



# Whale sharks as oceanic nurseries for Golden Trevally

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## ABSTRACT

The Golden Trevally, *Gnathanodon speciosus*, is a large predatory fish with an extremely broad tropical Indo-Pacific distribution that crosses many biogeographical boundaries. Both published information and freely available imagery suggest that small juvenile *G. speciosus* are often associated with whale sharks, *Rhincodon typus*; an association that could explain the unusually widespread distribution of *G. speciosus*, and suggests a novel nursery relationship. The possibility of such an association has the potential to reshape our understanding of the ecological roles played by long-range migrants such as *R. typus* and other megafauna, our understanding of the full extent of their conservation value, and how we manage both members of the relationship.

**Keywords:** commensalism, dispersal, *Gnathanodon speciosus*, Golden Trevally, Indo-Pacific, mobile nurseries, *Rhincodon typus*, whale shark.

## Introduction

Golden Trevally, *Gnathanodon speciosus*, is a large predatory carangid fish with an extremely broad tropical Indo-Pacific distribution (Grandcourt *et al.* 2004) that spans substantial biogeographic barriers (Bellwood and Wainwright 2002). They are found from the east coast of Africa (Blaber and Cyrus 1983; Berkström *et al.* 2012) across the Indian and Pacific Oceans to the Galápagos (Todd and Grove 2010) and the west coast of Central and North America (Gunter 1979; Strand 1988), north to the Ryukyu Islands (Shibuno *et al.* 2008) and south to northern Australia (Liu *et al.* 1985; Blaber *et al.* 1995). Adult and later juvenile *G. speciosus* utilise a diversity of nearshore habitats including sand, rocky and coral reefs (Grandcourt *et al.* 2004; Gomelyuk 2009), and seagrass meadows (Kimani *et al.* 1996; Henderson *et al.* 2017), as well as being found in artificial salt concentrator ponds (Molony and Parry 2006), and around fish aggregating devices (Folpp and Lowry 2006), floating logs (Hampton and Bailey 1992) and oil platforms (Torquato *et al.* 2017). They occur from shallow intertidal areas to depths of greater than 180 m (Sileesh *et al.* 2018).

*Gnathanodon speciosus* are captured artisanally (Assan and Dorto 2009) and are sought-after sport fish (Smith *et al.* 2007; Ryan *et al.* 2015), as well as being important targets in the aquarium trade (Okemwa *et al.* 2016). Although *G. speciosus* is an important fisheries species in some areas (Grandcourt *et al.* 2008), it comprises only a minor component of catches over most of its range (e.g. Ramm *et al.* 1993; Blaber *et al.* 1994), but is marketable when captured in large enough numbers (Errity and Fish 2003).

The relatively low fisheries importance of *G. speciosus* despite high marketable quality suggests that, notwithstanding its widespread distribution, it occurs in relatively low numbers over much of its range. An unusually extensive range, coupled with relatively low densities, suggests that *G. speciosus* has an unusual life history and/or dispersal mechanism. One interesting possibility is that *G. speciosus* may utilise an unconventional oceanic nursery strategy, with extensive dispersal across biogeographic boundaries, facilitated by a commensal relationship with large mobile organisms such as whale sharks, *Rhincodon typus*. There is some evidence to support this. While investigating the nursery role of inshore waters in northern Australia, Blaber *et al.* (1995) noted that *G. speciosus* was one of a small group of species where smaller juveniles were found

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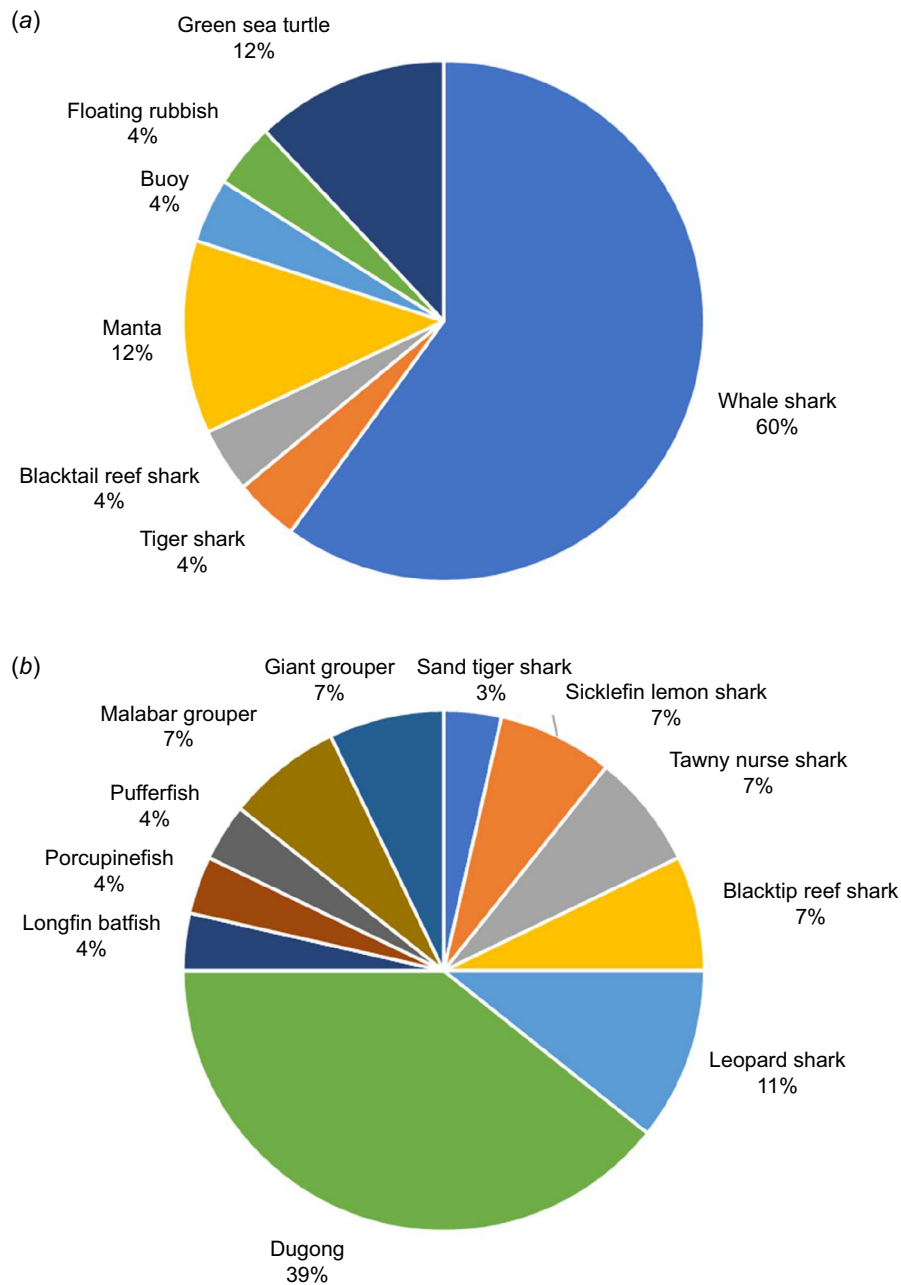
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offshore, despite larger juveniles occurring in inshore or estuarine areas. Additionally, while studying *R. typus*, Gunn et al. (1999) noted that most *R. typus* were accompanied by juvenile *G. speciosus* ranging from 30 to 150 mm fork length.

### Materials and methods

Exploring the possibility of a mobile *R. typus* nursery for *G. speciosus* is difficult because appropriate data are not

available and the types of studies needed to investigate the question would be expensive given the need to collect data over a wide geographic range. As a first step toward determining if extensive research makes sense we searched the World Wide Web for imagery depicting associations between *G. speciosus* and other fauna using the terms ‘*Gnathanodon speciosus*’, ‘*Gnathanodon speciosus*’ (a common misspelling) and the common name ‘Golden Trevally’. We then assessed the imagery to quantify associations between *G. speciosus* and animals and structures in the marine environment.



**Fig. 1.** Percentage of images depicting *G. speciosus* in close association with (a) pelagic host organisms or structures and (b) coastal/shallow water host organisms or structures.

## Results and discussion

Despite issues of potential biases in using online image data (e.g. selective focus on photos of particular hosts), the freely available image data do provide a source of independent validation of the idea that *R. typus* provide a mobile nursery that is used extensively by *G. speciosus* juveniles.

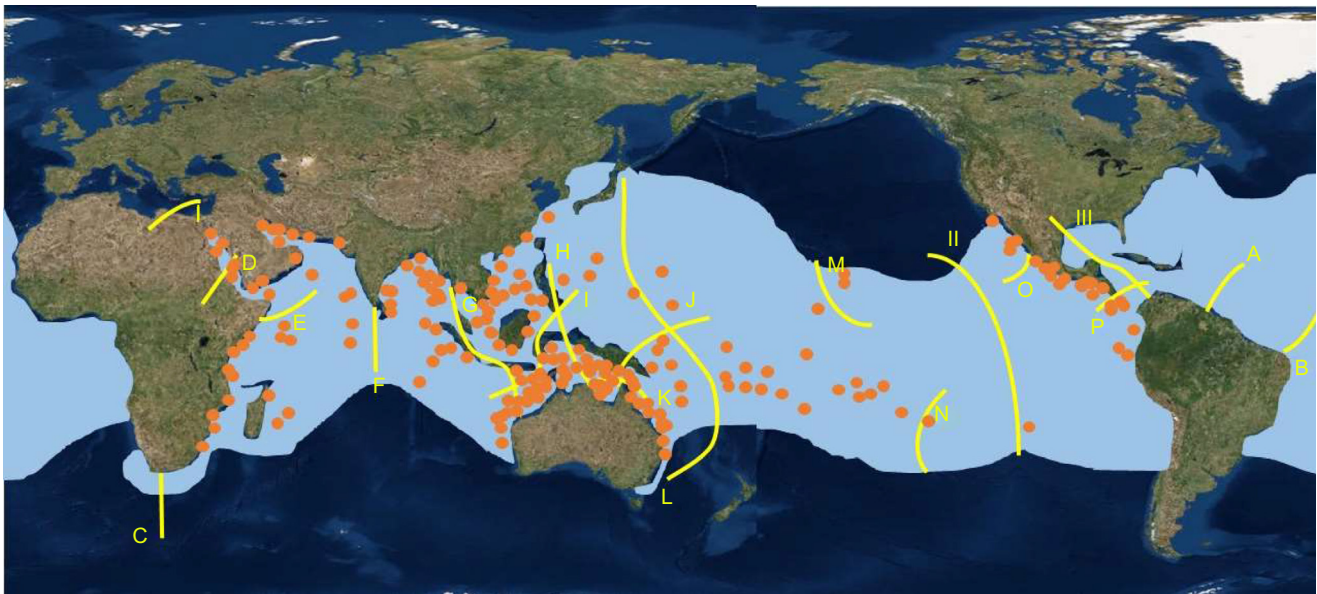
Fifty-two images, showing clearly identifiable *G. speciosus* closely associated with a host, remained once images that appeared to be of the same *G. speciosus*/host pair were excluded. Colour patterns indicated that all the *G. speciosus* demonstrating a close association with a host were juveniles or sub-adults, with no indication of associations between adults and any host. Twenty-eight images showed associations between *G. speciosus* and a variety of sharks, fish, dugongs and turtles in shallow water situations, usually over reef or seagrass (Fig. 1). In line with previous studies (Blaber *et al.* 1995) most of the *G. speciosus* involved in shallow water interactions appeared to be larger juvenile or sub-adults. In contrast, *R. typus* were by far the most commonly depicted host (15 images) in apparent pelagic situations, and in many cases the *G. speciosus* were positioned close to the shark's mouth, the location where individuals of 30–100 mm are usually found (Gunn *et al.* 1999). Additionally recent hydrodynamic models have shown that the front of *R. typus* seems to be where small fish benefit the most from reduced drag, thereby reducing their travel costs (Sumikawa and Miyoshi 2022).

The two offshore images that did not include *R. typus* show juvenile *G. speciosus* associated with a buoy and with floating rubbish. Very small juveniles have been reported to live

amongst the tentacles of jellyfish (Myers 1989; Lieske and Myers 1994). However, these reports lack defined citation tracks, and the available online images of juvenile carangids with yellow and black bars, that are associated with jellyfish are not juvenile *G. speciosus* but rather *Carangoides ferdau* juveniles, when images were clearly identifiable. Consequently, the extent to which hosts other than *R. typus* are used by small juvenile *G. speciosus* requires further investigation.

Although genetic studies are inconclusive about the extent of connectivity of *R. typus* populations across the Indo-Pacific (Vignaud *et al.* 2014), *R. typus* are known to undertake extremely long distance migrations over short periods of time, with one shark tagged in the tropical Eastern Pacific, travelling over 20 000 km to the western Indo-Pacific in 841 days (Guzman *et al.* 2018). This indicates that it could be possible for juvenile *G. speciosus* to make extensive cross-biogeographic boundary migrations utilising *R. typus* as vectors. If so, the use of this unusual nursery relationship could explain the broad distribution of *G. speciosus*, which appears insensitive to the biogeographic boundaries that constrain the distributions of most other species with reef/coastal associated adults (Bellwood and Wainwright 2002) (Fig. 2).

More extensive studies are required to validate and extend on the idea of a mobile nursery association between *G. speciosus* and *R. typus*, and indeed to investigate relationships between other fish and animal vectors or structures. There is an opportunity for future studies to work in collaboration with tourism operators and wildlife photographers to better understand these relationships and minimise the biases associated with photographing charismatic megafauna.



**Fig. 2.** Comparison of the global distribution of *G. speciosus* (orange dots) (derived from FishBase), the range of *R. typus* (light blue shaded areas) (derived from Womersley *et al.* 2022). The yellow lines indicate major reef fish biogeographic boundaries (after Bellwood and Wainwright 2002).

However, one of the most definitive lines of evidence could come from stable isotope studies of small juveniles, with the prediction that juveniles should consistently show oceanic isotope signatures for a much longer period than similar fish that only use pelagic oceanic habitats during the larval stage. Stable isotopes could also provide information on oceanic nursery duration via an isotopic clock methodology (Guelinckx et al. 2008). Another valuable study would be a comparison of the genetics of *G. speciosus*, *R. typus*, and pilot fish, *Naucrates ductor* (an oceanic fish often found associated with megafauna) across the Indo-Pacific range of *G. speciosus*.

If this unique commensal relationship is valid, there are implications for the way we understand the complexity of the ecological roles played by long-range migrants such as *R. typus* and other megafauna, how we understand the full extent of their conservation values, and how we manage both members of the relationship. In a practical sense, a mobile nursery relationship for *G. speciosus* extends the concept of connectivity between spawning, nursery and adult habitats beyond the scope of local-scale management, into the more complex international realm. Not only does this greatly complicate any attempt to manage *G. speciosus*, but it implies that decisions about the management of *R. typus* need to extend beyond a focus on the conservation of an important megafauna species to include consideration of the needs of an exploited fisheries species. Additionally, the possible presence of this unusual nursery relationship brings into question the relevance of this or similar models for other species.

## References

- Assan CN, Dorto JL (2009) Seychelles artisanal fisheries statistics for 2008. Seychelles fishing authority technical report. Available at <http://hdl.handle.net/1834/4974> [Accessed 7 May 2023]
- Bellwood DR, Wainwright PC (2002) The history and biogeography of fishes on coral reefs. In 'Coral reef fishes: dynamics and diversity in a complex ecosystem'. (Ed. PF Sale) pp. 5–32. (Academic Press)
- Berkström C, Gullström M, Lindborg R, Mwandya AW, Yahya SAS, Kautsky N, Nyström M (2012) Exploring 'knowns' and 'unknowns' in tropical seascape connectivity with insights from East African coral reefs. *Estuarine, Coastal and Shelf Science* **107**, 1–21. doi:10.1016/j.jecss.2012.03.020
- Blaber SJM, Cyrus DP (1983) The biology of carangidae (teleostei) in natal estuaries. *Journal of Fish Biology* **22**, 173–188. doi:10.1111/j.1095-8649.1983.tb04738.x
- Blaber SJM, Brewer DT, Harris AN (1994) Distribution, biomass and community structure of demersal fishes of the Gulf of Carpentaria, Australia. *Marine and Freshwater Research* **45**, 375–396. doi:10.1071/MF9940375
- Blaber SJM, Brewer DT, Salini JP (1995) Fish communities and the nursery role of the shallow inshore waters of a tropical bay in the gulf of Carpentaria, Australia. *Estuarine, Coastal and Shelf Science* **40**, 177–193. doi:10.1016/S0272-7714(05)80004-6
- Errity CM, Fish M (2003) A description of the NT finfish trawl fishery. Fishery report 68. Department of Business, Industry & Resource Development, Northern Territory Government, Australia.
- Folpp H, Lowry M (2006) Factors affecting recreational catch rates associated with a fish aggregating device (fad) off the NSW coast, Australia. *Bulletin of Marine Science* **78**, 185–193.
- Gomelyuk VE (2009) Fish assemblages composition and structure in three shallow habitats in north Australian tropical bay, Garig Gunak Barlu National Park, Northern Territory, Australia. *Journal of the Marine Biological Association of the United Kingdom* **89**, 449–460. doi:10.1017/S0025315408002634
- Grandcourt EM, Al Abdessalaam TZ, Francis F, Al Shamsi A (2004) Population biology and assessment of representatives of the family carangidae: *Carangoides bajad* and *Gnathanodon speciosus* (Forsskål, 1775), in the Southern Arabian Gulf. *Fisheries Research* **69**, 331–341. doi:10.1016/j.fishres.2004.06.008
- Grandcourt E, Al Abdessalaam T, Francis F, Al Shamsi A, Al Ali K, Al Ali S (2008) Management options for the demersal fishery of Abu Dhabi Emirate. Report number 02-23-0008-08. Marine Environmental Research Center, Abu Dhabi.
- Guelinckx J, Maes J, Geysen B, Ollevier F (2008) Estuarine recruitment of a marine goby reconstructed with an isotopic clock. *Oecologia* **157**, 41–52. doi:10.1007/s00442-008-1045-7
- Gunn JS, Stevens JD, Davis TLO, Norman BM (1999) Observations on the short-term movements and behaviour of whale sharks (*Rhincodon typus*) at ningaloo reef, Western Australia. *Marine Biology* **135**, 553–559. doi:10.1007/s002270050656
- Gunter G (1979) Marine fishes of Panama as related to the canal. *Gulf Research Reports* **6**, 267–273. doi:10.18785/grr.0603.07
- Guzman HM, Gomez CG, Hearn A, Eckert SA (2018) Longest recorded trans-Pacific migration of a whale shark (*Rhincodon typus*). *Marine Biodiversity Records* **11**, 8. doi:10.1186/s41200-018-0143-4
- Hampton J, Bailey KM (1992) Fishing for tunas associated with floating objects: a review of the Western Pacific fishery. In 'Proceedings of the international workshop on the ecology and fisheries for tunas associated with floating objects'. pp. 222–284. (Oceanic Fisheries Programme, Secretariat of the Pacific Community: Noumea, New Caledonia)
- Henderson CJ, Olds AD, Lee SY, Gilby BL, Maxwell PS, Connolly RM, Stevens T (2017) Marine reserves and seascape context shape fish assemblages in seagrass ecosystems. *Marine Ecology Progress Series* **566**, 135–144. doi:10.3354/meps12048
- Kimani EN, Mwatha GK, Wakwabi EO, Ntiba JM, Okoth BK (1996) Fishes of a shallow tropical mangrove estuary, Gazi, Kenya. *Marine and Freshwater Research* **47**, 857–868. doi:10.1071/MF9960857
- Lieske E, Myers R (2002) 'Coral reef fishes: Indo-pacific and Caribbean.' (Harper Collins Publishers)
- Liu H-C, Sainsbury KJ, Chiu T-S (1985) Trawl cod-end mesh selectivity for some fishes of North-Western Australia. *Fisheries Research* **3**, 105–129. doi:10.1016/0165-7836(85)90013-X
- Molony BW, Parry GO (2006) Predicting and managing the effects of hypersalinity on the fish community in solar salt fields in north-western Australia. *Journal of Applied Ichthyology* **22**, 109–118. doi:10.1111/j.1439-0426.2006.00714.x
- Myers RF (1989) 'Micronesian reef fishes: a practical guide to the identification of the coral reef fishes of the tropical central and western pacific.' (Coral Graphics: Barrigada, Guam)
- Okemwa GM, Kaunda-Arara B, Kimani EN, Ogotu B (2016) Catch composition and sustainability of the marine aquarium fishery in Kenya. *Fisheries Research* **183**, 19–31. doi:10.1016/j.fishres.2016.04.020
- Ramm DC, Mounsey RP, Xiao Y, Poole SE (1993) Use of a semi-pelagic trawl in a tropical demersal trawl fishery. *Fisheries Research* **15**, 301–313. doi:10.1016/0165-7836(93)90081-H
- Ryan KL, Hall NG, Lai EK, Smallwood CB, Taylor SM, Wise BS (2015) Statewide survey of boat-based recreational fishing in Western Australia 2013/14. Fisheries Research Division report 208. Department of Fisheries, Government of Western Australia.
- Shibuno T, Nakamura Y, Horinouchi M, Sano M (2008) Habitat use patterns of fishes across the mangrove-seagrass-coral reef seascape at Ishigaki Island, southern Japan. *Ichthyological Research* **55**, 218–237. doi:10.1007/s10228-007-0022-1
- Sileesh MS, Alphi K, Harish KC, Vijji V (2018) Species assemblages and community structure of deep-sea demersal ichthyofauna of the South-eastern Arabian Sea (SEAS). *Journal of the Marine Biological Association of the United Kingdom* **98**, 1775–1781. doi:10.1017/S0025315417001151
- Smith KA, Hammond M, Brown J (2007) A summary of data collected by the Angler's Daily Log Book and Fishing Tournament Monitoring Programs in 2004-2006. Fisheries occasional publications 40. Department of Fisheries, Western Australia.

- Strand S (1988) Following behavior: interspecific foraging associations among Gulf of California reef fishes. *Copeia* 351–357. doi:10.2307/1445875
- Sumikawa H, Miyoshi T (2022) The pressure drag reduction effect of tandem swimming by *Caranx sexfasciatus* and *Rhincodon typus*. *Ichthyological Research* 69, 132–139. doi:10.1007/s10228-021-00822-5
- Todd VLG, Grove JS (2010) First records of golden trevally (*Gnathodon speciosus*, carangidae), sharp-tail mola (*Masturus lanceolatus*, molidae) and evidence for white shark (*Carcharodon carcharias*, lamnidae) in the Galápagos Islands, Ecuador. *Marine Biodiversity Records* 3, E104. doi:10.1017/S1755267210000771
- Torquato F, Jensen HM, Range P, Bach SS, Ben-Hamadou R, Sigsgaard EE, Thomsen PF, Møller PR, Riera R (2017) Vertical zonation and functional diversity of fish assemblages revealed by ROV videos at oil platforms in The Gulf. *Journal of Fish Biology* 91, 947–967. doi:10.1111/jfb.13394
- Vignaud TM, Maynard JA, Leblois R, Meekan MG, Vázquez-Juárez R, Ramírez-Macías D, Pierce SJ, Rowat D, Berumen ML, Beeravolu C, Baksay S, Planes S, et al. (2014) Genetic structure of populations of whale sharks among ocean basins and evidence for their historic rise and recent decline. *Molecular Ecology* 23, 2590–2601. doi:10.1111/mec.12754
- Womersley FC, Humphries NE, Queiroz N, Vedor M, da Costa I, Furtado M, Tyminski JP, Abrantes K, Araujo G, Bach SS (2022) Global collision-risk hotspots of marine traffic and the world's largest fish, the whale shark. *Proceedings of the National Academy of Sciences* 119, e2117440119. doi:10.1073/pnas.2117440119

**Data availability.** All data are freely available online at [https://www.dropbox.com/sh/yjpjwryjqtst9/AABX\\_RqiDAdsiKW\\_zfx96Aaa?dl=0](https://www.dropbox.com/sh/yjpjwryjqtst9/AABX_RqiDAdsiKW_zfx96Aaa?dl=0).

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