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Spot Pattern Stability During Five Years of Growth of a Captive Giant Sea Bass, *Stereolepis gigas*

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Adult Giant Sea Bass (*Stereolepis gigas*) (GSB) are the largest teleosts inhabiting California's nearshore habitats. They attain a maximum total length of over 2.7 m, a weight of up to 255 kg, and an age of at least 76 years (Allen 2017; Allen and Andrews 2012; Domeier 2001). All lengths hereafter are total lengths. They range from Humboldt Bay, California to Oaxaca, Mexico, including the entire Gulf of California (Cornish 2004; Domeier 2001); 73% of the species' range occurs in Mexico (Ramirez-Valdez et al. 2021). Giant Sea Bass spend just under a month as floating eggs and planktonic larvae before settling to the bottom (Benseman and Allen 2018). After planktonic settlement, the young-of-the-year (YOY) of GSB of between 10 and 80 mm occupy habitat between 2 and 38 m in depth (Benseman and Allen 2018; Couffer and Benseman 2015; Couffer 2017). The YOY at this size range occupy wide expanses of open sand or sandy-mud away from rocks, jetties, piers, debris, and other hard structures (Benseman and Allen 2018; Benseman et al. 2019; Couffer and Benseman 2015; Couffer 2017). Benseman and Allen (2018) found that newly-settled YOY were most abundant over soft-bottomed habitat within 300 m of the heads of submarine canyons that begin close to shore. Couffer (2020) described the four centers of abundance for newly-settled YOY located by Benseman and Allen (2018) as GSB nursery sites. The known California nursery sites include Redondo Beach in Los Angeles County, Newport Pier and Big Corona del Mar State Beach in Orange County, and La Jolla Shores in San Diego County. No significant submarine canyons that closely approach sandy shorelines exist along the Pacific coast side of the Baja California Peninsula; however, potential nursery site habitat exists off the tip of the peninsula and within the Gulf of California. The topic of nursery sites within the Mexican portion of the species' range remains unexplored (Couffer 2020).

The smallest verified YOY found in a nursery site was 10 mm. However, on 11 June 2021, a school of nine fish smaller than 10 mm that appeared to have very similar body shape and behavior to newly-settled YOY was filmed by a diver in the La Jolla Shores nursery site; unfortunately, the image resolution was not high enough to conclusively identify the fish as GSB. Between 10 mm and 20 mm, YOY are black with several small white patches around the face and sides (Benseman and Allen 2018; Couffer and Benseman 2015). The white patches are too variable for long-term re-identification of individuals. Black-phase YOY have large black spiny dorsal and pelvic fins and translucent soft dorsal, pectoral, anal, and caudal fins. During the black phase, black spots do not exist on the sides. When stressed, the black background often lightens considerably but no black spots appear (Couffer 2017). From approximately 20 mm to 40 mm, their background pigmentation lightens from black through a brown phase into orange. Spiny dorsal fin pigmentation mirrors the background pigmentation seen on the sides. The large pelvic fins remain black. The black background morphs to a dark brown and as the brown lightens, faint black spots begin to appear. As the brown continues to lighten, the black spots

become more distinct (Couffer and Benseman 2015). The background morphs from dark brown through golden-brown to become orange.

In the orange phase, the black spots are distinct against the background and may be round, dumbbell-shaped, or square. When they are agitated, the sides and both spiny and soft dorsal fins often lighten significantly; however, regardless of the stage of agitation of the fish, the black spots remain prominent. Lightening of the background pigmentation enhances the visibility of the black spots, but can obscure some white patches. When YOY leave the nursery sites by approximately 80 mm, they still manifest the orange phase.

In 2015 the author captured and distributed several YOY among public aquaria to be raised to determine whether or not individual YOY could be identified by eye by comparing underwater photos of their spot patterns during the months when they occupy the nursery sites. Although the YOY leave these nursery sites by 80 mm in the orange phase (Couffer 2020) the spot pattern study attempted to follow the development of six fish for a year, several months longer than their time spent developing in the nursery sites. This study showed that individual YOY could be distinguished from one another by eye by comparing spot pattern photos for their first year of development (Couffer 2017).

After publication in 2017, the staff of Heal the Bay Aquarium in Santa Monica, Los Angeles County, California kept their fish to continue educating the public about GSB. This afforded the opportunity to continue the spot pattern project beyond the original one-year span by following the development of this single GSB. Photographs to record spot pattern changes were reduced to six-month intervals. After five years, this individual fish could still be recognized by eye when new photographs of its spot pattern were compared with photographs taken during its first year. Figures 1 to 10 document a gradual progression over time, and figures 11 and 12 compare years one and five directly.

After the five-year photographs and measurements were taken, the aquarium secured authorization from the California Department of Fish and Wildlife to release the fish under the author's Special Use Scientific Collecting Permit No. S-200570003-20059-001. A coded internal acoustic transmitter (Vemco Ltd. model V-16) was inserted into the fish's body cavity and the fish was released into King Harbor, Redondo Beach on 23 May 2021. Receivers detected the fish moving between points off Orange and Los Angeles counties from the day of the release through May 2022.

The four known California GSB nursery sites are separated by between five and 100 km of coastline. Due to the sedentary nature of the GSB developing in the nursery sites, no movement of YOY between even the closest nursery sites has been documented in 465 hrs of focused underwater surveys by the author or by photograph and sighting form submissions to the author by California's participating sport diving community during the past seven years. Once a fish turns from black-phase to brown-phase, its background pigment contrasts well with the black spots and the edges of the black spots are sharply defined. The sedentary nature of fish within the nursery sites that are resident for only a short time, the contrast between the fish's light background and their black spots, and the low numbers of potential matches in each nursery site allow for easy comparison of spot patterns by eye without computer assistance.

Once these long-lived fish leave the nursery sites and disperse into the general population, however, it would be extremely difficult to identify individuals by eye using underwater photos because of the extremely large number of potential matches. Furthermore, as they age, their individual spots become more diffuse and there is often little or no contrast between the spots and the background. Underwater photos do not always capture all of the spots on one side. If photos are taken when the fish is at an angle to the camera, some

spots are in focus but other spots closer or farther from the point of focus may be blurred or distorted. Too much flash can cause reflections that obscure spots and not enough flash may render a fish too dark. For these reasons, the spot patterns of older juvenile and adult fish are often much more difficult to compare by eye than the high-contrast spot patterns presented by brown and orange-phase YOY in the nursery sites.

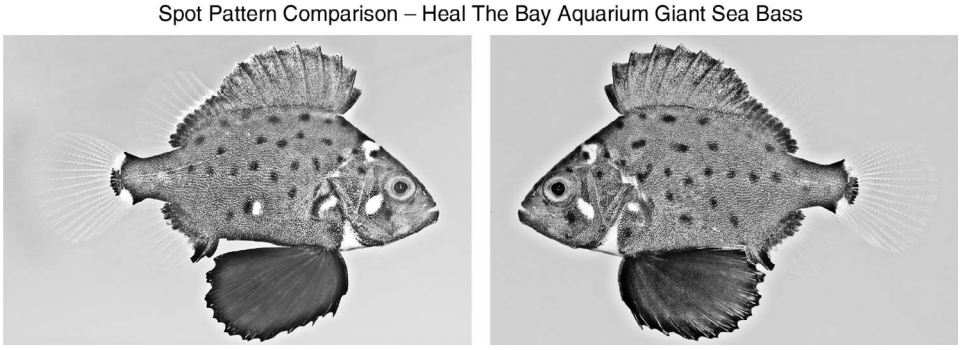

Fig. 1. Capture Date - 27 November 2015 (37.5 mm, 1.42 g).

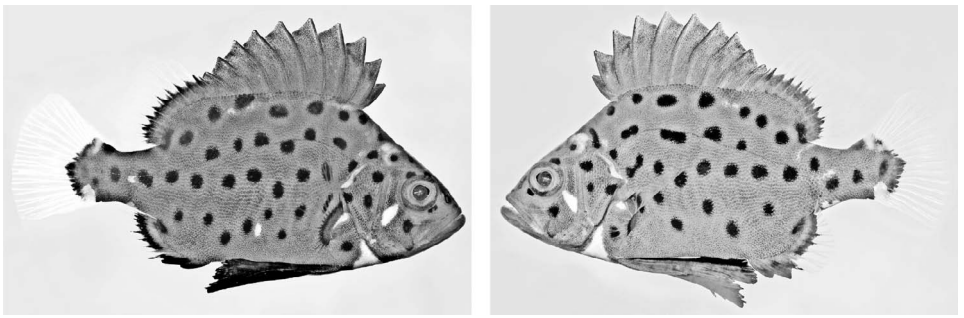

Fig. 2. 3 Months Old - 16 February 2016 (73 mm, 11 g).

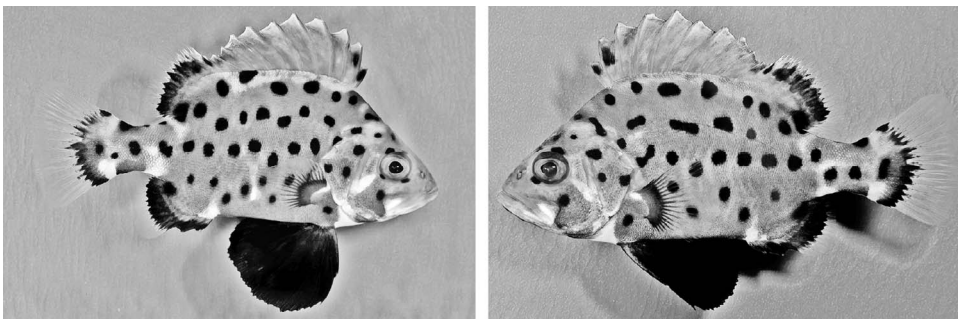

Fig. 3. 6 Months Old - 14 May 2016 (120 mm, 42 g).

Fig. 4. 9 Months Old - 19 August 2016 (146 mm, 67 g).

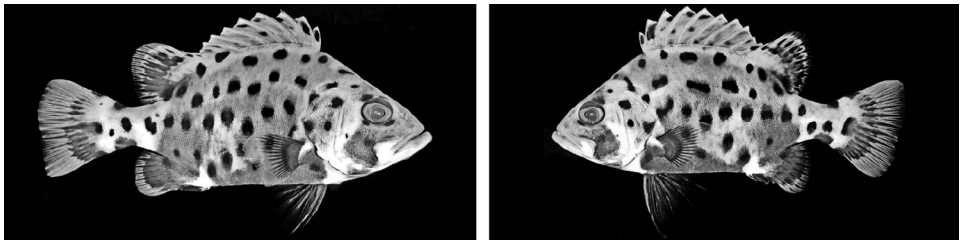

Fig. 5. 1 Year Old - 28 November 2016 (178 mm, 142 g).

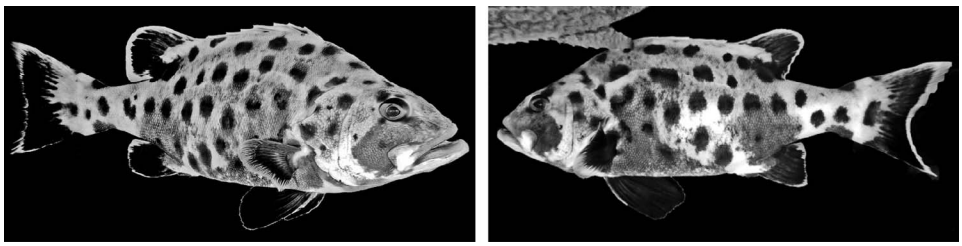

Fig. 6. 2 Years Old - 28 November 2017 (39.0 cm, 1.730 kg).

Fig. 7. 3 Years Old - 28 November 2018 (58.0 cm, 4.1 kg).

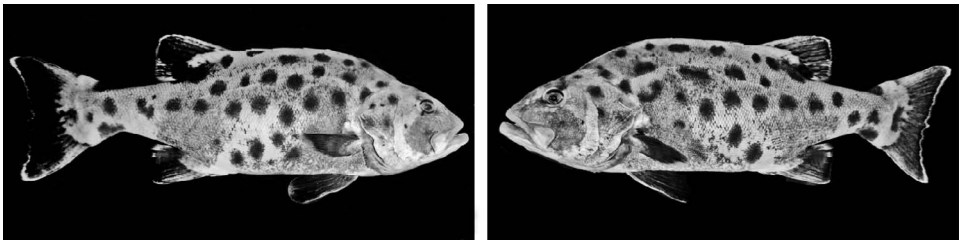

Fig. 8. 4 Years Old - 5 December 2019 (76.5 cm, 9.0 kg).

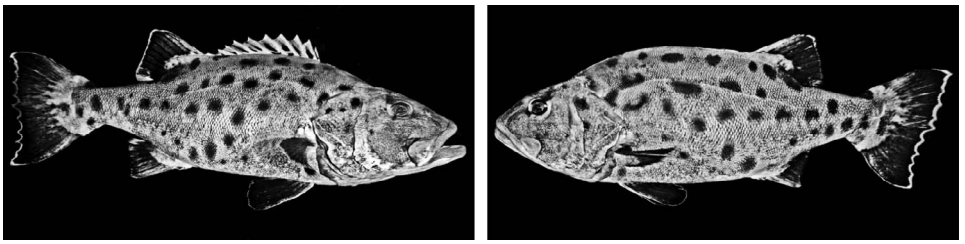

Fig. 9. 5 Years Old - 28 November 2020 (91 cm, 14.3 kg).

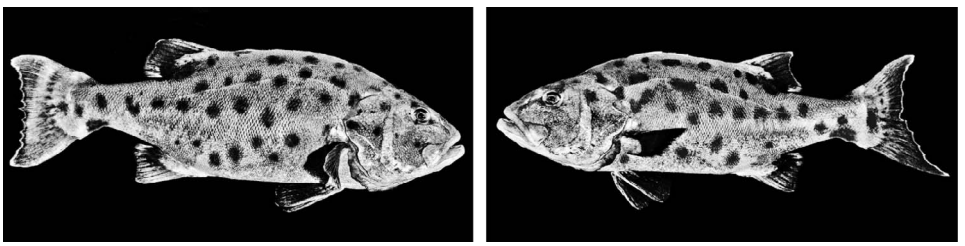

Fig. 10. 5.5 Years Old - 16 May 2021 (94 cm, 16.8 kg).

This study shows that the spot patterns can be stable enough for individual identification of GSB even after five years of growth when compared with other photos of the same fish. However, once a GSB leaves its nursery site, its spot pattern would need to be compared with all photos of fish of similar age or younger within the much larger general population so the likelihood of matching one GSB to another by eye drops precipitously. After GSB leave the nursery sites it becomes more efficient to identify and track them using pattern recognition programs coupled with databases such as a system operated at the University of California at Santa Barbara (https://spottinggiantseabass.msi.ucsb.edu) where a computer program reduces a large number of images to a few and matches are then made by eye, greatly reducing human effort needed to obtain matches (Love et al. 2018). Using this system, GSB can be matched across the species' entire geographic range for as long as the project continues. This highlights the importance of using spot pattern recognition software for GSBs outside of nursery sites, as identification of individuals by eye is only effective within the relatively closed populations of the GSB nursery sites.

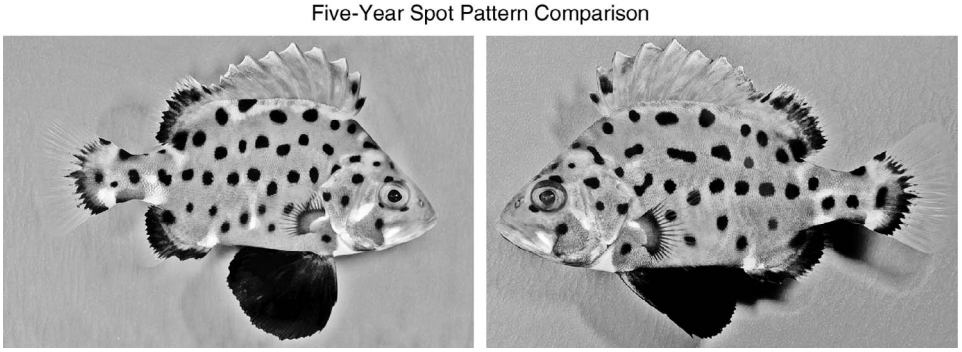

Fig. 11. 6 Months Old - 14 May 2016 (12 cm, 42 g).

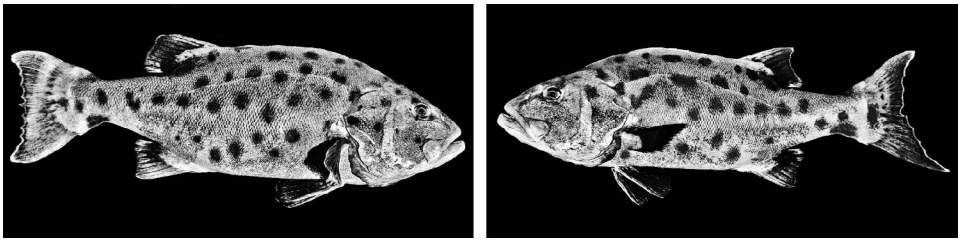

Fig. 12. 5.5 Years Old - 16 May 2021 (94 cm, 16.8 kg).

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I might not have begun study of the young-of-the-year of Giant Sea Bass were it not for the insights of Master of Science candidate Stephanie A. Benseman working with her advisor Larry G. Allen of California State University at Northridge who discovered where, when, and how to find the YOY. Their preliminary work on the distribution and recruitment, and later, our observations of the behavior of YOY provided the basis to expand our understanding of the early development of this species. I would also like to thank my anonymous reviewers for providing valuable editorial comments on manuscript drafts.

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