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*Communication*

# World Heritage, Hydropower, and Earth's Largest Freshwater Fish

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**Citation:** Lee, D.; Eschenroeder, J.C.; Baumgartner, L.J.; Chan, B.; Chandra, S.; Chea, S.; Chea, S.; Chhut, C.; Everest, E.; Hom, R.; et al. World Heritage, Hydropower, and Earth's Largest Freshwater Fish. *Water* **2023**, *15*, 1936. https://doi.org/10.3390/w15101936

Academic Editor: Bernardo Patti

Received: 14 April 2023
Revised: 17 May 2023
Accepted: 18 May 2023
Published: 20 May 2023



**Abstract:** The Mekong River is one of the most biodiverse, productive rivers in the world, supporting more than 1000 fish species and the livelihoods of tens of millions of people. The spatial dynamics and population status of many Mekong fish species, especially megafishes, are poorly understood. Therefore, this information is rarely incorporated into environmental risk assessments for large infrastructure projects, such as mainstream hydropower developments, which have been accelerating rapidly in the Mekong Basin. In this study, we present initial findings from the ongoing, collaborative, transnational acoustic telemetry monitoring of nearly 300 tagged fishes representing 27 species, which yield important insights into the potential impacts that proposed hydropower dams would have on populations of ecologically and economically important fish species. Included in these data are more than ten months of hydrophone records tracking the location of a 300 kg giant freshwater stingray, *Urogymnus polylepis* (Bleeker, 1852), currently the world's largest known freshwater fish, used to detect its migration behavior and distribution patterns. The telemetry data, combined with fisher surveys used to gather local ecological knowledge, provide evidence that the proposed dams would fragment the existing populations of this iconic species as well as those of other fish species that support river food web balance and local food systems. Furthermore, the existence of giant freshwater stringray populations and other unique megafauna reinforces the universal natural heritage value of the stretch of the Mekong River between the Lao People's Democratic Republic/Cambodia border and the city of Kratie. This stretch of river is located between two proposed megadams, the 900 MW Stung Treng Dam and the 2300 MW Sambor Dam. However, the Cambodian Ministry of Environment has also proposed this area for designation as a UNESCO World Heritage Site (Biosphere Reserve). The documentation of the movement of migratory fishes through this reach of the river using acoustic telemetry, the surprising discovery of the world's largest freshwater fish, the potential threat posed by dam construction, and the management ramifications of UNESCO World Heritage Site designation

underscore the importance of scientific research and community involvement in landscape-scale development decisions. The decisions made today will affect the fate of this global biodiversity hotspot, the world's most productive inland fisheries, and the livelihoods of millions of people throughout the Lower Mekong Basin.

**Keywords:** megafish; hydropower; fish migration; giant freshwater stingray; Mekong deep pools; 3S river; acoustic telemetry monitoring; Biosphere Reserve; UNESCO World Heritage Site; flagship species

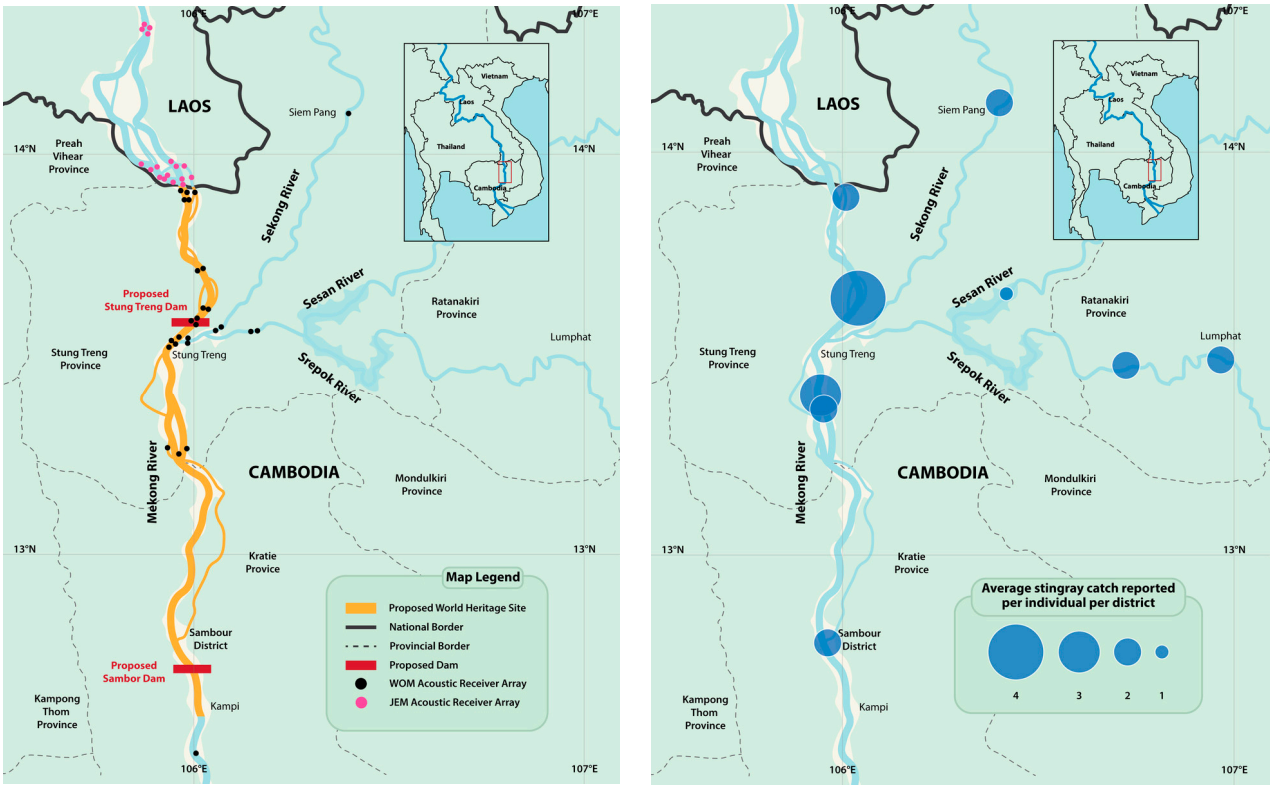
## Urgent Communication of Preliminary Findings

The Mekong River supports the largest inland fishery in the world, with an annual harvest reaching over 1.8 million metric tons and accounting for over 15% of the global freshwater catch [1,2]. The 180 km reach of the Mekong River flowing from the Cambodian border with the Lao People's Democratic Republic (Lao PDR) in the north to the provincial town of Kratie in the south (Figure 1) is of particular ecological and biological significance. This stretch of the upper Cambodian Mekong River provides habitat and spawning grounds for hundreds of fish species that support regional fisheries, contains increasingly rare, flooded forest habitats, and is connected to major tributaries (e.g., the 3S rivers: the Seskong, Sesan, and Srepok) that contribute sediment loads and seasonal flows that drive ecosystem productivity downstream [3–6]. In addition, its many deep pools are an important dry season refuge for Mekong megafauna [7], including the critically endangered Mekong giant catfish (*Pangasianodon gigas*), critically endangered giant barb (*Catlocarpio siamensis*), critically endangered seven-striped barb (*Probarbus jullieni*), critically endangered giant salmon carp (*Aatosyax grypus*), endangered striped catfish (*Pangasianodon hypopthalmus*), and endangered giant freshwater stingray (*Urogymnus polylepis*), among others. The risk of extinction of these flagship species calls for attention to this critical juncture in the management of the Mekong's natural resources and highlights the need to incorporate imperiled species and fishery data into future planning scenarios [8,9].

Evaluating tradeoffs between fisheries, biodiversity, livelihoods, and hydropower (i.e., risk assessment) is of increasing importance as dam development accelerates in the highly productive and diverse Lower Mekong Basin (hereafter LMB) [9–11]. There are currently 46 existing dams in the LMB that produce up to 8650 MW of electricity each year, with another 123 dams proposed that could add an additional 13,000 MW in the LMB countries [12]. A total of 11 of these 123 planned dams, including the proposed 900 MW Stung Treng and 2300 MW Sambor dams, are to be constructed in the mainstem river [12]. The construction and operation of these dams would dramatically alter the Cambodian Mekong. The resulting changes could be devastating for aquatic biodiversity and fishery stocks and would cause vast alterations to the hydrology and sediment transport dynamics that shape the river and its delta [11,13–16]. Potential changes in habitat and water quality may eliminate important environmental cues that fish use to initiate various life history stages, such as migration and spawning, reduce access to habitats critical for the completion of these life stages, and make watersheds more suitable for invasion by alien species [17]. Moreover, the predicted losses in fish harvests will necessitate alternative means of food production in the region. Modeling studies have suggested that dams may lead to significant expansion of agricultural land and increases in water use [18], which may result in further degradation of the riverine ecosystem.

The Mekong River and its tributaries (i.e., the 3S rivers) are the target of an ongoing transboundary acoustic telemetry study carried out by scientists from the USAID's Wonders of the Mekong (WoM) Project [19] in Cambodia and the Joint Environmental Monitoring (JEM) Program of the Mekong River Commission (MRC) in Lao PDR [20]. In Cambodia, project scientists, staff from the Inland Fisheries Research and Development Institute (IFReDI) and Fisheries Administration (FiA), and staff from Young Eco Ambassador (YEA) worked with local communities along the Mekong and its major tributaries to establish,

monitor, and maintain an acoustic receiver network spanning over 450 river kilometers when combined with the JEM efforts in Lao PDR (Figure 1a). Briefly, VEMCO VR2Tx receivers were affixed to custom-built floating platforms by the WoM team in Cambodia, while a combination of VR2Tx and VR2AR receivers were anchored to the substrate by the JEM team in Lao PDR. The receivers in both countries were deployed in pairs or arrays to provide detection coverage across the full width of the river channel at monitoring locations and were placed strategically to monitor movement throughout the mainstem Mekong as well as the 3S tributaries. In the case of the floating platforms in Cambodia, downloads and maintenance of the receivers have been conducted frequently since the receivers' deployment, whereas the JEM team began to conduct downloads only after recovering their sunken receivers in February of 2023. The tags used in the study include V9, V13, and V16 coded transmitters, which were surgically implanted into the abdominal cavities of the study fish. To date, the joint study has passively monitored over 300 fish moving throughout the LMB, furthered scientific understanding of the rate and distance of fish movements, confirmed the ability of fish to move past suspected barriers to migration, and documented the occurrence of transboundary fish movements.




(**a**) (**b**)

**Figure 1.** (**a**) The extent of the proposed World Heritage Site and the planned locations of the two proposed mainstem dams, as well as the locations of acoustic receivers in the WoM and JEM networks. Acoustic receiver locations are approximate, some points represent multiple receivers, and two additional receivers further south on the mainstem Mekong in the city of Kampong Cham are not included on this map. (**b**) Average reported stingray catch per survey respondent in each district along the mainstem Mekong and 3S rivers. Points do not represent precise capture locations but rather reflect the center of the nearest river in the district from which each capture was reported. Respondents reported on catches as far back as 1980 and as recently as 2022, and the reported data include catches of both giant freshwater stingray (*Urogymnus polylepis*) and Mekong stingray (*Hemitrygon laosensis*). Note that of the 10 districts represented in the surveys, only respondents from Krong Banlung, Ratanakiri Province (located between the the Sesan and Sre Pok rivers) reported never having captured stingrays.

In addition to the numerous migratory species that are being tracked with the network, a unique opportunity arose on 14 June 2022, when a team of Cambodian and international scientists began to collect the first empirical data on giant freshwater stingray (*Urogymnus polylepis*) movement in Cambodia. The team was contacted by fishers from a small community located along the Mekong River between the proposed sites of the Stung Treng and Sambor dams. The fishers had captured a large female giant freshwater stingray with a disc width of 2.20 m and total length of 3.98 m from the snout to the tip of the tail (Figure 2). With a total weight of 300 kg, this stingray is now recognized as the world's largest recorded freshwater fish [21]. Such megafish (often described as fish reaching weights of 30 kg or more) are particularly vulnerable to ecosystem disturbance due to their large body size, slow growth, late maturity, and specific habitat requirements [22]. Consequently, megafish populations have declined more than any other taxonomic group of large aquatic vertebrates, and their numbers are estimated to have dropped by 88% globally between 1970 and 2012 [23]. Megafish face a number of risks in the LMB, including overharvest [24], indiscriminate fishing [25], the use of illegal fishing gear such as electrofishing equipment [26], and the development of hydropower dams [11]. Previous research on dam impacts on megafish suggests that mainstem dams and the associated alterations of the river carry a significant risk of negatively impacting populations of megafish in Cambodia through blocked migrations, altered hydrology, changes in water quality, and fragmented or degraded habitats [27,28]. Negative impacts on megafish species following dam construction range from dramatic collapses in recruitment because of degraded habitat quality [29] to the total extirpation of populations resulting from habitat fragmentation [30].

**Figure 2.** The world record giant freshwater stingray *Urogymnus polylepis* that was tagged in June, 2022.

Following this opportunistic tagging, a workshop on the ecology and conservation of freshwater stingrays in Cambodia was convened on 11 August 2022, in the city of Stung Treng. The workshop included university scientists, officials from the FiA, IFReDI, and the Ministry of the Environment (MoE), related NGO staff, and fishers from villages throughout the 3S basin and Mekong River from Kratie to the border with Lao PDR. The objectives of this meeting included (1) collating local ecological knowledge and scientific knowledge on populations of the giant freshwater stingray and Mekong stingray (*Hemitrygon laosensis*) in Cambodia; (2) evaluating the current state of understanding of these endangered species;

and (3) identifying critical knowledge gaps. Local fishers reported catching both giant freshwater stingrays and Mekong stingrays in the reach between the Lao PDR border and Kratie, indicating that this ~180 km reach of the Mekong supports extant populations of these two iconic stingray species (Figure 1b). The workshop concluded with a joint declaration by the participating individuals and organizations with the aims to expand collaborative research efforts and develop a conservation action plan for populations of endangered giant freshwater stingrays in Cambodia.

To date, the tagged giant freshwater stingray has been detected across multiple acoustic receivers, providing a record of short-distance movements (~7.5 km) within a small home range (Figure 3). These data represent detections over a period of nearly a year and have yielded further insights into the habitat use and behavior of the species, which has thus far been understood only through local ecological knowledge. Furthermore, two additional adult giant freshwater stingrays weighing 180 kg and 143 kg were captured in the same general reach within a five-week period from May–June of 2022, suggesting that this reach of the river retains a population of these rays and may provide a critical habitat for this species. The tagging and monitoring of additional stingrays in the future could serve as a means of validating patterns indicated in the catch report survey by local fishers. The surveys suggest that stingrays occur throughout the mainstem Mekong and 3S rivers (Figure 1b), and that the proposed dams would likely fragment what appears to be a contiguous population. The life history and habitat requirements of the giant freshwater stingray are poorly understood. Although the large individual tagged in this study has exhibited only short-distance movements over a period of 10 months, it is possible that there may be differential movement behaviors over longer periods of time, in younger individuals, and/or in males. Until more individuals of varying sizes representing both sexes are tagged and tracked over longer periods of time, the potential impacts of river fragmentation caused by dam construction on stingray movement will remain unclear. However, the damming of the river would undoubtedly result in altered sediment and flow regimes, loss of suitable habitat, and fragmentation of the population, likely leading to reductions in genetic diversity and population abundance [31,32]. Notably, the IUCN lists the Thai subpopulation of giant freshwater stingray as critically endangered due to the impacts of dams, habitat degradation, and pollution of the rivers in central Thailand, such as the Chao Phraya [33].

Telemetry arrays and the data they collect can be used to inform both national and transboundary management decisions [34–36]. In addition to collecting data on the giant freshwater stingray, WoM scientists have successfully used the network in Cambodia to gather data on the movement patterns of numerous highly migratory species that support large fisheries in the region (Figure 3). Of the Mekong fish species whose migratory behaviors are known, 87% are known to migrate [1], and multiple long-distance migrants were targeted for this study to evaluate their movements through habitats in and around the proposed dam sites. To date, the network has already recorded rapid, long-distance movements of individuals belonging to nine different species (*Bagarius yarrelli*, *Cirrhinus microlepis*, *Helicophagus leptorhynchus*, *Hemibagrus wyckioides*, *Labeo barbatulus*, L. *chrysophekadion*, *Mekongina erythrospila*, *Pangasius conchophilus*, and *P. larnaudii*) through the proposed site for the Stung Treng Dam on the mainstem Mekong River (Figures 1a and 3) [12].

The data yielded from the current acoustic monitoring efforts may also help to provide further support for the official designation of the UNESCO World Heritage Site along the Mekong River that was recently proposed by the Minister of the Environment in Cambodia (Figure 1a) [37]. The proposal cites the importance of this reach of the river for the endangered Irrawaddy river dolphin (*Orcaella brevirostris*) and the critically endangered Mekong giant catfish, which occur sympatrically with the giant freshwater stingray. The designation of this reach of the Mekong River as a UNESCO World Heritage Site (Biosphere Reserve) could have profound effects on the health of the ecosystem, similar to the benefits experienced in the Prek Toal Core Area in the Tonle Sap Lake. This site was designated as a Biosphere Reserve in 1997, which resulted in dramatic increases in populations of

threatened bird species and fish stocks, as well as improvements in overall ecosystem health. Furthermore, this designation resulted in the active participation of local communities in conservation activities and an increase in alternative income generation through conservation and ecotourism [38].

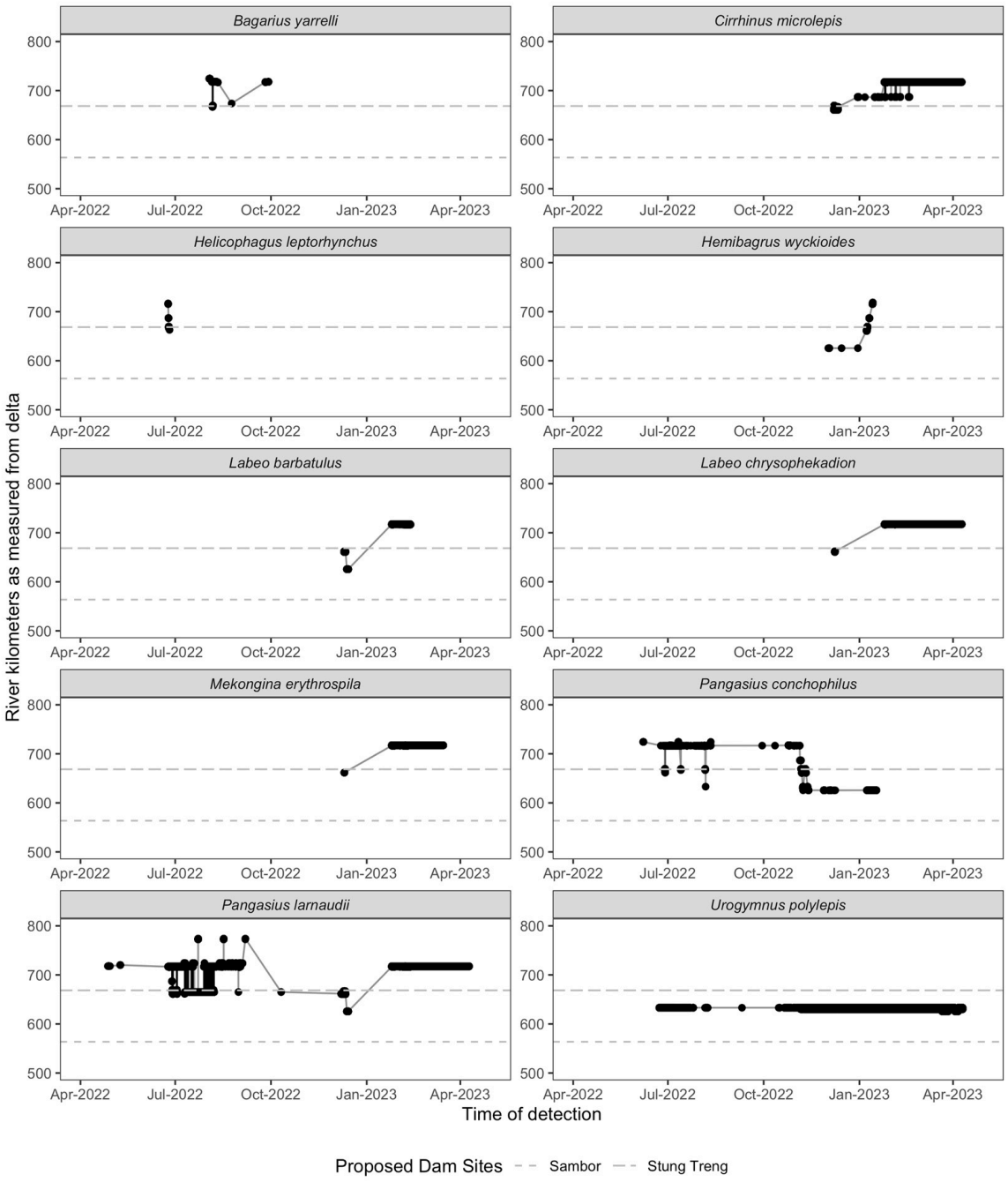



**Figure 3.** The distance movements of the farthest-moving individual of the nine different species that exhibited movement through the proposed Stung Treng dam site, as well as the short-distance movement of the tagged giant freshwater stingray. Black dots depict unique detection events for each individual fish. These plots depict data collected from April 2022 to April 2023. Note that all tagged fish were released in the vicinity of their initial capture location.

With both World Heritage Site designation and dam feasibility studies in progress, the Cambodian Mekong currently stands at a critical decision point. While the Royal Government of Cambodia recently reaffirmed its commitment to a free-flowing Mekong,

there is an urgent need to evaluate the potential outcomes of future development in order to inform decisions about the best path forward for the people of Cambodia, for the LMB as a whole, and for global biodiversity. The immense value of fisheries in this region makes it imperative to thoroughly assess the potential economic loss and damage to existing fisheries presented by future developments. Furthermore, flagship species have been a valuable tool in spurring international cooperation in conservation efforts across the globe [39,40], and megafish such as the giant freshwater stingray may serve in this capacity for the LMB. The stingray is both a symbol of pride for Cambodians and an indicator of ecosystem health, and the conservation of this species is a national and international issue of great significance.

**Author Contributions:** Conceptualization, D.L, J.C.E., Z.S.H. and S.L.; writing—original draft preparation, D.L. and J.C.E.; writing—review and editing, D.L., J.C.E., Z.S.H., B.C., S.L., L.J.B., W.R., E.E., K.H., S.S., R.H., L.S., S.C. (Sothearoth Chea), S.O., C.C., S.C. (Seila Chea) and S.C. (Sudeep Chandra). All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded through the United States Agency for International Development (USAID) 'Wonders of the Mekong' Cooperative Agreement No: AID-OAA-A-16-00057. Additional funding was provided by the Australian Water Partnership.

**Data Availability Statement:** Data are available upon request.

**Acknowledgments:** The authors would like to thank the numerous Cambodian communities that have provided significant support for the establishment and maintenance of the acoustic telemetry network, as well as the sourcing of fish for tag implantation. In addition, we thank the fishers who notified the Wonders of the Mekong project team about the capture of the giant freshwater stingray and kept the fish in good condition to allow for its tagging. Furthermore, we thank the staff from Young Eco Ambassador, the Inland Fisheries Research and Development Institute, and the Fisheries Administration, whose tireless and enthusiastic support of the field activities and community engagement have made this project possible. We also thank the Royal University of Agriculture student Soksan Chhorn for her assistance in coordinating the stingray workshop and reviewing the draft manuscript. Finally, we thank the FISHBIO staff members Matt Peterson, Tyler Pilger, and Michael Hellmair for their helpful feedback on the manuscript; Dee Thao for creating the map images used in this manuscript; Tara Lamb for assisting with the mapping of acoustic tag detection data; and Patrick O'Bryan for assisting with the tagging of the stingray and installation of the acoustic receiver network.

**Conflicts of Interest:** The authors declare no conflict of interest.

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