 2010). Data of larger mobile vertebrates, such as deep-sea shark species, are commonly limited to opportunistic observations, especially *via* strandings or incidents of by-catch. With an increase in deep-sea exploration efforts, as well as the development of cheaper technology that can go to greater depths for longer periods, data on species distributions have increased, which have resulted in many new species observations and range extensions (Buglass *et al.*, 2020; Cerutti-Pereyra

et al., 2018; Nethupul *et al.*, 2022; Penney *et al.*, 2020). These new insights can play an important role in species conservation and management.

Somniosidae (sleeper sharks), a family of slow-growing sharks, contain six genera ranging in sizes from small (40–69 cm) to gigantic (>6 m or more) (Ebert *et al.*, 2021). The taxonomy of the genus *Somniosus* has evolved over the past century, and a recent review by Yano *et al.* (2004) concluded that this genus includes two subgenera (*Somniosus* and *Rhinoscyrnus*) and five species. In 2020, *Somniosus cheni* from Taiwan was added under *Rhinoscyrnus* (Hsu *et al.*, 2020), bringing the total number of species to six. The subgenus *Somniosus* includes only three species: *Somniosus microcephalus* and *Somniosus pacificus* found in

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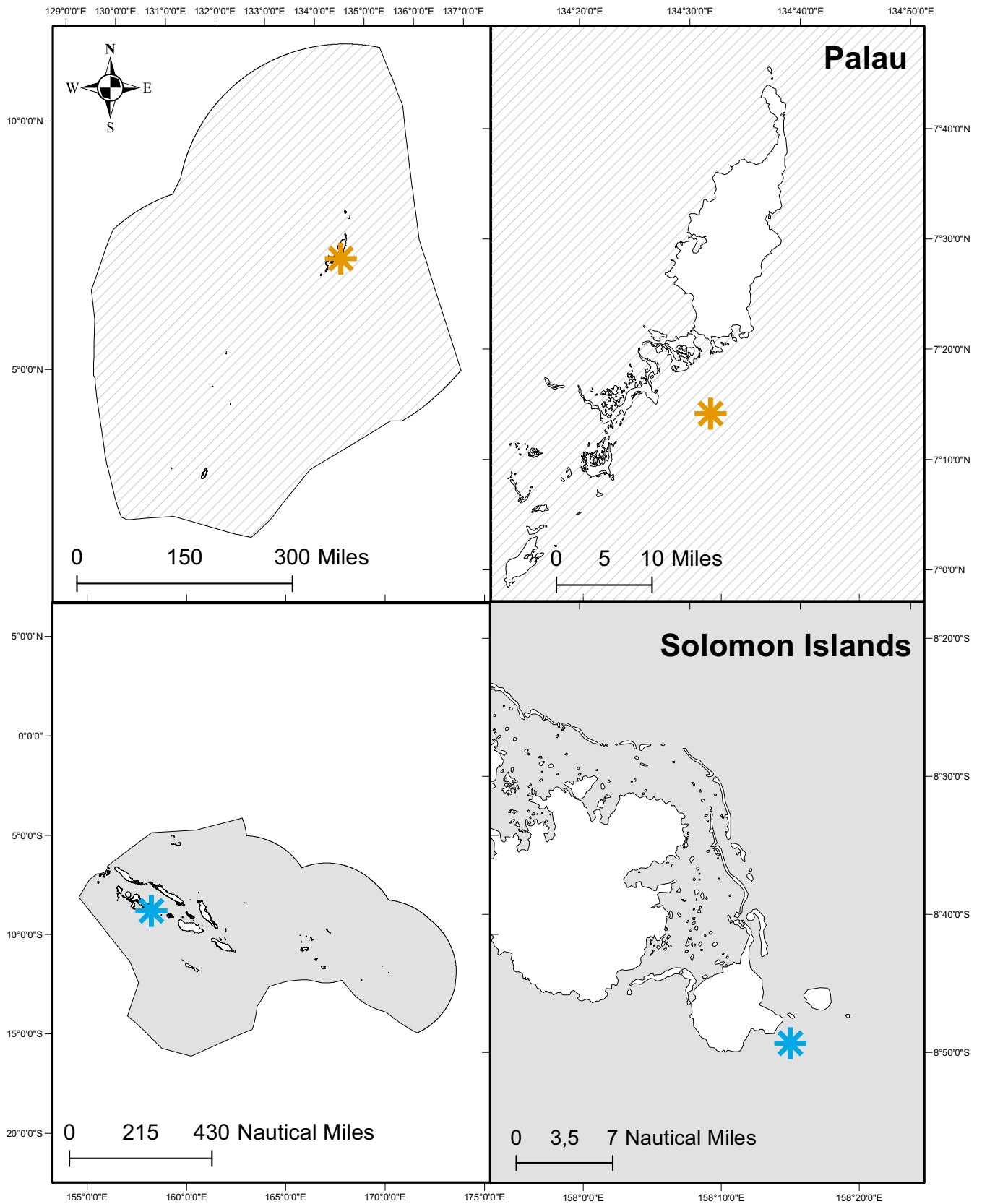


FIGURE 1 Palau (top) and Solomon Islands (bottom) exclusive economic zones with a close-up of the *Somniosus cf. pacificus* sighting location at each site (Flanders Marine Institute, 2019)

the Northern Hemisphere and *Somniosus antarcticus* found in the Southern Hemisphere (Yano *et al.*, 2004). An increase in information on the occurrence of *Somniosus* spp. has occurred over the past decade. Specifically, information on the range of these sharks has increased with several new observations in previously unknown locations (Acero *et al.*, 2018; Benfield *et al.*, 2008; Benz *et al.*, 2004; Benz *et al.*, 2007; Kasana *et al.*, 2022; Wang & Yang, 2004). These observations were either made serendipitously during exploratory research cruises or through stranding or by-catch reports.

S. pacificus Bigelow & Schroeder, 1944 is a large, sluggish deep-water shark that is pelagic and demersal on the continental shelf up to depths of 2000 m (Ebert *et al.*, 1987). According to Orlov and Bautalyuk (2014), *S. pacificus* is considered to be endemic to the North Pacific Ocean, and general distribution data for *S. pacificus* have mainly originated from fisheries records within the northern Pacific Ocean with abundance and distribution within this region relatively well known (Orlov & Bautalyuk, 2014; Orlov, 2017). *S. pacificus* has been recorded in the northern Pacific Ocean from Taiwan to the Chukchi Sea in the Arctic Circle (Benz *et al.*, 2004; Bright, 1959; Datsky, 2015; Mecklenburg *et al.*, 2011; Orlov & Bautalyuk, 2014; Wang & Yang, 2004). *Somniosus* sp. has also been observed in the eastern Pacific from Hawaii to Mexico (Benfield *et al.*, 2008; Benz *et al.*, 2007). More recently, a sleeper shark (possibly *S. microcephalus*) was observed in the western Caribbean during a research cruise (Kasana *et al.*, 2022). Contrary to normally living in relatively shallow depths in higher latitudes, *S. pacificus* tends to remain in much deeper water in lower latitudes where it becomes a benthic shark which seldom comes to the surface (Compagno, 1984; Ebert, 2003). In higher latitudes, Pacific sleeper sharks have been found to undergo diurnal migrations, remaining below the photic zone during the day and moving towards the ocean surface during the night (Hulbert *et al.*, 2006).

Here the authors present two new observations of *S. cf. pacificus*¹ in the western tropical Pacific Ocean, in Palau and the Solomon Islands. These observations substantially extend the southern range of this species by 2000 nm and provide new insights into its occurrence within tropical waters. A greater understanding of the range of this Near Threatened (Rigby *et al.*, 2021) species will help guide any future conservation and management actions.

The Solomon Islands (9.6457° S, 160.1562° E) is a chain of over 900 islands situated between Papua New Guinea and Vanuatu in the western Pacific Ocean (Figure 1). Kavachi is an active submarine volcano located in the Western Province of the Solomon Islands, with a crater that rises within 50 m of the surface from surrounding waters exceeding 1000 m depth (Johnson & Tuni, 1987). This region is geologically complex, characterized by a subducted active spreading centre “triple junction” creating a western deep-sea trench and an eastern island-forming backarc (Chadwick *et al.*, 2009). An expedition to Kavachi in January 2015 found an active community of sharks and reef fish inside the active crater using a National Geographic deep-sea camera system (Phillips *et al.*, 2016). Camera deployments were also conducted in deeper waters surrounding Kavachi to depths of 484–1761 m, with c. 1 kg of local tuna used as bait, with deployments lasting 4–7 h each.

The Republic of Palau (7.5150° N, 134.5825° E) is a chain of over 700 islands at the southern extension of the Kyushu-Palau Ridge (Kobayashi, 2004) (Figure 1). A wealth of information is available on the shallow coastal environments of Palau, in particular coral reefs (e.g., Colin, 2009), as well as deeper mesophotic reefs (e.g., Baker *et al.*, 2016; Colin & Lindfield, 2019; Slattery & Lesser, 2012). Limited research focus has, however, been given to Palau's deep-sea environments and diversity (Friedlander *et al.*, 2014; Kobayashi, 2004; Kobayashi *et al.*, 1997; Stewart & Jamieson, 2018). The first survey of the deep-sea environment of Palau conducted in 2014 by National Geographic Society (NGS) Pristine Seas using an earlier version of the Exploration Technology Lab's deep-sea camera system (Turchik *et al.*, 2015), with depths ranging from 260 to 3500 m, recorded 26 fish taxa from 19 families (Friedlander *et al.*, 2014). Cutthroat eels from the Synbranchidae family were most common and accounted for half of the fishes observed, followed by rattails from the Macrouridae family (Friedlander *et al.*, 2014). In December 2021, a repeat survey was conducted at some of the sites surveyed in 2014. The newest version of NGS's Exploration Technology Lab's deep-sea camera system (Giddens *et al.*, 2021) was used with two deployments conducted on the east coast and one on the west coast of Palau. Deployment depths ranged from 643 to 1288 m, each with a 3-h soak time. Cameras were baited with 1 kg of locally caught sardines.

The NGS's deep-sea camera system is an example of a cost-effective technology for video surveys of deep-sea megafauna (Giddens *et al.*, 2021). Two generations of the camera system were used during the separate expeditions, with the Solomon Islands expedition using the first generation (Turchik *et al.*, 2015), and the Palau expedition using the next generation (Giddens *et al.*, 2021). The NGS deep-sea camera system is an autonomous benthic lander platform, which consists of a single ultra-high-definition camera housed in a borosilicate glass pressure sphere (Vitrovex, NautilusMarine, GmbH, Germany), rated to 11,000 m, and 6000 m depths (Solomon Islands and Palau, respectively).

During both expeditions a large sleeper shark (*Somniosus* sp.) was observed: in Solomon Islands at 937 m (Video S1), 20 km east of Kavachi (Figure 2a) and in Palau, at a depth of 1288 m (Video S2) on the east side of the main island (Figure 2b). On both expeditions, the individuals were dark grey to blackish in colour with white/grey spots. They had a large, cylindrical heavy-bodied shape characteristic of the three large known *Somniosus* species, with a short, rounded snout and a thin-lipped, nearly transverse mouth (Ebert *et al.*, 2021). The spineless dorsal fins were equal sized and low. The pectoral fins were short and rounded at the rear tips. The caudal peduncle was short, and the caudal fin heterocercal in shape, with a long lower lobe and short upper lobe. In Palau the individual also had dark spots along the body.

The individual observed in Palau arrived within the field of view 2 h and 17 min after deployment. After an initial five passes the shark disappeared from the field of view for about 10 min; then it returned and stayed within the field of view for the remainder of the deployment (c. 15 min). During this time, the shark interacted with the camera/bait canister, bumping into the camera and moving it, although no bite marks were visible on the camera housing or bait canister upon

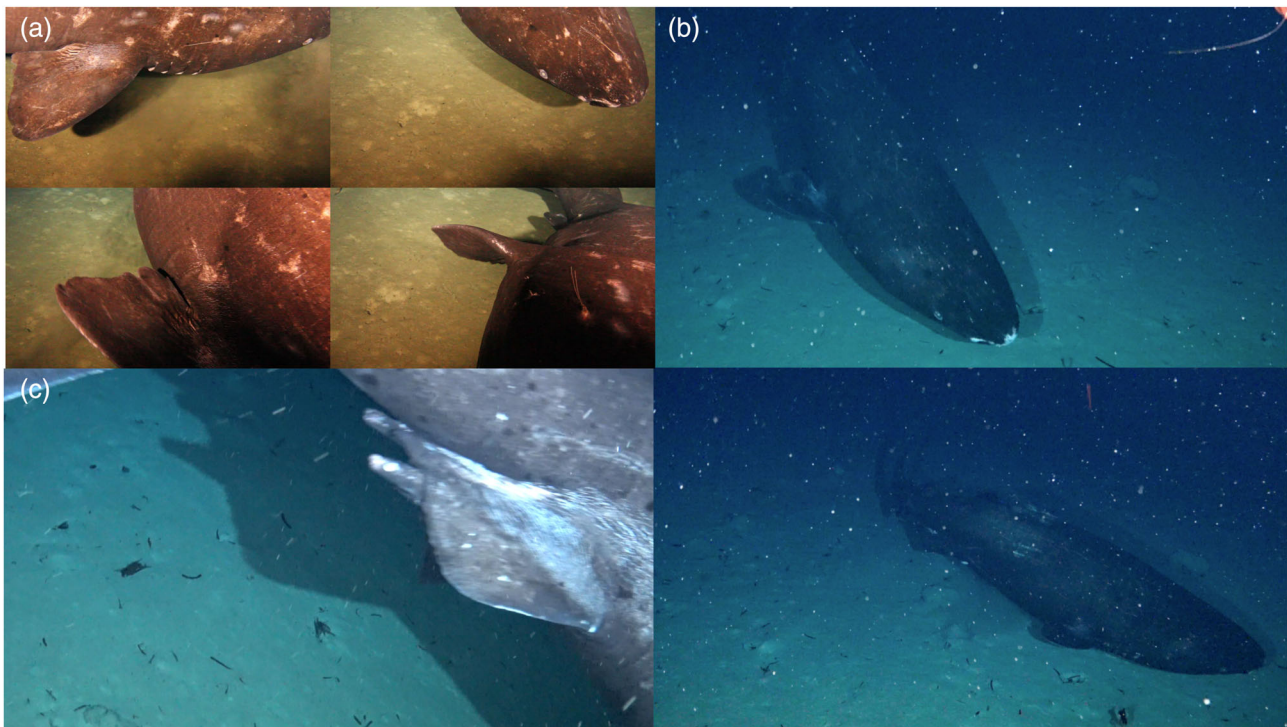


FIGURE 2 Observations of a Pacific sleeper shark (*Somniosus cf. pacificus*) in (a) Solomon Islands at 937 m depth; (b) Palau at 1288 m depth and (c) visible claspers used to classify the individual observed in Palau as a male

retrieval. The individual was deemed to be an adult male based on elongated (extending beyond the posterior free rear tips of the pelvic fins), rigidly calcified claspers that are clearly visible in the footage (Figure 2c). Similarly, the shark observed in the Solomon Islands also interacted with the camera/bait canister after c. 3 h of the camera reaching the seafloor. The sleeper shark made at least two passes and directly attacked the bait, and then it moved out of the field of view after c. 3 min.

The *S. cf. pacificus* observed in the Solomon Islands was found in deep waters very close to shore (within 5 nm) of Gatokae Island. This is consistent with the observation from Palau where *S. cf. pacificus* was also seen alongside a deep drop-off within close proximity of land. Occurrence at the head of submarine canyons, insular slopes and other areas of steep relief adjacent to landmasses and islands are well known for these large sleeper sharks (Ebert *et al.*, 2021). An increased availability of food could be one reason for the close proximity to land and deep drop-offs for these sharks – especially in terms of scavenging on prey originating from the reef and land.

Separation of the three large *Somniosus* species (*S. antarcticus*, *S. microcephalus*, *S. pacificus*) is difficult without close examination as the external characteristics are subtle. Nonetheless, based on the known biogeographic range of these species, the authors excluded *S. microcephalus* as it is known only from the North Atlantic and Caribbean Sea (Ebert *et al.*, 2021). The known biogeography for *S. pacificus* is the North Pacific, whereas *S. antarcticus* is known only from the Southern Hemisphere and mostly from higher latitudes (Ebert

et al., 2021). Also, the inter-dorsal distance for *S. microcephalus* is about equal to the distance from the snout tip to the first gill opening, whereas this distance is shorter in the other two species (Yano *et al.*, 2004). Therefore, the authors excluded *S. microcephalus* from further consideration.

Given the locations of these two observations where no large *Somniosus* species had been reported before, the authors based their identification on the approximate distance between the inter-dorsal fin distance and length from the snout tip to the first gill slits. Based on these body length ratios, and an estimated inter-dorsal length of about c. 70% vs. c. 80%, they tentatively identified these individuals as *S. cf. pacificus*. Further support for these identifications comes from the height of the dorsal fins being over 3% of precaudal length (*S. cf. pacificus*) vs. less than 3% (*S. antarcticus*). Yano *et al.* (2004) used these same external characteristics to separate these two large *Somniosus* species. Even though definitive species-level identification was not possible, both observations are considered closest to *S. pacificus*, and to clearly show this the modifier term “cf.” is included in the identification.

This paper presents two new observations of *S. cf. pacificus* in Solomon Islands and Palau which extends the range of this species almost 2000 nautical miles south and into the western Pacific tropics (Figure 3). An increase in the use of deep-water cameras over the past few years has resulted in various “first record” observations of *Somniosus* outside its historic range further south (Benfield *et al.*, 2008; Benz *et al.*, 2007).

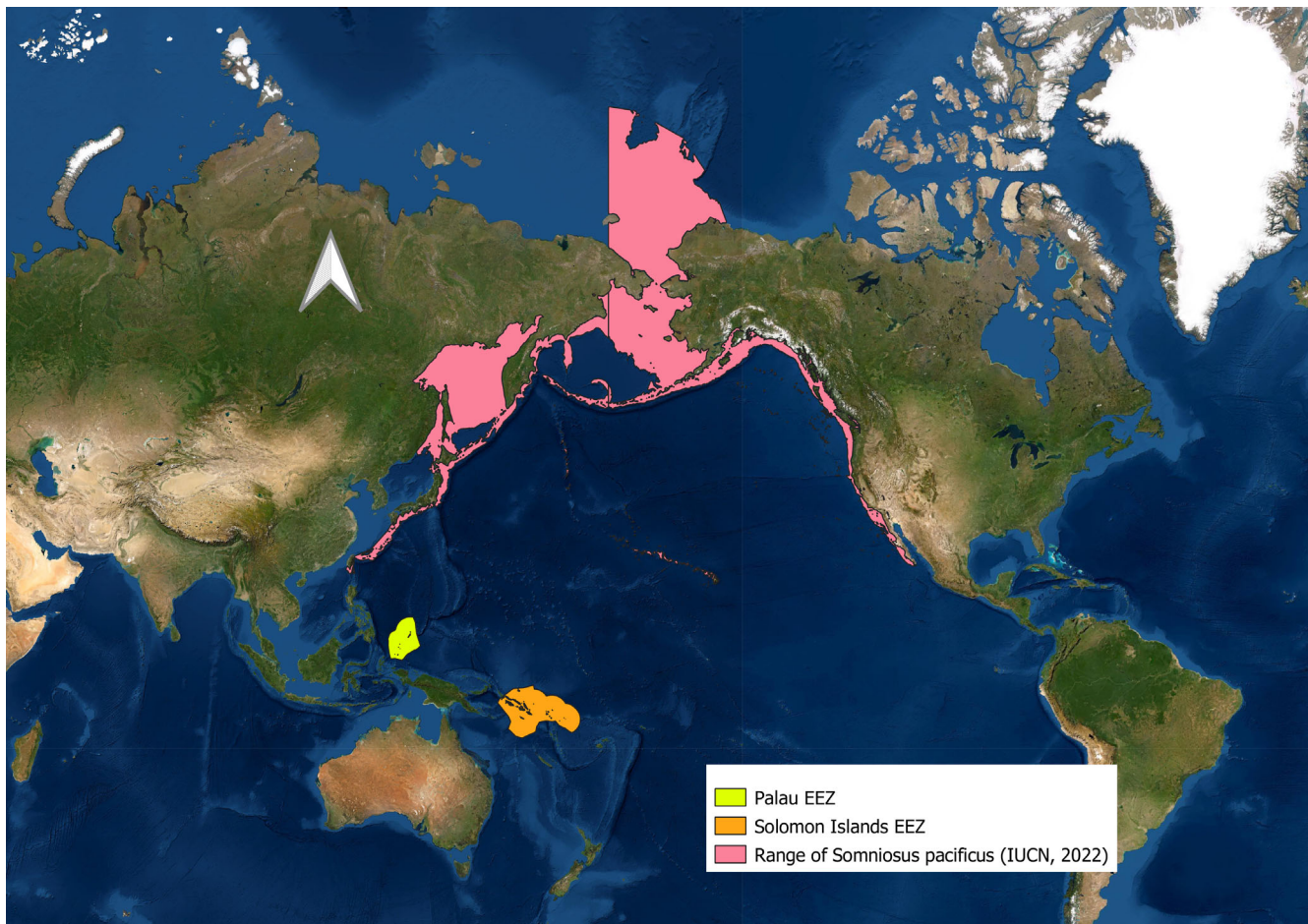


FIGURE 3 The extant range of the Pacific sleeper shark (*Somniosus cf. pacificus*) (IUCN, 2022) shows that the two observations presented in this paper (Palau and Solomons with white and grey shading, respectively) extend the range for this species to the western south Pacific Ocean

Some taxonomic confusion exists within the *Somniosus* genus (Yano *et al.*, 2004; Benz *et al.*, 2007), in particular between *S. pacificus* and *S. antarcticus*. Whitley (1939) briefly described *S. antarcticus* from a sketch and descriptive data from a *Somniosus* found dead on a beach at Macquarie Island in the Antarctic. The specimen itself was not preserved, but tooth and skin samples were saved, although it is unknown if these samples still exist. The description and sketch definitely indicate that the specimen was a large *Somniosus* species, but the generalized description did not demonstrate differentiation between the new species and *S. microcephalus* (Ebert, 2013). The species was long synonymized with *S. microcephalus* until Yano *et al.* (2004) reviewed the genus and concluded the species was valid. *S. pacificus* was described by Bigelow and Schroeder (1944), and although their description was also brief, they differentiated between their new species and *S. microcephalus*, but without mentioning Whitley's description, which they may have been unaware of.

The close external morphological similarity, lack of distinct differences and inadequate original descriptions between the three large species have resulted in confusion in identifying them. Large Southern Hemisphere *Somniosus* species were generally referred to as *S. microcephalus*, with *S. antarcticus* being considered a junior

synonym due to the poor original description. In a detailed revision of the genus, Yano *et al.* (2004) formally resurrected *S. antarcticus* as being distinct. Their revision showed a closer relationship between *S. antarcticus* and *S. pacificus* than either to *S. microcephalus*. Furthermore, most of the characteristics separating these three species are internal (e.g., tooth, precaudal vertebral and spiral valve turn counts), with external differences being more subtle (Yano *et al.*, 2004). A genetics study on these three large *Somniosus* species revealed that *S. microcephalus* is distinct from the other two large *Somniosus* species, but the genetic structure within the *S. antarcticus* – *S. pacificus* clade was more ambiguous showing little to no variation (Murray *et al.*, 2008). Although beyond the scope of this study, further molecular examination of mtDNA and nuclear markers may be required to determine the species status of *S. antarcticus* and *S. pacificus*. Therefore, species-specific identification by the authors as being close to *S. cf. pacificus* is subject to re-identification as new information becomes available.

Regardless of the species-specific identity, these are the first observations of a large sleeper shark (*Somniosus* sp.) within the western Pacific tropics. The observations presented here support the idea that large *Somniosus* species occur at deeper depths at lower latitudes. One reason for this depth variability across latitudes is thought to be

related to temperature and this species' association with cold water. At higher latitudes with colder water temperatures, this species can be found throughout the water column (Ebert, 2003) and even very shallow (Orlov & Bautalyuk, 2014). To maintain suitable cold-water temperatures at lower latitudes, the shark seems to occur in deeper, colder environments and thus greater water depths (see Kasana *et al.*, 2022).

Limited information exists for this species in the southern end of its range, and the observations presented here provide much-needed information on the occurrence of *S. cf. pacificus* within the tropics. Limited seasonal migrations have been observed for *S. pacificus* (Orlov & Bautalyuk, 2014), and the individuals observed here can be regarded as being resident within these areas. *S. cf. pacificus* thus seems to be much more widely distributed across the Pacific Ocean than previously thought, and this range extension should be taken into consideration for future conservation actions. The observations presented here provide much-needed information on the range of this species which can help guide future management and conservation actions.

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ENDNOTE

¹ The modifier term “cf.” is used here to express a possible identity, or at least a significant resemblance to *S. pacificus*.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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