Tagging Green Sturgeon with Acoustic Transmitters for Evaluation of Habitat Use Along the Washington Coast

Annual Report
20 May 2022

Prepared for and funded by: U.S. Navy, Commander, Pacific Fleet
Submitted to Naval Facilities Engineering Systems Command Southwest under Cooperative Agreement #N62473-20-2-0005

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Suggested Citation: Heironimus, L.B., M.T. Sturza, and S.M. Schade. 2022. Tagging Green Sturgeon with Acoustic Transmitters for Evaluation of Habitat Use Along the Washington Coast. Interim Report. Prepared for: U.S. Navy, Commander, Pacific Fleet. Prepared by Washington Department of Fish and Wildlife under Cooperative Agreement #N62473-20-2-0005. 20 May 2022. 16 pp.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
20-05-2022	Monitoring report	2020 –2021

4. TITLE AND SUBTITLE
TAGGING GREEN STURGEON WITH ACOUSTIC TRANSMITTERS FOR EVALUATION OF HABITAT USE ALONG THE WASHINGTON COAST

5a. CONTRACT NUMBER
N62473-20-2-0005

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER
KB16

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander, U.S.Pacific Fleet, 250 Makalapa Dr. Pearl Harbor, HI

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Southern distinct population segment (DPS) of green sturgeon Acipenser medirostris is federally listed as a threatened species under the U.S. Endangered Species Act (ESA). Large aggregations of both the Northern DPS and Southern DPS of green sturgeon can be found congregating in Washington's coastal estuaries mid-summer. This provides a unique opportunity to capture and study this elusive species. Existing telemetric data indicates that these fish make long migrations along the Pacific Coast with a possible year-round presence in near-shore marine waters along Washington and Oregon's coastline. The U.S. Navy is interested in the occurrence of the threatened Southern DPS of green sturgeon in the Northwest Training and Testing (NWTT) study area, which is offshore of Washington, Oregon, and northern California.

Through a multi-agency collaborative effort, multiple acoustic receiver arrays were placed alongthe Pacific Northwest coast and estuaries to analyze the migratory patterns of green sturgeon and other migratory species, including an offshore acoustic receiver array along the coast of Washington and Oregon (funded by the U.S. Navy and operated by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service [NOAA-NMFS], a freshwater array within and at the mouth of Grays Harbor, Washington (funded by the U.S. Navy and NOAA NMFS, operated by Washington Department of Fish and Wildlife [WDFW]), a freshwater array within and at the mouth of Willapa Bay, Washington (funded by the U.S. Navy and NOAA NMFS, operated by WDFW and NOAA-NMFS), and a freshwater array within the ColumbiaRiver estuary, Washington (funded by NOAA-NMFS, operated WDFW). WDFW's operations to capture and sample a total of 230 green sturgeon in Grays Harbor and Willapa Bay in 2020 and 2021 was also a multi-

agency collaborative effort. The U.S. Navy funded the costs associated with acoustic tags implanted in 50 of the 110 total tagged fish, and the genetic analysis of all 188 fish analyzed, including 109 tagged fish (one tagged fished was not assigned to DPS due to an error in the field collecting the genetic sample). The U.S. Army Corps of Engineers provided 10 acoustic transmitters that were implanted in fish captured in Grays Harbor in 2020. NOAA-NMFS contributed funding the 2021 tagging operations, except WDFW provided the 50 acoustic transmitters implanted in fish captured during 2021.

During the 2020 tagging period, we (WDFW) attempted to tag only the first five fish of every 10 cm FL size range so that we could collect acoustic data across a range of sizes. After this goal was met, we tagged any fish captured in good condition to meet our tagging goal (2020 goal: 60 fish tagged, 2021 goal: 50 fish tagged). If a fish was in poor condition upon capture or too many fish were captured at the same time, fish were counted and released immediately to ensure survival this resulted in 40 green sturgeon releases without any tags applied across both years. In total, we implanted VEMCO 69-kHz V16 acoustic transmitters in 110 green sturgeon and implanted Biomark 12mm Passive Integrated Transponder (PIT) tags in 185 green sturgeon in Grays Harbor and Willapa Bay, Washington. No green sturgeon mortalities were detected as a result of this study. Using a genetics technique involving single nucleotide polymorphism (SNP) assay data, 188 total fish were assigned to either the Northern DPS (n=134 fish; 71%) or Southern DPS (n=54 fish; 29%). Of the fish implanted with acoustic tags, 71 fish (65%) were assigned to the Northern DPS, 38 fish (35%) were assigned to the Southern DPS, and one fish was not assigned.

Initial exploratory analysis of the acoustic data indicates that some green sturgeon can be detected on the offshoreacoustic receiver array year-round, with peak detections occurring around May. A majority of individual fish were detected on the offshore acoustic receiver array moving back and forth between the Columbia River estuary, Willapa Bay, and Grays Harbor during this period, though some individuals displayed long migrations up the coast and were detected off the coast of British Columbia. We intend to monitor the array for another year to explore differences in the spatial and temporal use of the offshore array between the Northern and Southern DPS of green sturgeon.

15. SUBJECT TERMS

Acoustic monitoring, Green Sturgeon, Northwest Training and Testing, acoustic transmitters

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
			UU	53	Department of the Navy
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified			**19b. TELEPONE NUMBER (*Include area code*)** 808-471-6391

Abstract

The Southern distinct population segment (DPS) of green sturgeon *Acipenser medirostris* is federally listed as a threatened species under the U.S. Endangered Species Act (ESA). Large aggregations of both the Northern DPS and Southern DPS of green sturgeon can be found congregating in Washington's coastal estuaries mid-summer. This provides a unique opportunity to capture and study this elusive species. Existing telemetric data indicates that these fish make long migrations along the Pacific Coast with a possible year-round presence in near-shore marine waters along Washington and Oregon's coastline. The U.S. Navy is interested in the occurrence of the threatened Southern DPS of green sturgeon in the Northwest Training and Testing (NWTT) study area, which is offshore of Washington, Oregon, and northern California.

Through a multi-agency collaborative effort, multiple acoustic receiver arrays were placed along the Pacific Northwest coast and estuaries to analyze the migratory patterns of green sturgeon and other migratory species, including an offshore acoustic receiver array along the coast of Washington and Oregon (funded by the U.S. Navy and operated by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service [NOAA-NMFS], a freshwater array within and at the mouth of Grays Harbor, Washington (funded by the U.S. Navy and NOAA-NMFS, operated by Washington Department of Fish and Wildlife [WDFW]), a freshwater array within and at the mouth of Willapa Bay, Washington (funded by the U.S. Navy and NOAA-NMFS, operated by WDFW and NOAA-NMFS), and a freshwater array within the Columbia River estuary, Washington (funded by NOAA-NMFS, operated WDFW). WDFW's operations to capture and sample a total of 230 green sturgeon in Grays Harbor and Willapa Bay in 2020 and 2021 was also a multi-agency collaborative effort. The U.S. Navy funded the costs associated with acoustic tags implanted in 50 of the 110 total tagged fish, and the genetic analysis of all 188 fish analyzed, including 109 tagged fish (one tagged fished was not assigned to DPS due to an error in the field collecting the genetic sample). The U.S. Army Corps of Engineers provided 10 acoustic transmitters that were implanted in fish captured in Grays Harbor in 2020. NOAA-NMFS contributed funding the 2021 tagging operations, except WDFW provided the 50 acoustic transmitters implanted in fish captured during 2021.

During the 2020 tagging period, we (WDFW) attempted to tag only the first five fish of every 10 cm FL size range so that we could collect acoustic data across a range of sizes. After this goal was met, we tagged any fish captured in good condition to meet our tagging goal (2020 goal: 60 fish tagged, 2021 goal: 50 fish tagged). If a fish was in poor condition upon capture or too many fish were captured at the same time, fish were counted and released immediately to ensure survival – this resulted in 40 green sturgeon releases without any tags applied across both years. In total, we implanted VEMCO 69-kHz V16 acoustic transmitters in 110 green sturgeon and implanted Biomark 12mm Passive Integrated Transponder (PIT) tags in 185 green sturgeon in Grays Harbor

and Willapa Bay, Washington. No green sturgeon mortalities were detected as a result of this study. Using a genetics technique involving single nucleotide polymorphism (SNP) assay data, 188 total fish were assigned to either the Northern DPS (n=134 fish; 71%) or Southern DPS (n=54 fish; 29%). Of the fish implanted with acoustic tags, 71 fish (65%) were assigned to the Northern DPS, 38 fish (35%) were assigned to the Southern DPS, and one fish was not assigned.

Initial exploratory analysis of the acoustic data indicates that some green sturgeon can be detected on the offshore acoustic receiver array year-round, with peak detections occurring around May. A majority of individual fish were detected on the offshore acoustic receiver array moving back and forth between the Columbia River estuary, Willapa Bay, and Grays Harbor during this period, though some individuals displayed long migrations up the coast and were detected off the coast of British Columbia. We intend to monitor the array for another year to explore differences in the spatial and temporal use of the offshore array between the Northern and Southern DPS of green sturgeon.

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Acronyms and Abbreviations

cm	Centimeters
DPS	Distinct Population Segment
ESA	United States Endangered Species Act
FL	Fork Length
FR	Federal Register
ITS	Incidental Take Statement
NAVFAC	Naval Facilities Engineering Command
nDPS	Northern Distinct Population Segment
NM	Nautical Mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWTT	Northwest Training and Testing Study Area
OCNMS	Olympic Coast National Marine Sanctuary
OPR	Office of Protected Resources
PIT	Passive Integrated Transponder
rkm	River Kilometer
sDPS	Southern Distinct Population Segment
SNPs	Single Nucleotide Polymorphisms
WDFW	Washington Department of Fish and Wildlife

Introduction

North American green sturgeon *Acipenser medirostris* are a long-lived, anadromous species, endemic along the west coast of North America. They depart their natal watersheds after only a few years, returning upon first spawning, and subsequent spawning events. Their sub-adult and adult life stages are spent mostly in the nearshore ocean and estuarine waters of the Pacific Northwest. Two distinct population segments (DPS) make up the overall population—the Southern DPS (sDPS), listed as threatened under the Endangered Species Act primarily due to ongoing threats to spawning and rearing habitat (ESA; 71 FR 17757, April 7, 2006; NMFS 2018) and the Northern DPS (nDPS), identified as a species of concern (Doukakis 2014). Adult sDPS green sturgeon are only known to spawn within the Sacramento River basin, California (NOAA 2018). However, existing telemetric data indicates that these fish make long migrations along the Pacific Coast with green sturgeon of both DPS coexisting in marine and estuarine waters from Alaska to Mexico and a possible year-round presence in near-shore marine waters along Washington and Oregon's coastline (Colway and Stevenson 2007; Lindley et al. 2008; Rosales-Cassian and Almeda-Juaregui 2009). From late spring to autumn, sub-adult and adult green sturgeon aggregate in relatively large concentrations in the Columbia River estuary, Willapa Bay, and Grays Harbor estuary (Moser and Lindley 2007; Lindley et al. 2011; Langness et al. 2014). These summer aggregations provide a unique opportunity to study and improve our understanding of general life history attributes of both DPS; however, genetic analysis is currently the only method available to identify fish to DPS within this range.

The U.S. Navy is interested in the occurrence of the threatened Southern DPS of green sturgeon in the Northwest Training and Testing (NWTT) study area, specifically off the Washington coast and coinciding with the timing of training and testing events. Between 2010 and 2012, Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) cumulatively captured a total of 1,335 individual green sturgeon across the Columbia River estuary, Grays Harbor, Willapa Bay, and the Umpqua River estuary (Langness et al. 2014). Additionally, 339 total green sturgeon were implanted with VEMCO 69-kHz V16 acoustic transmitters with a 10-year battery life during this study. Although at the time there was no acoustic receiver array available to evaluate the distribution of green sturgeon in nearshore marine waters, the long-life on the tags from this study allowed for detection data to be collected in May–September 2019 on an acoustic receiver array off the Washington coast, managed by researchers from the NOAA-NMFS. This study provided the initial detection data used to evaluate the occurrence of green sturgeon within the NWTT and determine potential project impacts and mitigation measures (OPR 2020). However, the majority of these tags have now come to the end of that battery life and cannot contribute further information to evaluate the presence of green sturgeon within the NWTT.

The primary objectives of this project are to (1) increase the number of fish tagged with passive integrated transponder (PIT) tags and acoustic transmitters, (2) analyze genetic samples to assign tagged fish to a DPS, and (3) assess the occurrence and distribution of ESA-listed Southern DPS green sturgeon in nearshore marine waters along the Washington coast, and specifically within the Northwest Training and Testing (NWTT) study area, using an offshore acoustic receiver array to evaluate the risks posed to the ESA-listed sDPS green sturgeon.

Methods

Fish Capture and Tagging

We targeted green sturgeon for capture in Grays Harbor and Willapa Bay, Washington during August to early September of 2020 and 2021—a period when green sturgeon congregate in large numbers and capture rates are high (Moser and Lindley 2007; Lindley et al. 2011; Langness et al. 2014). A contract commercial fisher was hired to assist in capturing fish using sinking gillnets, set stationary and perpendicular to the current whenever possible. The green sturgeon research nets consisted of three panels of between 18–24 cm (7.25, 8.50, and 9.75 inches) stretch mesh made of 6–18 strand monofilament, joined to form a 150-fathom (274 meters) net. Each panel measures 50-fathom (91 meters) by 5-fathom (9 meters). The single wall netting was evenly hung or hung slightly loose (> 2:1 ratio), without trammels or apron.

Nets were soaked during daylight hours, when bird and marine mammal activity can be observed, for approximately 15-minute sets, timed from the end of set to start of pull. If concentrations of birds or marine mammals were observed, set locations were moved to avoid gear entanglement. The nets were set at the beginning of the slack tide and fished no longer than early ebb or flood tide to avoid gear loss. When green sturgeon were observed in the net prior to the full length of the net being deployed, only 1–2 panels would be deployed in order to reduce the number of fish captured.

Figure 1. Image of the fish car attached to the side of the research vessel. This equipment is used to provide access to fresh oxygenated water for captured sturgeon prior to sampling and release for the purpose of decreasing handling stress and increasing the likelihood of post-release survival.

Fish sampling

During the 2020 tagging period, we (WDFW) attempted to tag only the first five fish of every 10 cm FL size range so that acoustic detection data would represent a range of different sized individuals. After this goal was met, we

Figure 2. Image of a green sturgeon examined with an obvious fin deformity.

tagged any fish captured in good condition to meet our tagging goal (2020 goal: 60 fish tagged, 2021 goal: 50 fish tagged). Captured fish were placed in the fish car (developed during the FY2010–2013 Section 6 grant study; Langness et al. 2014) to reduce stress until sampled (Figure 1). Fish were subsequently examined for deformities, erosion, lesions, and tags (DELTS; Figure 2), measured to the nearest cm fork length (FL), measured to the nearest cm girth, tagged with a PIT tag if no tags are present, and photographed. Due to limitations in equipment and deck space and the desire to limit handling stress, a majority of fish were not weighed as a part of this study; however, girth data was collected as surrogate information to inform fish condition. For genetic analysis and assignment of individuals to the Southern or Northern DPS, we removed a small fin clip from the pelvic fin and sent the desiccated sample to the genetics lab at the Southwest Fisheries Science Center to be analyzed using the single nucleotide polymorphisms (SNPs) analysis technique (Anderson et al. 2017). Additionally, in a subsample of fish we opportunistically collected blood plasma to evaluate sex and maturity through sex-steroid analysis and a fin ray section for age analysis, though the analyses of these collections were not a funded part of this project. Finally, we surgically implanted a VEMCO 69-kHz V16 acoustic transmitter (10-year battery life; Figure 3) before releasing the fish directly to the bay or estuary. Details on the state and federal agencies responsible for the sampling efforts and funding for this work can be found in Table 1.

Figure 3. Image of a WDFW researcher in the process of suturing the incision wound on a green sturgeon after implanting a VEMCO 69-kHz V16 acoustic transmitter (Left Panel) and a image of a pair of complete sutures closing an incision wound (Right Panel).

Sturgeon that appeared to be stressed were returned to the fish car and kept there until equilibrium, breathing, and strength return (Figure 1). When more fish were captured than could safely be held within the confines of the fish car, the additional fish were not tagged with an acoustic transmitter to reduce handling stress and were returned directly to the bay or estuary after sampling.

Table 1. Summary of the funded sturgeon sampling activities described in this report and the agencies responsible for funding each activity. Agencies described under the "funding" headers include: (A) Washington Department of Fish and Wildlife, (B) U.S. Navy, Commander, Pacific Fleet, (C) National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and (D) U.S. Army Corps of Engineers-Seattle District.

Year	Area	Action	n	unit	Funding
2020	Willapa Bay	Gillnetting/Vessel Operations	4	days on water	B
		Green Sturgeon Captured	38	fish handled	B
		Acoustic Transmitters	25	fish tagged	B
		Genetic Analysis	38	clips analyzed	B
	Grays Harbor	Gillnetting/Vessel Operations	6	days on water	B
		Green Sturgeon Captured	87	fish handled	B
		Acoustic Transmitters	25	fish tagged	B
		Acoustic Transmitters	10	fish tagged	D
		Genetic Analysis	85	clips analyzed	B
2021	Grays Harbor	Gillnetting/Vessel Operations	4	days on water	C
		Green Sturgeon Captured	105	fish handled	C
		Acoustic Transmitters	50	fish tagged	A
		Genetic Analysis	65	clips analyzed	B
Total	Combined	Gillnetting/Vessel Operations	13	days on water	
		Green Sturgeon Captured	230	fish handled	
		Acoustic Transmitters	110	fish tagged	
		Genetic Analysis	188	clips analyzed	

Acoustic Receivers

WDFW operated four VEMCO 69-kHz VR2W acoustic receivers at the mouth of Grays Harbor from May 5 to October 22, 2020 and from May 20 to October 22, 2021 to assess green sturgeon tagging survival and to determine the period of migration of tagged individuals from the estuarine to marine environment (Table 2; Figure 4). For the same purpose, WDFW operated another two VEMCO 69-kHz VR2W acoustic receivers at the mouth of Willapa Bay from August 10 to October 15, 2020 and from June 3, 2020 to January 21, 2022 (Table 2; Figure 4). Throughout 2020 and 2021, estuarine habitat use was monitored using VEMCO 69-kHz acoustic receiver arrays in Grays Harbor and the Columbia River estuary operated by WDFW and in Willapa Bay operated by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service

(NOAA-NMFS). Additionally, a primarily U.S. Navy-funded offshore acoustic receiver array, comprised of 87–181 VEMCO 69-kHz acoustic receivers, was operated by NOAA-NMFS research staff from 2019 through 2021 (Table 2; Figure 4). Green sturgeon detections on this offshore array were monitored to evaluate migrations along the coast and within the NWTT. Details on the state and federal agencies responsible for the operations and funding for these acoustic receiver arrays can be found in Table 2.

Table 2. Summary of the funded acoustic receiver deployments from which detection data described in this report originated and the agencies responsible for operating and funding these receiver deployments. The count "n" is a sum of the total receivers included in that line item. Agencies described under the "operations" and "funding" headers include: (A) Washington Department of Fish and Wildlife, (B) U.S. Navy, Commander, Pacific Fleet, (C) National Oceanic and Atmospheric Administration, National Marine Fisheries Service, (D) U.S. Army Corps of Engineers-Seattle District, and (E) Department of Fisheries and Oceans Canada.

Year	Area	n	Operations	Funding
2019	Columbia River	11	A	C
	Willapa Bay	10	C	C
	Grays Harbor	7	A	C
	Offshore – USA	181	C	B/C
	Offshore – Canada	0	F	F
2020	Columbia River	6	A	C
	Willapa Bay	2	A	B
	Willapa Bay	9	C	C
	Grays Harbor	2	A	B
	Grays Harbor	6	A	C
	Offshore – USA	87	C	B
	Offshore – Canada	0	F	F
2021	Columbia River	5	A	C
	Willapa Bay	2	A	B
	Willapa Bay	9	C	C
	Grays Harbor	2	A	B
	Grays Harbor	8	A	C
	Offshore – USA	154	C	B
	Offshore – Canada	39	F	F

Sampling Permits

The proposed project "Tagging Green Sturgeon with Acoustic Transmitters in Washington Coastal Estuaries" has been granted ESA authorization under the ESA Section 4(d) Rule. While ESA Section 9 prohibits take of listed species, ESA Section 4(d) limits the prohibition of take for specific existing state and local programs and creates a means for NOAA to approve programs if

they meet certain standards set out in the rule. The specific standards regarding this project are set out in Limit 7, "Scientific Research Activities Conducted by The States". The NOAA reference numbers for this project's authorizations are "23319" for 2020, "24120" for 2021, and "26172" for 2022.

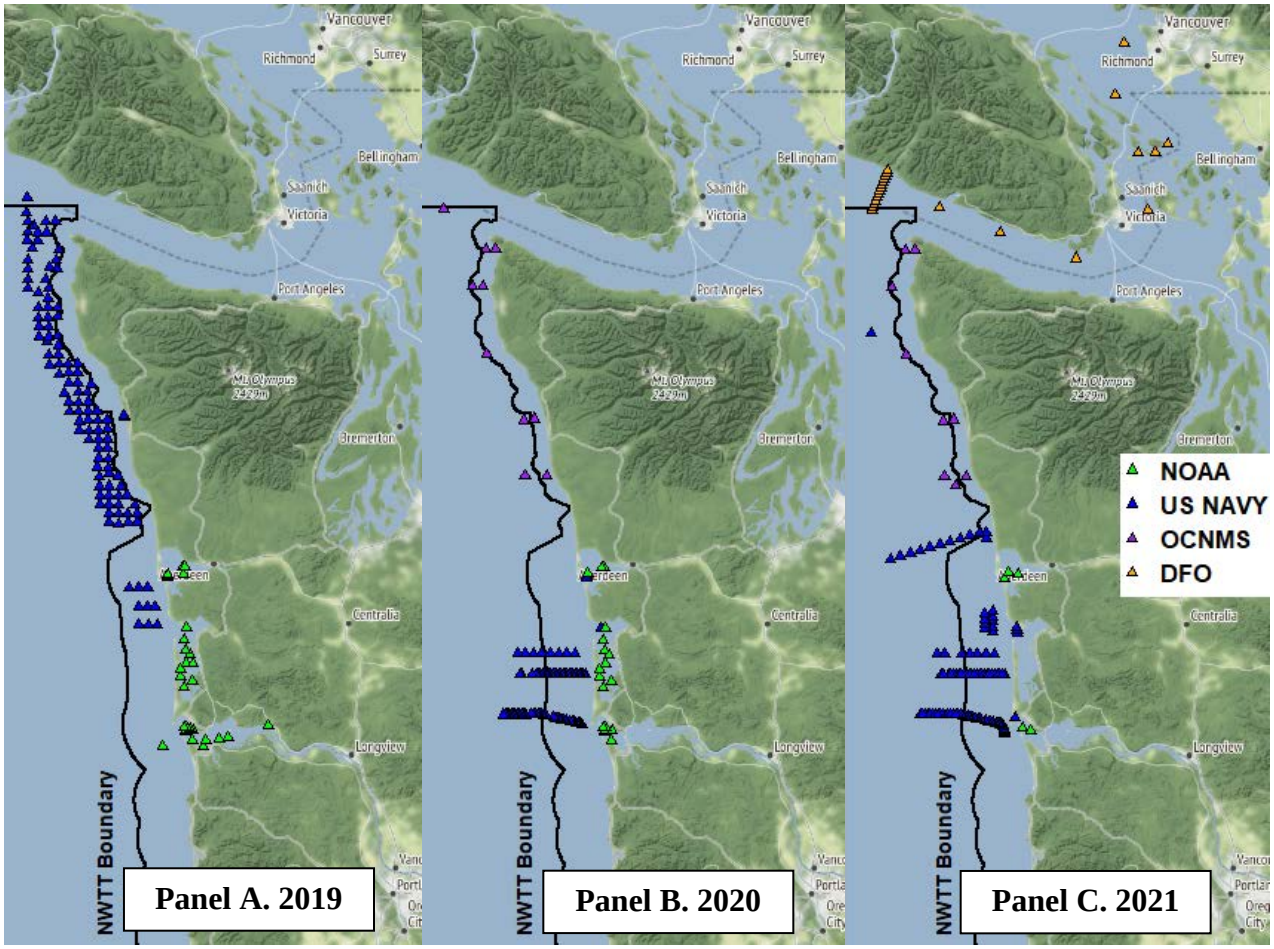

Figure 4. A map of acoustic receivers analyzed for green sturgeon detections, deployed during 2019 (Panel A), 2020 (Panel B), and 2021 (Panel C). The fill color of each symbol indicates the funding source for each receiver deployment, green symbols were funded by National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA-NMFS; labeled as NOAA), blue symbols were funded by the U.S. Navy (labeled as US Navy), purple symbols are within the Olympic Coast National Marine Sanctuary and funded by NOAA-NMFS (labeled: OCNMS), and orange symbols were funded by Department of Fisheries and Oceans Canada (DFO).

Preliminary Results and Discussion

Fish Capture and Tagging

A total of 230 green sturgeon were captured in Grays Harbor and Willapa Bay in 2020 and 2021. Of those, 125 green sturgeon were captured during 334 minutes of fishing over 20 net sets in 2020 and 105 green sturgeon were captured during 92 minutes of fishing over 6 nets sets in 2021. We

had originally planned for half hour net sets, but it took less time than anticipated for an adequate number of fish to be captured. No green sturgeon mortalities were detected as a result of this study.

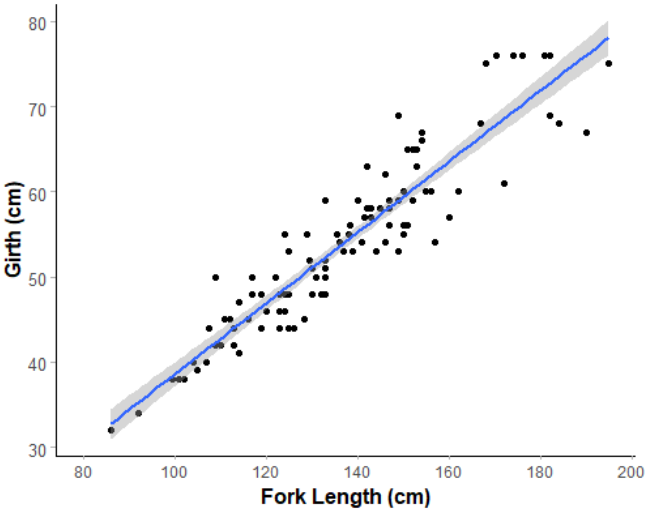

Figure 5. Plot of fork length (cm) and girth (cm) data for all green sturgeon sampled in 2020 and 2021. The correlation coefficient between these variables indicated a strong relationship, r=0.93.

The 38 green sturgeon captured in Willapa Bay during August 10–13, 2020, ranged 102–191 cm Fork Length (FL) and 38–76 cm girth (Figure 5). The 87 green sturgeon captured in Grays Harbor during August 17–20 and August 25–26, 2020, ranged 74–195 cm FL and 32–80 cm girth. During August 26, 27, 30, and September 2, 2021, another 105 green sturgeon were captured in Grays Harbor, ranging in size 92–190 cm FL and 34–76 cm girth. Girth data was collected in place of weight data as a surrogate for evaluating fish condition. The linear relationship between FL and girth has a strong coefficient of r=0.93, indicating a strong relationship between these variables with no obvious outliers. The relationship becomes weaker at larger sizes, which we hypothesize may be related to spawning maturity and differences between sexes; however, this information is not available to evaluate.

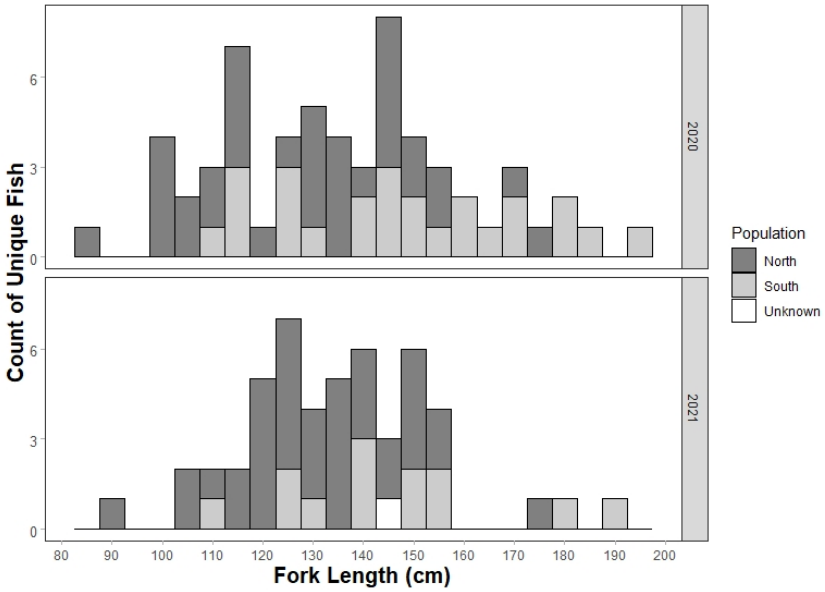

Figure 6. Length-frequency histograms of green sturgeon implanted with acoustic transmitters in 2020 (top panel) and 2021 (bottom panel). Shading indicates population assignment to either the northern DPS (dark gray), the southern DPS (light gray), or unknown assignment (white).

All fish were scanned for a pre-existing PIT tag prior to release, including the 39 fish captured in a single set on September 2, 2021, which were released immediately due to the high catch rates and the desire to reduce the overall handling time, and the two fish captured in poor condition, which were released immediately after recovery in the fish car. A PIT tag was implanted in 185 fresh green sturgeon (meaning no prior PIT tag was detected), 188 green sturgeon

were sampled for genetic tissue (fin tissue), 18 fish were weighed, 33 fin ray sections were collected (from the bony section of the fin ray), and 132 blood plasma samples were collected.

A total of 110 green sturgeon were implanted with acoustic transmitters across 2020 and 2021 (Figure 6; Table 3); of those, 25 were captured and released in Willapa Bay in 2020, 35 fish were captured and released in Grays Harbor in 2020, and 50 fish were captured and released in Grays Harbor in 2021. Of those tagged, 50 transmitters were contributed by the US. Navy, 10 transmitters were contributed by the U.S. Army Corps of Engineers, and 50 transmitters were contributed by WDFW (Table 1).

Table 3. Length and girth statistics for green sturgeon implanted with acoustic transmitters and assigned to the Northern DPS or the Southern DPS collected in Willapa Bay and Grays Harbor in 2020 and 2021. A genetics sample was not collected for the one fish un-assigned to a DPS.

		Sample	Fork Length (cm)		Girth (cm)	
Year	Area	Size	Mean	Range	Mean	Range
Northern DPS						
2020	Willapa Bay	20	130.4	86.0–176.0	53.1	32.0–76.0
	Grays Harbor	15	126.7	102.0–157.0	48.7	38.0–58.0
2021	Grays Harbor	36	130.9	92.0–174.0	51.0	34.0–76.0
Southern DPS						
2020	Willapa Bay	15	152.9	113.0–195.0	60.8	42.0–76.0
	Grays Harbor	10	141.4	103.0–184.0	56.0	48.0–76.0
2021	Grays Harbor	13	145.3	111.0–190.0	56.4	43.0–69.0
Un-assigned DPS						
2021	Grays Harbor	1	144.0	144.0	53.0	53.0

Using a genetics technique involving single nucleotide polymorphism (SNP) assay data, 188 total fish sampled in 2020 and 2021 were assigned to a genetic population. Of those, 134 green sturgeon (71% of the total analyzed) were assigned to the nDPS and 54 green sturgeon (29% of the total analyzed) were assigned to the sDPS. A subset of the fish analyzed were implanted with acoustic transmitters, including 71 green sturgeon assigned to the nDPS (65% of tagged fish) and 38 green sturgeon assigned to the sDPS (35% of tagged fish; Figure 6; Table 3). One fish implanted with an acoustic transmitter was not assigned to a DPS due to an error in the field collecting the genetic sample (Figure 6; Table 3). During a WDFW-led study that took place in 2010–2012, the ratios of sDPS to nDPS fish were more even (Langness et al. 2014). In that study, 87 green sturgeon were assigned to sDPS (51% of the total analyzed) and 82 green sturgeon were assigned to nDPS (49% of the total analyzed). The differences in the proportion of each DPS represented from the earlier study to the recent study are unknown but may be a result of differences in sampling area and timing or changes in population abundances for one or both DPS.

Acoustic Receivers

All WDFW operated acoustic receivers that were recovered from the 2020 and 2021 field seasons have been downloaded and assessed for green sturgeon detections. Of the four acoustic receivers funded by the U.S. Navy, three were recovered in 2020 and 2021. The missing receiver in both years was lost near the entrance to Willapa Bay and other nearby researchers have been notified in case it is recovered.

WDFW staff coordinated with NOAA-NMFS researchers operating the offshore array to collect acoustic receiver deployment and fish detection data from May 2019 through February 2022. The greatest number of acoustic receivers within the NWTT (n=97) were deployed May 2019 through March 2020 and were distributed between the Canadian border and the entrance to Grays Harbor, Washington (Figures 9–19). Between April and June 2020, there were no acoustic receivers present within the NWTT (Figures 20–22). During July 2020, three rows of receivers oriented east to west were deployed between the Columbia River mouth and the entrance to Willapa Bay, of which only a portion were situated within the NWTT (Figure 23).

Fish Detections

Among the fish that were tagged in Grays Harbor in 2020 and 2021 each individual was detected for a minimum of one month at multiple receivers within the estuary or at the entrance to the bay (suggesting an exit of Grays Harbor to the Pacific Ocean). This detection period suggests no immediate mortalities resulting from the tagging procedure. In 2020, we detected all but two of the fish tagged in Willapa Bay at the recovered receiver that was set at the entrance to the bay. Due to the placement of the recovered receiver; we assume that these detections likely include fish that were physically located within the deeper north channel at the mouth of Willapa Bay. Eight fish tagged in 2020 were detected in both Grays Harbor and Willapa Bay, half of these moved north from Willapa Bay to Grays Harbor and the other half moved south from Grays Harbor to Willapa Bay. This includes one fish that moved progressively south from Grays Harbor to Willapa Bay and finally the Columbia River estuary. Eight of the fish tagged in Grays Harbor during 2021 were subsequently detected in Willapa between August and October 2021. Three different fish tagged in 2021 were also detected within the Columbia Estuary between September and October 2021.

Green sturgeon were detected in the offshore acoustic receiver array nearly every month in which data was available between March 2019 and February 2022, with the exception of the period in which no receivers were present in the NWTT (from April through June 2020) and the notable lack of detections from both July 2020 and July 2021 (Figure 7). The lack of any July 2020 and 2021 detections may be a result of the receiver deployment schedule or poor coverage within the NWTT; however, detection data from within the coastal estuaries supports previous

findings that green sturgeon are aggregating in large numbers within the estuarine waters during these summer months (Figures 11–13; Figures 23–25; Figures 35–37). Additionally, preliminary results indicate no obvious differences in detections within the NWTT between the sDPS and nDPS green sturgeon.

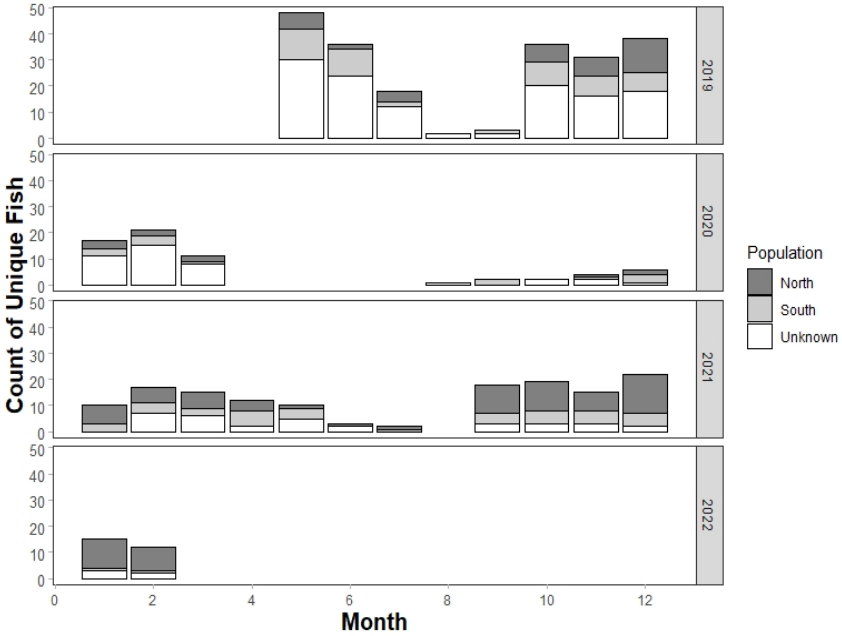

Figure 7. Frequency of unique green sturgeon detections within the NWTT from May 2019 (top panel) through February 2022 (bottom panel). Shading indicates population assignment to either the northern DPS (dark gray), the southern DPS (light gray), or unknown assignment (white). No acoustic receivers were deployed within the NWTT in April through June 2020.

To evaluate green sturgeon occurrence within the NWTT during the training and testing period, July 1 through September 30, it is important to consider the acoustic receiver spatial and temporal coverage in addition to the detections of tagged fish. The best coverage for evaluating green sturgeon detections in the NWTT north of Grays Harbor occurred in 2019, prior to the tagging efforts that took place in 2020 and 2021. Therefore, all green sturgeon detected within this time range were tagged during previous studies.

Green sturgeon were detected within the NWTT during each month between May 2019 and March 2020, but the highest count of unique fish was in May 2019 (Figures 7). In July–September 2019, a total of 23 unique green sturgeon were detected within the NWTT, including 18 green sturgeon in July, 2 green sturgeon in August, and 3 green sturgeon in September. During this same time period, a total of 102 unique green sturgeon were detected on all other acoustic receivers, outside of the NWTT, including 82 green sturgeon in July, 101 green sturgeon in August, and 71 green sturgeon in September. Indicating the abundance of green sturgeon inside of the NWTT decreased during the summer as fish moved into coastal Washington estuaries, and increased as fish moved back offshore during October. This is consistent with findings from Moser and Lindley (2007), where green sturgeon were only detected in Willapa Bay during the summer months when estuarine water temperature was high relative to the coastal ocean, primarily May through September.

Both the number of fish detected and the total number of detections decreased during January – March 2020 relative to the fall of 2019; which is likely a result of reaching the end-of-life on the ten-year acoustic transmitters in previously tagged fish. Due to the more limited spatial distribution of the offshore array, acoustic detections occurred primarily within the coastal estuaries during the summer of 2020 (Figures 23–25). Detections within the NWTT were observed between August 2020 and June 2021 on the aforementioned three rows of acoustic receivers, but were still primarily concentrated east of the NWTT boundary (Figures 24–35). The majority of acoustic receivers that had been used to detect green sturgeon north of Grays Harbor in 2019 were not deployed within the same region of the NWTT in 2020; therefore, monitoring of the consistency green sturgeon occupancy of this habitat is not possible during this period.

Similar to the previous two years, detections were primarily concentrated within the coastal estuaries during the summer of 2021 (Figures 35–37). A row of offshore receivers primarily situated within the NWTT was deployed during September 2021 north of the entrance to Grays Harbor (Figure 37). There were no detections observed on this row of receivers until November 2021, with the peak number of fish and detections during December 2021, before declining between January–February 2022 (Figures 38–41). Similar to 2020, the majority of acoustic receivers that had been used to detect green sturgeon north of Grays Harbor in 2019 were not deployed within the same region of the NWTT in 2021; therefore, monitoring of the consistency green sturgeon occupancy of this habitat is not possible during this period.

The offshore array dataset also included information pertaining to the depths at which acoustic receivers were deployed. Using this information, we can evaluate the depths at which green sturgeon were commonly detected (Figure 8). Year-round data suggests that a majority of green sturgeon occupy depths less than 110m, consistent with findings from Erickson and Hightower (2007). However, we did detect a few individuals in deeper marine waters, with at least one individual detected at depths ranging 275–300m. During the July 1–September 30 period, all detections were in waters less than 100m, with no detections occurring in 2020 (Figure 8).

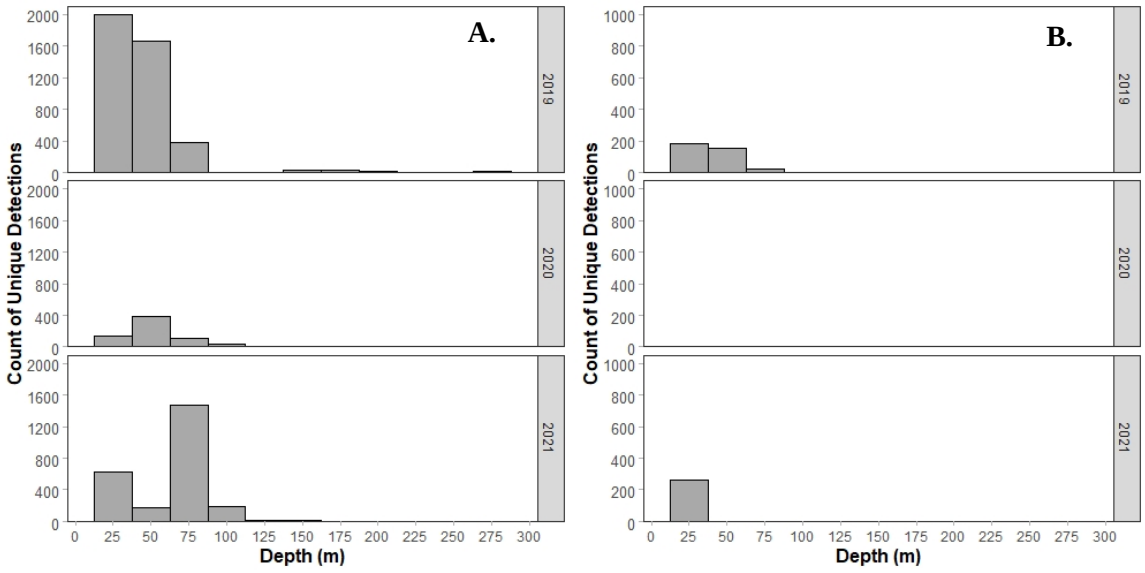

Figure 8. Unique detections of green sturgeon within the NWTT boundary by depth (bin width=25 m), between 2019–2021. Panel A includes year-round acoustic detections. Panel B includes acoustic detections during July 1 through September 30 only.

Current Project Status

Over the course of the next year, we intend to collaborate with researchers at NOAA-NMFS, U.S. Fish and Wildlife Service, University of California-Davis, California Department of Fish and Wildlife, California Department of Water Resources, the Yurok Tribe, and Department of Fisheries and Oceans Canada on the collection of acoustic data and to further explore the temporal and spatial distribution of the tagged green sturgeon. We plan to analyze the acoustic data to assess similarities and differences between the Northern and Southern DPS of green sturgeon in their distribution and migratory habits along the offshore array, as well as collect data from California researchers to better capture the full range of migration for these fish.

Acknowledgements

Thanks to Dave Hollingsworth and family for providing a gillnetting boat and invaluable fishing experience to help us locate, capture, and sample all of the study fish. Thanks to the WDFW staff, including James Losee, Jody Pope, Zachary Forster, Phillip Dionne, and Bradley Cady for their project support. Thanks to Drs. David Huff, Joe Smith, Mary Moser, and Steve Corbett of NOAA-NMFS for coordinating and collecting acoustic telemetry data. Thank you to Vanessa Pepi of the U.S. Army Corps of Engineers, Seattle District for providing additional acoustic transmitters for this project. This research was funded by the U.S. Navy, Commander, Pacific Fleet, under the Navy's Marine Species Monitoring Program, through a CESU agreement (Cooperative Agreement #N62473-20-2-0005) administered by Naval Facilities Engineering Command (NAVFAC)

Southwest. Thanks to Andrea Balla-Holden (Pacific Fleet), Chris Hunt (NAVFAC Northwest), Jessica Curran (NAVFAC Southwest), Brittany Bartlett (NAVFAC Pacific), and Dr Jessica Chen (NAVFAC Pacific) for providing invaluable assistance in making this project successful.

References

Anderson, E.C., T.C. Ng, E. Crandall, and J.C. Garza. 2017. Genetic and individual assignment of tetraploid green sturgeon with SNP assay data. Conservation Genetics. 18. 10.1007/s10592-017-0963-5.

Colway, C. and D. E. Stevenson. 2007. Confirmed Records of Two Green Sturgeon from the Bering Sea and Gulf of Alaska. Northwestern Naturalist 88:188–192.

Doukakis, P. 2014. Informal status review for the Northern Distinct Population Segment of the North American Green Sturgeon (Acipenser medirostris). NOAA Fisheries.

Erickson, D. L. and J. E. Hightower. 2007. Oceanic Distribution and Behavior of Green Sturgeon. American Fisheries Society Symposium 56:197–211.

Langness, O.P., P.E. Dionne, C.W. Wagemann, P.A. McHugh, D.L. Warren, M.L. Brown, B.W. James, A.J. Storch, and E.S. Van Dyke. 2014. Green sturgeon distribution and abundance in Washington and Oregon coastal estuaries. Report A in Study of Green Sturgeon in the west coast of the United States. C. Mallette editor. Final report for NOAA Fisheries Protected Species Conservation and Recovery Grant Number NA10NMF720037. 197p.

Lindley, S. T., M. L. Moser, D. L. Erickson, M. Belchik, D. W. Welch, E. L. Rechisky, J. T. Kelly, J. Heublein, and A. P. Klimley. 2008. Marine Migration of North American Green Sturgeon. Transactions of the American Fisheries Society 137(1):182–194.

Lindley, S. T., D. L. Erickson, M. L. Moser, G. Williams, O. P. Langness, B. W. McCovey, M. Belchik, D. Vogel, W. Pinnix, J. T. Kelly, J. C. Heublein, and A. P. Klimley. 2011. Electronic Tagging of Green Sturgeon Reveals Population Structure and Movement among Estuaries. Transactions of the American Fisheries Society 140(1):108–122.

Moser, M.L., and S.T. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Env. Biol. Fish. 79:243–253.

NMFS (National Marine Fisheries Service). 2018. Recovery Plan for the Southern Distinct Population Segment of North American Green Sturgeon (Acipenser medirostris). National Marine Fisheries Service, Sacramento, CA.

OPR (Office of Protected Resources). 2020. Biological and Conference Opinion on (1) U.S. Navy Northwest Training and Testing Activities (NWTT); and (2) the National Marine Fisheries Service's promulgation of regulations and issuance of a letter of authorization pursuant to the Marine Mammal Protection Act for the U.S. Navy to "take" marine mammals incidental to NWTT activities from November 2020 through November 2027. OPR-2019-00786. Published by Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 998 p. DOI: <https//doi.org/10.25923/7034-6a18>

Rosales-Cassian, J. R. and C. Almeda-Juaregui. 2009. Unusual Occurrence of a Green Sturgeon (Acipenser medirostris) at El Socorro Bay, Baja California, Mexico California Cooperative Fisheries Investigations. CalCOFI Reports 50:169–171.

Appendix A. Detection Maps

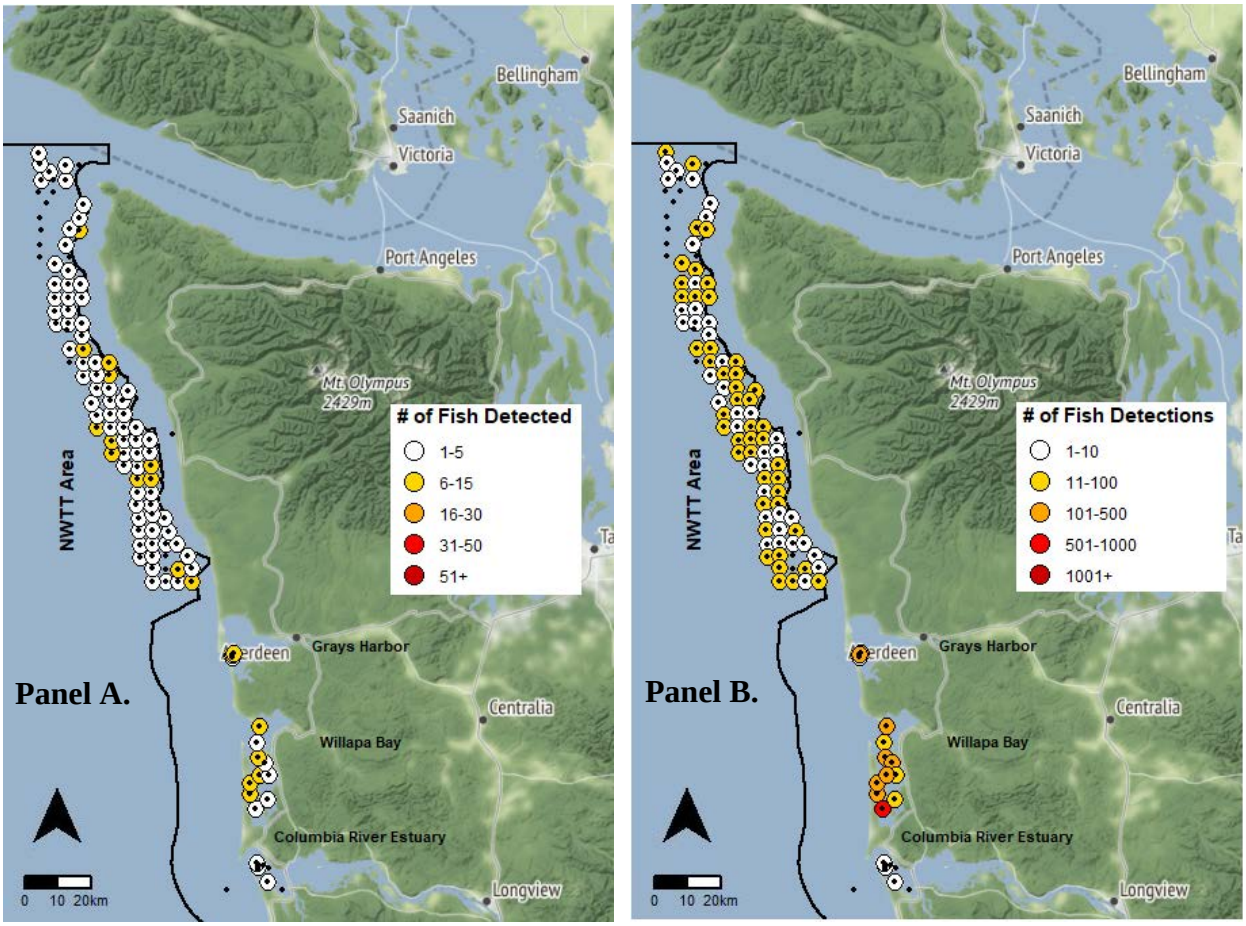

Figure 9. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of May 2019. A total of 64 unique individuals were detected during this period.

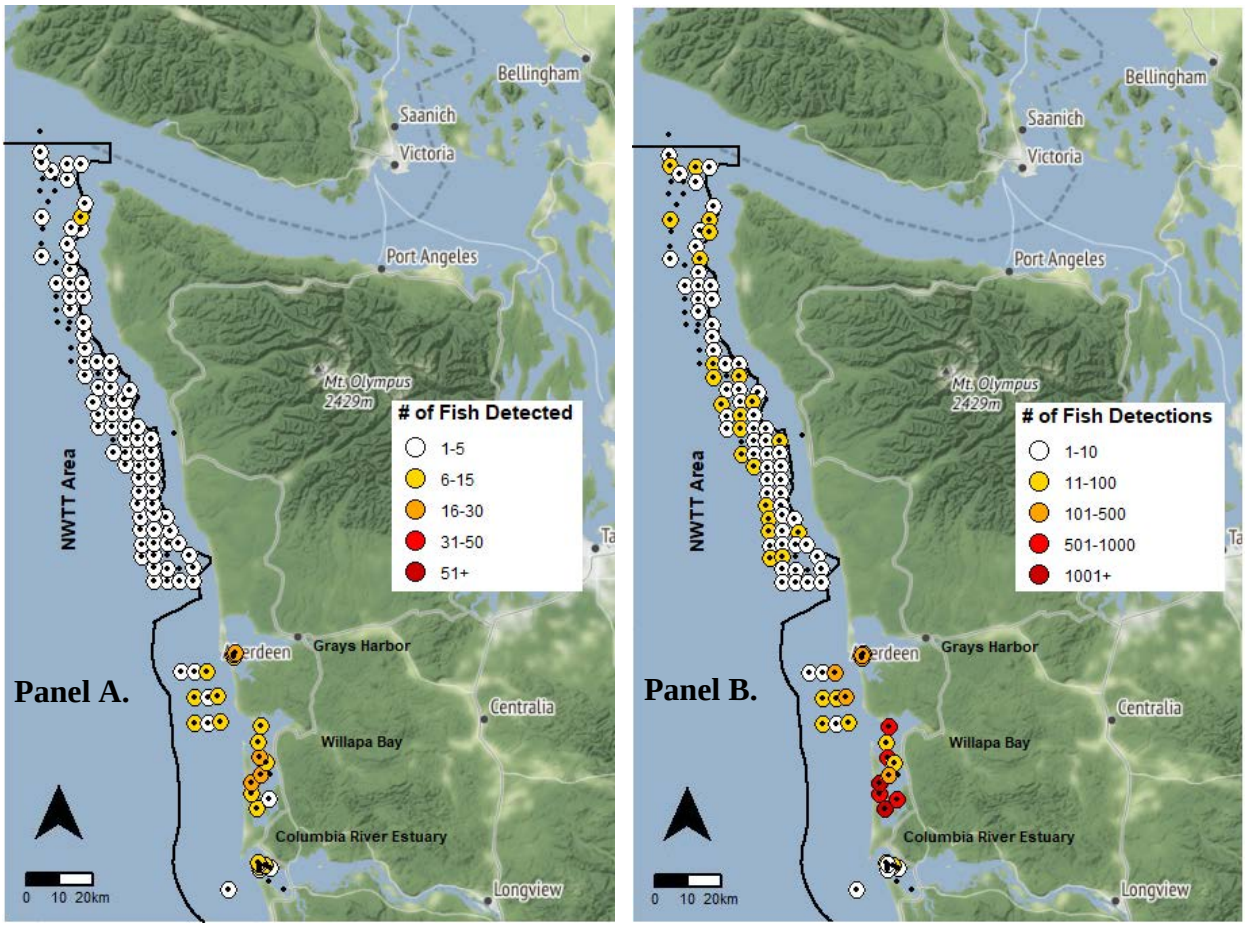

Figure 10. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of June 2019. A total of 93 unique individuals were detected during this period.

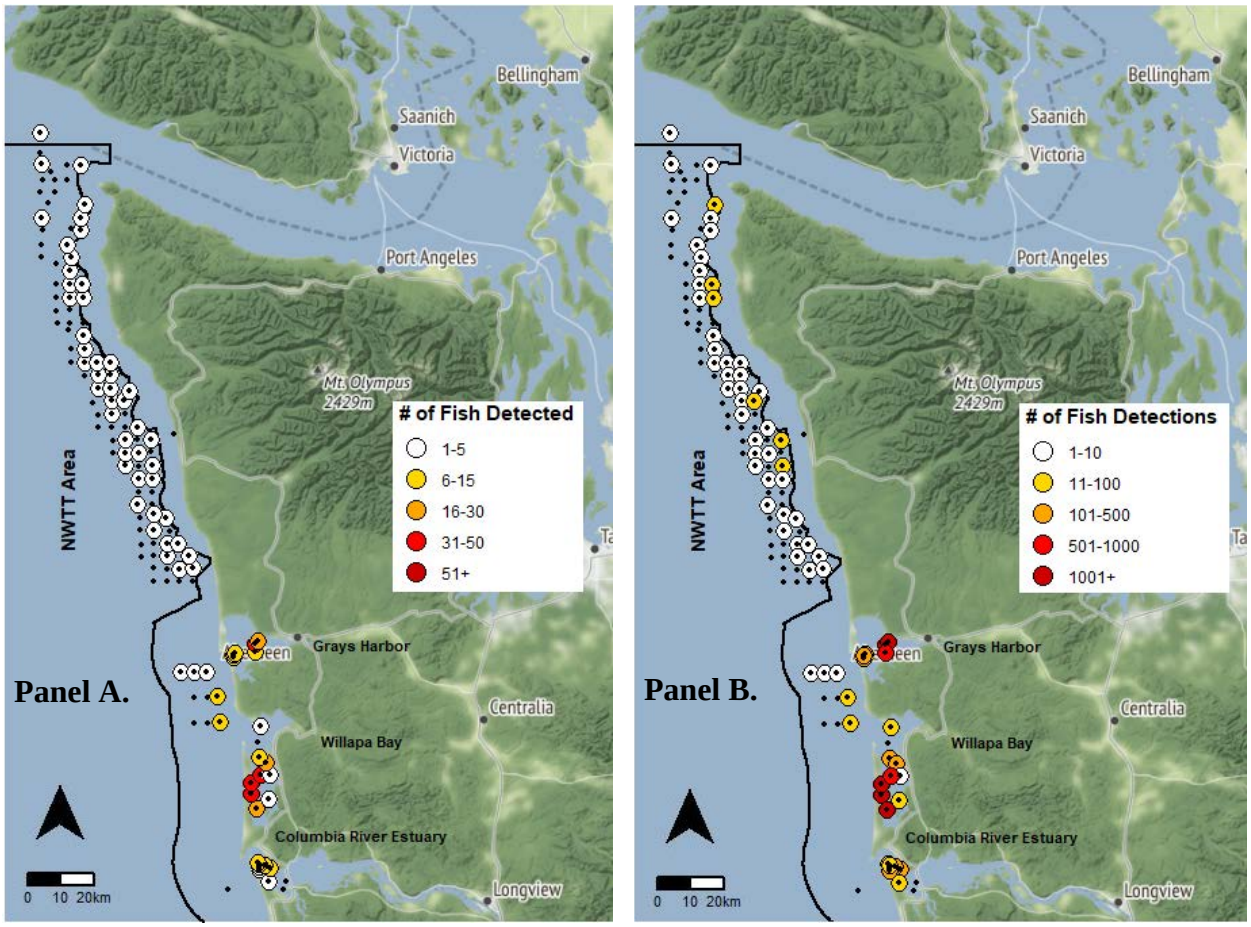

Figure 11. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of July 2019. A total of 100 unique individuals were detected during this period.

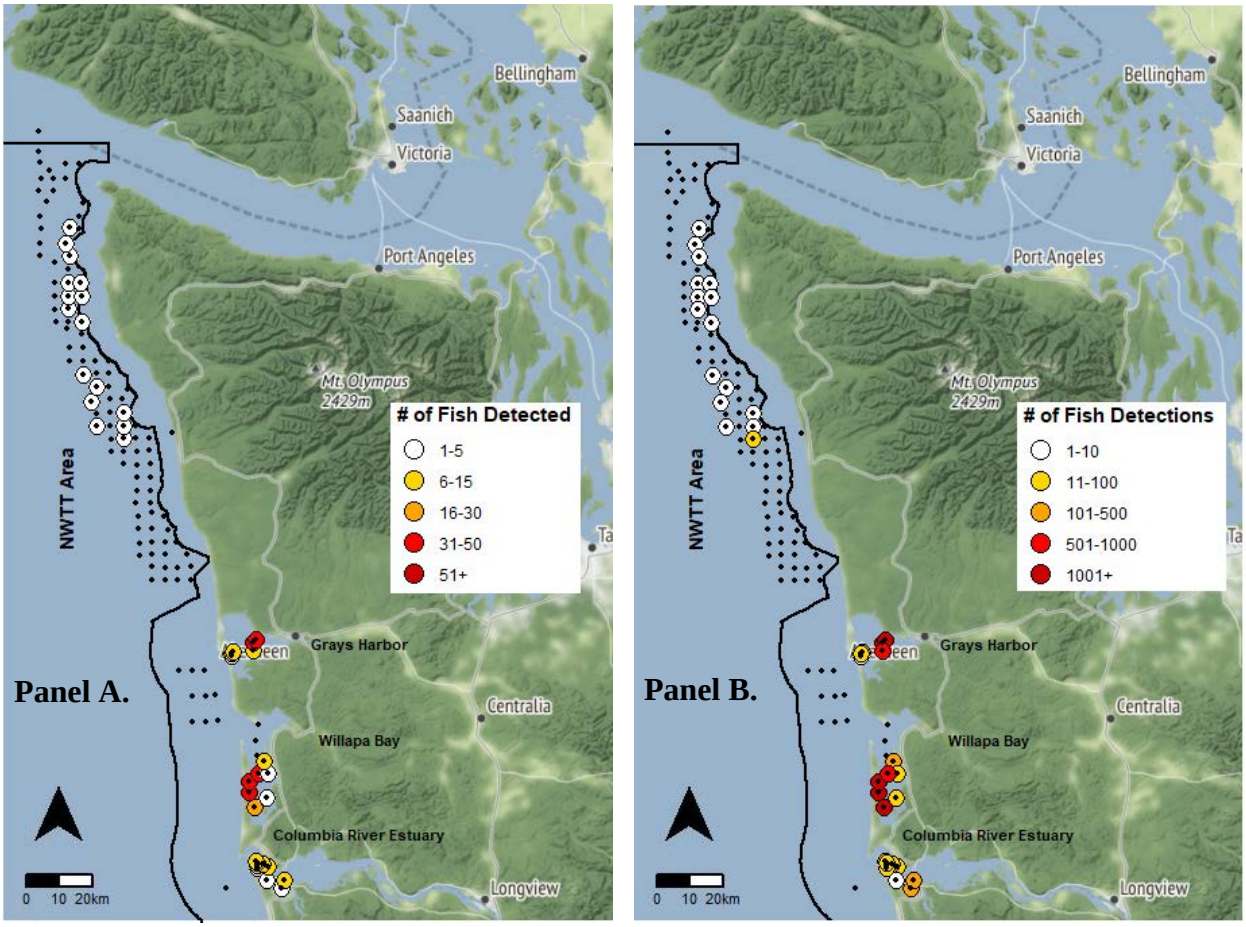

Figure 12. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of August 2019. A total of 103 unique individuals were detected during this period.

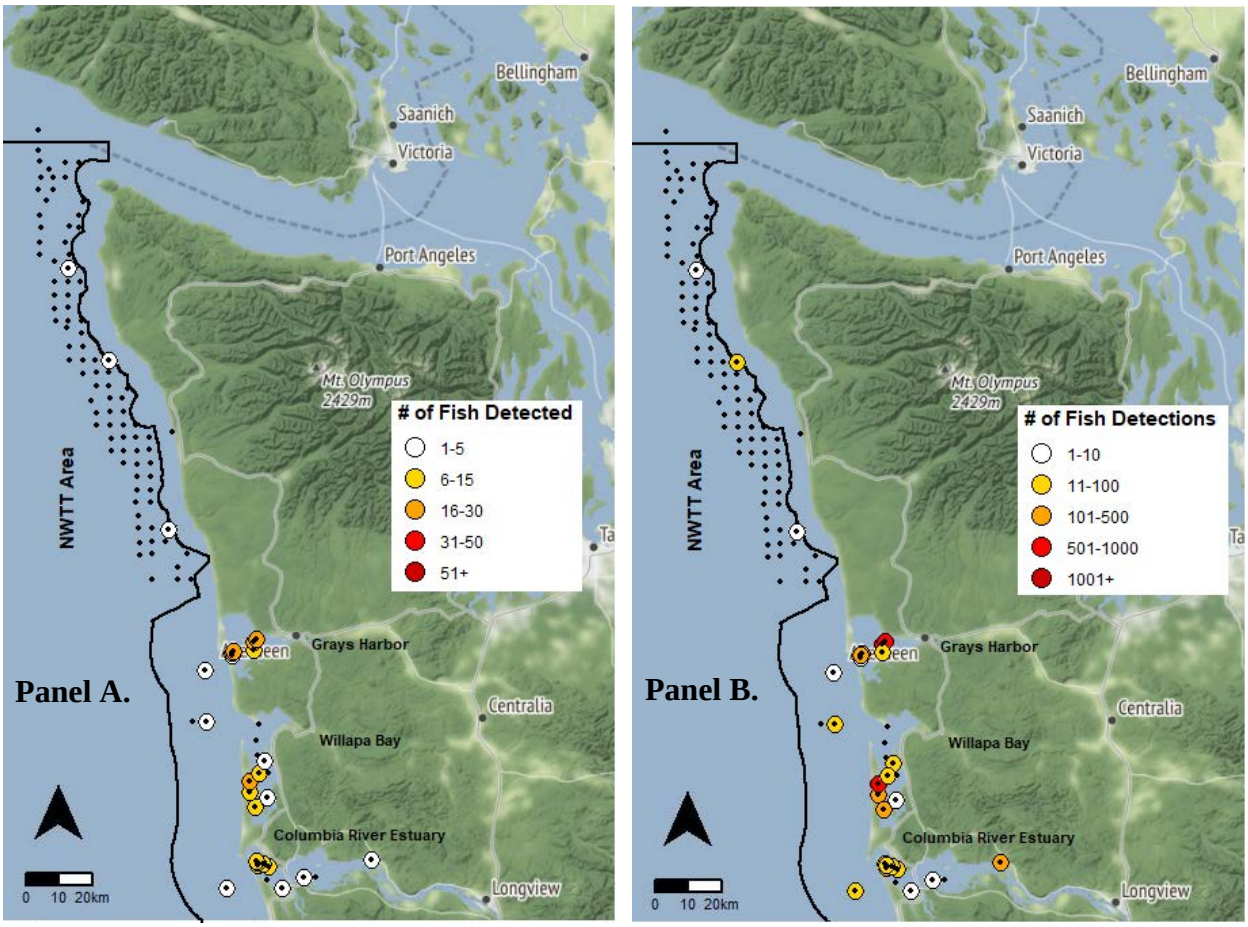

Figure 13. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of September 2019. A total of 74 unique individuals were detected during this period.

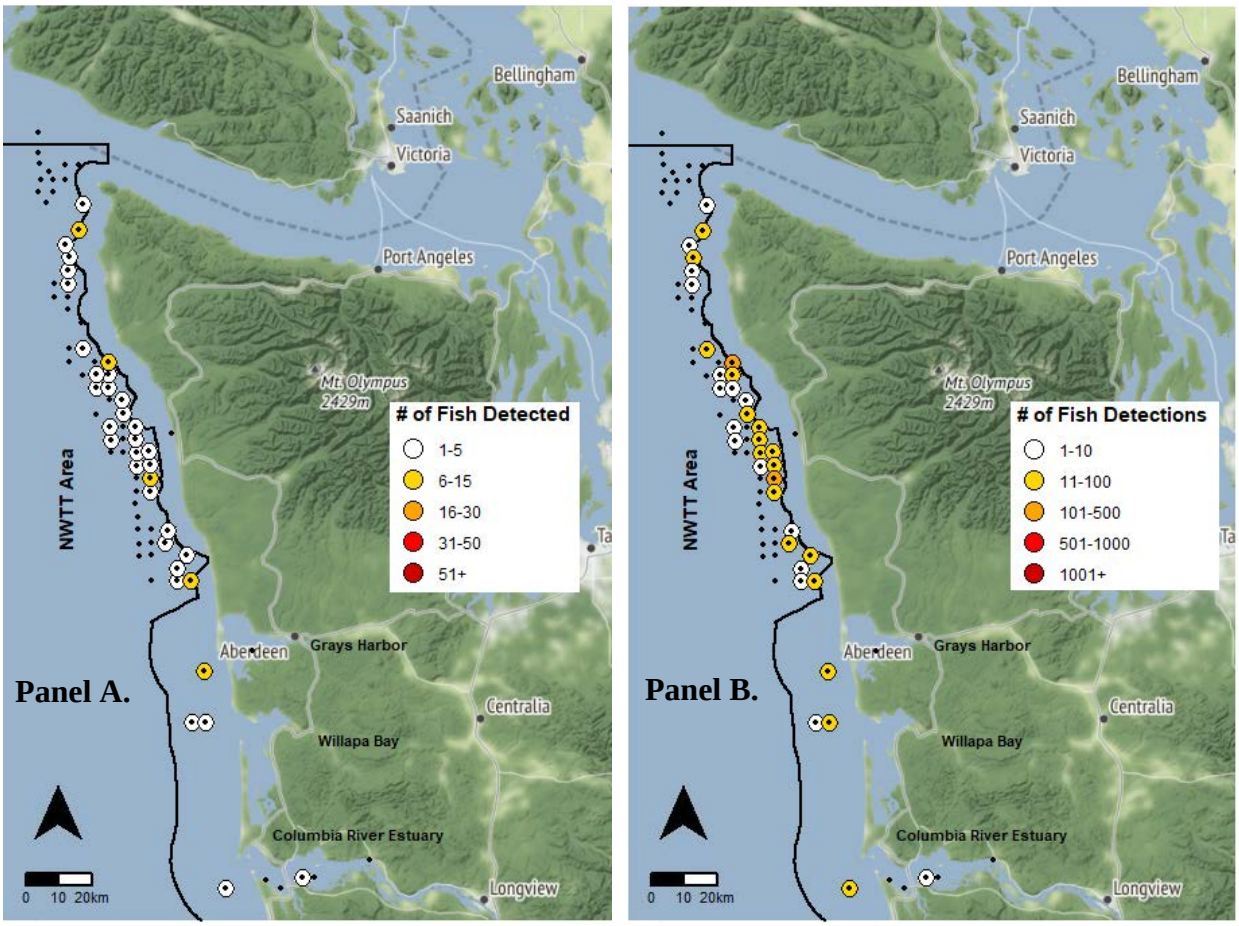

Figure 14. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of October 2019. A total of 44 unique individuals were detected during this period.

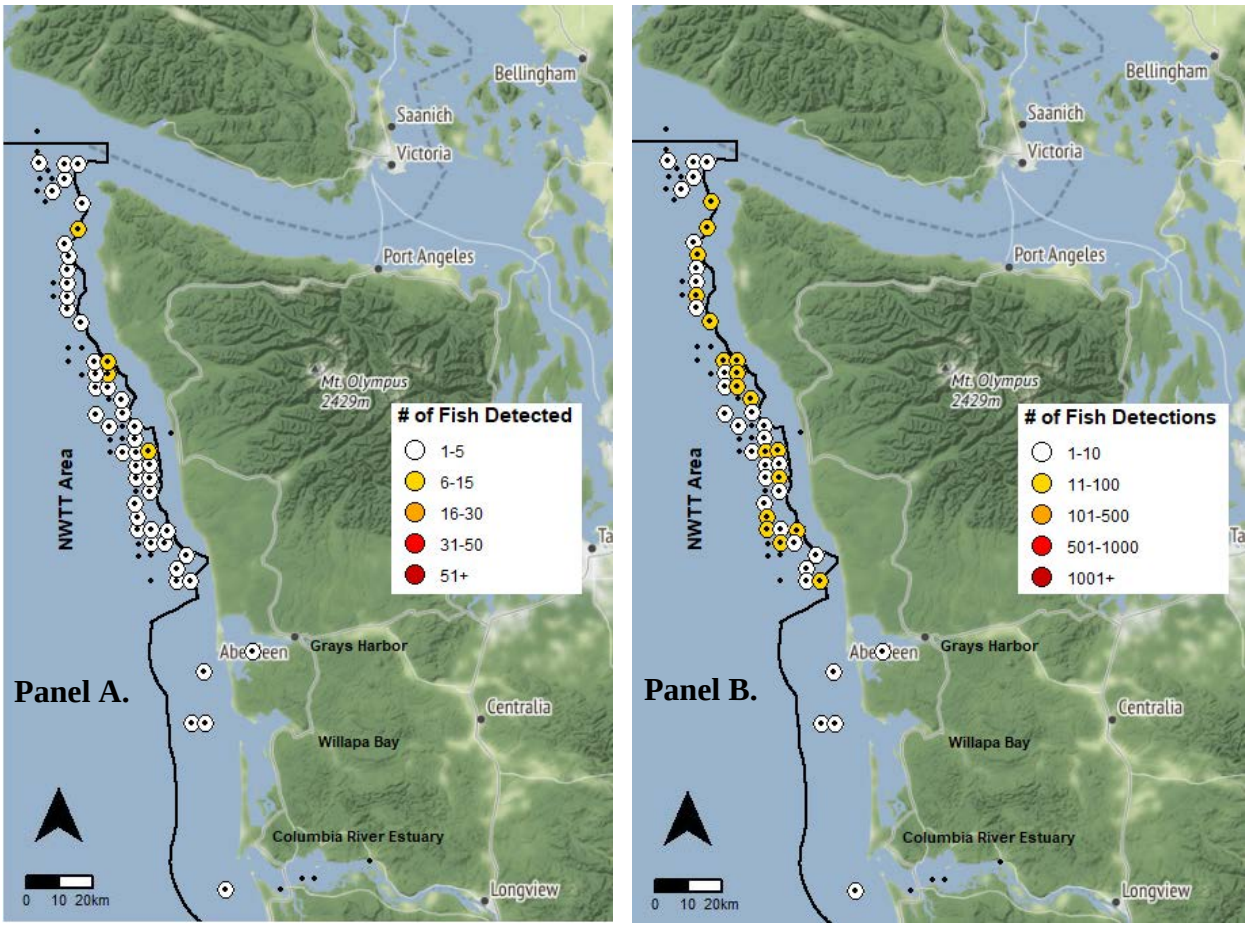

Figure 15. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of November 2019. A total of 37 unique individuals were detected during this period.

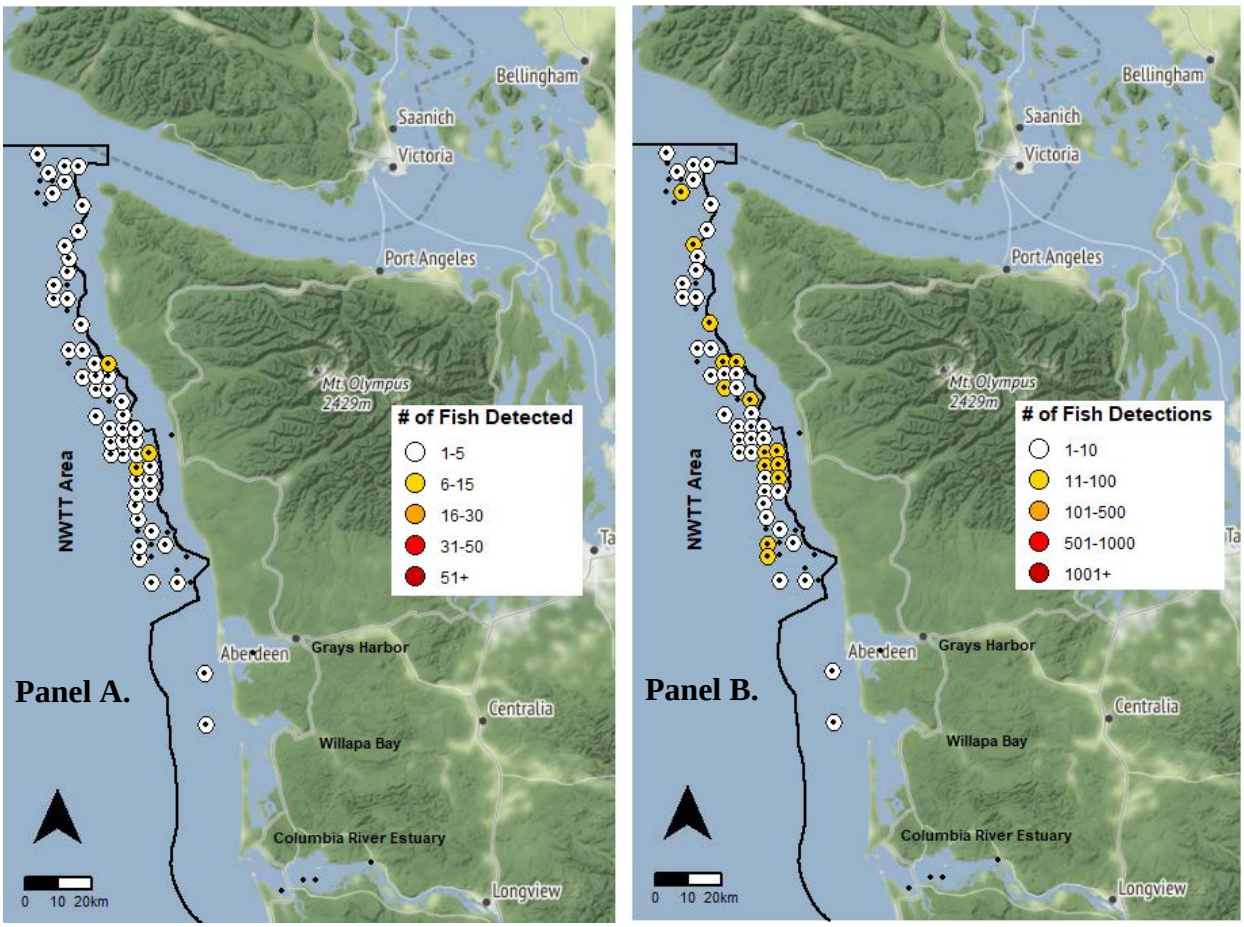

Figure 16. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of December 2019. A total of 38 unique individuals were detected during this period.

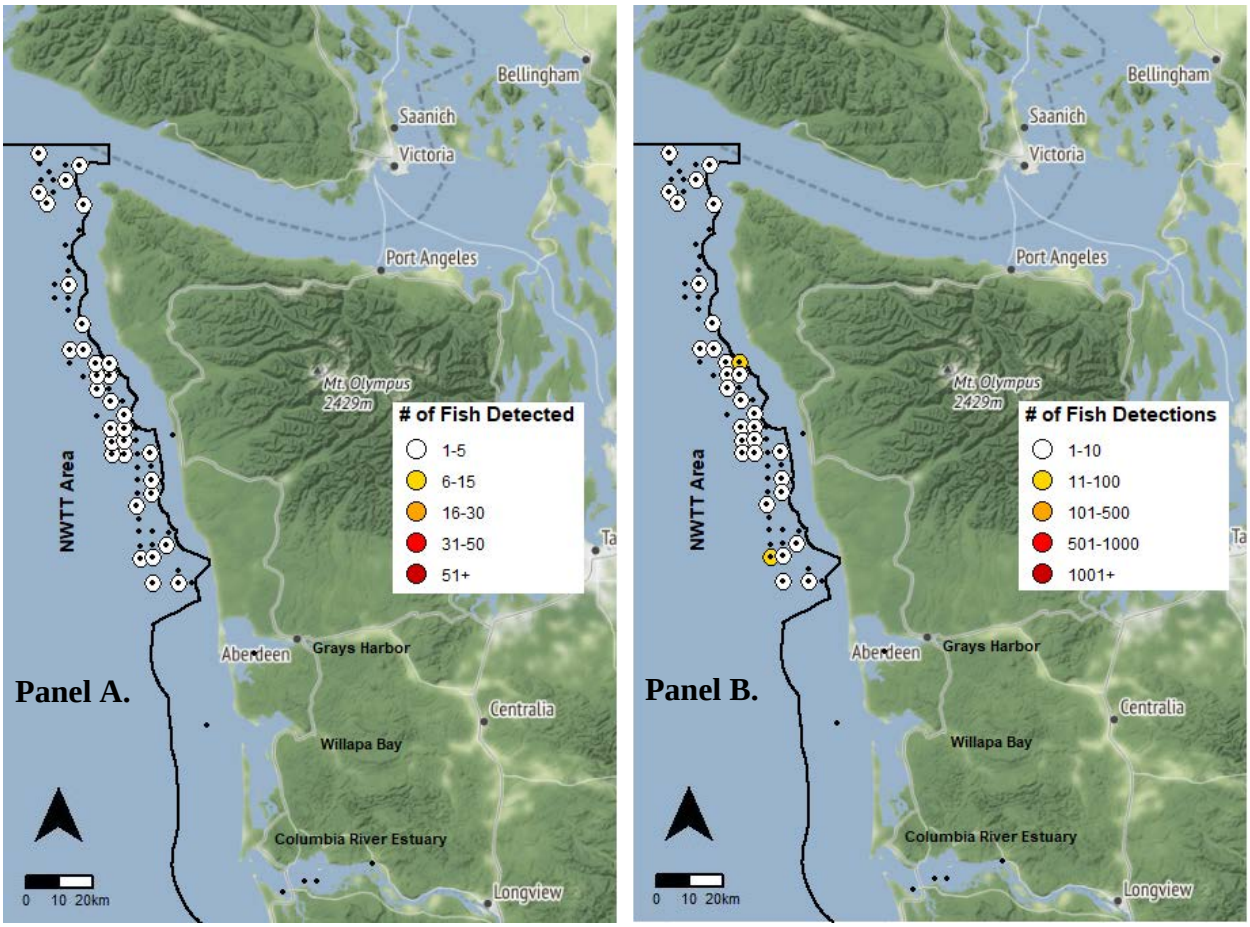

Figure 17. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of January 2020. A total of 18 unique individuals were detected during this period.

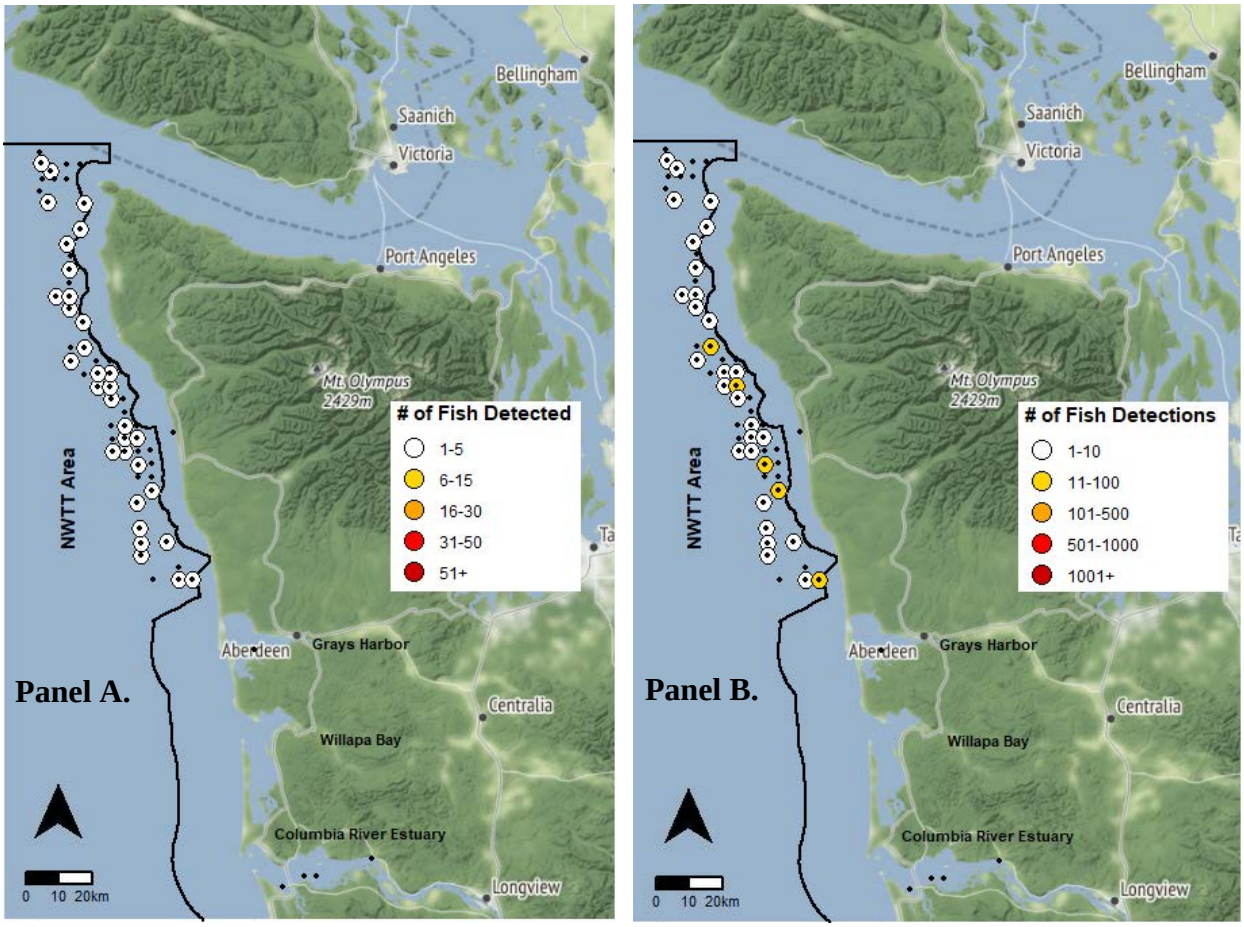

Figure 18. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of February 2020. A total of 21 unique individuals were detected during this period.

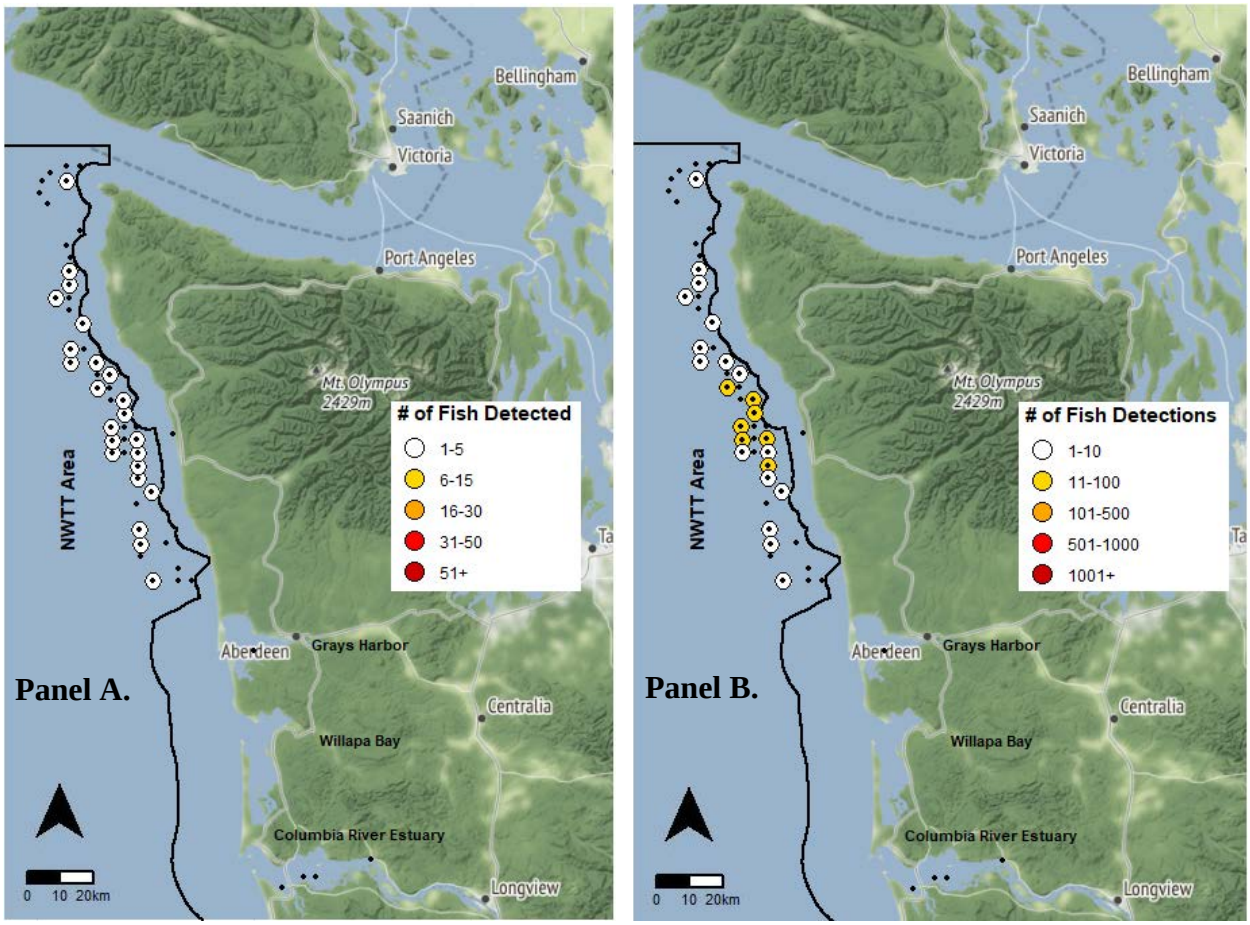

Figure 19. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of March 2020. A total of 11 unique individuals were detected during this period.

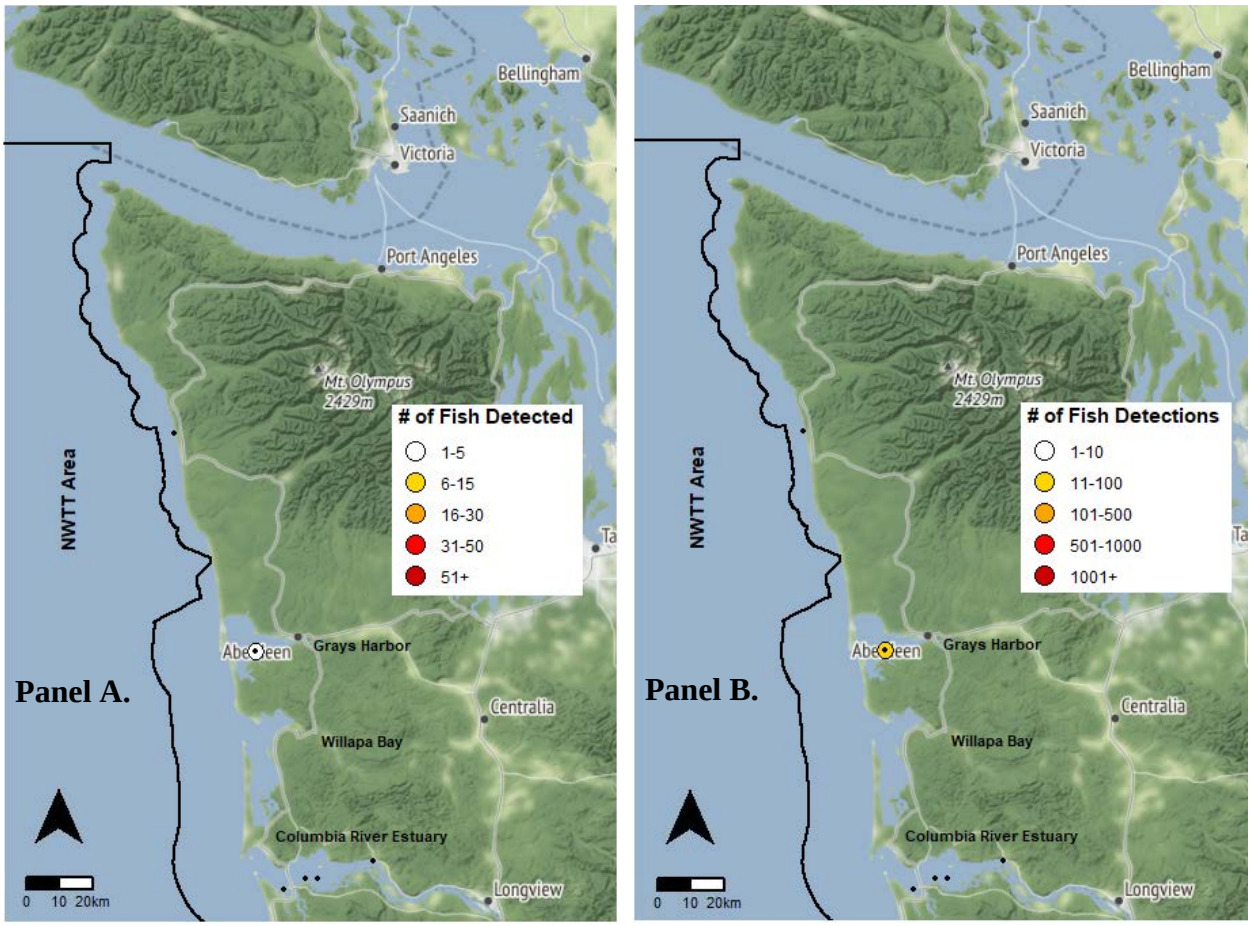

Figure 20. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of April 2020. A total of 3 unique individuals were detected during this period.

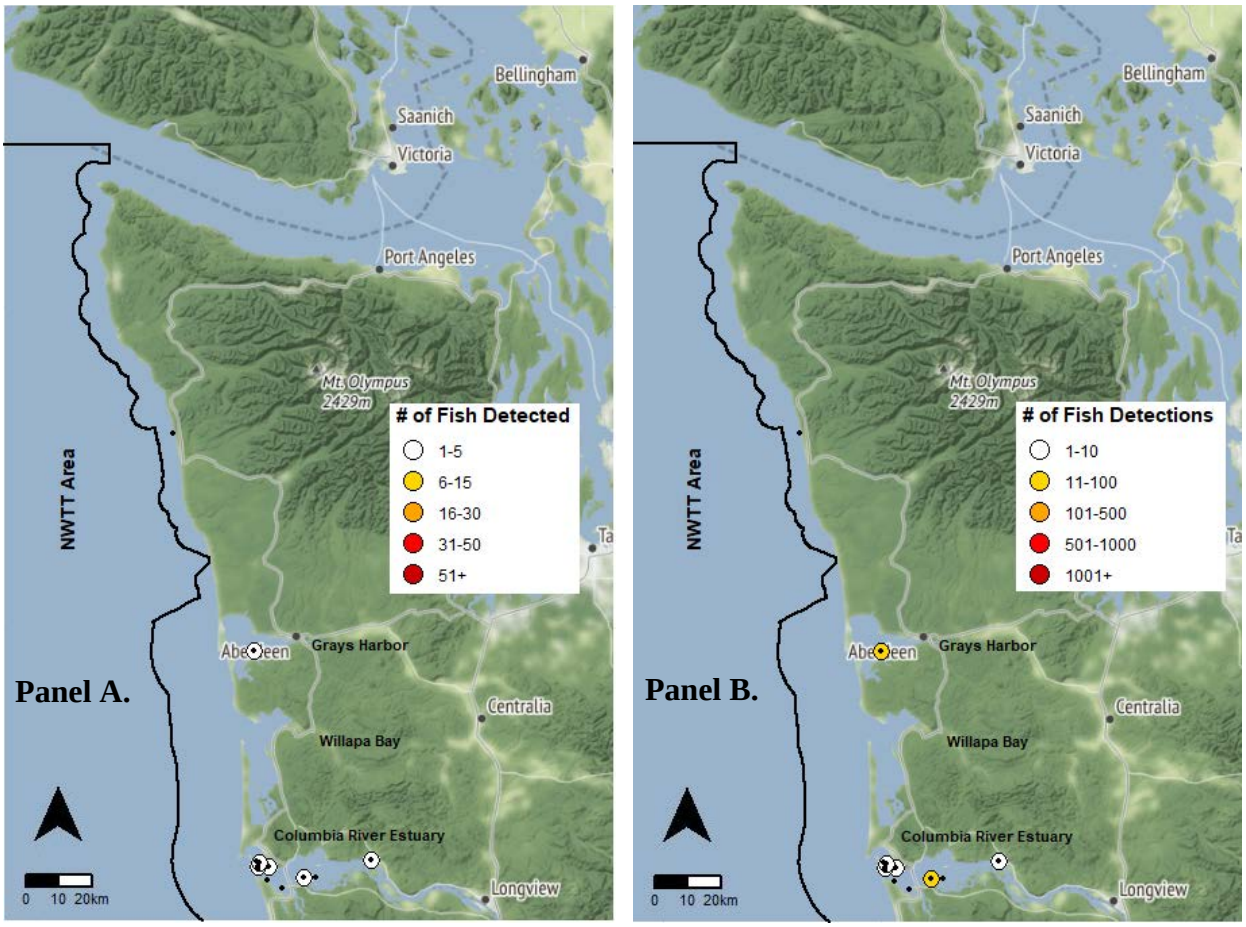

Figure 21. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of May 2020. A total of 10 unique individuals were detected during this period.

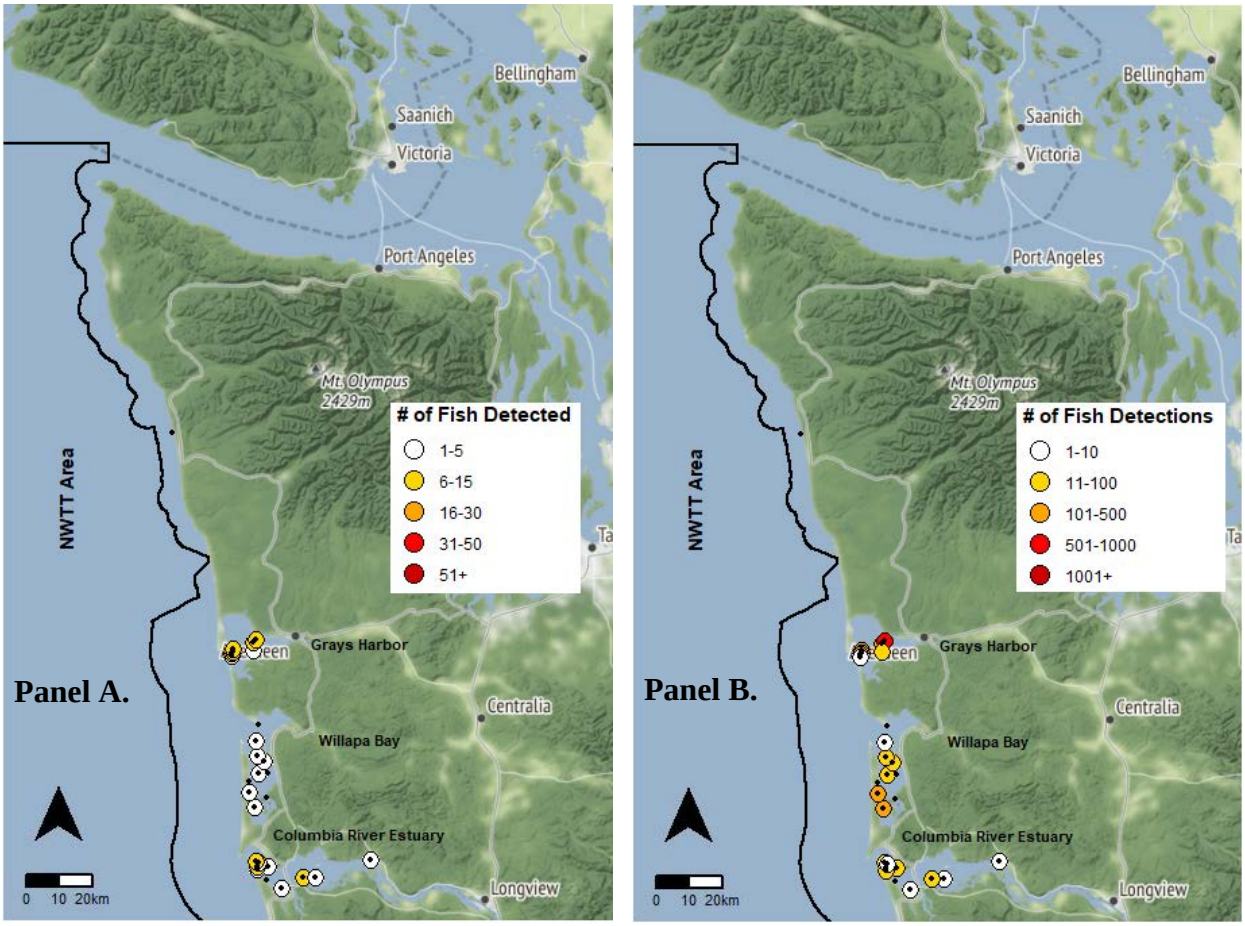

Figure 22. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of June 2020. A total of 52 unique individuals were detected during this period.

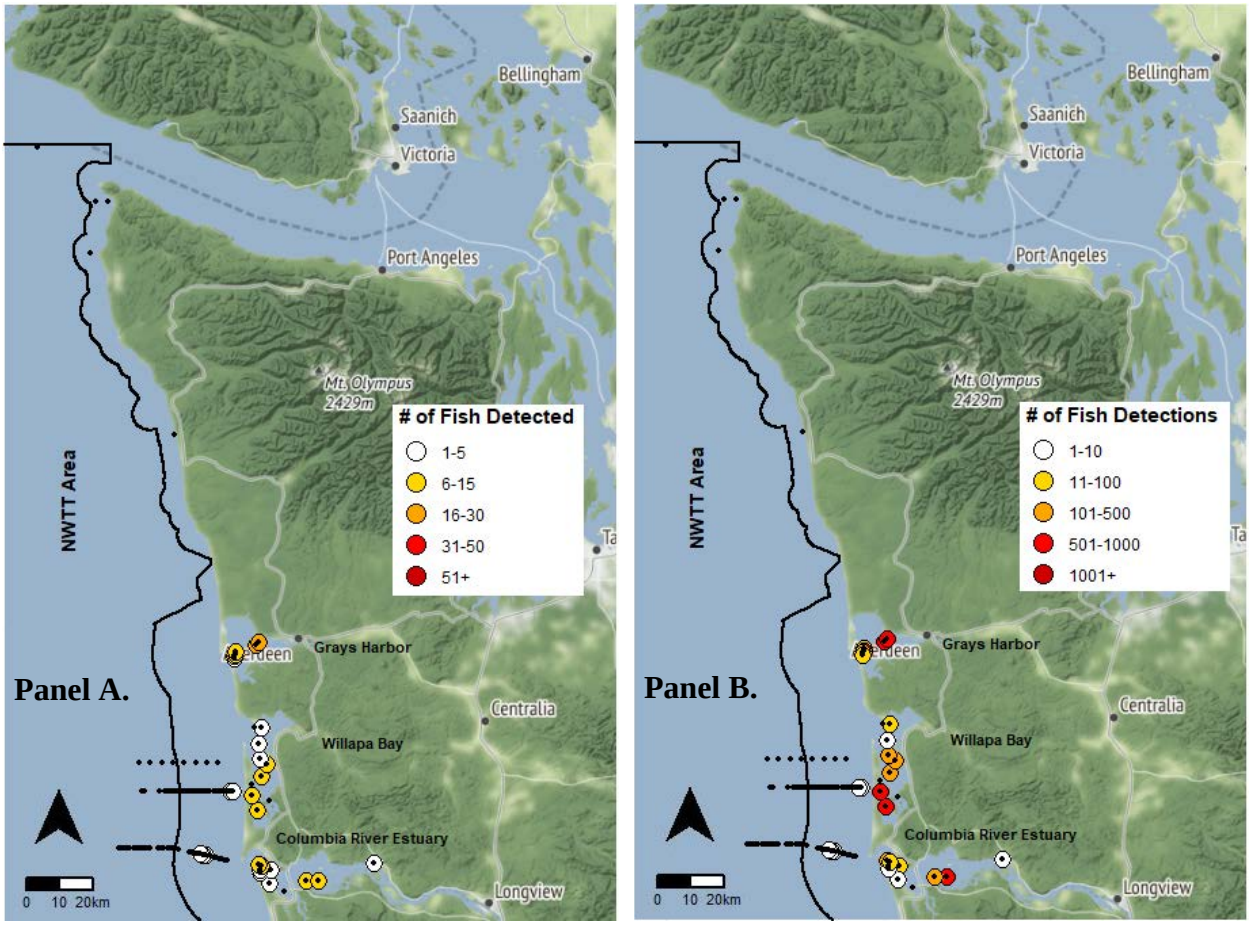

Figure 23. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of July 2020. A total of 62 unique individuals were detected during this period.

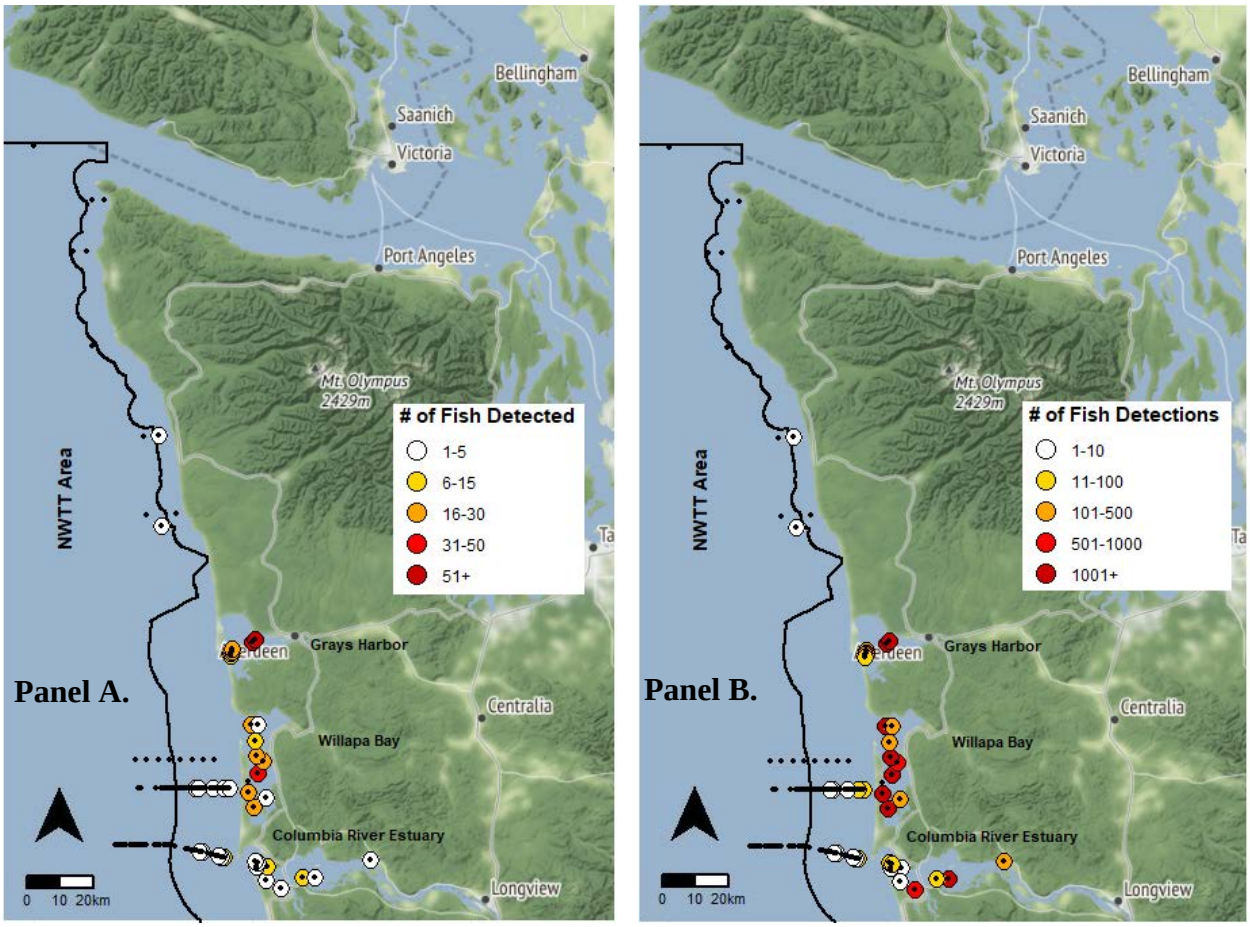

Figure 24. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of August 2020. A total of 130 unique individuals were detected during this period.

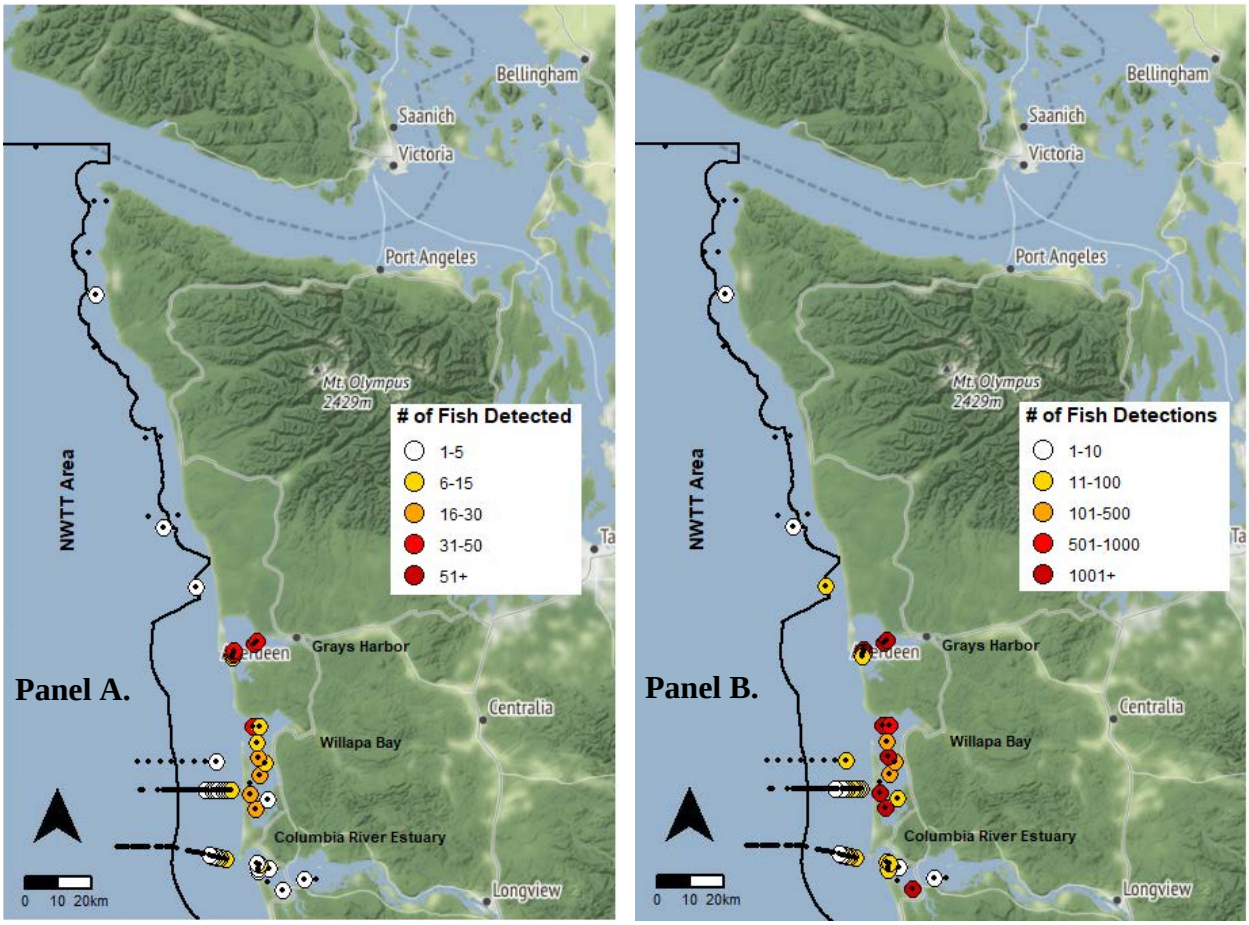

Figure 25. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of September 2020. A total of 114 unique individuals were detected during this period.

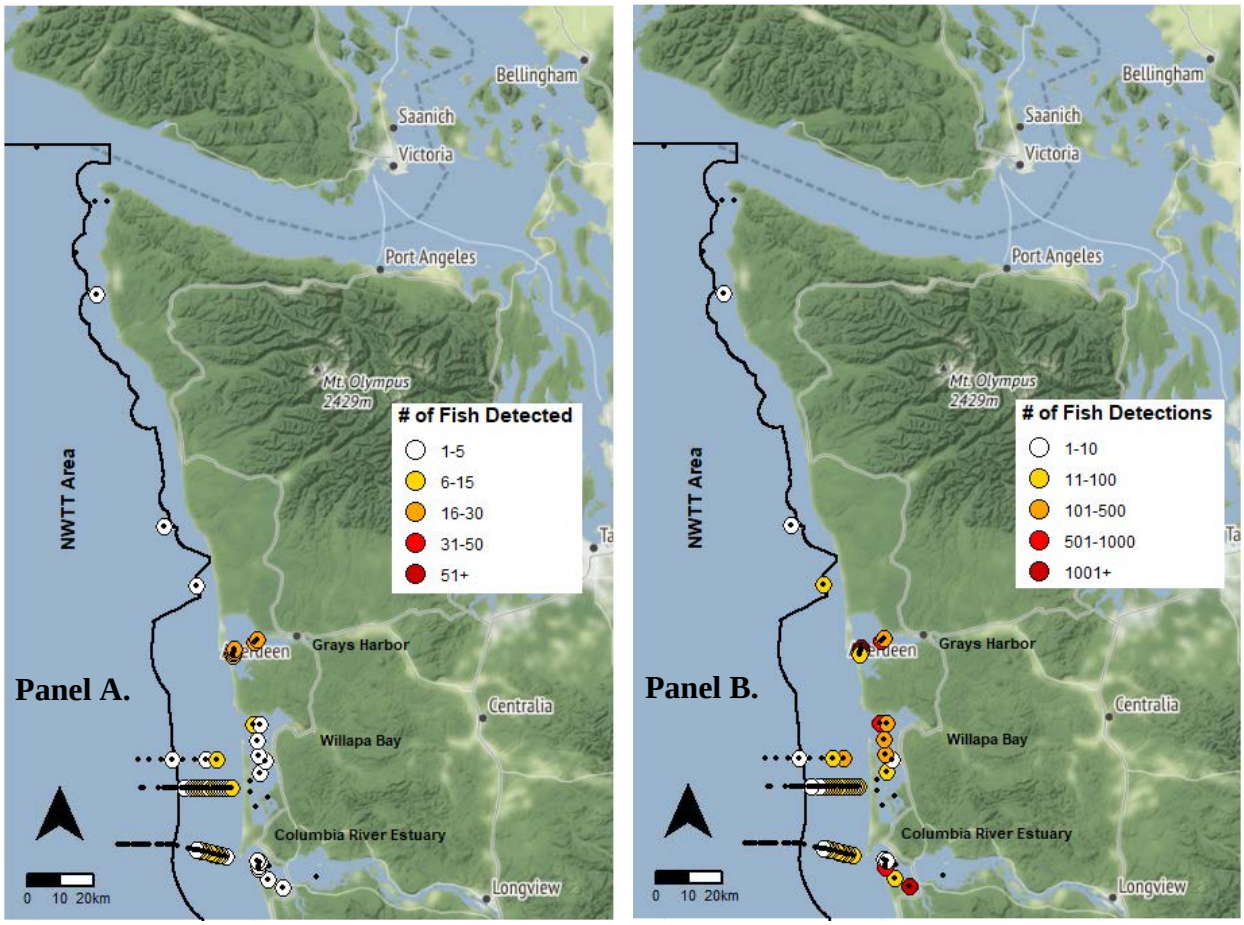

Figure 26. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of October 2020. A total of 83 unique individuals were detected during this period.

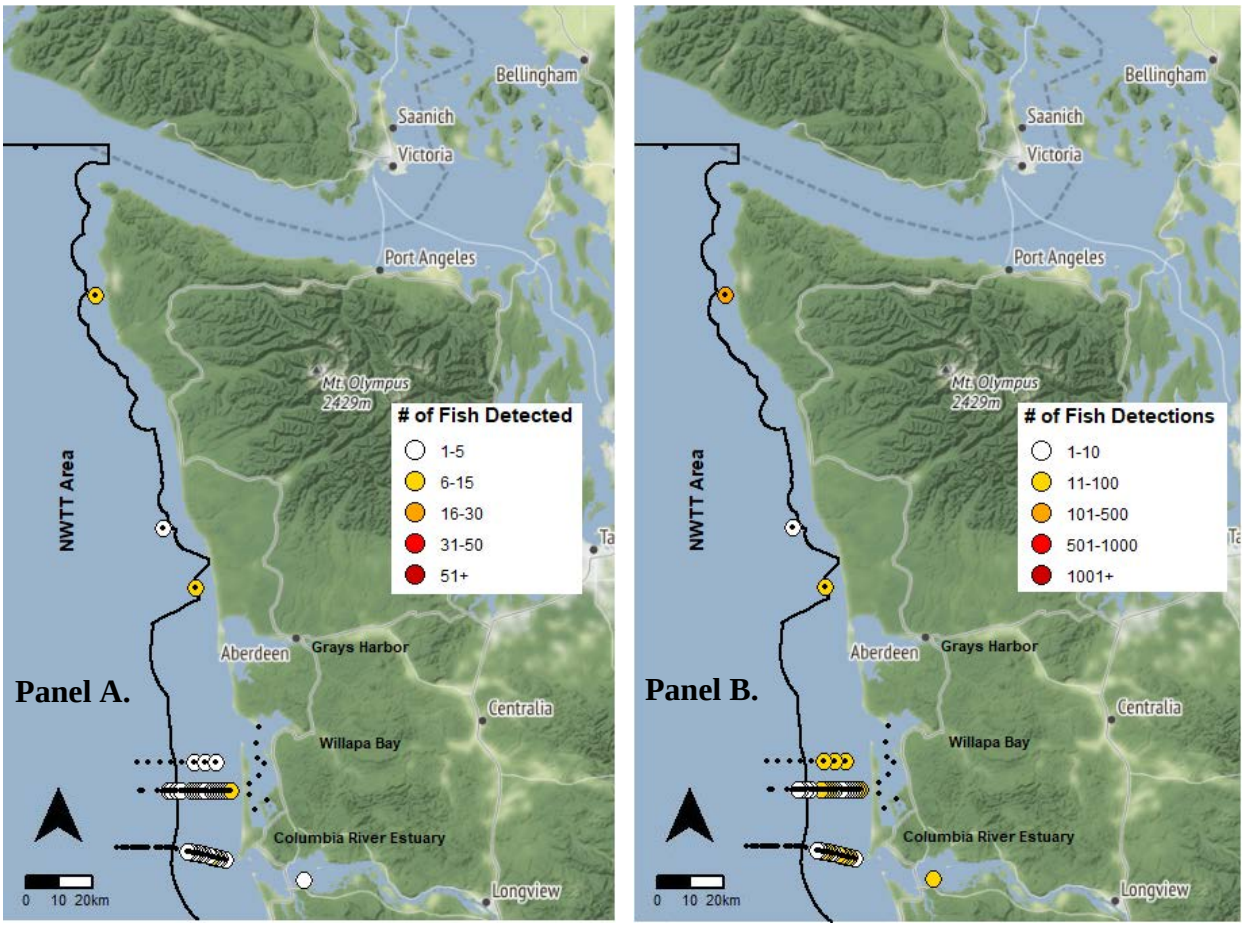

Figure 27. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of November 2020. A total of 43 unique individuals were detected during this period.

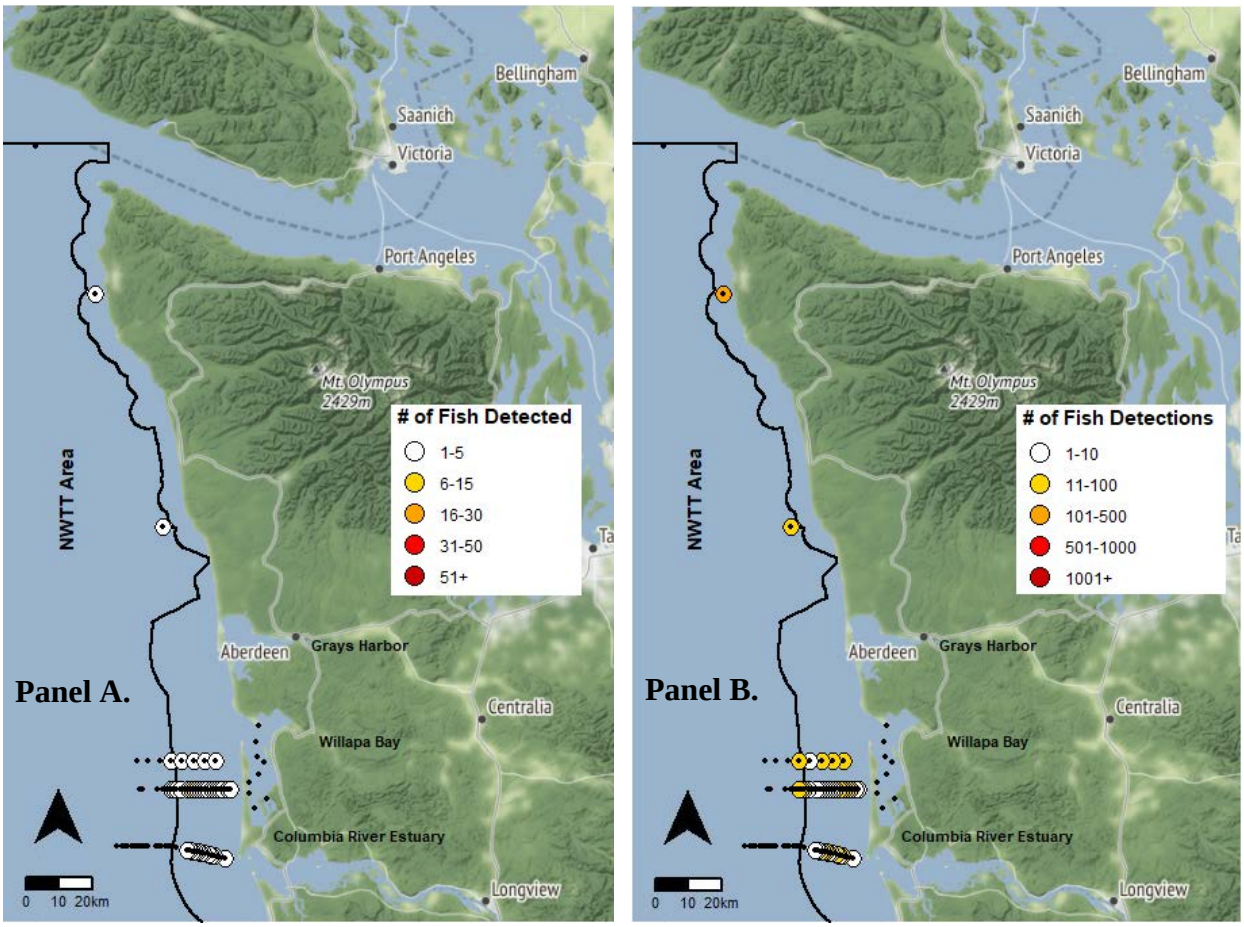

Figure 28. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of December 2020. A total of 22 unique individuals were detected during this period.

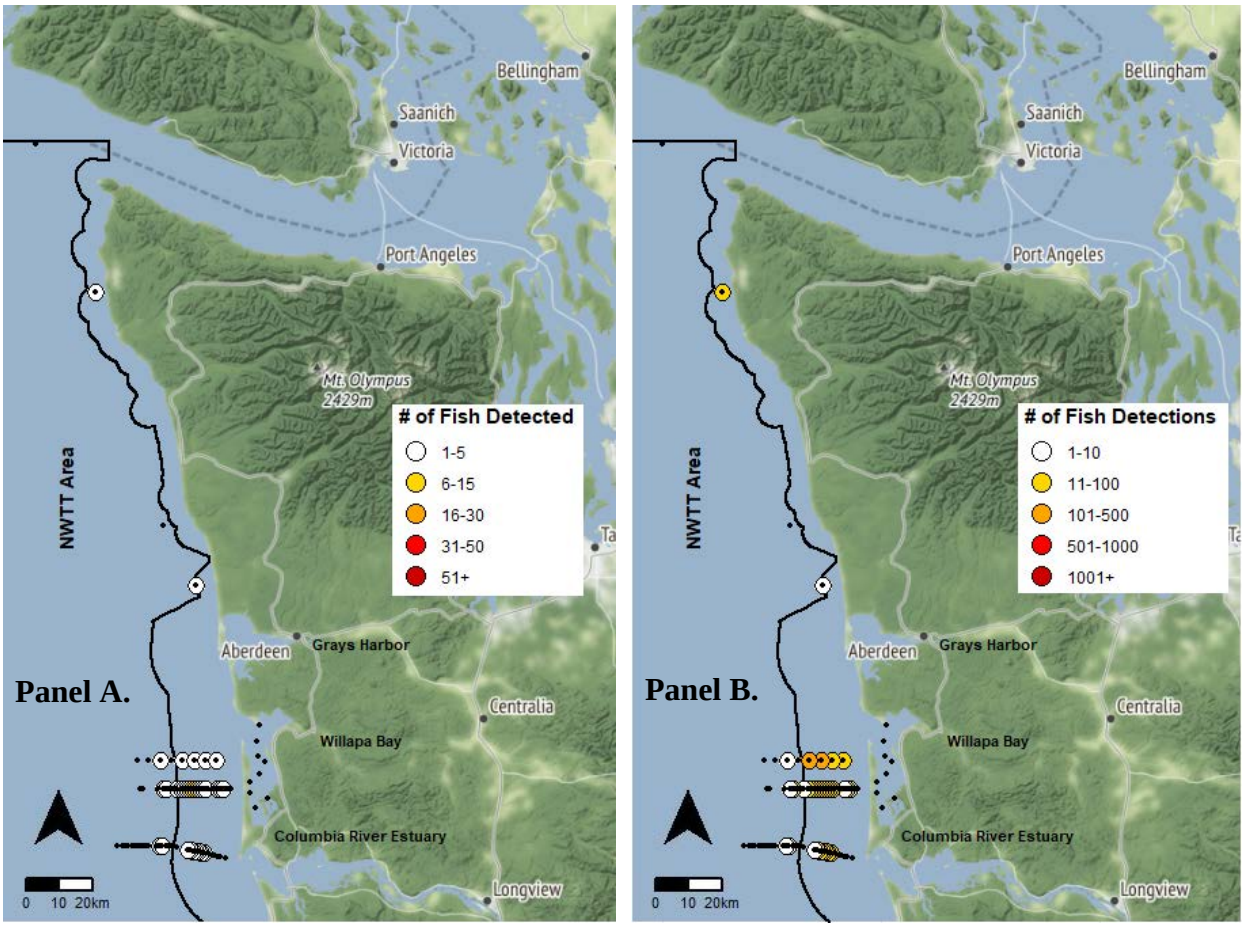

Figure 29. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of January 2021. A total of 25 unique individuals were detected during this period.

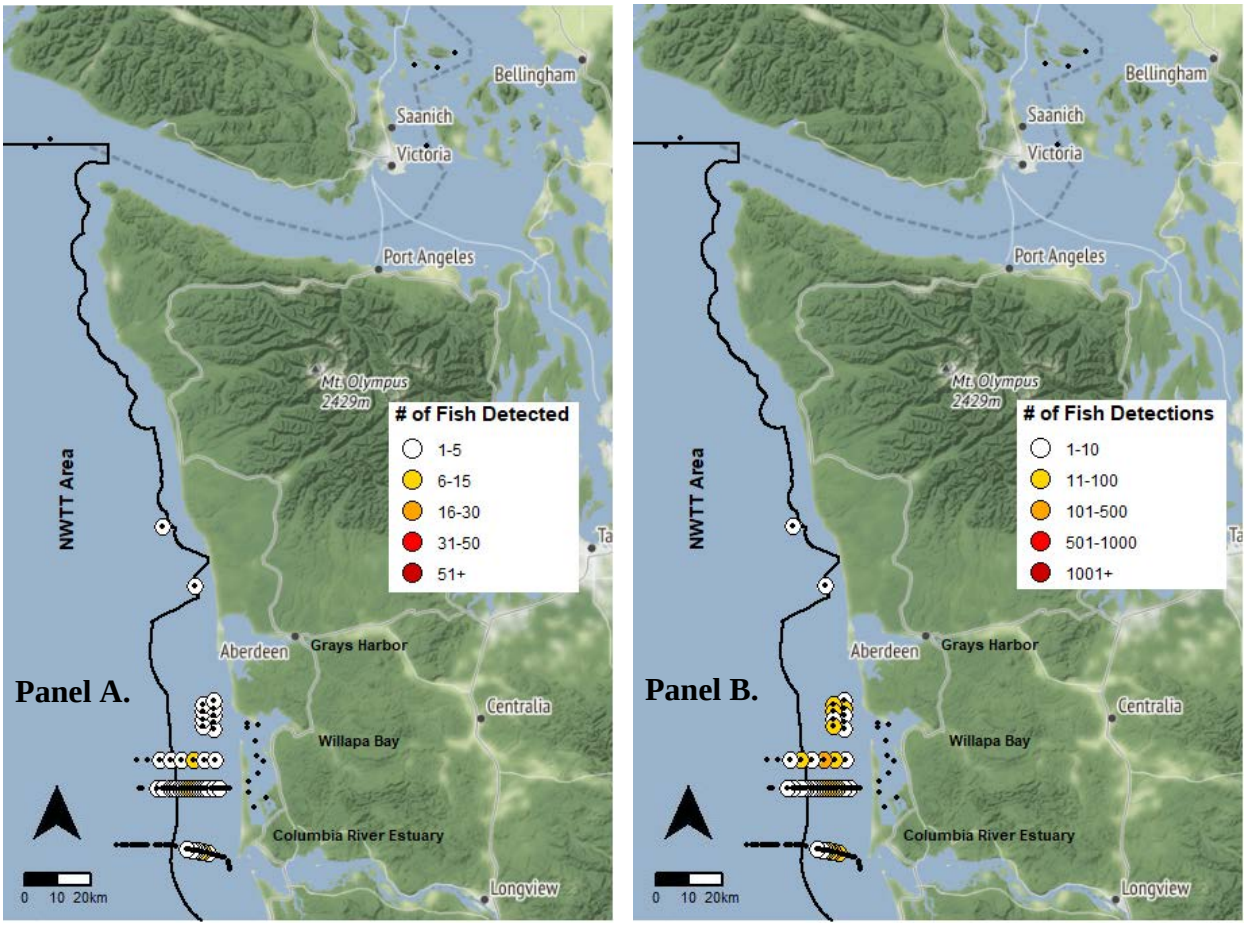

Figure 30. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of February 2021. A total of 34 unique individuals were detected during this period.

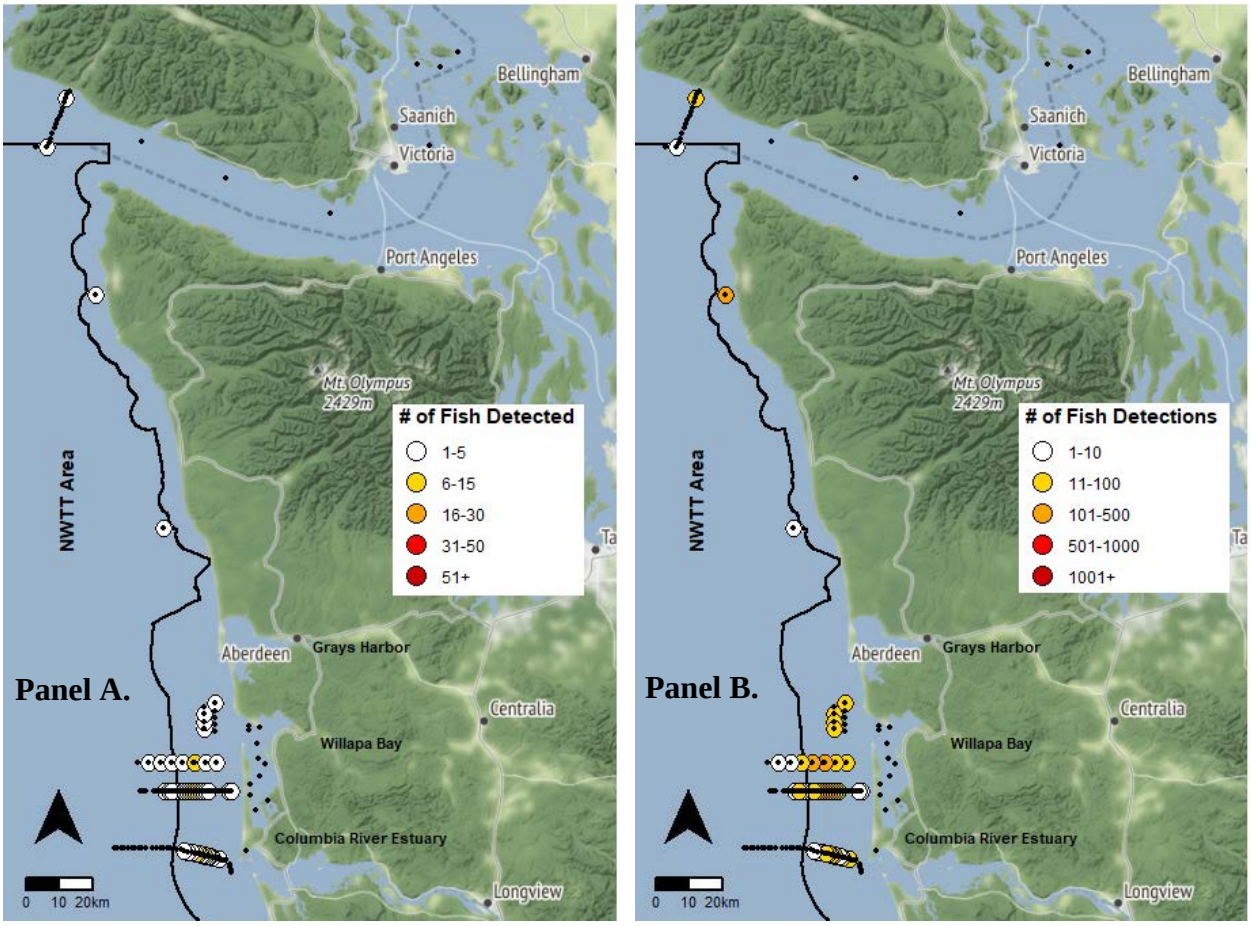

Figure 31. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of March 2021. A total of 33 unique individuals were detected during this period.

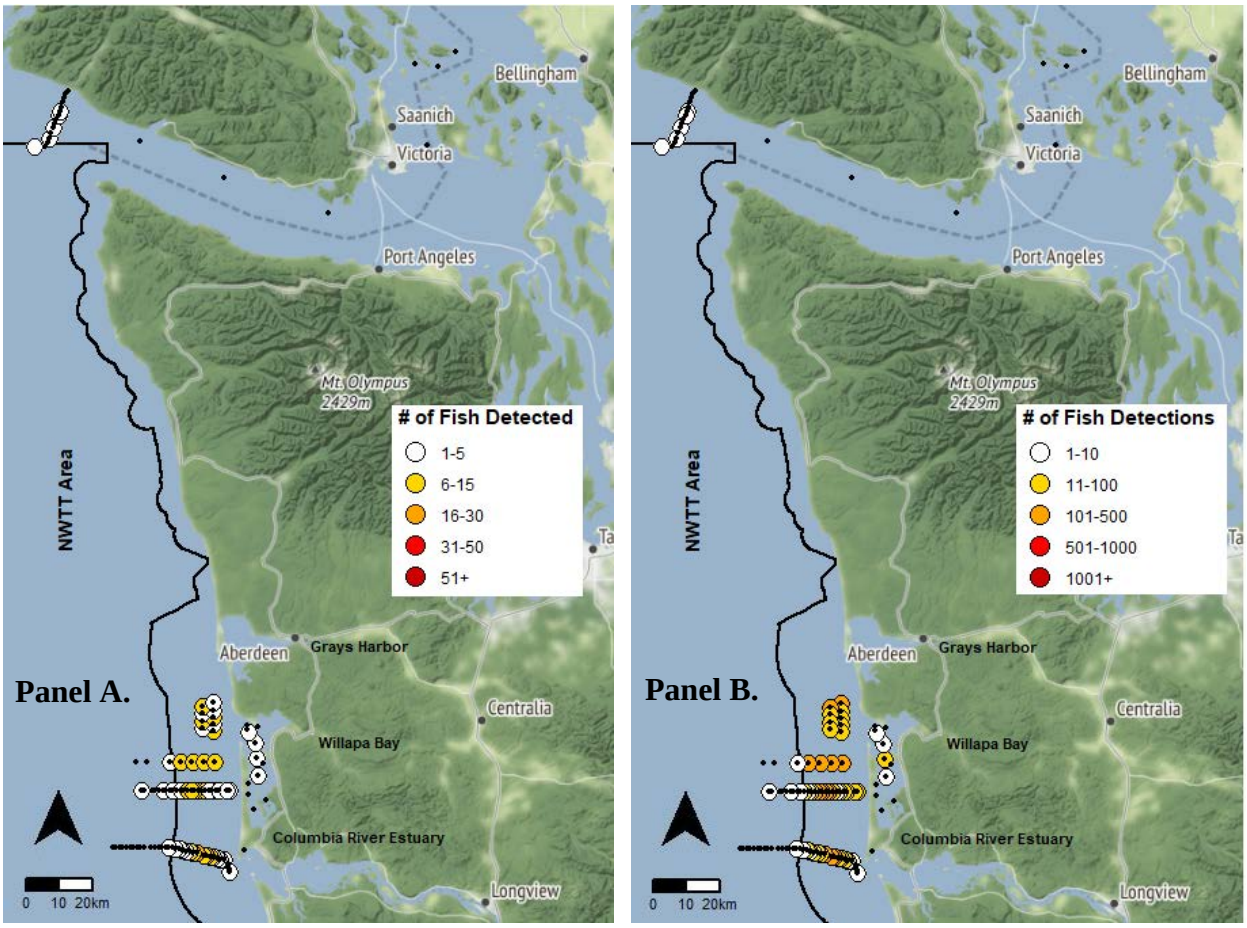

Figure 32. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of April 2021. A total of 65 unique individuals were detected during this period.

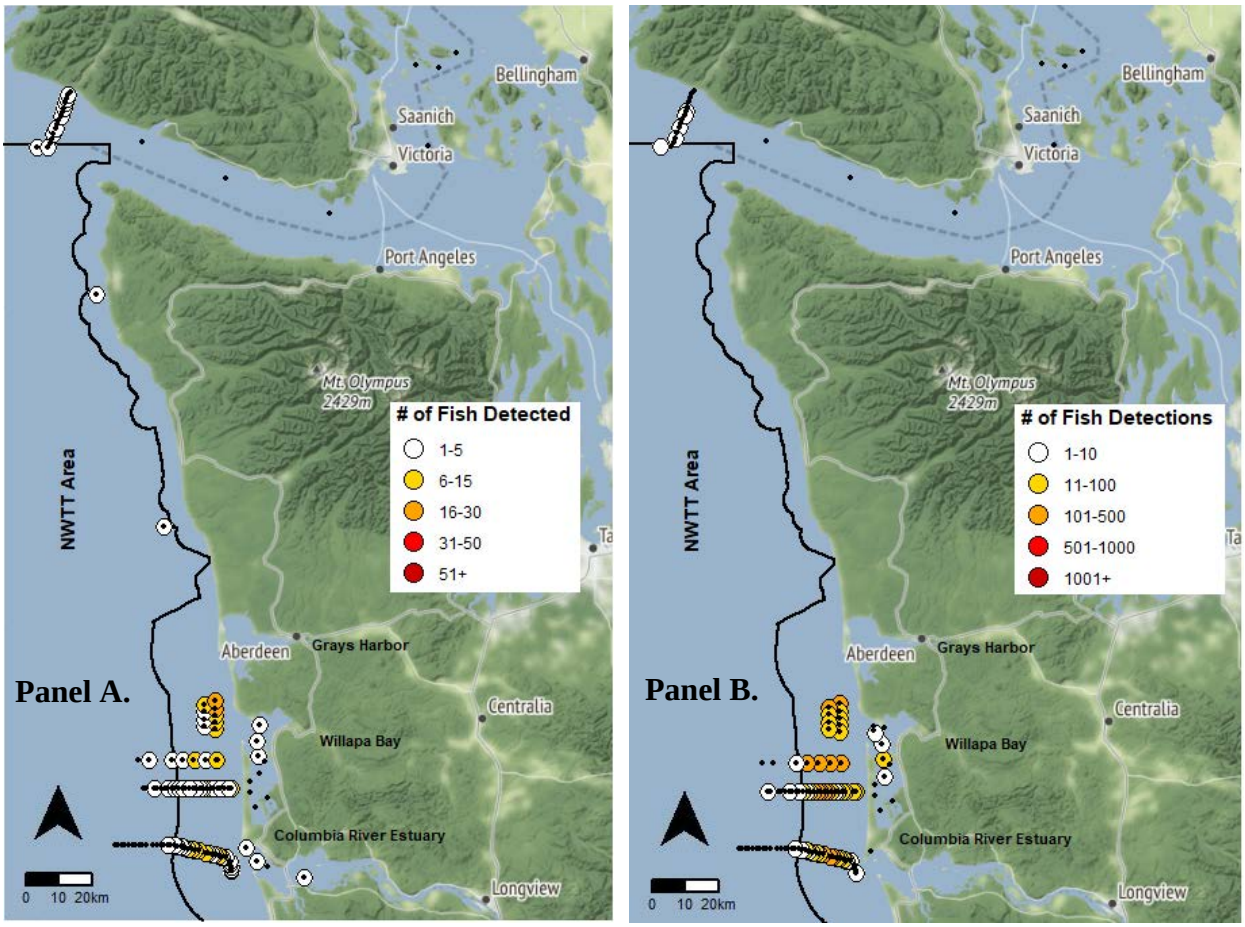

Figure 33. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of May 2021. A total of 74 unique individuals were detected during this period.

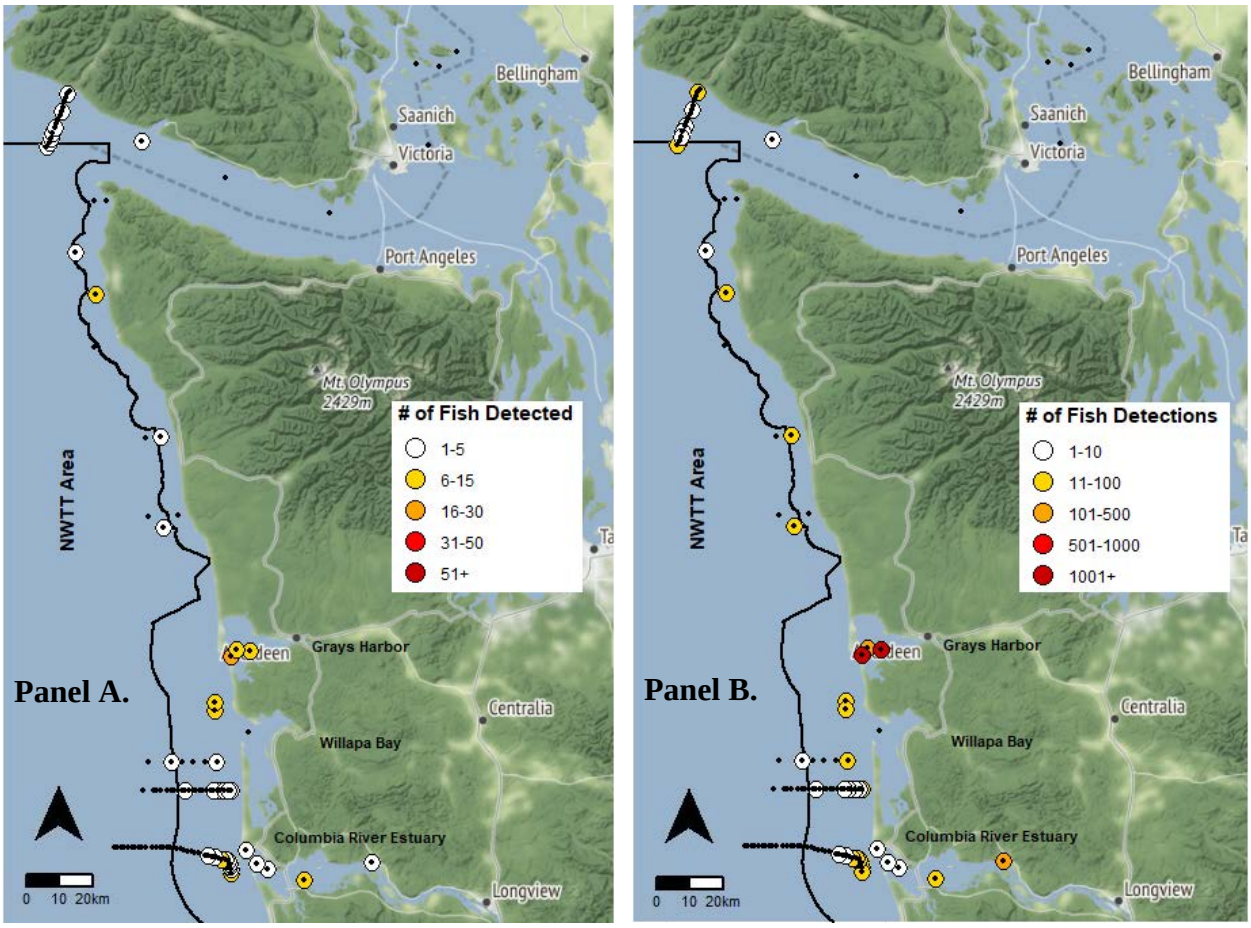

Figure 34. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of June 2021. A total of 77 unique individuals were detected during this period.

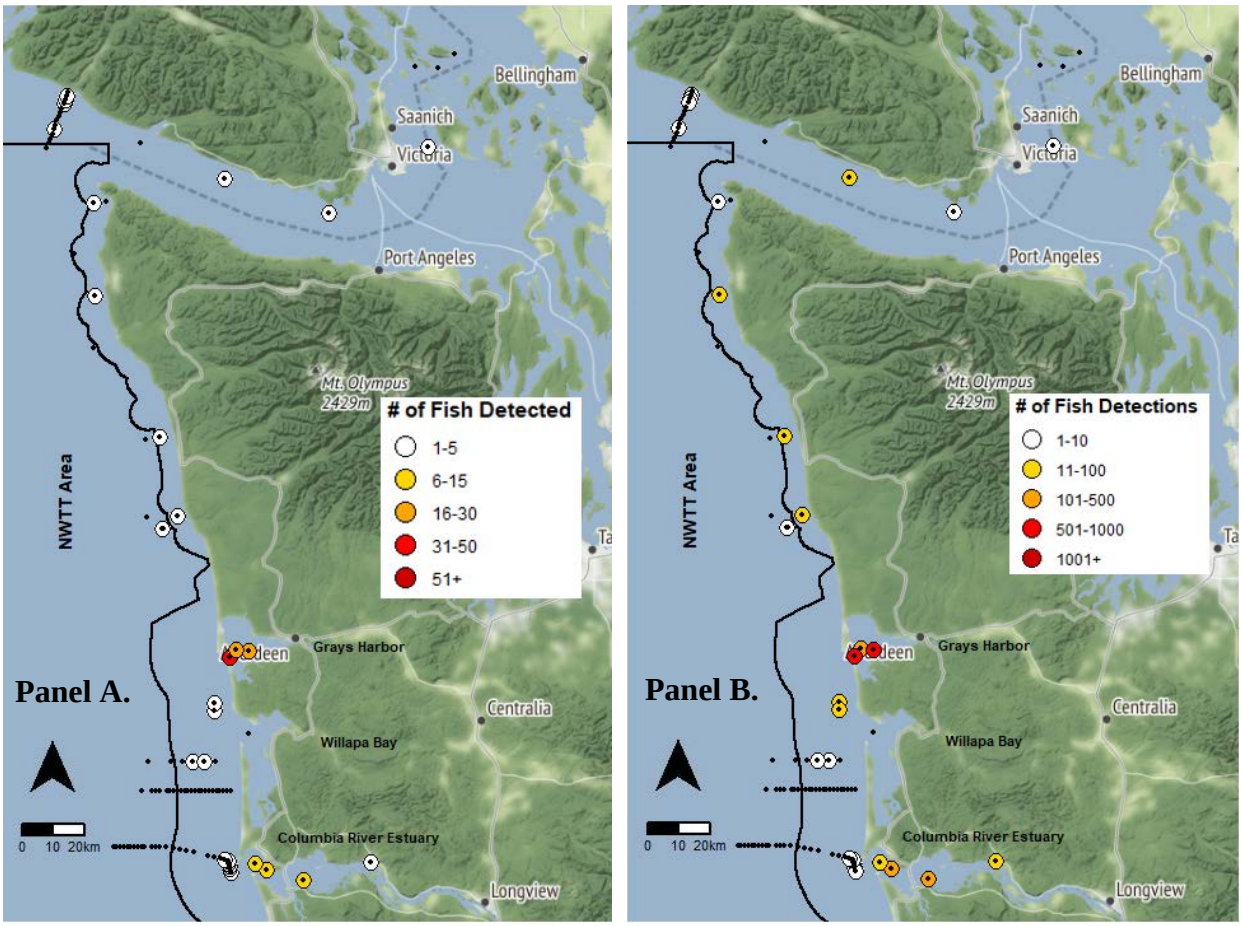

Figure 35. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of July 2021. A total of 80 unique individuals were detected during this period.

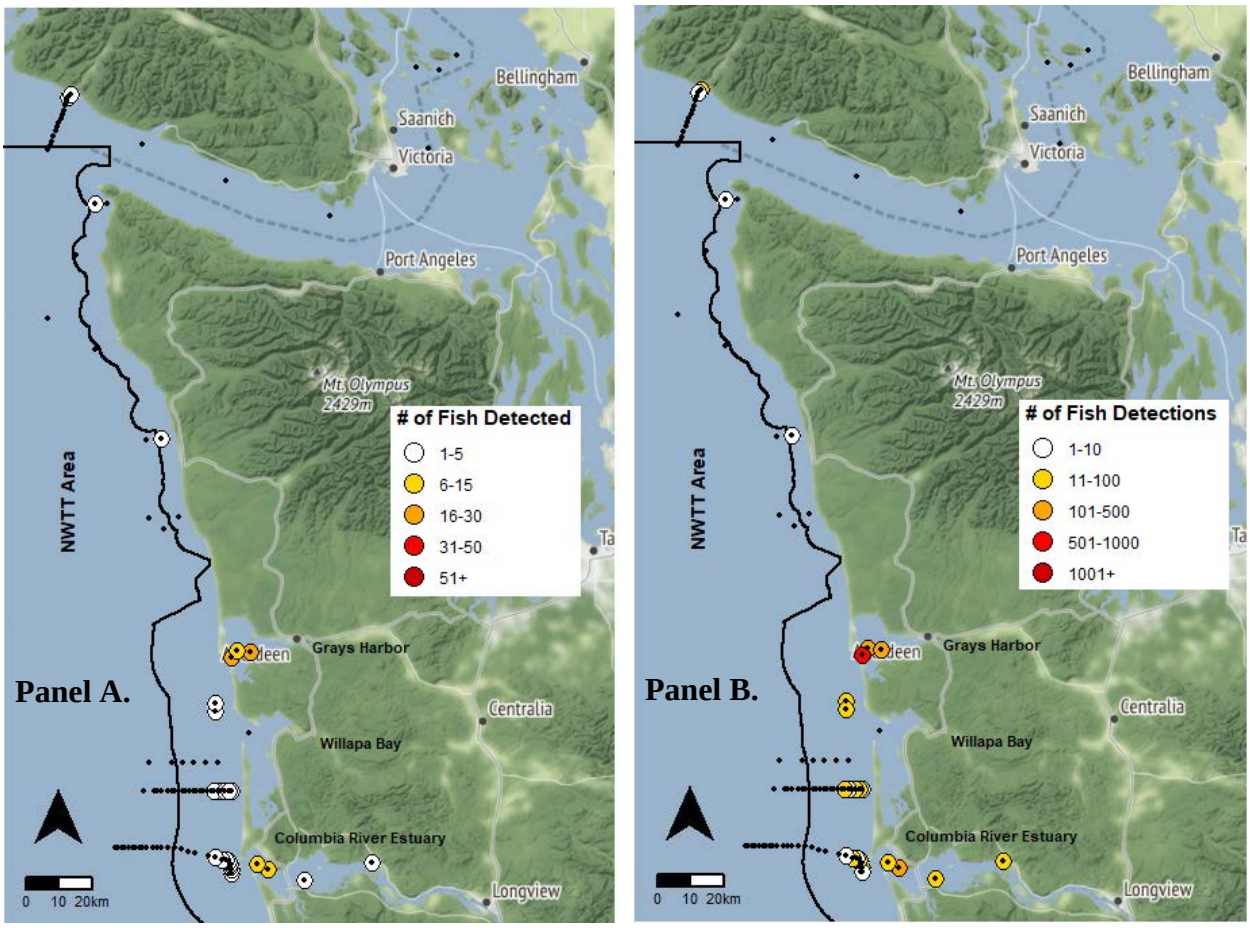

Figure 36. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of August 2021. A total of 69 unique individuals were detected during this period.

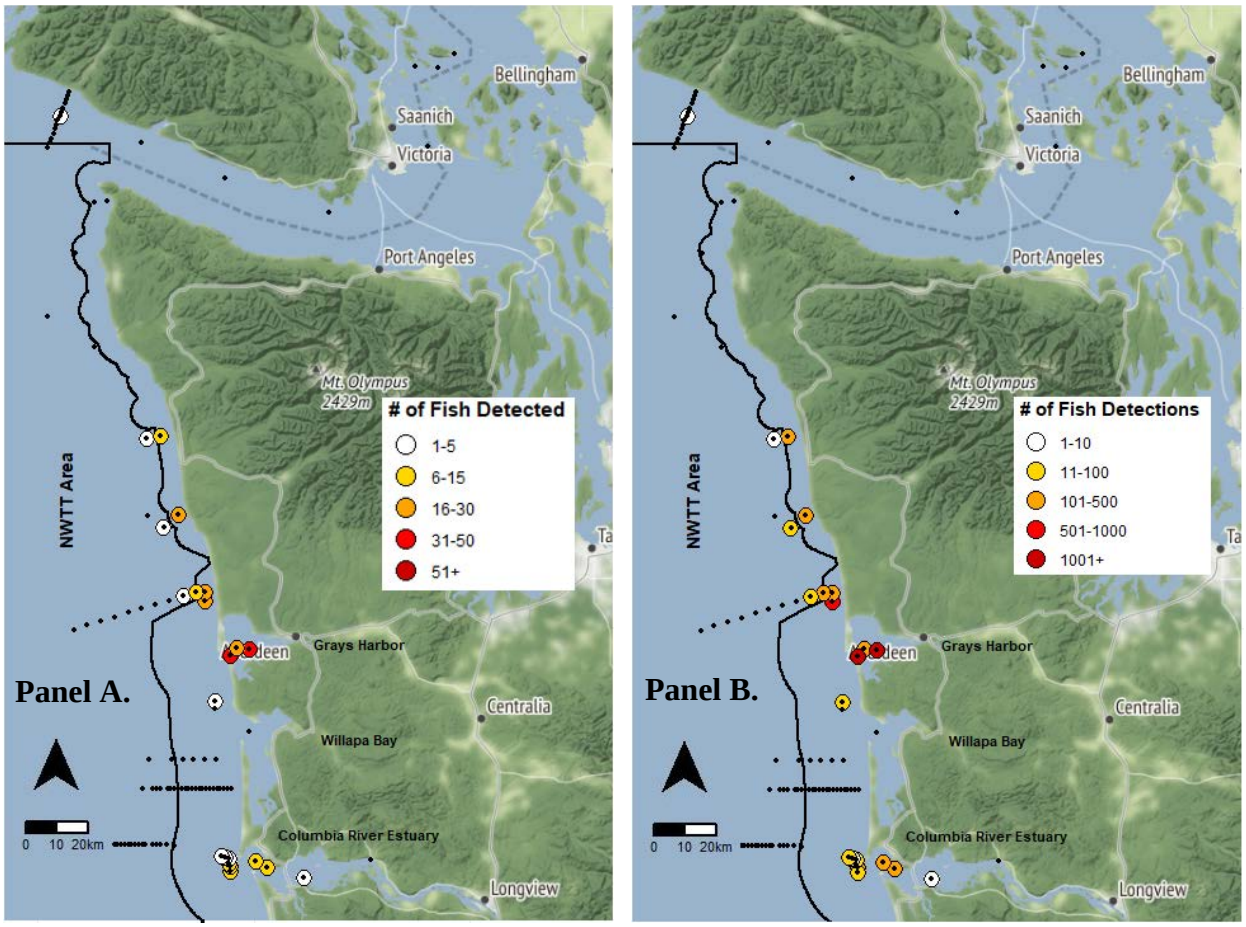

Figure 37. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of September 2021. A total of 123 unique individuals were detected during this period.

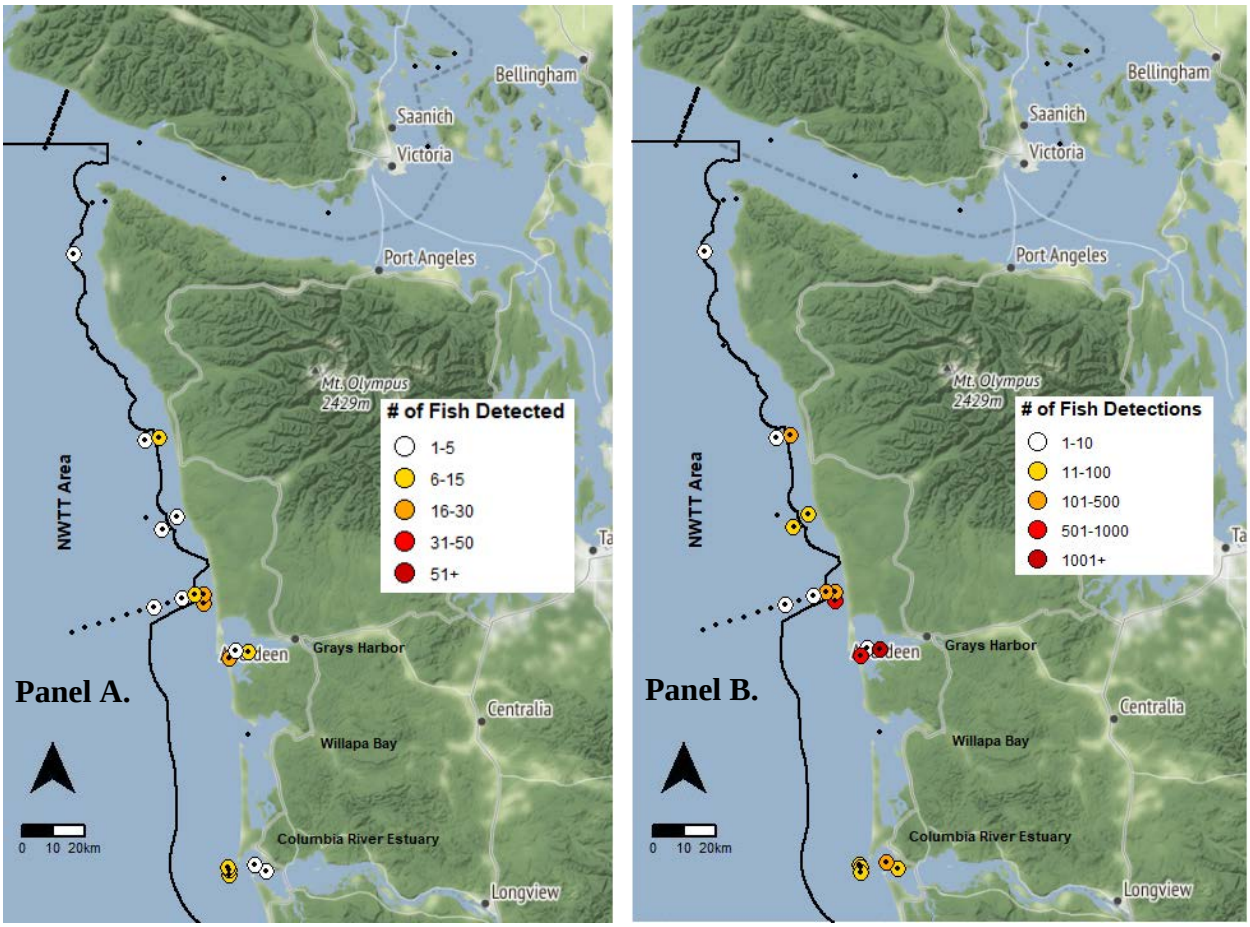

Figure 37. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of October 2021. A total of 90 unique individuals were detected during this period.

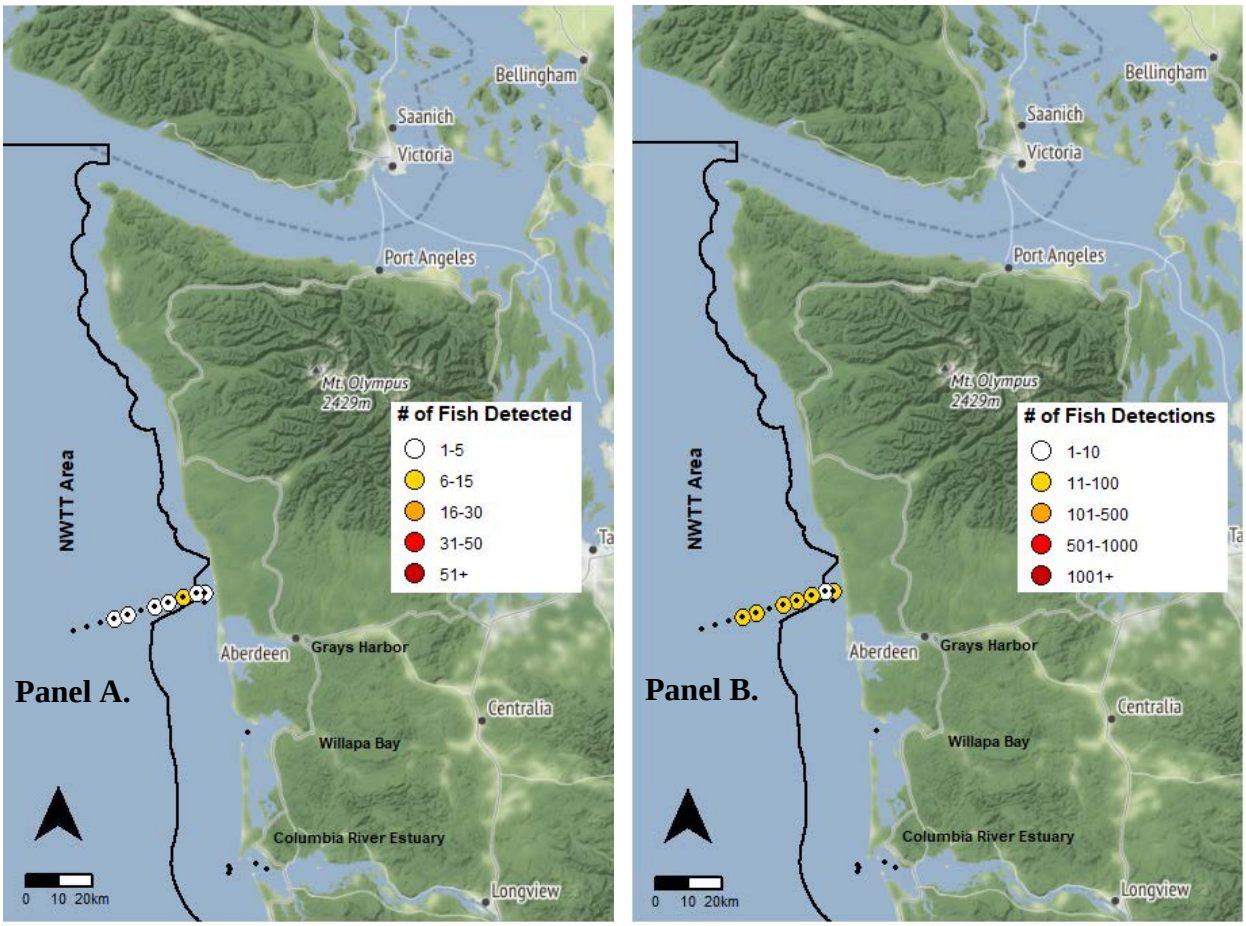

Figure 38. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of November 2021. A total of 17 unique individuals were detected during this period.

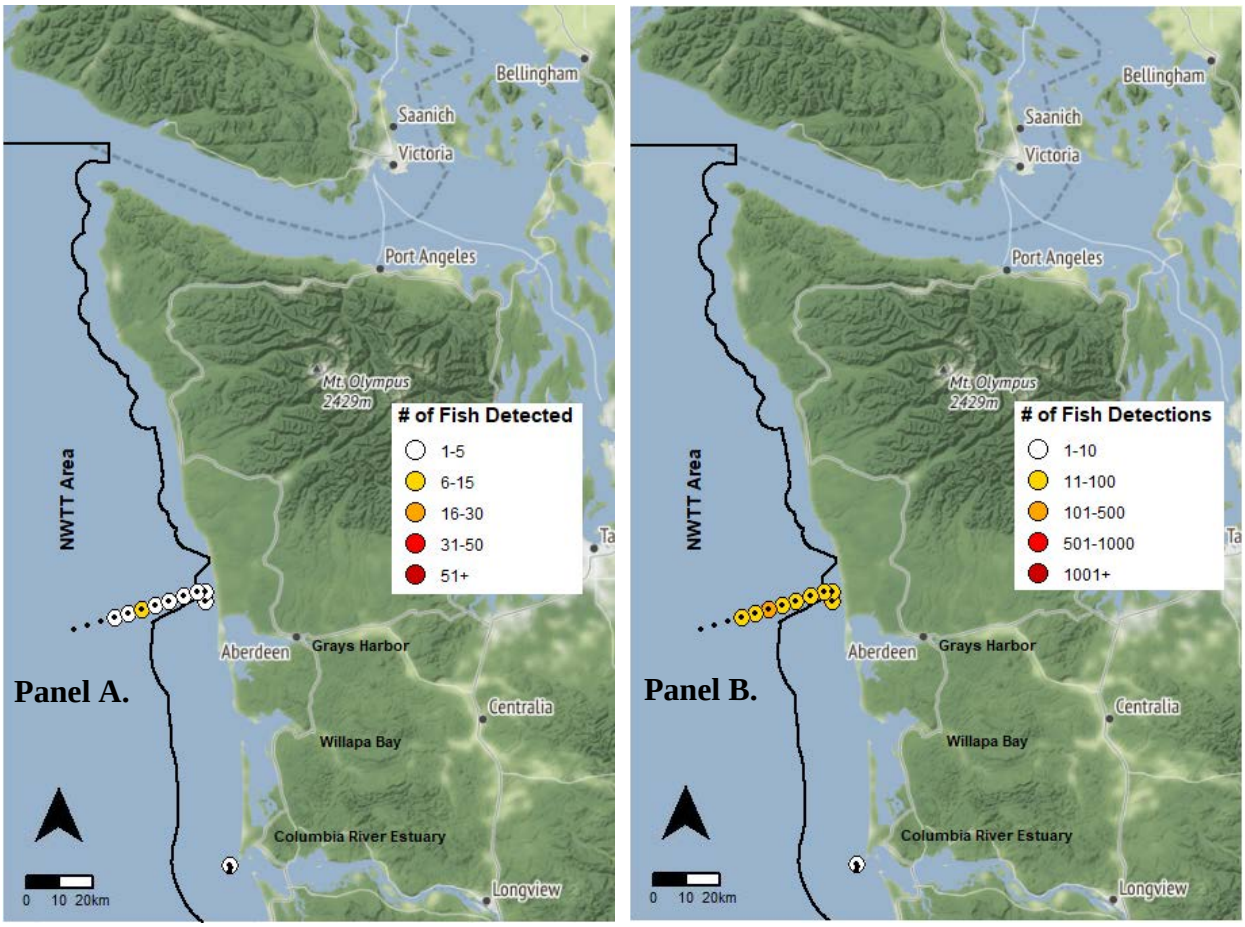

Figure 39. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of December 2021. A total of 27 unique individuals were detected during this period.

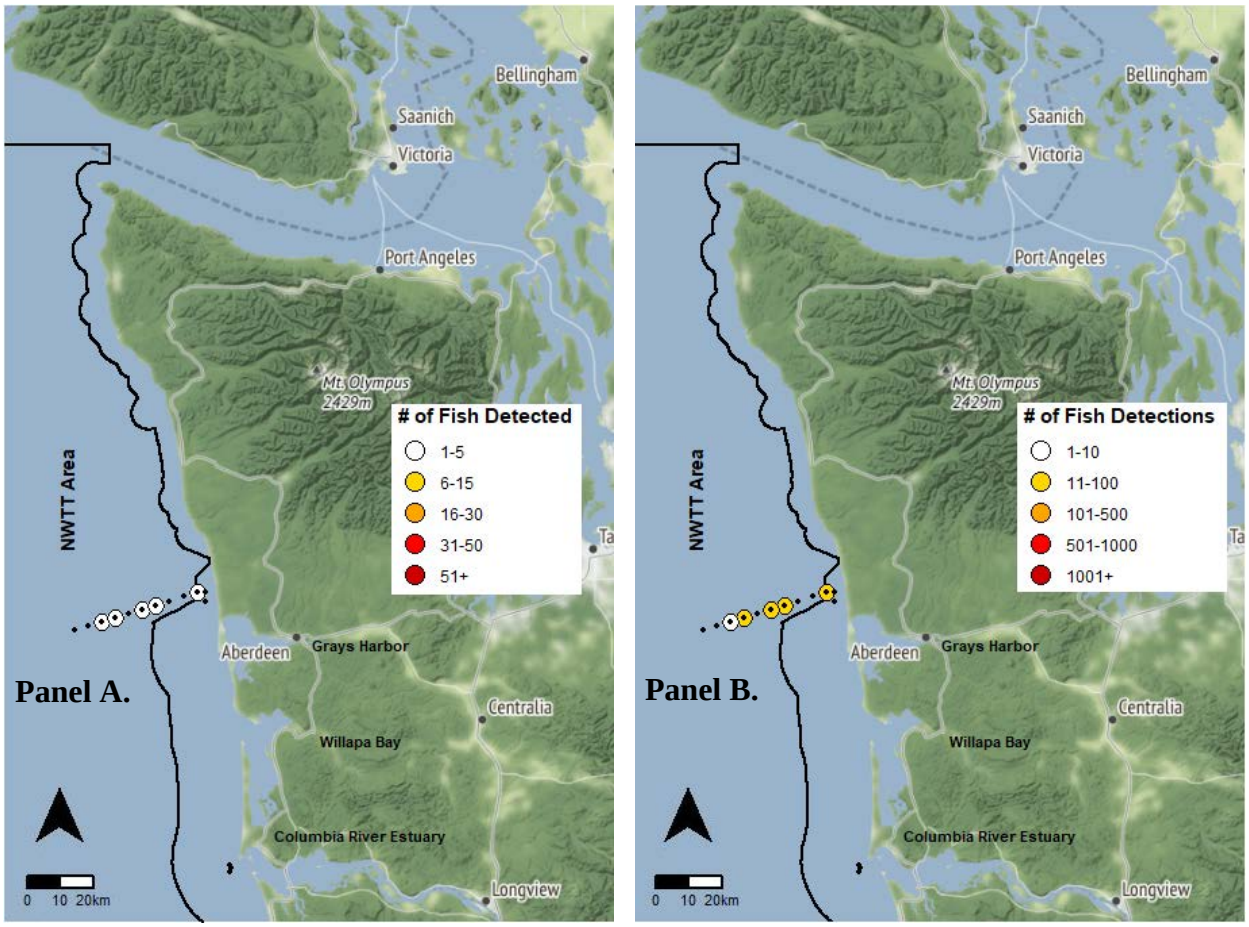

Figure 40. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of January 2022. A total of 19 unique individuals were detected during this period.

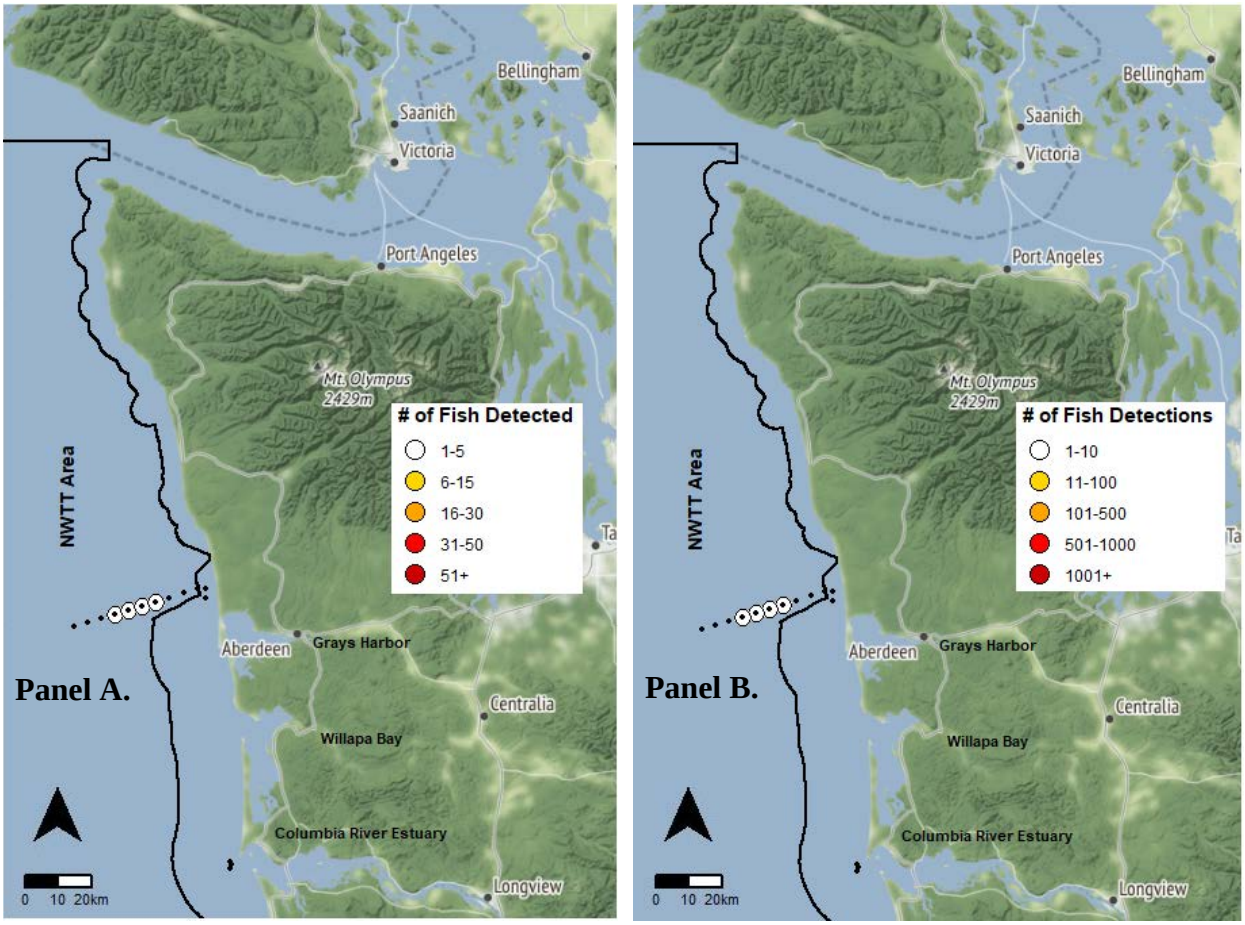

Figure 41. The number of individual green sturgeon detected (Panel A) and the total number of green sturgeon detections (Panel B.) on acoustic receivers during the month of February 2022. A total of 12 unique individuals were detected during this period.