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Report on the post-release mortality rates of great hammerhead sharks *Sphyrna mokarran* in the recreational, catch and release, shore-based fishery in Florida, USA.

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Summary: Great hammerhead sharks (*Sphyrna mokarran)* are targeted by recreational anglers along the coast of Florida. We estimated the post-release mortality rates for those great hammerhead sharks captured by rod and reel shore-based recreational anglers using short-term, pop-off satellite archival tags (PSATs). All sharks were tagged within the normal release procedures by anglers, and the handling time was not extended to collect other data. One of 13 sharks with reporting tags (7.7%) died post-release.

Introduction

Recreational shark fishing is a popular activity throughout the United States and other countries such as Australia and South Africa. Anglers target sharks in nearshore water from boats and from shore. Shore-based shark anglers use a variety of gear types to target numerous species including blacktip (*Carcharhinus limbatus*; Weber et al. 2020), sand tiger (*Carcharias taurus*; Kilfoil et al. 2017), and great hammerhead sharks. Shore-based fishing requires the deployment of bait from beaches, piers, and bridges by casting, kayaking or, more recently, by unoccupied aerial vehicles (UAVs) and remotely operated underwater vehicles (ROUVs). There is a scarcity of data regarding this fishery, in part because it often occurs at night, therefore potentially limiting its inclusion in traditional Access Point Angler Intercept Surveys. The participation in this activity appears to be increasing and therefore is it important to understand the impacts of the fishery on targeted (and non-target) species.

The great hammerhead shark (*Sphyrna mokarran*), which is actively targeted in this fishery, is a highly migratory species found circumglobally in coastal-pelagic and semi-oceanic waters (Compagno 1984). Great hammerheads are frequently caught as bycatch, have relatively long-life spans, a maximum of 44 years (Passerotti et al. 2010), and a biennial reproductive cycle (Stevens and Lyle 1989) which have contributed to population decreases in several regions, warranting a recent categorization of Critically Endangered by the IUCN (Rigby et al 2019). In the western Atlantic Ocean, great hammerheads range extends from Massachusetts to Uruguay, including the Gulf of Mexico and Caribbean Sea (Compagno et al. 2005, Hammerschlag et al. 2011, Rigby et al. 2019).

Florida is considered Essential Fish Habitat for great hammerheads during all life stages with possible nurseries in the estuaries on the southeast coast (Macdonald et al. 2021) and along the west coast (Hueter & Tyminski 2007). Great hammerheads exhibit seasonal site fidelity on the east of Florida (Guttridge et al 2017). Florida is also a hotspot for shark fishing with more than 4,000 HMS permit holders, or 20% of all U.S. permit holders (NOAA SAFE Report, 2019) and specifically shore-based with more than 14,000 holders of the state-mandated shore-based shark fishing permit (FWC pers. comm.)

Although catch and release is practiced by most shark anglers (Press et al. 2015), this does not ensure the survival of the shark. Post-release mortalities can occur and depend on the physiological status of the individual, the respiratory mode of the species, gear types, fishing, and handling practices of the anglers (Cooke and Schramm 2007).

Authorities in Florida granted protection to the hammerhead complex by prohibiting the harvest of great, smooth, and scalloped hammerheads in the state's jurisdictional waters (Fla. Admin. Code R. 68B-44.002(4)), allowing anglers to target them but requiring the sharks' immediate release. Despite this rule, there are occasional dead great hammerhead sharks found on the shore. Despite anglers releasing the sharks after capture, the physiological stress of the fishing event may result in a mortality. For the great hammerhead, an obligate ram-ventilating species, any form of capture or entanglement can result in post-release behavioral impairment due to elevated levels of stress and exhaustive exercise (Gallagher et al. 2014; Dapp et al. 2016). Great hammerheads suffer higher post-release mortality rates than many other species of sharks, with high mortality rates in trawls (97.6%), protective nets (98.3%), and gillnets (71.5%-89.3%; reviewed in Ellis et al. 2017). However, there are no published data on great hammerhead post-release mortality from the rod and reel-based fishery, especially for shore-based angling where sharks are reeled into shallow, warm water and may have trouble navigating back to deep water upon release.

Previous studies have outlined the stress response and fisheries-related mortality of this species across several modes of research and commercial fishing. The present study included active recreational anglers' participation to deploy short-term pop-up satellite archival transmitting tags (PSATs) to determine the rates of the post-release mortality of great hammerheads in the shore-based shark fishery.

Materials and Methods

Sampling location and design

Sharks were caught by recreational anglers using their personal rod, reel, and tackle from shore in southeast Florida. There was no input from the authors about time or location of the fishing effort, the fishing gear, fight or handling techniques. Fishing took place from May 2018 to February 2021 and sharks were caught, landed, tagged, and sampled at three main locations (Table 1).

Table 1. Capture locations for the 16 Great Hammerheads (*Sphyrna mokarran*) tagged in Florida, USA.

Capture location	Number of sharks tagged
Singer Island, FL	14
Lake Worth, FL	1
Hutchinson Island, FL	1

The time the bait was dropped in the water was recorded for each rod each fishing day to determine fishing effort. The type of rod, reel, terminal tackle (including leader and hook type and size), species and weight of bait, number of anglers on a 'team' and various time intervals for a fishing event were recorded. Fight time was recorded from the time of the initial strike of the shark on the hook to the time the angler stopped reeling and the anglers had a hand on the shark. . The handling was defined as the time the anglers had their hand on the shark until the time when the animal was released (i.e., zero contact with the shark). The anglers decided how to handle the sharks and their position on the shore therefore sampling conditions varied from .5 m of water with no waves to 1-1.5 m breaking waves. During the handling time when anglers completed their preferred tasks (i.e., tail roping, cutting out or removing the hook, measuring, taking pictures), the species was confirmed, sex was determined, measurements were taken (cm), and species other than great hammerheads were tagged with NOAA Cooperative Shark Tagging Program M-type dart tags.

To avoid artificially delaying the release of the shark due to sampling, satellite tag attachment was prioritized. Great hammerheads were tagged with pop-off satellite archival tags, PSATs, (4 x High-Rate X-tags by Microwave Telemetry, Inc. Columbia, MD USA and 12 x PSATLife tags by Lotek Wireless Inc. Newmarket, Canada). The Microwave X-tags were 12x3.2 cm (without antenna) and weigh 40 grams. The X-tags were programmed to record and archive temperature, light and pressure every five minutes for a 30-day deployment. The Lotek PSATLife tags were 12.5 cmx1.9 -4 cm diameter weighing 89 grams and were programmed for 28-day deployment, also logging external temperature, pressure and light every 5 minutes. Both tag types were programmed to release if the pressure measurements remained constant, +/- 5 dBar pressure for 3 days (Lotek) and 3m depth for 2 days (Microwave) consecutively, indicating a mortality event or a tag that had been shed before the 28–30-day period.

PSAT tags were attached to the animal by using a stainless-steel metal dart inserted into the musculature at the base of the dorsal fin. The tag was attached to the dart by a short tether of coated monofilament/wire. After an increase in tag shedding events, some tags were deployed with 2 tethers with darts that were inserted into the musculature on both sides at the base of the dorsal fin, allowing the tag to trail just behind the back edge of the fin (in the hopes to reduce scraping). If time allowed, DNA samples were taken.

Survivorship was inferred by assessing the data retrieved from the tags through the Argos CLS/Woods Hole Group system.

Environmental conditions were recorded at the start of each fishing effort, including tide, SST, wind temperature and direction, current speed and direction, and cloud cover.

Data Analysis

The rate of post-release mortality for great hammerheads in the recreational shore-based fishery was calculated as a percentage of the total number of tagged sharks that died after release as inferred from the PSAT data that was retrieved.

Results

A total of 16 great hammerhead sharks were caught and tagged with PSATs (11 female, 5 male), ranging in size from 274 to 411 cm Total Length (338 ±45, mean ± SD). All sharks swam away after release, and no immediate fatalities had occurred. Three tags failed to report any data to the Argos satellite system and therefore are not included in the assessment of the post-release mortality rate. All reporting tags were shed prior to the 28/30 day deployment period and none were physically recovered. Tag retention ranged from 3 – 16 days (mean: 7.6 days).

The pressure profile of one (shark ID GH2) of the 13 reporting tags indicated that the shark sunk to and remained at approximately 14 m within 2 hours of release, triggering the "constant depth" release of the PSAT. Shark GH2 was a 380 cm TL female that was caught during one of the longer recorded fight times of 45 minutes and the longest handling time of 8 minutes. Wave height during the handling of this individual was 1.5 m.

None of the pressure profiles of the other 13 tags indicated a detachment due to constant depth release, therefore, acknowledging a small sample size, this species in this fishery experiences a post-release mortality rate of 7.7%.

Table 2. Capture characteristics of great hammerhead sharks tagged with PSATs

Shark ID	Fight time (mins)	Handling time (mins)	PSAT Deployment Duration (d)	Sex	Size (cm)	Survivorship
GH1	15	4	6	male	300	Y
GH2	45	8	3	female	380	N
GH3	51	3	6	female	400	Y
GH4	8	4	16	male	275	Y
GH5	32	2	3	male	289	Y
GH6	13	1	6	female	342	Y
GH7	11	6	9	male	290	Y
GH8	27	3	14	female	340	Y
GH9	17	2	8	female	274	Y
GH10	32	5	4	male	365	Y
GH11	42	2	10	female	411	Y
GH12	33	3	8	female	350	Y
GH13	19	3	6	female	366	Y
GH14	7	1	Did not report	female	304	Unknown
GH15	15	3	Did not report	female	335	Unknown
GH16	29	3	Did not report	female	381	Unknown

Discussion

This study provides insights on post-release mortality rates of great hammerheads in the recreational, shore-based shark fishery, an activity that is growing in participation with management and regulatory challenges. The post-release mortality rate for great hammerhead sharks in this fishery is estimated to be 7.7%. Understanding the impacts of the different modes of recreational fishing has on the great hammerhead is important to for effective management, to identify factors that may improve survival rates of this vulnerable species.

The estimated PRM rate determined by the study is lower than estimations for other fisheries with different modes of capture. The characteristics of this specific fishery were initially thought to be even more stressful for this species (i.e., long fight and handling times, low DO environment of the surf zone, air exposure, effects of gravity) and predicted to result in a higher PRM rate. We acknowledge that there are likely biases in our study that may have led to this unexpected low mortality rate. Firstly, like with many co-produced research projects, we collaborated with anglers that are willing to work with, and be observed by scientists which could lead to anglers being on their 'best behaviour'. These anglers also likely care about the conservation of the species and of the fishery and strive for responsible fishing techniques. To better understand the fishery, and the potential biases in our study design, we conducted a survey of the FWC SBSF permit holders in 2020 (Guay et al. In Press; Kent, BSc thesis, 2021). A separate Technical Report can be provided with survey results if required, but in brief, almost 900 anglers that actively target sharks from shore in Florida completed the survey, of which 217 placed Great Hammerhead in their top three preferred species. Almost a third of those 'great hammerhead anglers' were under the age of 20, and almost half had only been fishing for sharks for 1-5 years (Kent, BSc thesis, 2021). Of all the SBSF anglers, 140 had reported catching 371 great hammerheads from shore within the previous 12 months of taking the survey, and interestingly, approximately half of those were caught by 'non great hammerhead anglers', or those that had placed this species in their bottom 3 of preferred species, possibly indicating a high level of bycatch. Gear types varied between the two types of anglers, and size of shark also differed by bait deployment techniques; larger sharks were caught by kayak deployment vs casting. This could be because of smaller sharks using shallower, coastal waters, or perhaps misidentification of species with scalloped hammerheads or bonnetheads caught on light gear cast from shore. The anglers that caught the sharks in our tagging study were more experienced (i.e., more than 1- 5 years of shark fishing) and used heavier gear types capable of reeling in sharks to shore quicker. Our survey has showed that not all great hammerheads are caught under these conditions, and therefore sampling of a wider array of angler types, experience levels, and gear combinations is recommended.

It is important to determine whether the current shore-based regulations are sufficient to minimize post-release mortality of great hammerheads. Understanding the factors that improve survival (i.e., associated with gear types, angling and handling procedures, and environment [temperature, proximity to deep water]) underpin production of 'best practices' advice for anglers. It is even more important to ensure up-take of these best practices among the angling community.

References

Compagno, L.J.V. 1984. Sharks of the World. An annotated and illustrated catalogue of shark species known to date. Part II (Carcharhiniformes). FAO Fisheries Synopsis No. 125, Vol. 4, Part II. FAO, Rome.

Compagno LJV, Dando M, Fowler S (2005) Sharks of the world. Collins field guide. Harper Collins Publishers, London

Cooke, S.J., Schramm, H.L. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. Fish. Manage. Ecol. 14: 73-79.

Dapp, D.R., Walker, T.I., Huveneers, C., Reina, R.D. 2016. Respiratory mode and gear type are important determinants of elasmobranch immediate and post-release mortality. Fish. Fish. 17: 507-524.

Ellis, J.R., McCully, Phillips, S.R., Poisson, F. 2017. A review of capture and post release mortality of elasmobranchs. J. Fish. Biol. 90: 653-722.

Gallagher, A.J., Serafy, J.E., Cooke, S.J., Hammerschlag, N. 2014. Physiological stress response, reflex impairment, and survival of five sympatric shark species following experimental capture and release. Mar. Ecol. Prog. Ser. 496: 207-218.

Guay, J.D., J.L. Brooks, J.M. Chapman, H. Medd, S.J. Cooke and V.M. Nguyen. In Press. Survey-derived angler characteristics and perspectives in the shore-based shark fishery in Florida. Marine and Coastal Fisheries. 00:000-000

Guttridge, T.L. Van Zinicq Bergmann, M.P.M., Bolte, C., Howey, L.A., Finger, J.S., Kessel, S.T., Brooks, J.L., Winram, W., Bond, M.E., Jordan, L.K.B., Cashman, R.C., Tolentino, E.R., Grubs, R.D., Gruber, S.H. 2017. Philopatry and regional connectivity of the great hammerhead shark, *Sphyrna mokarran* in the U.S. and Bahamas. Frontiers in Marine Science, 4:3.

Hammerschlag, N., Gallagher, A.J., Lazarre, D.M., and Slonim, C. 2011. Range extension of the Endangered great hammerhead shark *Sphyrna mokarran* in the Northwest Atlantic: preliminary data and significance for conservation. Endangered Species Research, 13:111-116.

Hueter, R. E., & Tyminski, J. P. (2007). Species-specific distribution and habitat characteristics of shark nurseries in Gulf of Mexico waters off peninsular Florida and Texas. In C. T. McCandless, H. L. Pratt, Jr., & N. E. Kohler (Eds.), American Fisheries Society Symposium (Vol. 50, p. 193). Bethesda, MD: American Fisheries Society.

Kent, E. 2021. Angler differences within the shore-based shark fishery: are great hammerhead anglers a distinct community? BSc thesis, Department of Science, Carleton University.

Kilfoil, J.P., Wetherbee, B.M., Carlson, J.K., Fox, D.A. 2017. Targeted catch-and-release of prohibited sharks: sand tigers in coastal Delaware waters. Fisheries. 42: 281-287.

Macdonald, C., Jerome, J., Pankow, C., Perni, N., Black, K., Shiffman, D., Wester, J. 2021. First identification of probably nursery habitat for critically endangered great hammerhead *Sphyrna mokarran* on the Atlantic Coast of the United States. Conservation Science and Practice, 3:e418

NOAA, Atlantic Highly Migratory Species Management Division. 2020. 2019 Stock Assessment and Fishery Evaluation Report for Atlantic Highly Migratory Species (SAFE Report). https://media.fisheries.noaa.gov/dam-migration/2019_safe_report_for_atlantic_highly_migratory_species.pdf

Passerotti MS, Carlson JK, Piercy AN, Campana SE. 2010. Age validation of great hammerhead shark (Sphyrna mokarran), determined by bomb radiocarbon analysis. Fish Bull. 108: 346–351.

Press, K.M., Mandelman, J.W., Burgess, E., Cooke, S.J., Nguyen, V.M., Danylchuk, A.J. 2016. Catching sharks: recreational saltwater angler behaviours and attitudes regarding shark encounters and conservation. Aquat. Conserv. Mar. Freshw. Ecosyst. 26: 689-702.

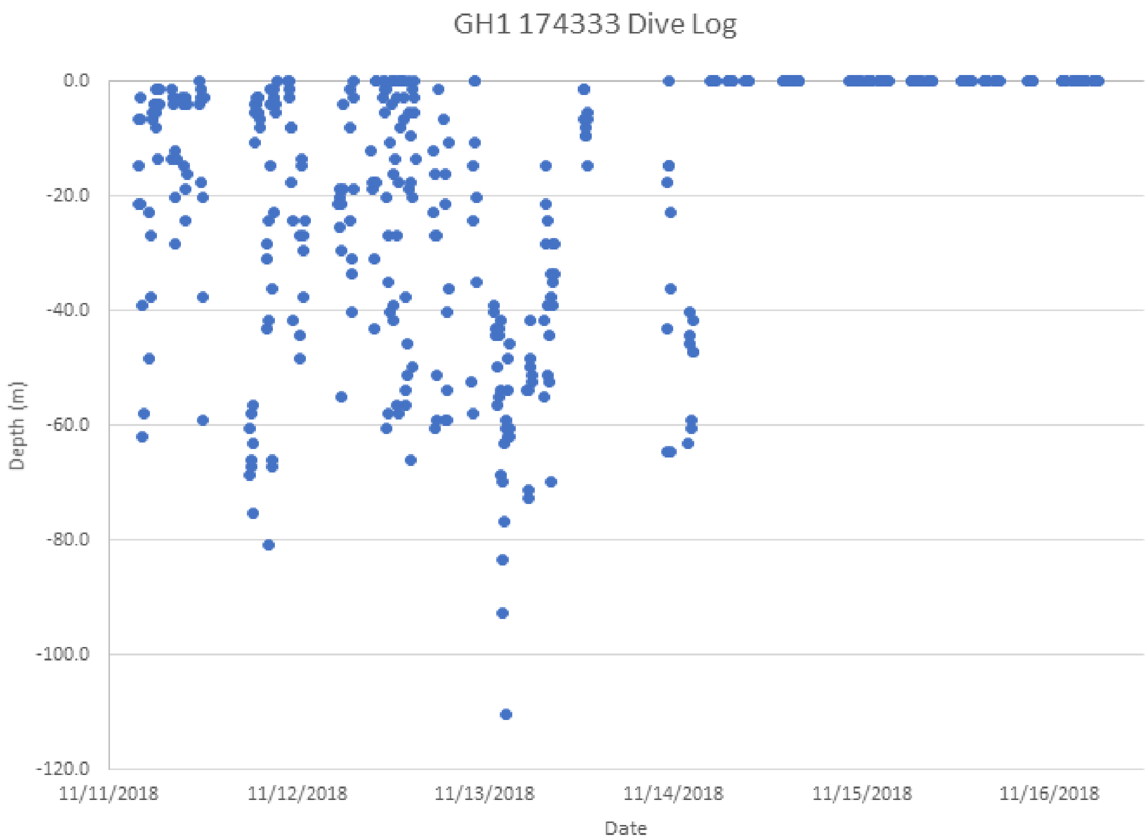
Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B. & Winker, H. 2019. *Sphyrna mokarran*. *The IUCN Red List of Threatened Species* 2019: e.T39386A2920499. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39386A2920499.en.

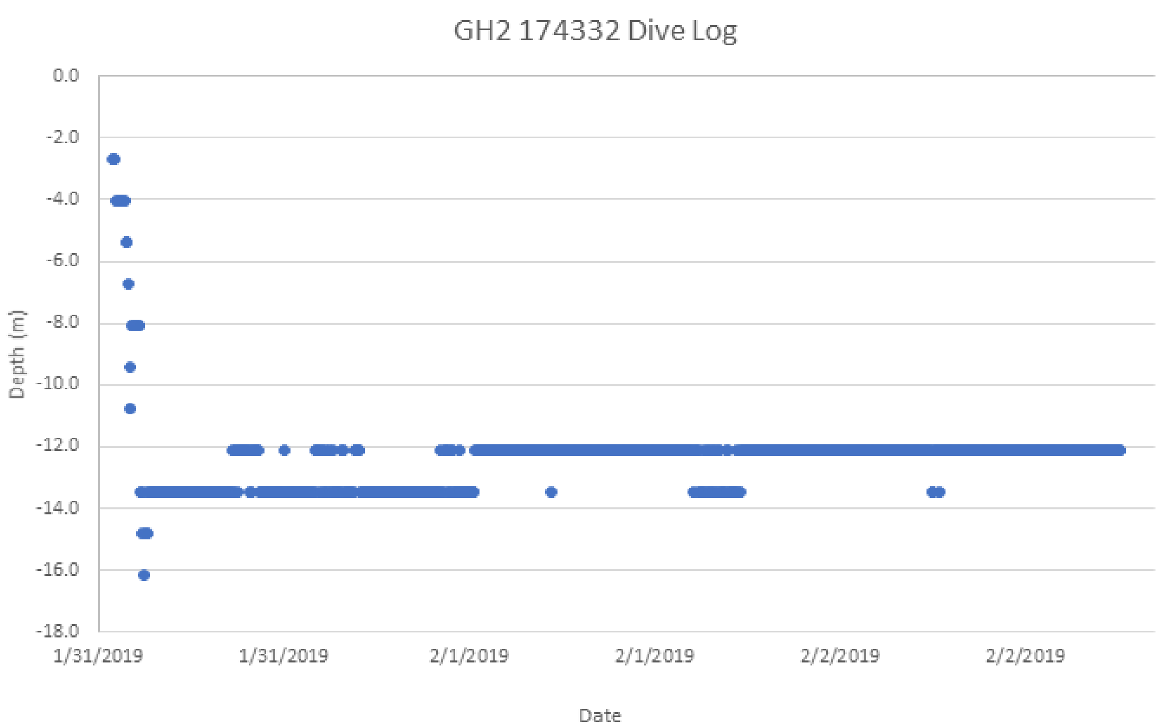
Stevens JD, Lyle JM (1989) Biology of three hammerhead sharks (Eusphyra blochii, *Sphyrna mokarran, and S. lewini*) from northern Australia. Aust J Mar Freshw Res 40:129–146

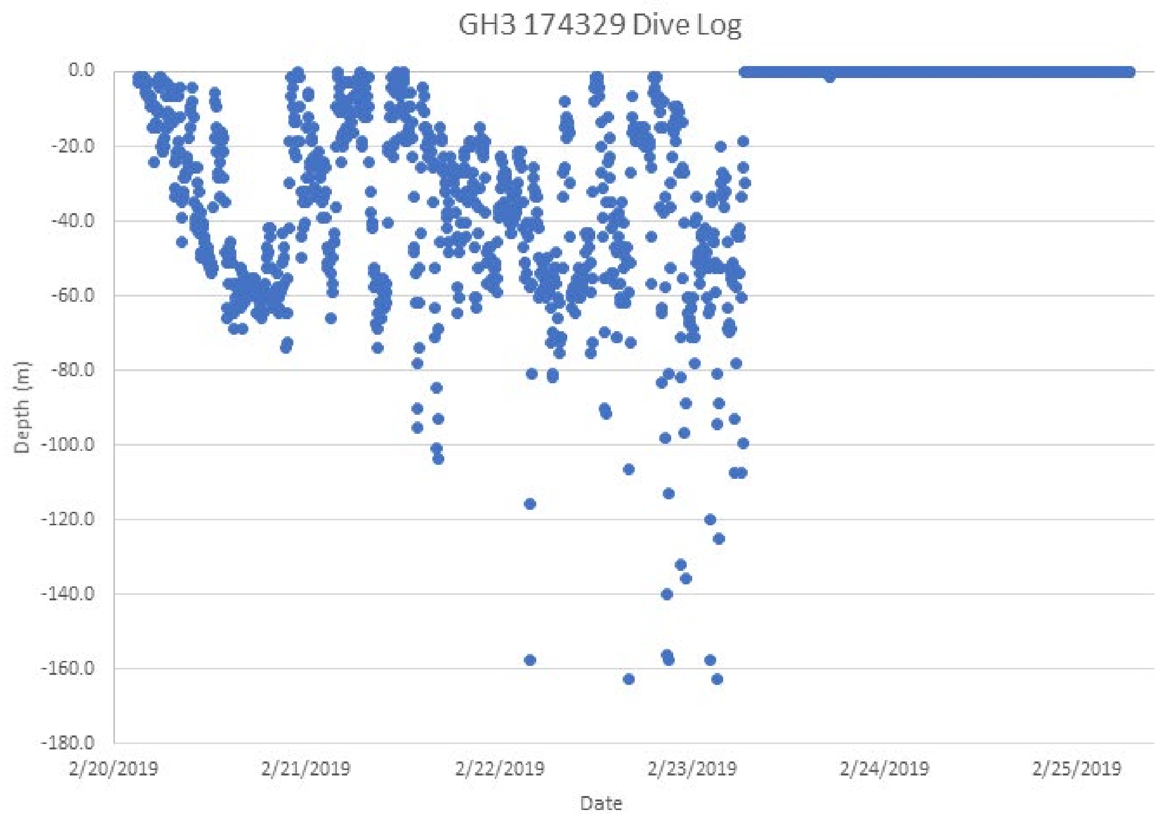
Weber, D.N., Frazier, B.S., Whitney, N.M., Gelsleichter, J., and Sancho, G. 2020. Stress response and postrelease mortality of blacktip sharks (*Carcharhinus limbatus*) captured in shore-based and charter-boat-based recreational fisheries. Fishery Bulletin, 118:297-314.

Essential Fish Habitat 2017. https://www.habitat.noaa.gov/application/efhinventory/docs/a10_hms_efh.pdf

Appendix I. PSAT data







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-40.0
-60.0
-80.0
-100.0
-120.0
-140.0
-160.0
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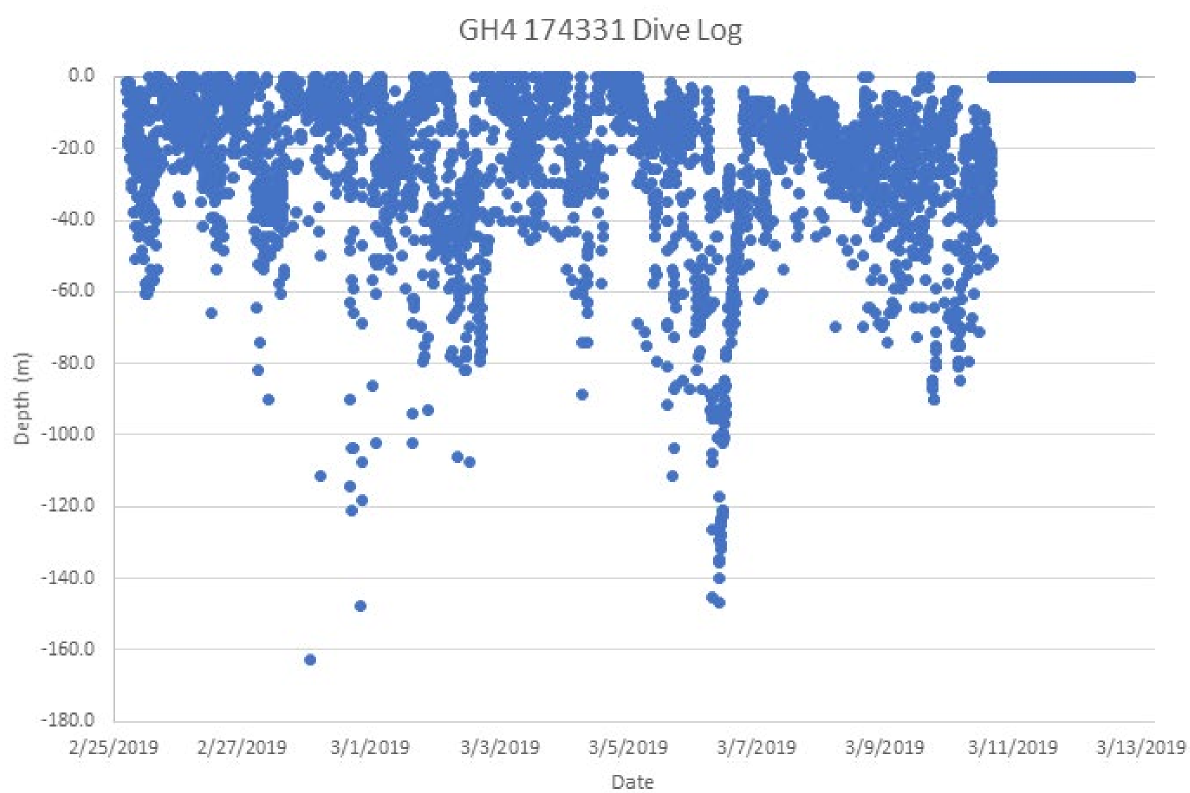
2/20/2019
2/21/2019
2/22/2019
2/23/2019
2/24/2019
2/25/2019
Date



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-60.0
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Depth (m)
2/25/2019
2/27/2019
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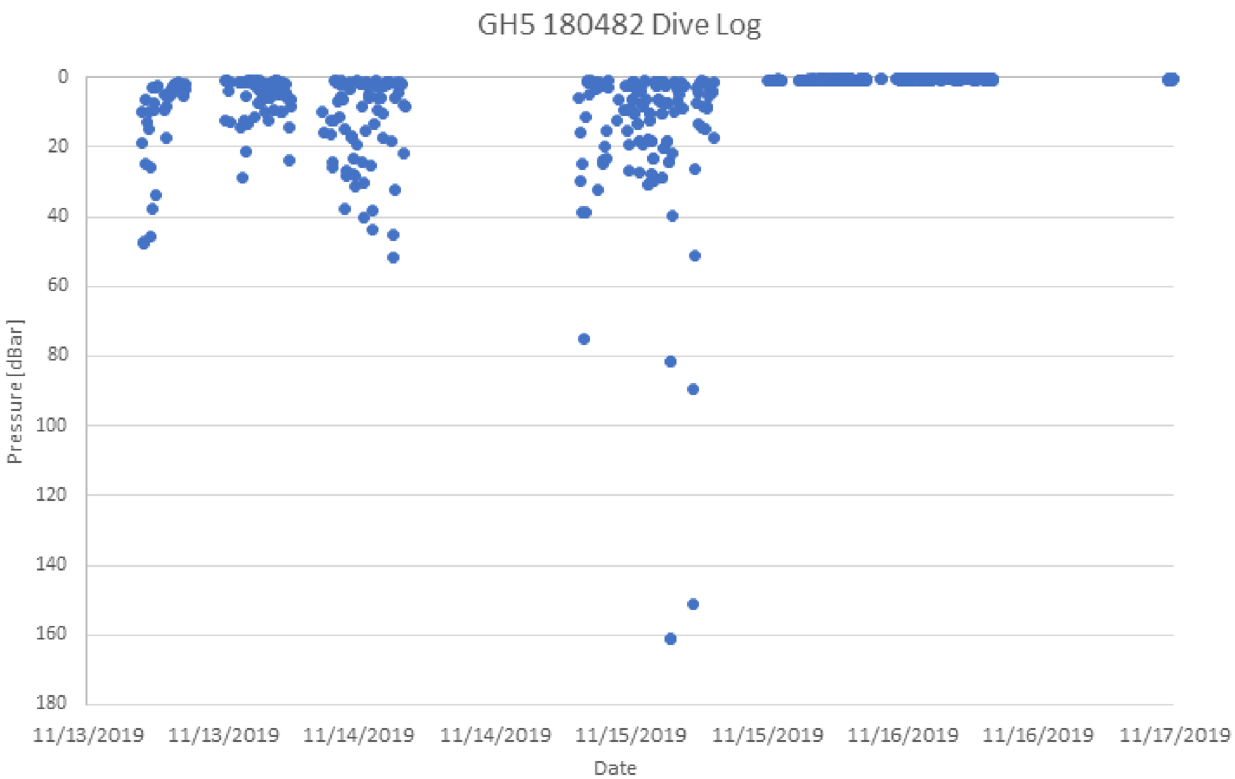
3/7/2019
3/9/2019
3/11/2019
3/13/2019
Date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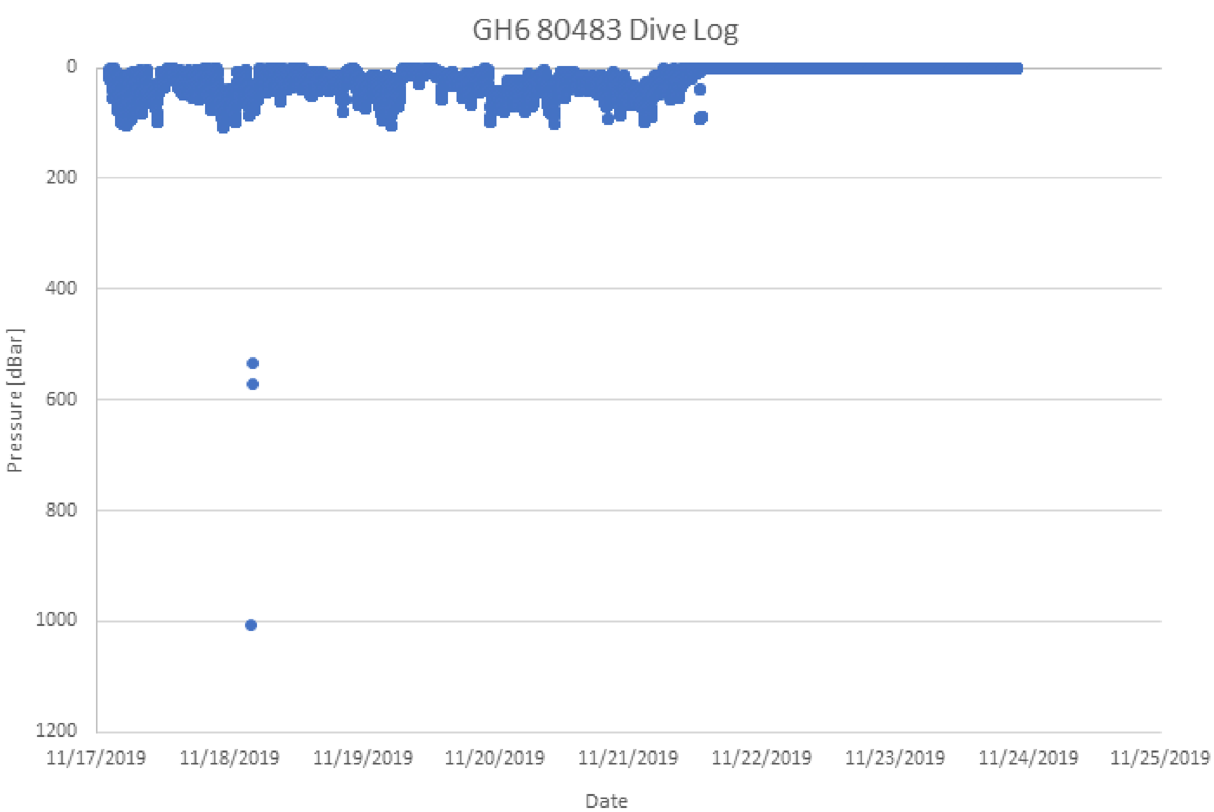
Date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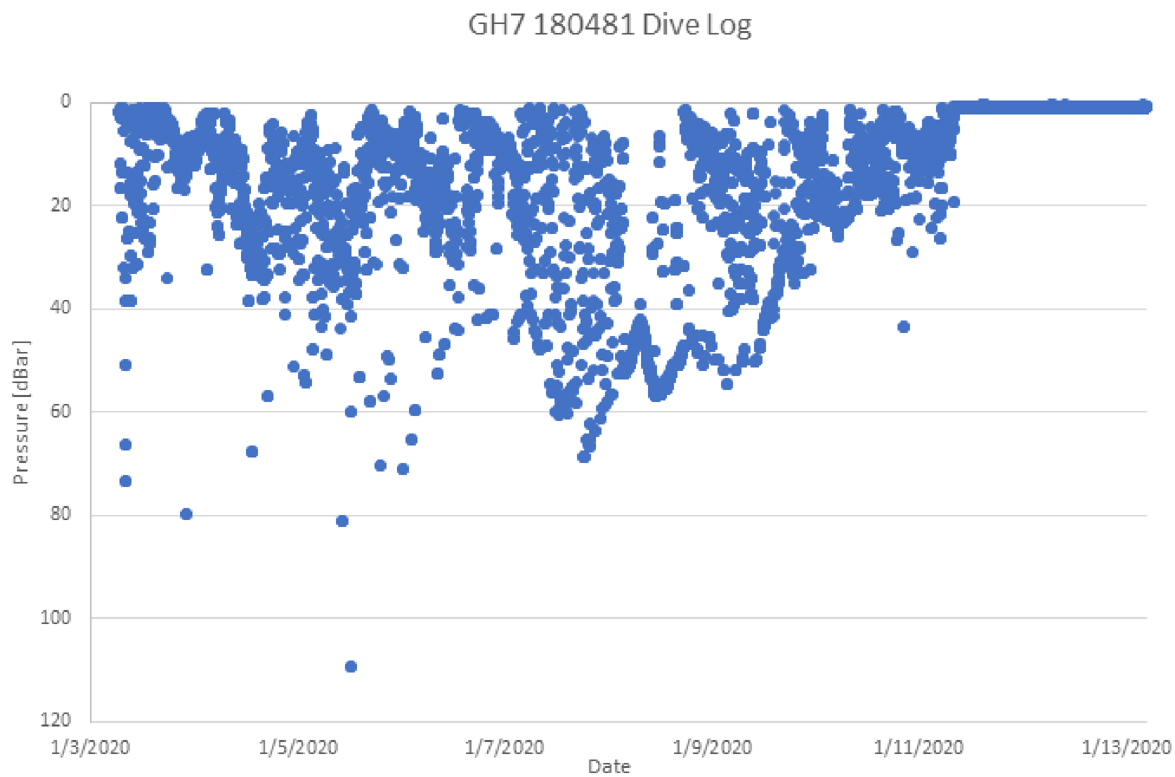

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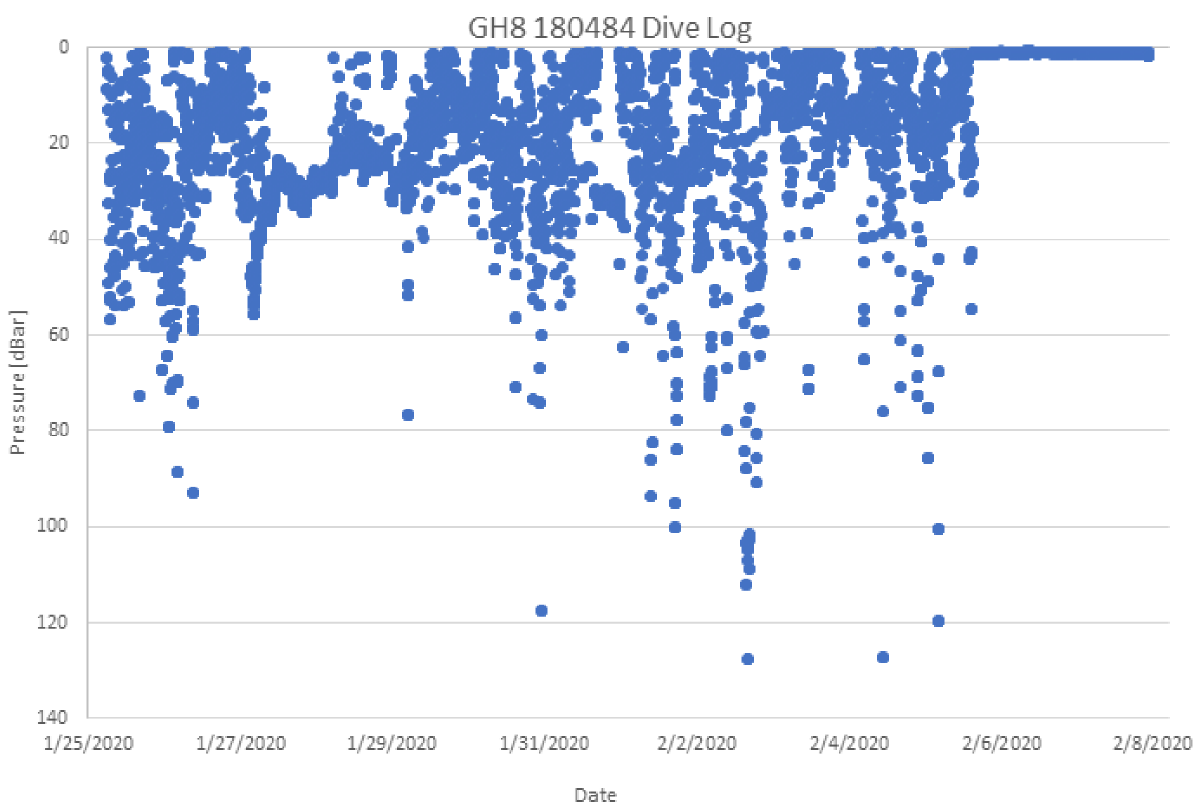

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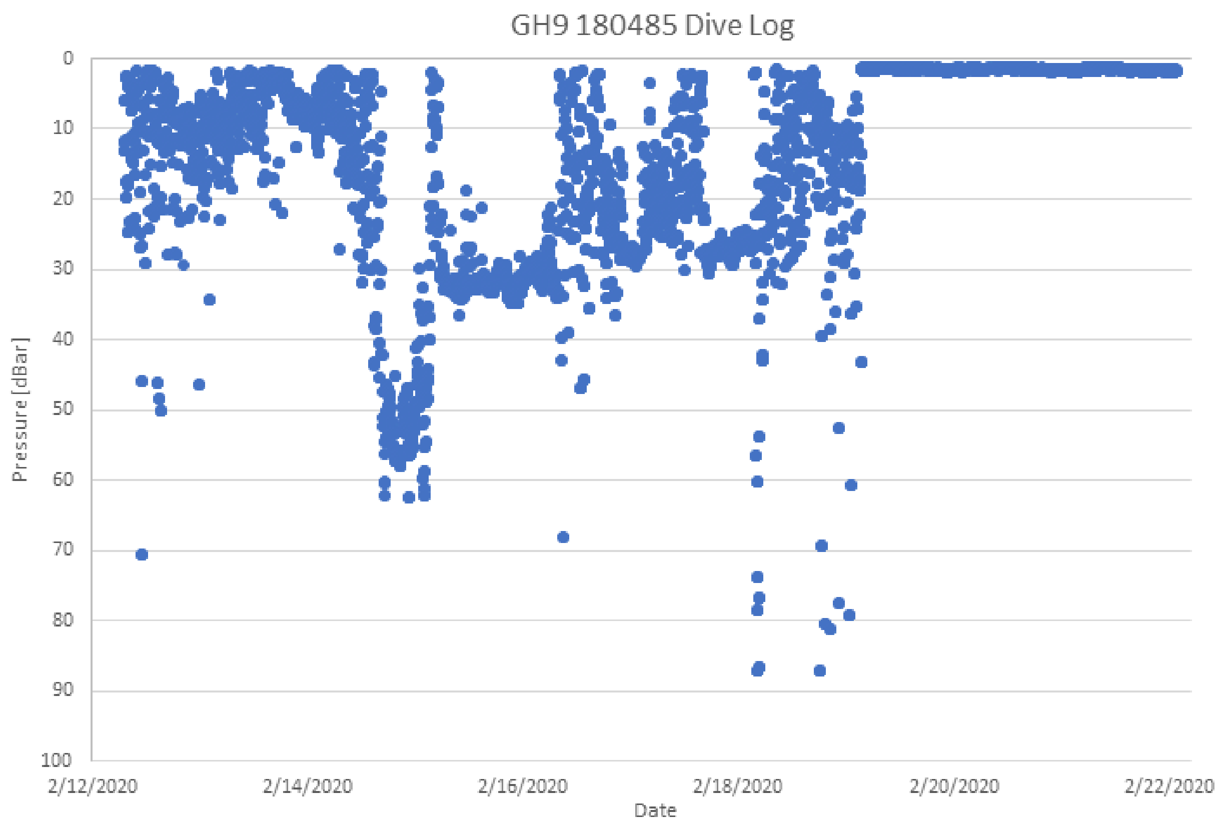
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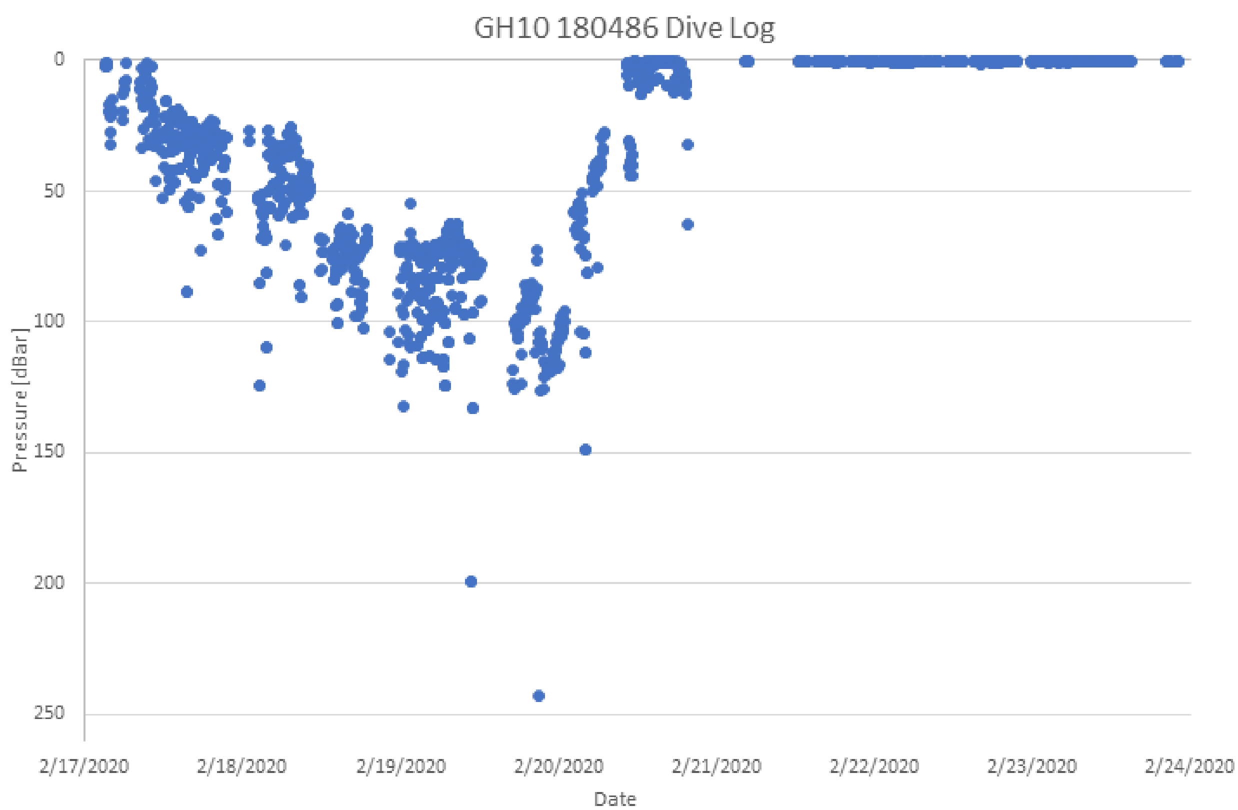
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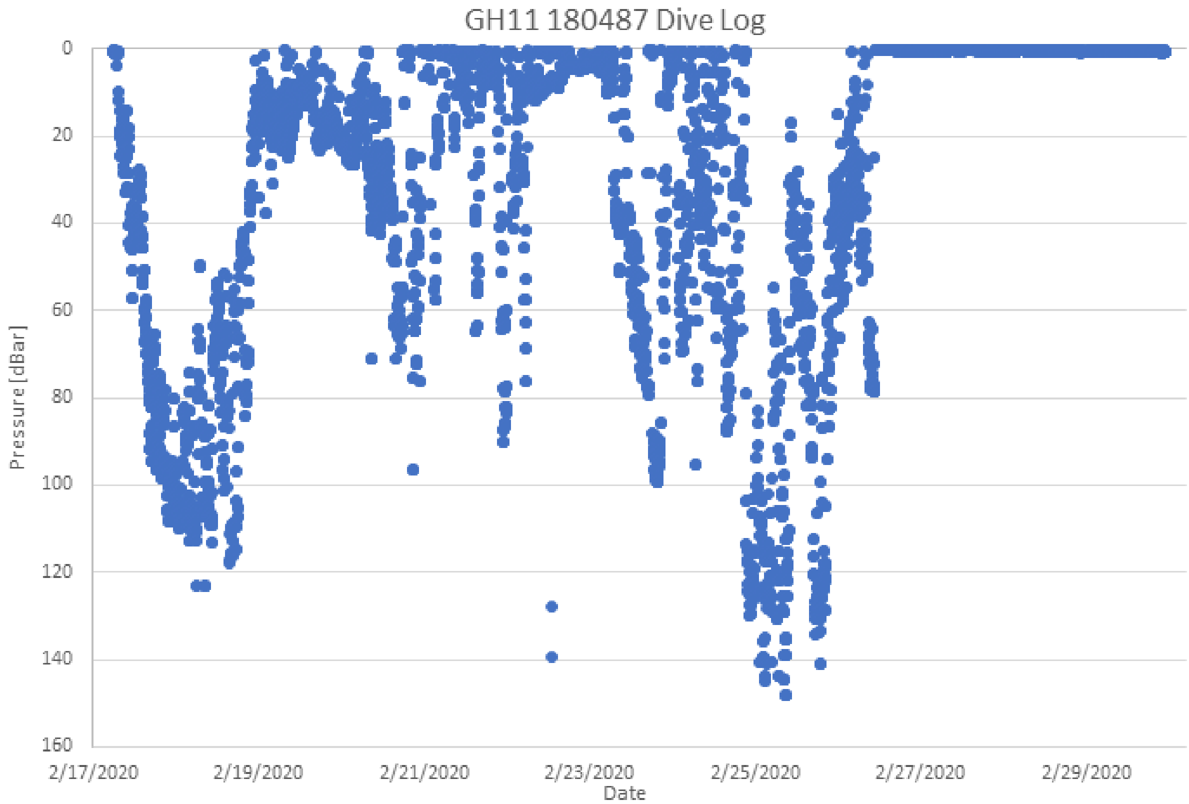
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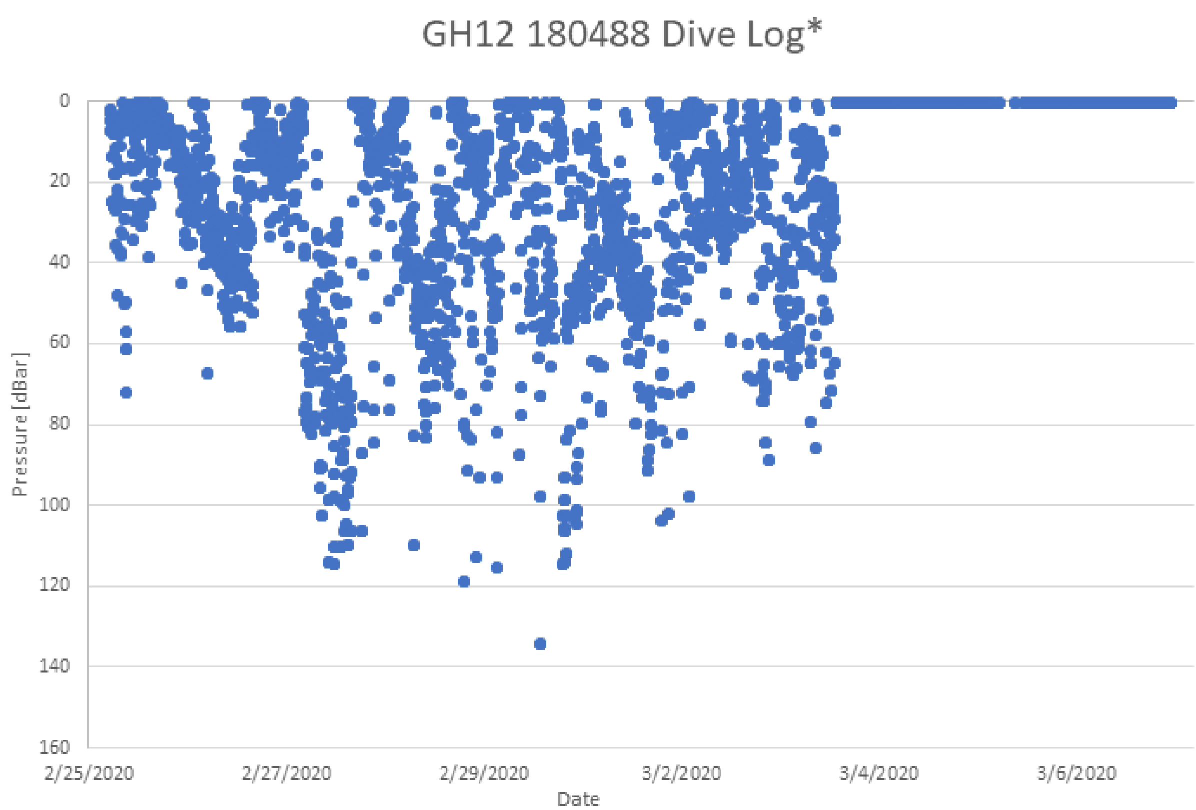
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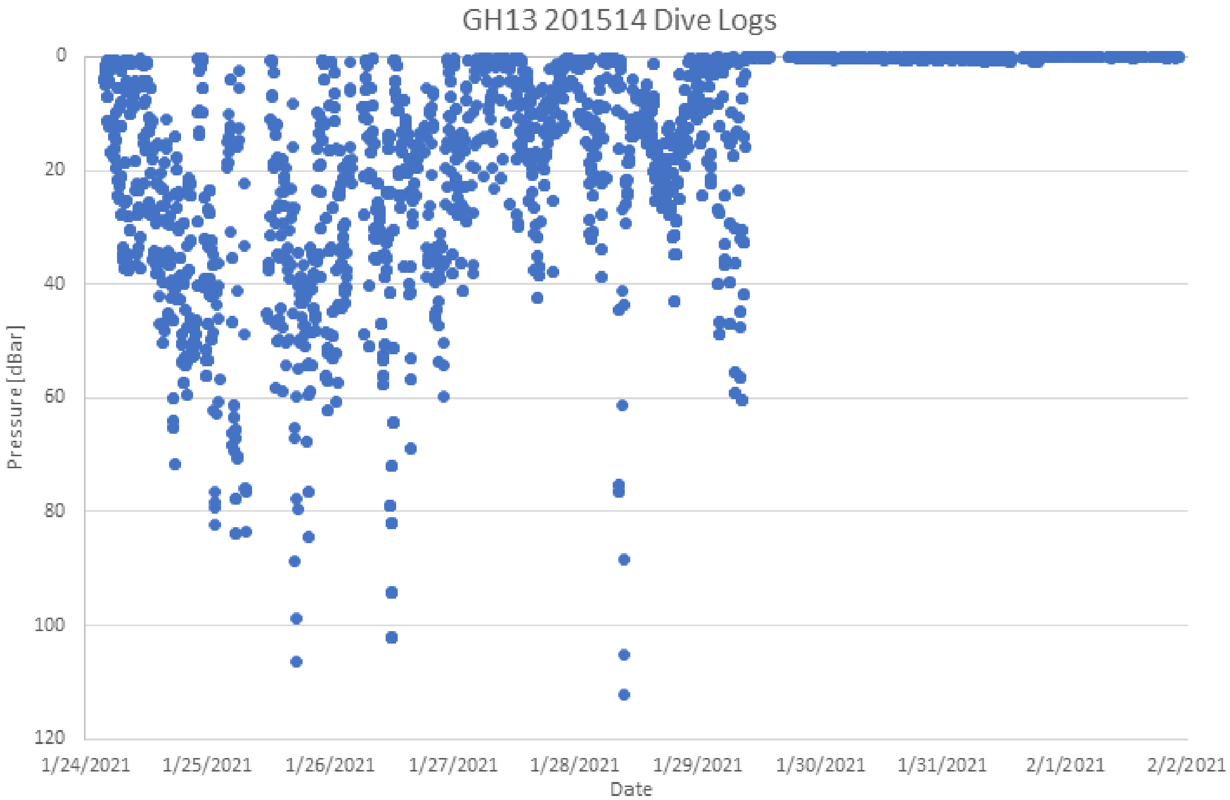
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