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

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Laura B. Heironimus, Matthew T. Sturza, and Shaffryn M. Schade
Columbia River Management Unit
Washington Department of Fish and Wildlife
5525 South 11th Street
Ridgefield, WA 98642

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Laura B. Heironimus
Matthew T. Sturza
Shaffryn M. Schade

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Columbia River Management Unit
Washington Department of Fish and Wildlife
5525 South 11th Street
Ridgefield, WA 98642

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**14. ABSTRACT**
The Southern distinct population segment (sDPS) of green sturgeon Acipenser medirostris is federally listed as a threatened species under the United States (U.S.) Endangered Species Act (ESA). Large aggregations of both the Northern distinct population segment (nDPS) and sDPS 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 sDPS 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 by WDFW). All acoustic telemetry data was collected on VEMCO 69-kHz VR2W, VR2Tx, or VR2AR acoustic receivers. WDFW's operations to capture and sample 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 implanting 50 fish with acoustic transmitters out of the 110 total fish implanted with acoustic transmitters described in this study. Additionally, The U.S. Navy funded the genetic analysis of 188 fish, including 109 of the fish implanted with acoustic transmitters (an error in the field resulted in the missed collection of the genetic sample from one tagged fish). 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 for the 2021 tagging operations, except WDFW provided the 50 acoustic transmitters implanted in fish captured during 2021.

In total, 230 green sturgeon were handled in Grays Harbor and Willapa Bay, Washington in 2020 and 2021. In that time, 110 green sturgeon were implanted with VEMCO 69-kHz V16 acoustic transmitters, 108 of which were also newly tagged with Biomark 12mm Passive Integrated Transponder (PIT) tags. Two of the fish receiving acoustic transmitters already had a PIT tag upon 4 capture. An additional 77 green sturgeon were newly tagged with PIT tags and another two fish already had a PIT tag upon capture, totaling to 185 fish receiving new PIT tags and four fish previously PIT tagged upon capture out of the 230 fish handled. 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 41 green sturgeon releases without any tags applied or detected from previous sampling events across both years. No green sturgeon mortalities were detected as a result of this study.

To evaluate detections unique to each distinct population segment (DPS), a small fin clip was collected for genetic assignment to DPS from 188 fish sampled, including 109 of the fish implanted with acoustic transmitters. Using a genetics technique involving single nucleotide polymorphism (SNP) assay data, fish were assigned to either the nDPS (n=134 fish; 71%) or sDPS (n=54 fish; 29%). Of just the fish implanted with acoustic transmitters, 71 fish (65%) were assigned to the nDPS, 38 fish (35%) were assigned to the sDPS.

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. Within the NWTT, there were no significant differences in residence time between distinct population segments (DPSs) in 2019–2022; however inconsistent and limited array coverage within the NWTT limit further analysis within this area. Within the coastal estuaries, there were no significant differences in residence time between DPSs in any estuary in 2019–2022, with the exception of 2019 and 2020 in which the nDPS spent significantly more time than the sDPS fish within Grays Harbor. Finally, with additional data provided from collaborators operating acoustic receivers within the San Francisco Estuary and into the Sacramento River, we were able to evaluate the time at large for fish migrating between California and the Pacific Northwest. On average, fish migrating South were at large for approximately 5 months, while fish migrating North averaged 8 months at large. If funding allows, we intend to continue collecting telemetry data for another year to further evaluate the differences in the spatial and temporal use of the offshore array between the nDPS and sDPS of green sturgeon.

**15. SUBJECT TERMS**
Acoustic monitoring, Green Sturgeon, Northwest Training and Testing, acoustic transmitters

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## Executive Summary

The Southern distinct population segment (sDPS) of green sturgeon *Acipenser medirostris* is federally listed as a threatened species under the United States (U.S.) Endangered Species Act (ESA). Large aggregations of both the Northern distinct population segment (nDPS) and sDPS 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 sDPS 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 by WDFW). All acoustic telemetry data was collected on VEMCO 69-kHz VR2W, VR2Tx, or VR2AR acoustic receivers.

WDFW's operations to capture and sample 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 implanting 50 fish with acoustic transmitters out of the 110 total fish implanted with acoustic transmitters described in this study. Additionally, The U.S. Navy funded the genetic analysis of 188 fish, including 109 of the fish implanted with acoustic transmitters (an error in the field resulted in the missed collection of the genetic sample from one tagged fish). 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 for the 2021 tagging operations, except WDFW provided the 50 acoustic transmitters implanted in fish captured during 2021.

In total, 230 green sturgeon were handled in Grays Harbor and Willapa Bay, Washington in 2020 and 2021. In that time, 110 green sturgeon were implanted with VEMCO 69-kHz V16 acoustic transmitters, 108 of which were also newly tagged with Biomark 12mm Passive Integrated Transponder (PIT) tags. Two of the fish receiving acoustic transmitters already had a PIT tag upon

capture. An additional 77 green sturgeon were newly tagged with PIT tags and another two fish already had a PIT tag upon capture, totaling to 185 fish receiving new PIT tags and four fish previously PIT tagged upon capture out of the 230 fish handled. 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 41 green sturgeon releases without any tags applied or detected from previous sampling events across both years. No green sturgeon mortalities were detected as a result of this study.

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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. Within the NWTT, there were no significant differences in residence time between distinct population segments (DPSs) in 2019–2022; however inconsistent and limited array coverage within the NWTT limit further analysis within this area. Within the coastal estuaries, there were no significant differences in residence time between DPSs in any estuary in 2019–2022, with the exception of 2019 and 2020 in which the nDPS spent significantly more time than the sDPS fish within Grays Harbor. Finally, with additional data provided from collaborators operating acoustic receivers within the San Francisco Estuary and into the Sacramento River, we were able to evaluate the time at large for fish migrating between California and the Pacific Northwest. On average, fish migrating South were at large for approximately 5 months, while fish migrating North averaged 8 months at large. If funding allows, we intend to continue collecting telemetry data for another year to further evaluate the differences in the spatial and temporal use of the offshore array between the nDPS and sDPS of green sturgeon.

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# Acronyms and Abbreviations

| | |
|---|---|
| cm | Centimeters |
| DPS | Distinct Population Segment |
| DPSs | Distinct Population Segments |
| ESA | United States Endangered Species Act |
| FL | Fork Length |
| FR | Federal Register |
| ITS | Incidental Take Statement |
| NAVFAC | Naval Facilities Engineering Systems 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 |
| ODFW | Oregon Department of Fish and Wildlife |
| OPR | Office of Protected Resources |
| PIT | Passive Integrated Transponder |
| rkm | River Kilometer |
| sDPS | Southern Distinct Population Segment |
| SNPs | Single Nucleotide Polymorphisms |
| U.S. | United States |
| 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 (DPSs) make up the overall population—the Southern distinct population segment (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 distinct population segment (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 DPSs 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 DPSs; however, genetic analysis is currently the only method available to identify fish to a specific distinct population segment (DPS) within this range.

The United States (U.S.) Navy is interested in the occurrence of the threatened sDPS 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, funded by the U.S. Navy and managed by researchers from the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA-NMFS). This study provided the initial detection data used to evaluate the occurrence of green sturgeon within the NWTT and determine potential training and testing impacts and mitigation measures (NMFS 2020). However, the majority of the 2010–2012 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 VEMCO 69-kHz V16 acoustic transmitters, (2) analyze genetic samples to assign tagged fish to a DPS, and (3) assess the occurrence and distribution of the ESA-listed sDPS 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. Additional objectives added to this report as data became avialable, are (1) evaluating the timing and use of Washington's coastal estuaries, including the Columbia River estuary, Willapa Bay, and Grays Harbor, to provide context to nearshore marine detections, (2) evaluating the similarities and differences in nearshore marine and estuarine use by DPS, and (3) evaluating the time-at-large for green sturgeon migrationing between the acoustic receiver arrays of the Pacific Northwest and those found within California waters to evaluate risks posed to sDPS sturgeon throughout the southern extent of the NWTT.

## Methods

*Fish Capture and Tagging*

Green sturgeon were targeted 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.

**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.

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.

*Fish sampling*

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 FL, measured to the nearest cm girth, tagged with a sterilized PIT tag if no tags are present, and photographed. PIT tags were injected into the tissue posterior to the dorsal fin on the left side of the spine. Due to limitations in equipment and deck space and the desire to limit handling stress, most fish sampled were not weighed as a part of this study; however, girth data was collected as surrogate information to inform fish condition.

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

For genetic analysis and assignment of individuals to a DPS, a small fin clip was removed 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 blood plasma was opportunistically collected 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, a VEMCO 69-kHz V16 acoustic transmitter (10-year battery life; Figure 3) was surgically implanted before releasing the fish directly to the bay or estuary. During the 2020 tagging period, acoustic transmitters were implanted in only the first five fish of every 10 centimeters (cm) fork length (FL) size range so that acoustic detection data would represent a range of different sized individuals. After this goal was met, acoustic transmitters were implanted into any fish captured in good condition until the tagging goal was met (2020 goal: 60 fish tagged, 2021 goal: 50 fish tagged).

**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 an image of a pair of completed sutures closing an incision wound (Right Panel).

Sturgeon receiving an acoustic transmitter require no anesthesia as they enter a state of torpor when rolled to position, ventral side up. The fish in operation were kept wet with fresh water flowing over the gills throughout the duration of the surgery. A scalpel (size #4 handle, size #12 blade) was used to make a 3-4 cm incision through ventral surface of the fish anterior of the pelvic fin and slightly off the midline. Each transmitter was checked to ensure it was in an operational status and then sterilized with 70% isopropyl alcohol prior to insertion into the body cavity. After insertion, the incision was closed with two or three interrupted knots using Oasis violet monofilament absorbable suture (PDO II size 1, NCP-1 cutting needle; Figure 3).

During sampling, 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. Additional details regarding the state and federal agencies responsible for the sampling efforts and funding for this work can be found in Table 1.

**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 | 14 | days on water | |
| | | Green Sturgeon Captured | 230 | fish handled | |
| | | Acoustic Transmitters | 110 | fish tagged | |
| | | Genetic Analysis | 188 | clips analyzed | |

*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.

*Acoustic Receiver Deployments*

The acoustic data analyzed in this report represents data collected within two unique areas, within the Pacific Northwest and California. The first unique area is found in the Pacific Northwest and is made up of several smaller arrays managed by various state and federal agencies within the Washington coastal estuaries and the nearshore marine waters off the coasts of Washington and British Columbia (Figure 4). The receiver coverage in this area provides coverage of only a small fraction of the NWTT area which varies through time. The second unique area is found in California and is also made up of several smaller arrays managed by various state and federal agencies, and researchers at the University of California-Davis (Figure 4). No usable detection data were found between these two unique areas, therefore it is unknown whether fish migrate within or outside of the NWTT when traveling along the coastline between these areas.


**Figure 4.** The full boundary of the Northwest Testing and Training (NWTT) area, outlined in black, and the approximate areas in which the deployed acoustic transmitters analyzed in this study were located, outlined in white (the Pacific Northwest array is outlined with a solid white line, the California array is outlined in a dashed white line).

WDFW operated four VEMCO 69-kHz VR2W acoustic receivers at the mouth of Grays Harbor, Washington from May 5 to October 22, 2020, from May 20 to October 22, 2021, and from June 7 to October 31, 2022 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 5). For the same purpose, WDFW operated another two VEMCO 69-kHz VR2W acoustic receivers at the mouth of Willapa Bay, Washington from August 10 to October 15, 2020 and from June 3, 2020 to January 21, 2022 (Table 2; Figure 5). In 2020 through 2022, estuarine habitat use was monitored using VEMCO 69-kHz acoustic receiver arrays in Grays Harbor and the Columbia River estuary, Washington operated by WDFW and in Willapa Bay operated by 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 2022 (Table 2; Figure 5). In 2021 only, the Department of Fisheries and Oceans Canada shared the deployment and detection data from 39 additional acoustic receivers deployed along the British Columbia coastline

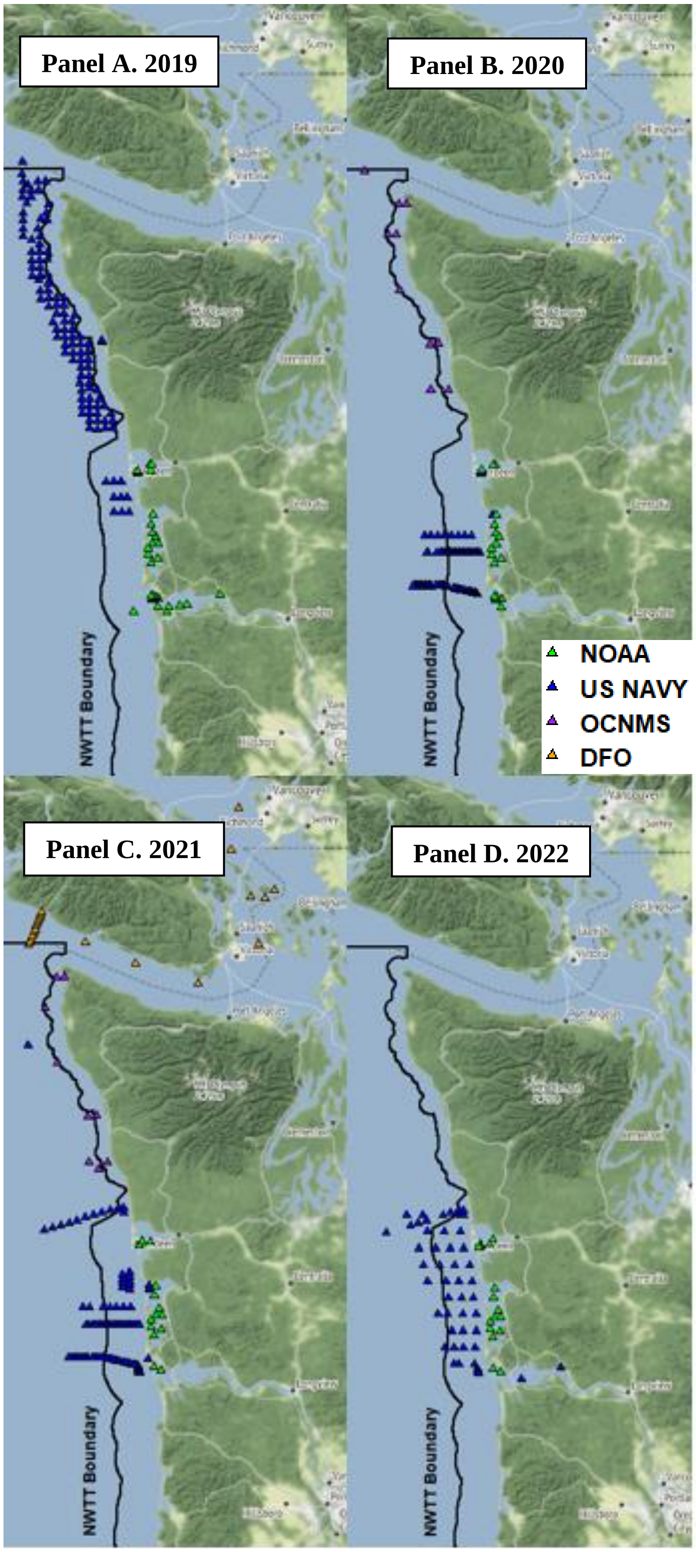


**Figure 5.** A map of acoustic receivers analyzed for green sturgeon detections, deployed during 2019 (Panel A), 2020 (Panel B), 2021 (Panel C), and 2022 (Panel D). The fill color of each symbol indicates the funding source for each receiver deployment, green symbols were funded by National Oceanic 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).

(Table 2; Figure 5). Green sturgeon detections on this offshore array were monitored to evaluate migrations along the coast and within the NWTT. Additional details regarding 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 in the Pacific Northwest 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, and (D) 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 | -- | -- |
| 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 | -- | -- |
| 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 | D | D |
| 2022 | Columbia River | 2 | A | C |
| | Willapa Bay | 9 | C | C |
| | Grays Harbor | 6 | A | C |
| | Offshore – USA | 50 | C | B |
| | Offshore – Canada | 0 | -- | -- |

Additionally, we requested and received green sturgeon detection data from acoustic receivers deployed within San Francisco Bay and the Sacramento River Basin (hereafter referred to as the California array). For the purposes of this report, we only included detections that occurred between May 2019 and November 2022. Due to the sensitivity in publishing shared data and the extent to which we agreed to analyze these detections, the acoustic deployments for California detection data are not included in the adjoining figures. For the purpose of this study, data from the California array was used to evaluate the total time-at-large for individual fish between the two distinct regions and not within the California array itself. The agencies that shared this data include the California Department of Fish and Wildlife, the California Department of Water Resources, the University of California-Davis, the University of California-Santa Cruz, and the Pacific States Marine Fish Commission.

## Results and Discussion

*All Fish Sampling*

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.

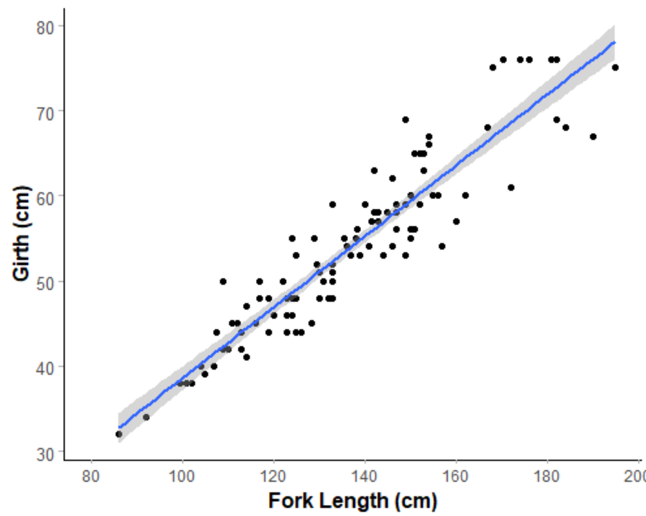


**Figure 6.** Plot of fork length (cm) and girth (cm) data for all green sturgeon sampled in 2020 and 2021. The correlation coefficient between these variables indicated a strong relationship, r=0.93.

The 38 green sturgeon captured in Willapa Bay during August 10–13, 2020, ranged 102–191 cm FL and 38–76 cm girth (Table 3). 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 (Table 3). 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 (Table 3). 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 (Figure 6). 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.

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. Four fish sampled had a PIT tag implanted from a previous sampling event. 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 clip), 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.

**Table 3.** Sampling statistics for all fish handled in Willapa Bay and Grays Harbor, Washington, in 2020 and 2021.

| **Sampling Method** | **Willapa Bay 2020** | **Grays Harbor 2020** | **Grays Harbor 2021** | **Total** |
|---|---|---|---|---|
| PIT tags applied | 37 | 83 | 65 | 185 |
| PIT tags detected | 1 | 1 | 2 | 4 |
| Acoustic tags applied | 25 | 35 | 50 | 110 |
| Weights measured | 11 | 7 | 0 | 18 |
| Weight range (kg) | 9.0–19.0 | 4.3–32.0 | | |
| Lengths measured | 38 | 86 | 65 | 189 |
| Fork Length range (cm) | 102.0–191.0 | 74.0–195.0 | 92.0–190.0 | |
| Girths measured | 38 | 85 | 64 | 187 |
| Girth (cm) | 38.0–76.0 | 32.0–80.0 | 34.0–76.0 | |
| Fin rays collected | 14 | 19 | 0 | 33 |
| Blood plasma collected | 34 | 35 | 63 | 132 |
| Genetic samples collected | 38 | 85 | 65 | 188 |
| Assigned to nDPS | 24 | 61 | 49 | 134 |
| Assigned to sDPS | 14 | 24 | 16 | 54 |
| Released without PIT or Acoustic tag | 0 | 3 | 38 | 41 |
| **Total Green Sturgeon Handled** | **38** | **87** | **105** | **230** |

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 (Table 3). 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 higher proportion of sDPS fish were sampled in Willapa Bay in 2020 (37% sDPS) than the proportion of sDPS sampled in Grays Harbor in either 2020 (28% sDPS) or 2021 (25% sDPS). In contrast, during a WDFW-led study that took place in 2010–2012, the ratios of sDPS to nDPS fish sampled 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 DPSs.

*Acoustic Tagged Fish Sampling*

A total of 110 green sturgeon were implanted with acoustic transmitters across 2020 and 2021 (Figure 7; Table 4); 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, the 50 transmitters contributed by the U.S. Navy were split evenly between the two areas in 2020, and the 10 transmitters contributed by the U.S. Army Corps of Engineers in 2020 and the 50 transmitters contributed by WDFW in 2021 were implanted in fish within Grays Harbor only (Table 1).

A subset of the fish genetically analyzed include 109 of the fish 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 7; Table 4). One fish implanted with an acoustic transmitter was not assigned to a DPS due to an error in the field collecting the genetic sample.

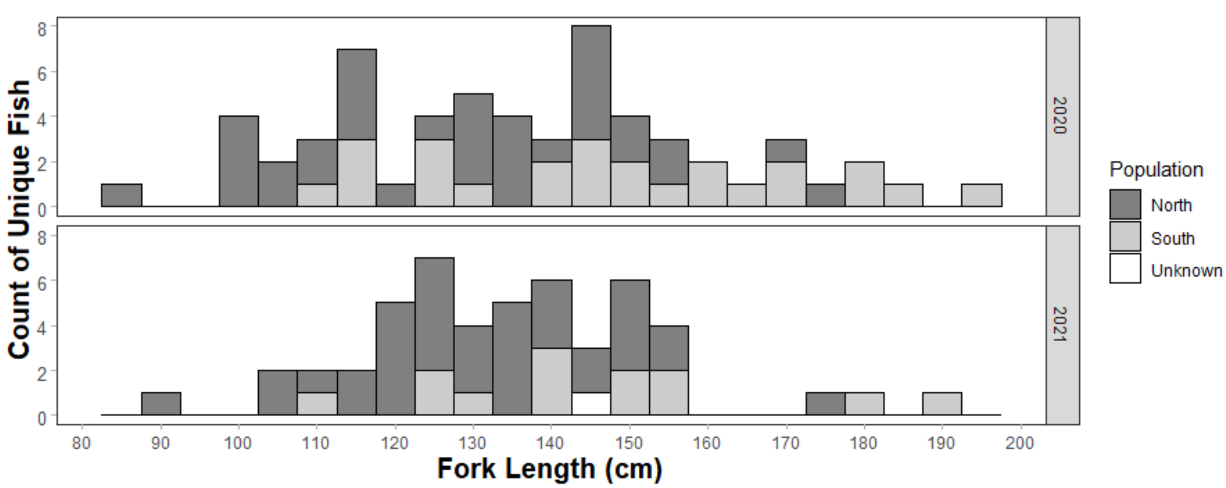


**Figure 7.** Length-frequency histogram of green sturgeon implanted with acoustic transmitters in 2020 (top panel) and 2021 (bottom panel). Shading indicates population assignment to either the northern DPS (dark gray), the southern DPS (light gray), or unknown assignment (white).

**Table 44.** 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 not assigned to a DPS.

| Year | Area | Sample Size | Fork Length (cm) | | Girth (cm) | |
|---|---|---|---|---|---|---|
| | | | Mean | Range | Mean | Range |
| ***Northern DPS*** | | | | | | |
| 2020 | Grays Harbor | 20 | 130.4 | 86.0–176.0 | 53.1 | 32.0–76.0 |
| | Willapa Bay | 15 | 126.7 | 102.0–157.0 | 48.7 | 38.0–58.0 |
| 2021 | Grays Harbor | 36 | 130.9 | 92.0–174.0 | 51 | 34.0–76.0 |
| ***Southern DPS*** | | | | | | |
| 2020 | Grays Harbor | 15 | 152.9 | 113.0–195.0 | 60.8 | 42.0–76.0 |
| | Willapa Bay | 10 | 141.4 | 103.0–184.0 | 56 | 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 | 144.0 | 53 | 53.0 |

*Acoustic Receiver Deployments*

All WDFW-operated acoustic receivers that were recovered from the 2020–2022 field seasons were downloaded and assessed for green sturgeon detections. Of the four deployed acoustic receivers funded by the U.S. Navy for the 2020-2021 field seasons, three were recovered in both 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 Navy-funded offshore array to collect acoustic receiver deployment and fish detection data from May 2019 through September 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 A1–A11). Between April and June 2020, there were no acoustic receivers present within the NWTT (Figures A12–A14). During July 2020, three rows of receivers oriented east to west were deployed between the Columbia River mouth and the entrance to Willapa Bay (Figure A15). From this date forward, receivers were deployed and removed through time within the offshore array in various arrangements; however only a portion of the receivers were situated within the NWTT (Figure A16–A41).

*Detections in Washington's Estuaries*

Among the fish that were tagged in Grays Harbor in 2020 and 2021 each individual was detected 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. Among the fish that were tagged in Willapa Bay in 2020 each individual was detected at multiple receivers within the estuary, and all but two were detected 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 Bay between August and October 2021. Three different fish tagged in 2021 were also detected within the Columbia Estuary between September and October 2021.

The general trend of detection data across all three estuaries indicates similar increases in tag counts in late-June and decreases in tag counts in mid-September with peak densities occurring between mid-July and mid-August (Figure 8). This is consistent with the results found by Moser and Lindley (2007) in which they correlated the timing of migration into the estuaries with a high estuarine salinity concentration and a shift in estuarine water temperatures to 2° C warmer than ocean temperatures. In 2022, the deployment of receivers in Grays Harbor was delayed until June, at which point relatively higher counts of both DPSs were immediately detected within the estuary (Figure 8). The generally low detections of both DPSs in the Columbia River estuary may be a result of either low estuarine use or the lack of receiver coverage in this area (Figure 8).

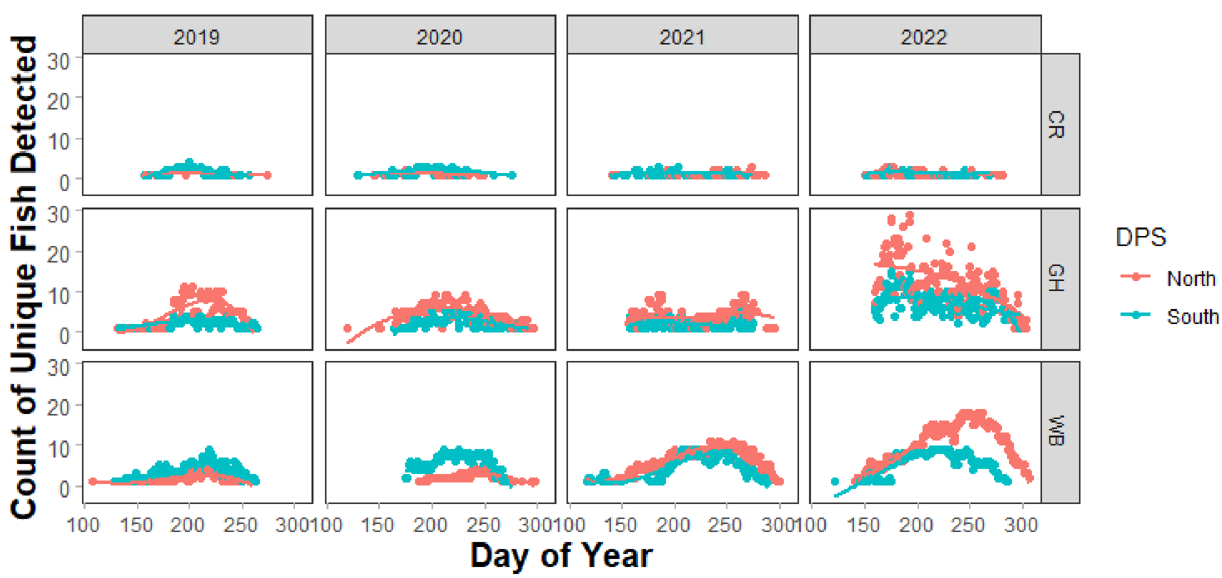


**Figure 8.** The 2019–2020 daily counts of unique fish detections within each of the three Washington coastal estuaries, the Columbia River (CR; indicated in red), Grays Harbor (GH; indicated in green), and Willapa Bay (WB; indicated in blue). The top two panels represent nDPS fish detections in 2019 (left) and 2020 (right) while the bottom two panels represent sDPS fish detections in same years, respectively.

To compare the DPS-specific use of estuaries, detection data for returning fish, excluding only detections from fish tagged within the same year, were analyzed in 2019–2022. The receiver coverage in each of the estuaries was inadequate to conduct occupancy modeling; however, evaluation of DPS-specific residence times in each estuary is appropriate, assuming that the detection probability of both DPSs within an estuary is equal among the existing receivers. A series of Student's t-tests were used to evaluate differences in DPS-specific residence times between estuaries and years. For the purpose of this analysis, residence time was defined as the difference in time between the first and last detection of a unique acoustic tag ID within a given area, with no detections occurring in any other area during that period. Due to the highly migratory nature of green sturgeon, some individual fish may have multiple residence times calculated for different areas within the same year. Due to variations in receiver array coverage and detection probabilities within the different estuaries, residence times cannot be directly compared between estuaries. In 2019 and 2020, nDPS spent significantly more time in Grays Harbor than the sDPS (p-values for the 2019 and 2020 comparisons in Grays Harbor are 0.008 and 0.05, respectively; Figure 9). In all other estuaries and years, there were no significant differences in residence times between DPSs (Figure 9).

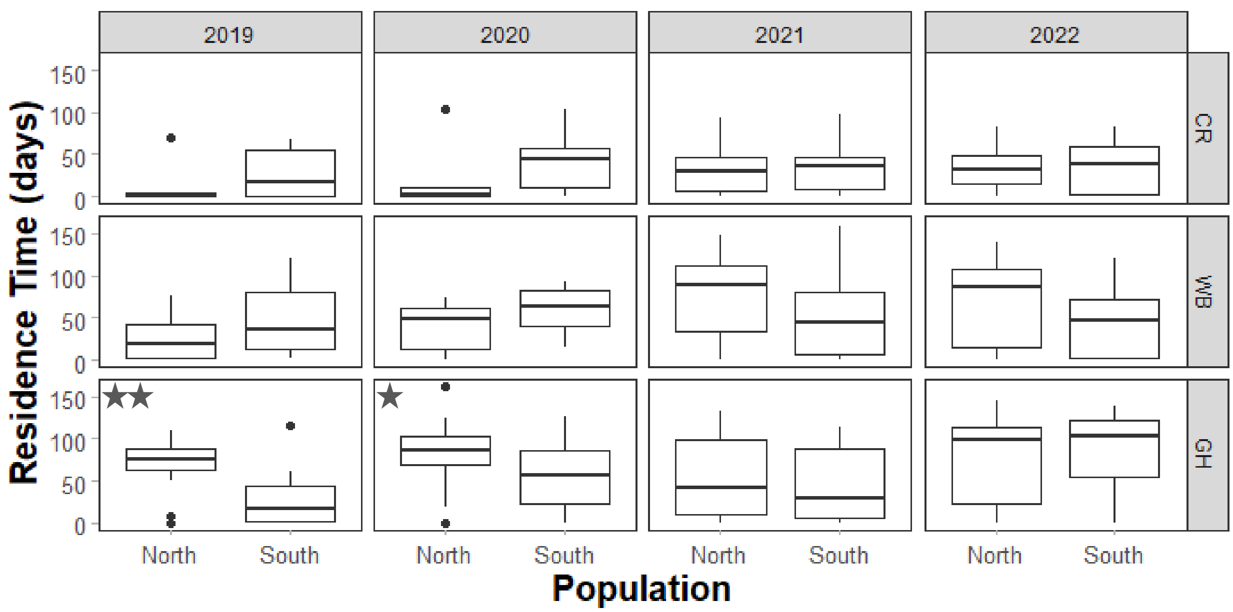


**Figure 9.** Comparison of residence times between the nDPS (North) and the sDPS (South) of green sturgeon across years and estuaries (CR = Columbia River, WB = Willapa Bay, and GH = Grays Harbor). Stars indicate level of significance (one star = p-value<0.1, two stars = p-value<0.01).

*Detections along the Pacific Northwest Coast*

Green sturgeon were detected within the offshore acoustic receiver array nearly every month in which data was available between March 2019 and July 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 in both July 2020 and August 2021 (Figure 10). The lack of any July 2020, August 2021, and August or September 2022 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 A3–A5; Figures A15–A17; Figures A27–A29, Figures A39–A41).

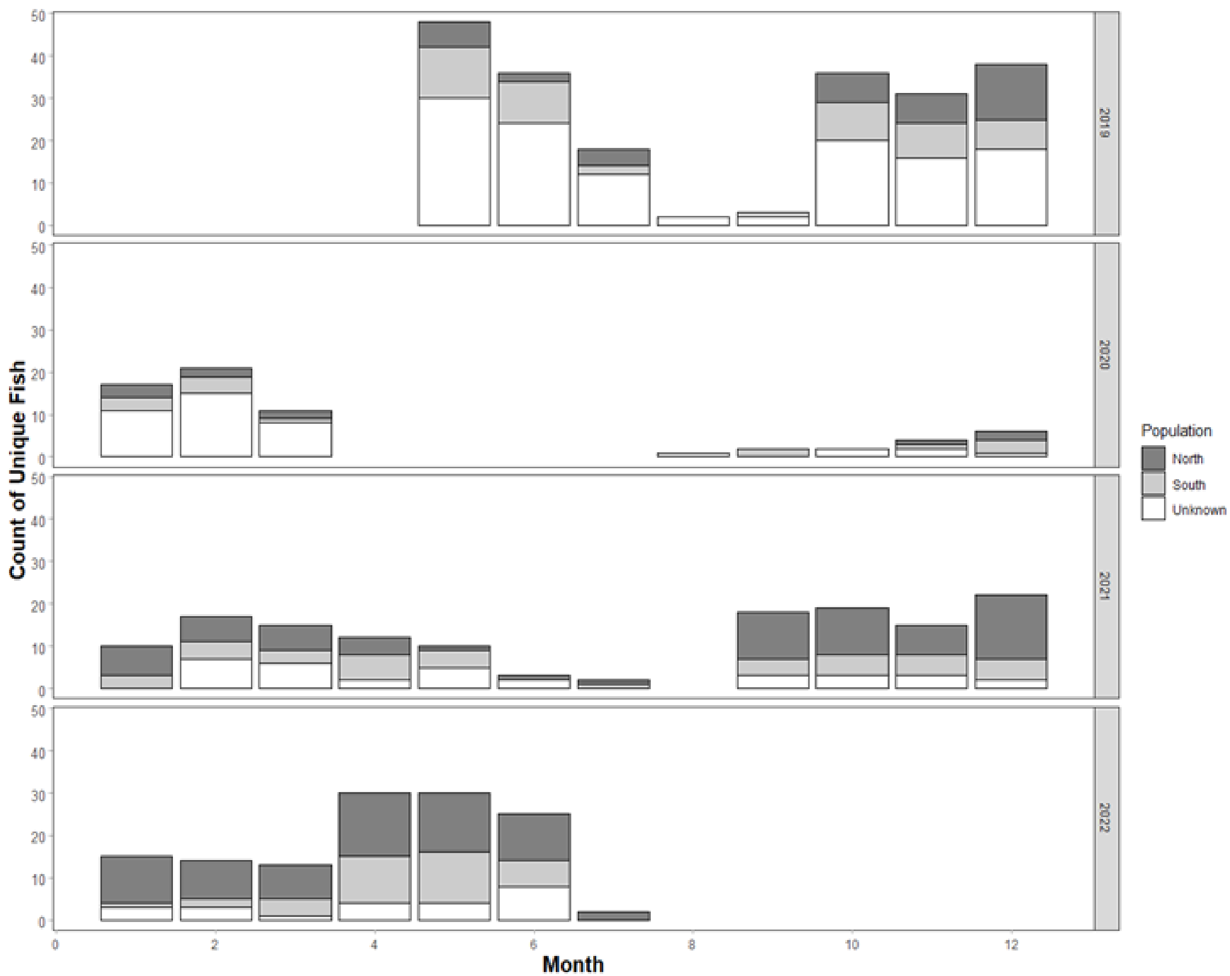


**Figure 10.** Frequency of unique green sturgeon detections within the NWTT from May 2019 (top panel) through November 2022 (bottom panel). Shading indicates population assignment to either the nDPS (dark gray), the sDPS (light gray), or unknown assignment (white). No acoustic receivers were deployed 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. Additionally, the spatial coverage of acoustic receiver deployments in the offshore array were not consistent between years; therefore, a detailed analysis of green sturgeon occupancy within the NWTT is not possible during the study period.

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 (Figure 10). 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 A15–A17). 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 A16–26).

Similar to the previous two years, detections were primarily concentrated within the coastal estuaries during the summer of 2021 (Figures A27–A29). A row of offshore receivers primarily situated within the NWTT was deployed during September 2021 north of the entrance to Grays Harbor (Figure A29). 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 A30–34).

The receivers deployed off the Washington coast in 2022 were located between the mouth of the Columbia River and just north of Grays Harbor. The majority of receiver deployments and detections occurred east of the NWTT boundary during this year. Detections within the NWTT occurred in March–July 2022 but were most common during March–May 2022 (Figures A35–A39. Both the number of individual fish detected and the overall number of detections within the NWTT peaked during April 2022 before declining as fish moved into the coastal estuaries.

Between June and September 2022, more than 100 fish were detected each month, nearly all occurring within these coastal estuaries (Figures A38–A41).

To compare the DPS-specific use of the NWTT, detection data for returning fish, excluding only detections from fish tagged within the same year, were analyzed in 2019–2022. The receiver coverage across the NWTT was inadequate to conduct occupancy modeling; however, evaluation of DPS-specific residence times is appropriate, assuming that the detection probability of both DPSs within the NWTT is equal among the existing receivers. A series of Student's t-tests were used to evaluate differences in DPS-specific residence times between years. For the purpose of this analysis, residence time was defined as the difference in time between the first and last detection of a unique acoustic tag ID within a given area, with no detections occurring in any other area during that period. Due to the highly migratory nature of green sturgeon, some individual fish may have multiple residence times calculated within the same year. Across all years, there were no significant differences in residence times between DPSs (Figure 11). Year-to-year variability in residences times may be explained by variations in environmental conditions within and around the NWTT, data which was not available for the purpose of this analysis.

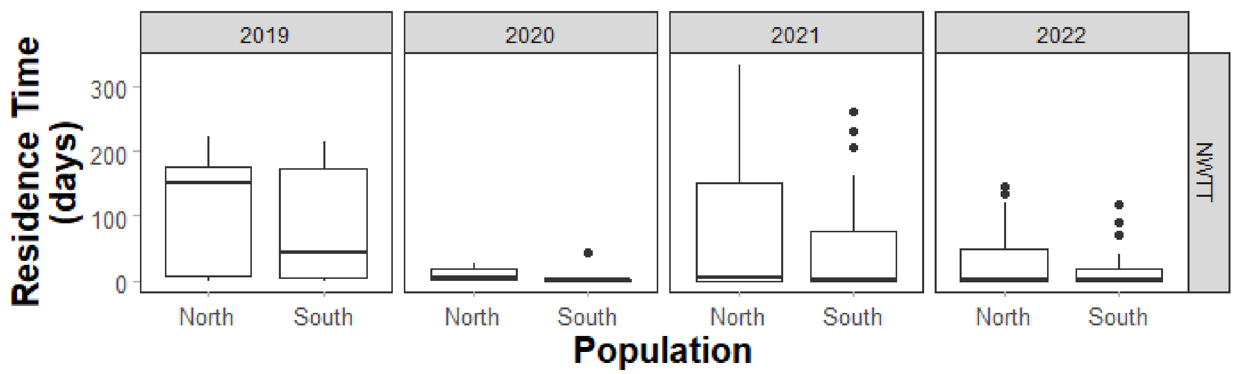


**Figure 11.** Comparison of residence times between the nDPS (North) and the sDPS (South) of green sturgeon across years within the NWTT. There were no significant differences in residence times by DPS detected within any year tested.

The offshore array dataset included information pertaining to the depths at which acoustic receivers were deployed; however inconsistent receiver coverage and a lack of coverage in deeper waters limits analysis of the green sturgeon preferred depths. Despite this limitation, the depths at which green sturgeon were commonly detected was evaluated (Figure 12). 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 suggesting that they may use these depths more frequently than can be identified with the data available in this study. During the July 1–September 30 period, all detections were in waters less than 100m, with no detections occurring in the NWTT in 2020 (Figure 12).

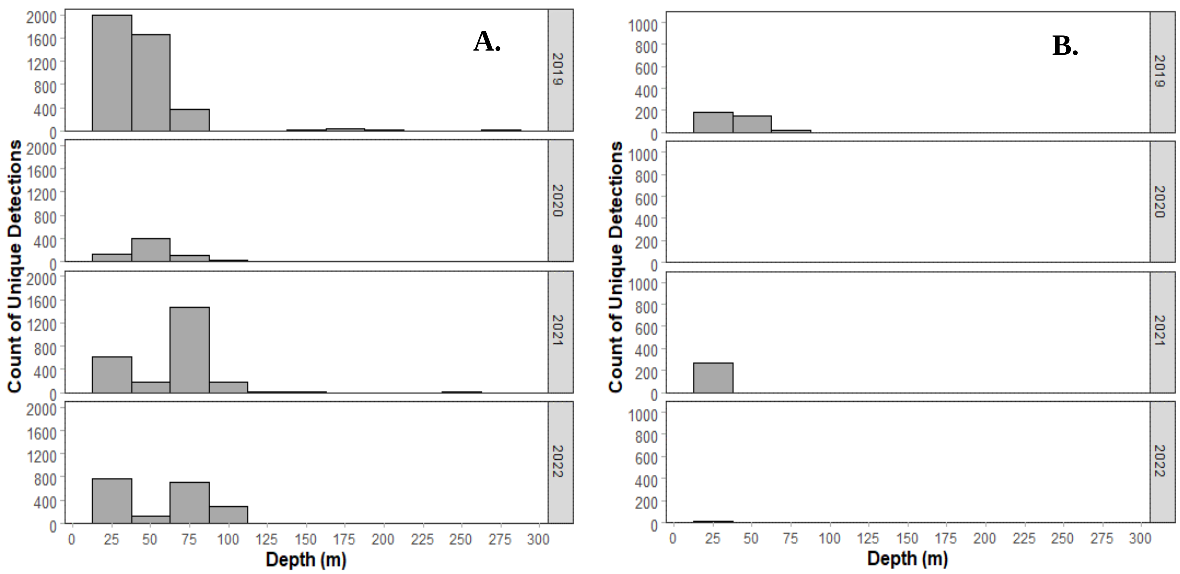


**Figure 12.** Unique detections of green sturgeon within the NWTT boundary by depth (bin width=25 m), between 2019–2022. Panel A includes year-round acoustic detections. Panel B includes acoustic detections from July 1 through September 30, only.

*Migrations between the Pacific Northwest and California*

Green sturgeon implanted with acoustic transmitters have been detected within the San Francisco Bay and the Sacramento River basin (hereafter referred to as the California array), presumably migrating to the Sacramento River basin sDPS green sturgeon spawning grounds. A total of 49 fish were detected migrating between the California array and the Washington coast between 2019 and 2022. Of these 49 fish, 22 were detected only moving South from the Washington coast to the California array, 14 fish were detected only moving North from the California array to the Washington Coast, and 13 fish were detected making migrations in both directions (Figure 13). Within this range, detection data indicates that all 49 fish were at large for at least a portion of this time period between October and March, most commonly between February through December (Figure 13). On average, fish migrating South were at large for approximately 5 months, while fish migrating North averaged 8 months at large (Figure 14). This difference in the length of time traveling between areas is likely related to the strength of the California Current at the time of travel. The southward flowing California Current may allow fish to move south along the coast more quickly but slow the northward journey. Four fish were at-large, presumably moving northward between the two regions, for a year or longer (Figure 14). Telemetric data indicates sDPS Green Sturgeon have been detected in Oregon's coastal estuaries

(Huff et al. 2012) and between the Pacific Northwest and California arrays, it is unknown what migration path these fish take, or if that path is direct. This data indicates that migrating fish may be present within coastal estuaries, the nearshore marine areas, and potentially within the NWTT along the Oregon and northern California coastline throughout this winter migration period.

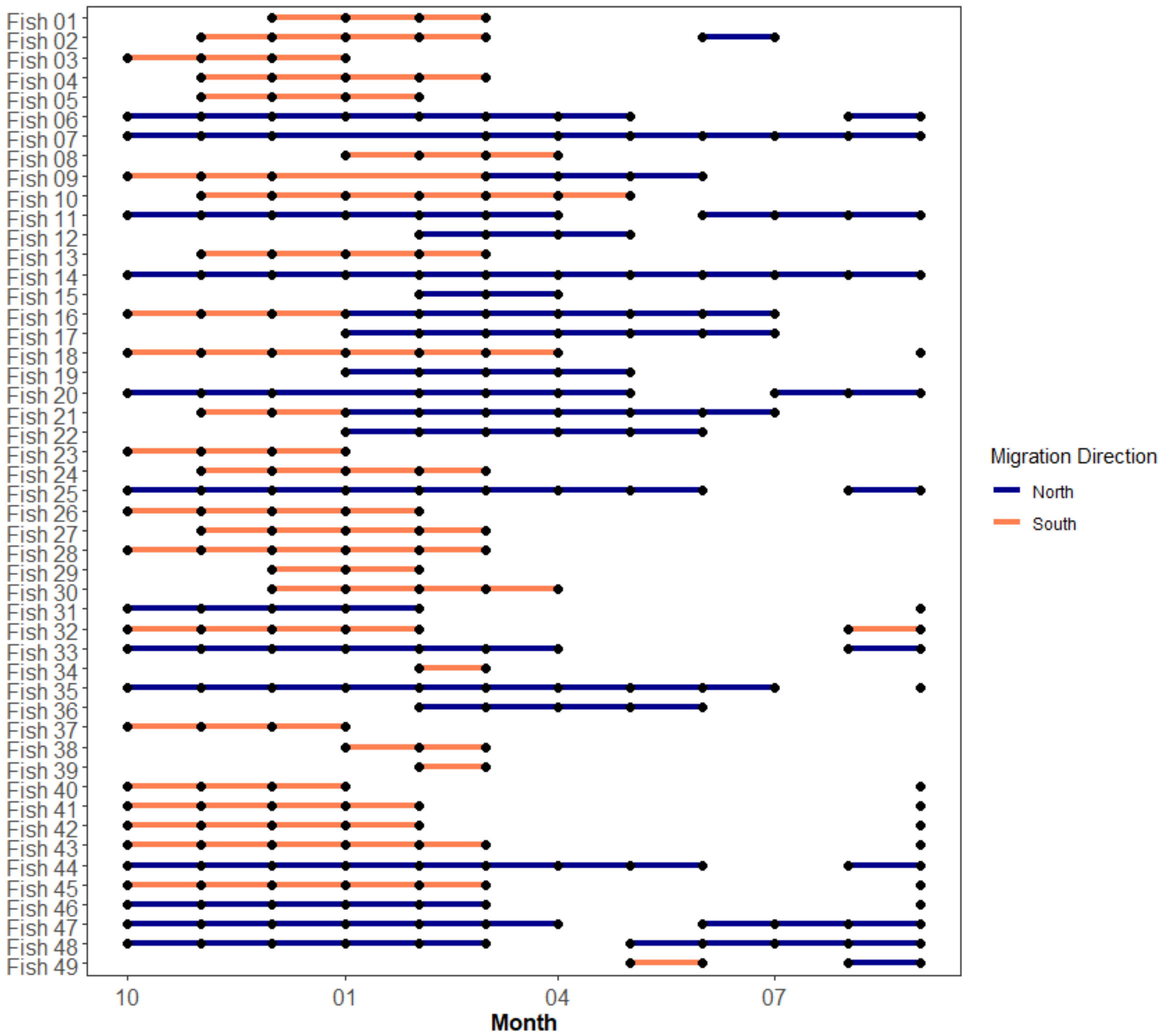


**Figure 13.** The months individual green Sturgeon were at large between the coast of Washington and San Francisco Bay. Lines represent months when green Sturgeon are assumed to be migrating between these areas and the direction they were moving. Data are from May 2019 through November 2022.

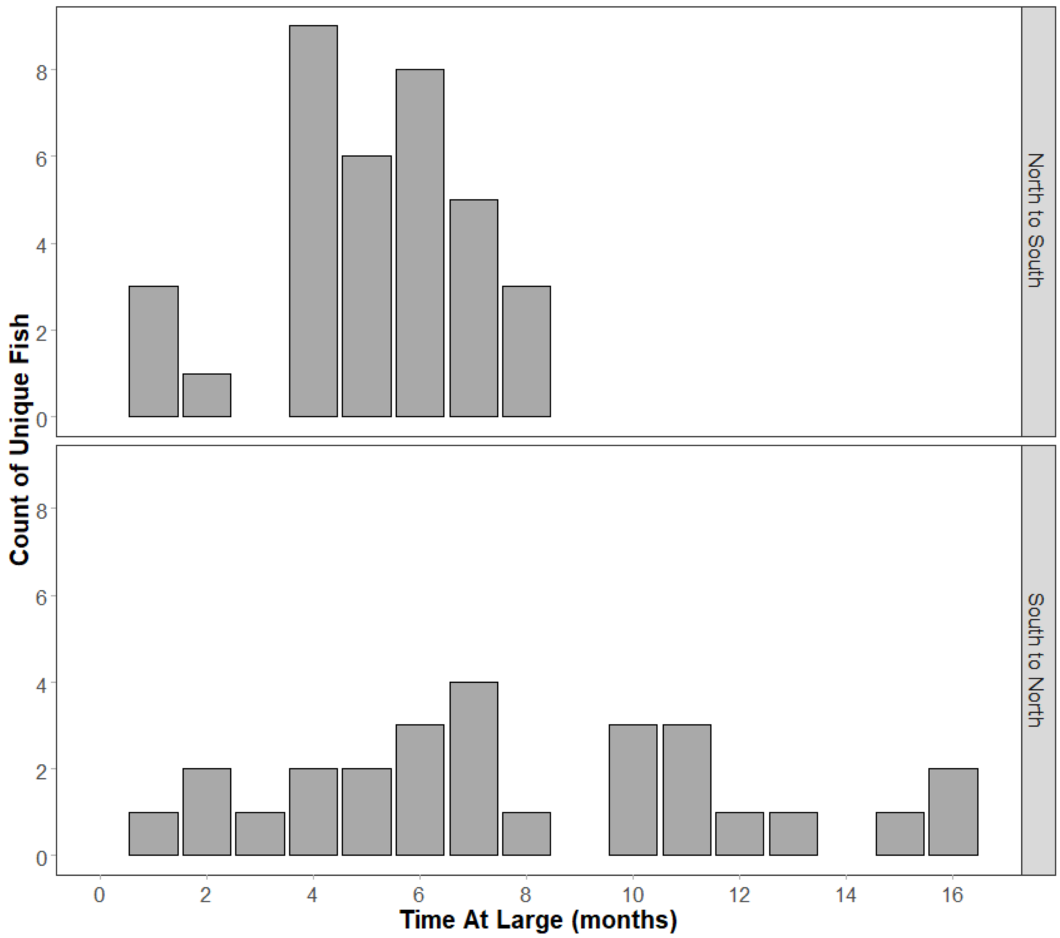


**Figure 14.** The count of unique fish for time at-large, in months, between the last detection off the coast of Washington and the subsequent first detection within the California array (top panel; Southern migration) and between the last detection within the California array and the subsequent first detection off the Washington coast (bottom panel; Northern migration). Data represent acoustic detections from May 2019 through November 2022.

*Limitations and Future Research*

Some limitations of this project include a lack of consistent and thorough acoustic receiver coverage within the NWTT between years and the lack of consistent environmental data available throughout the study time period to align with detection data. As a result of these limitations, a thorough evaluation of green sturgeon use of the NWTT was not possible. Additionally, evaluation of the influence of environmental effects on between year variation in migratory behavior was not possible throughout this time range. If funding allows, we intend to work closely with project collaborators over the next year to incorporate additional acoustic detection and environmental data, where available, to continue expanding on the evaluation and analyses presented in this report.

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# Appendix A. Detection Maps

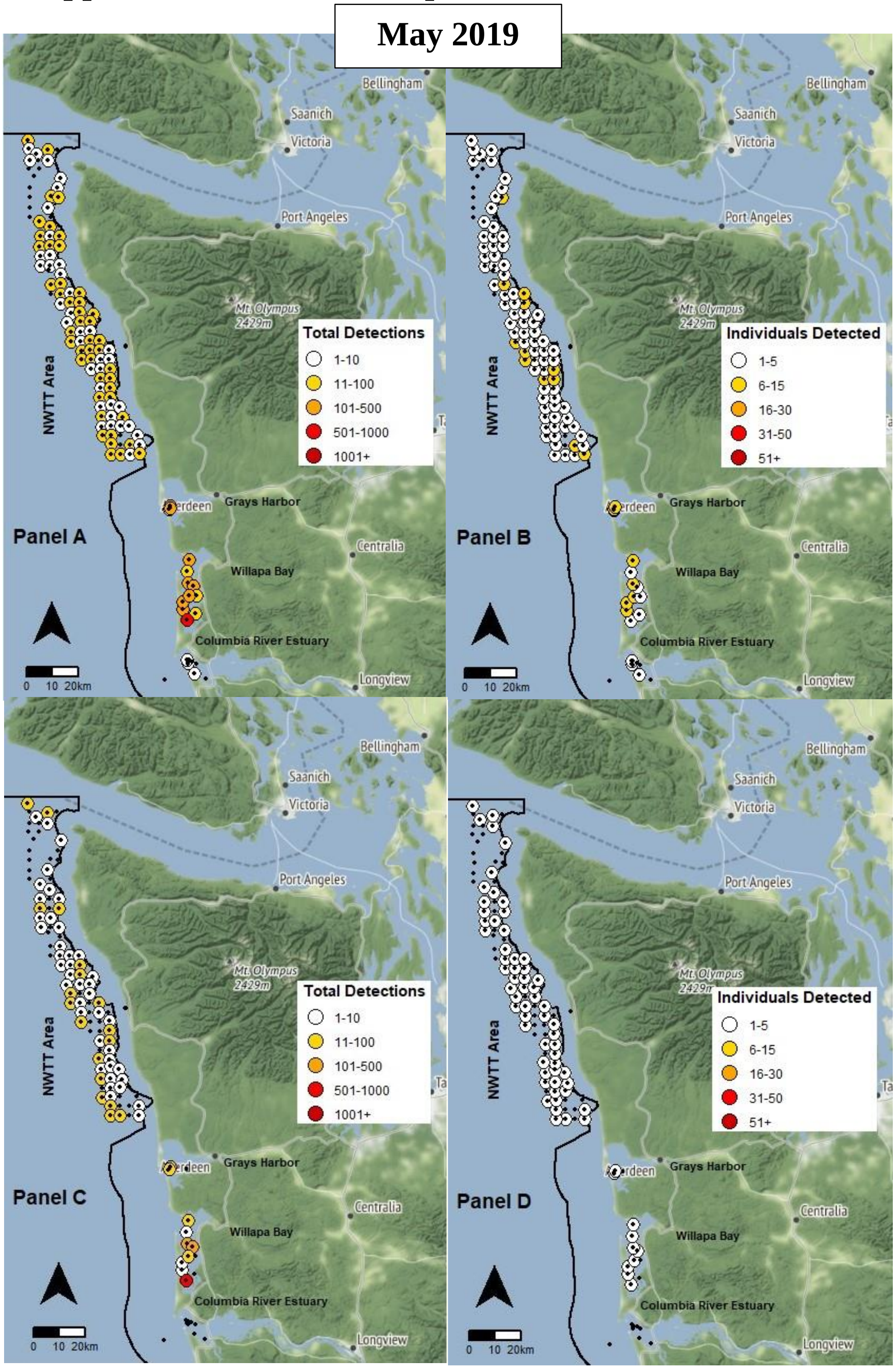


**Figure A- 1.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during May 2019. Black points represent receiver locations during this month. A total of 15 sDPS green sturgeon and 64 unique individuals were detected during this period.

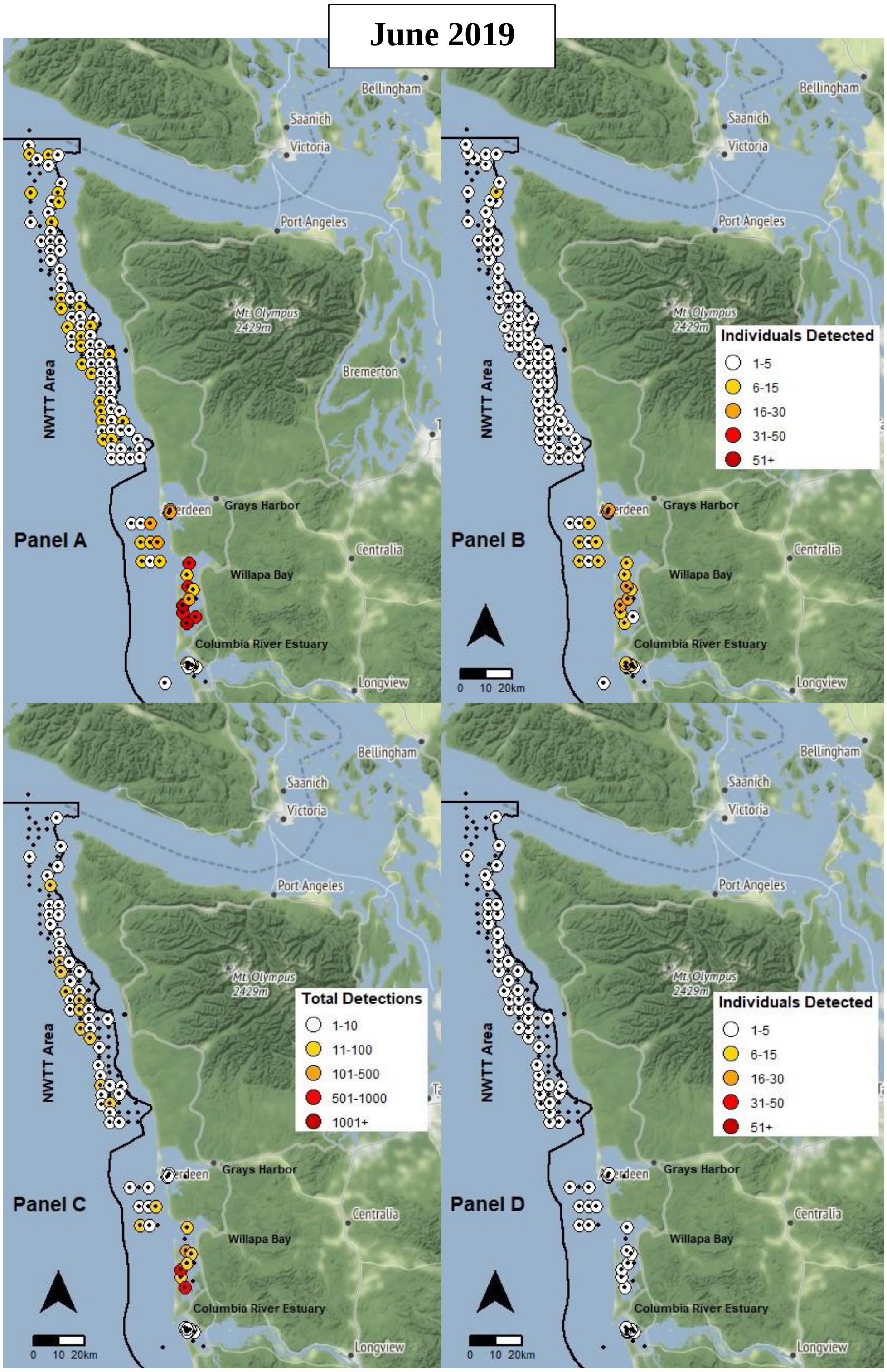


**Figure A- 2.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during June 2019. Black points represent receiver locations during this month. A total of 20 sDPS green sturgeon and 93 unique individuals were detected during this period.

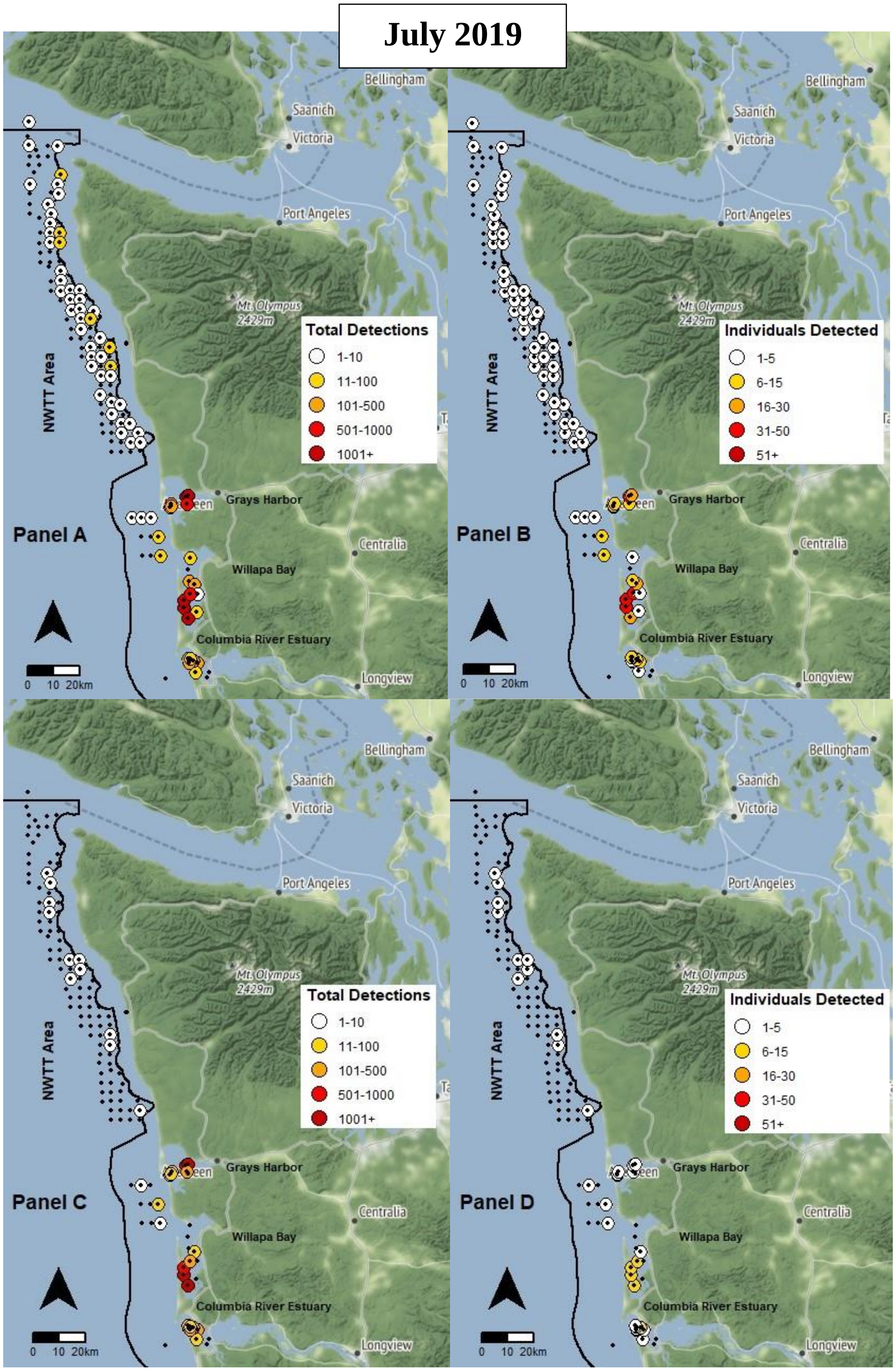


**Figure A- 3.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during July 2019. Black points represent receiver locations during this month. A total of 20 sDPS green sturgeon and 100 unique individuals were detected during this period.

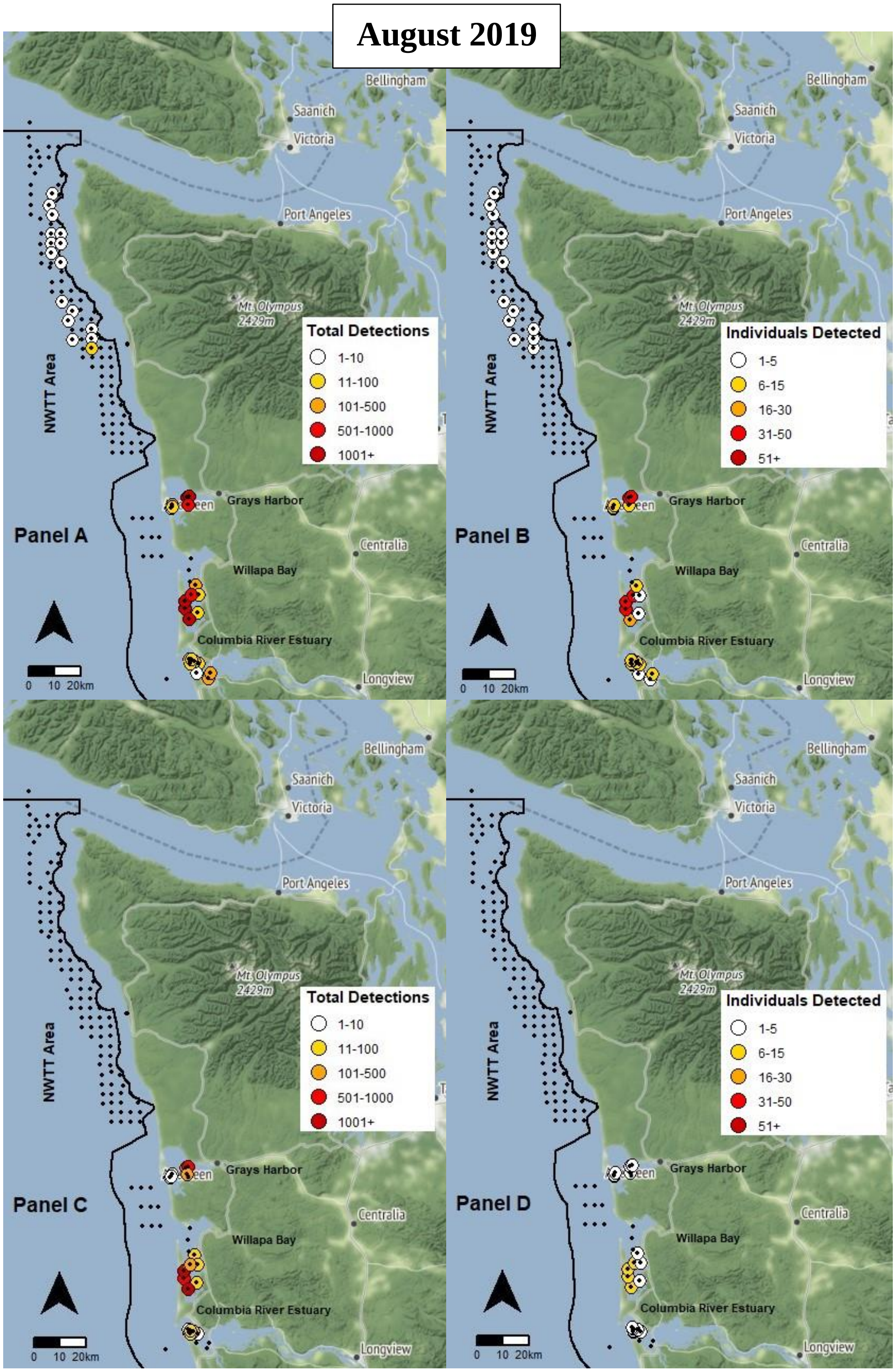


**Figure A- 4.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during August 2019. Black points represent receiver locations during this month. A total of 19 sDPS green sturgeon and 103 unique individuals were detected during this period.

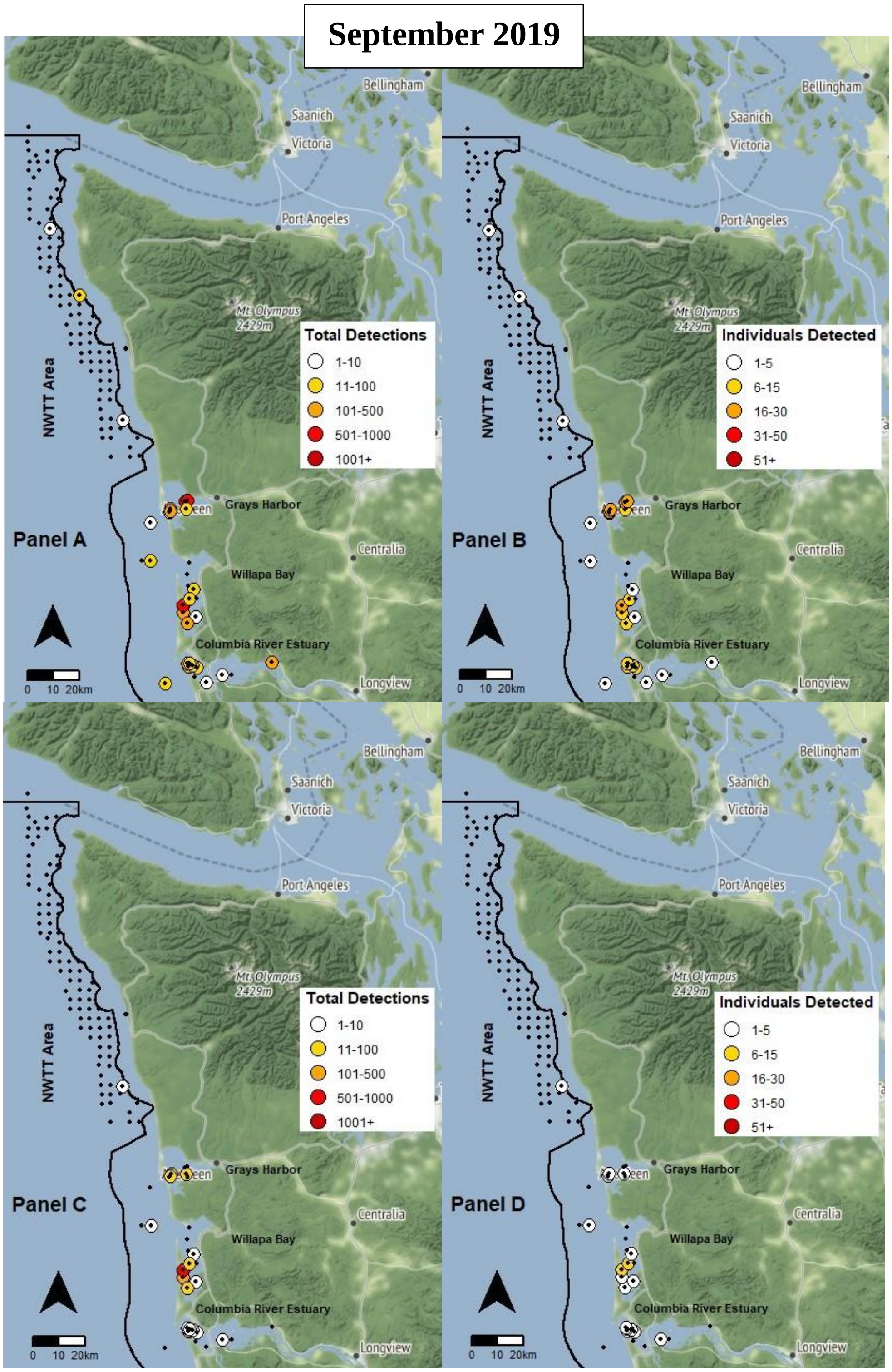


**Figure A- 5.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during September 2019. Black points represent receiver locations during this month. A total of 14 sDPS green sturgeon and 74 unique individuals were detected during this period.

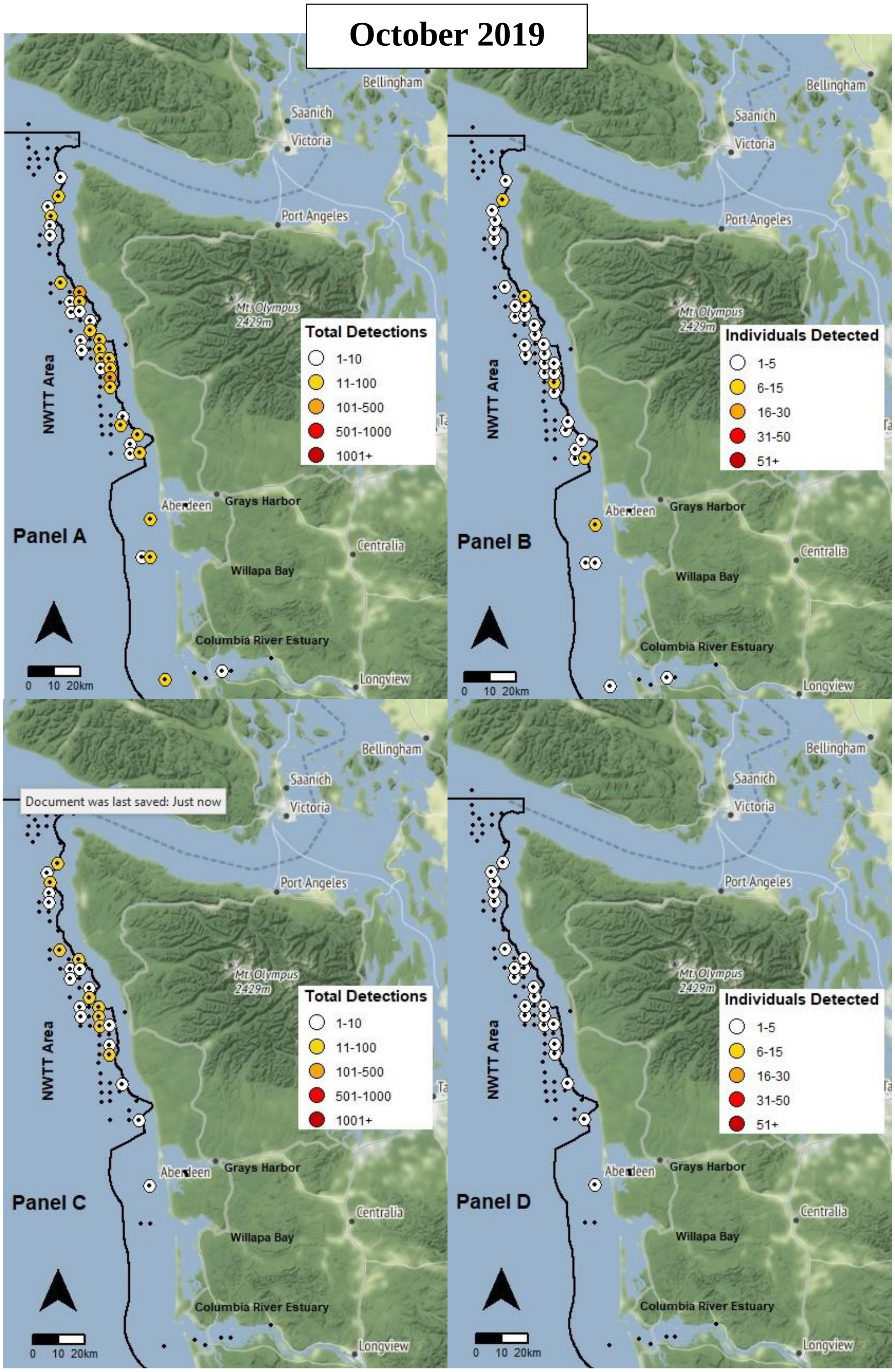


**Figure A- 6**. The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during October 2019. Black points represent receiver locations during this month. A total of nine sDPS green sturgeon and 44 unique individuals were detected during this period.

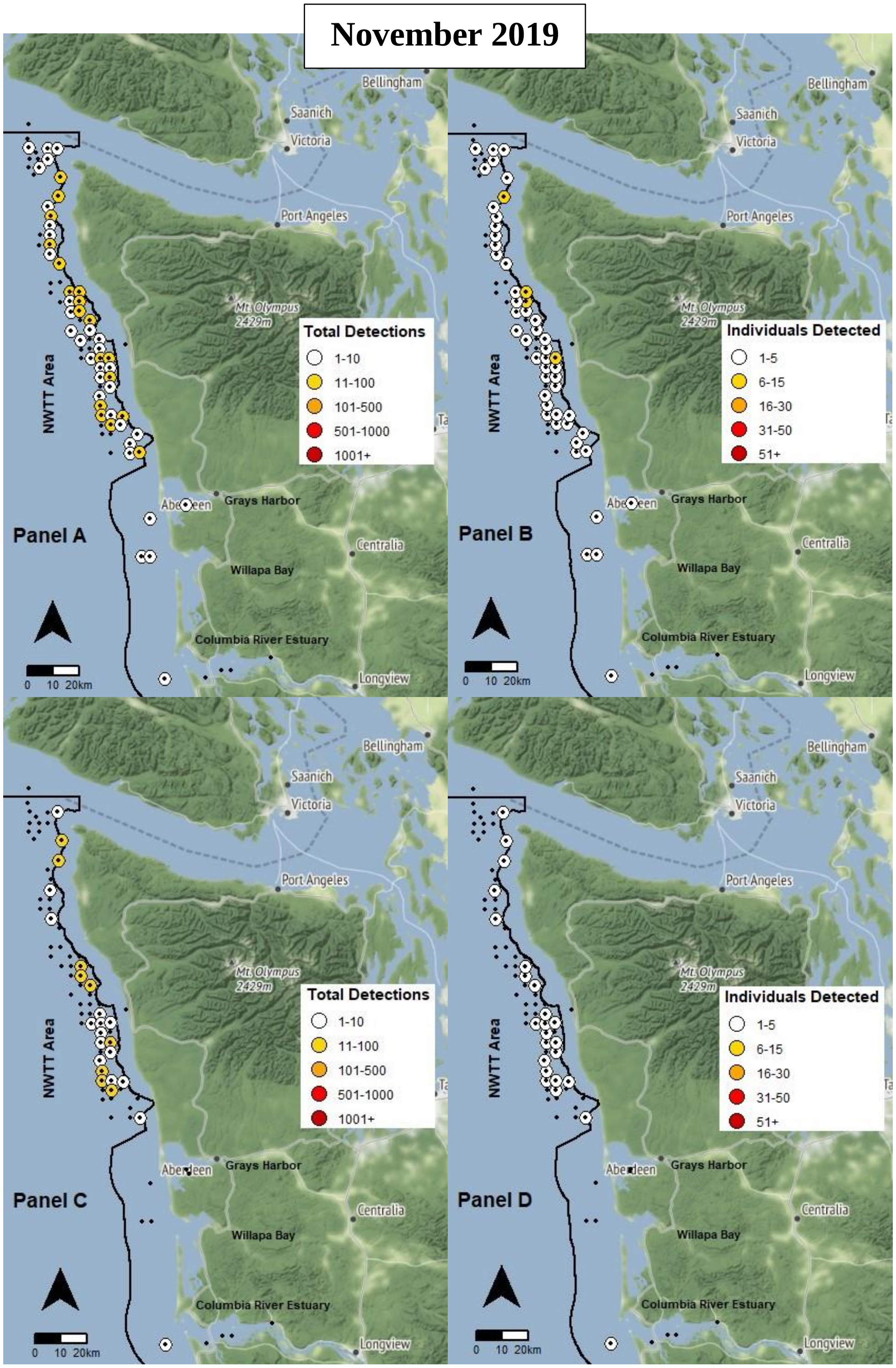


**Figure A- 7.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during November 2019. Black points represent receiver locations during this month. A total of nine sDPS green sturgeon and 37 unique individuals were detected during this period.

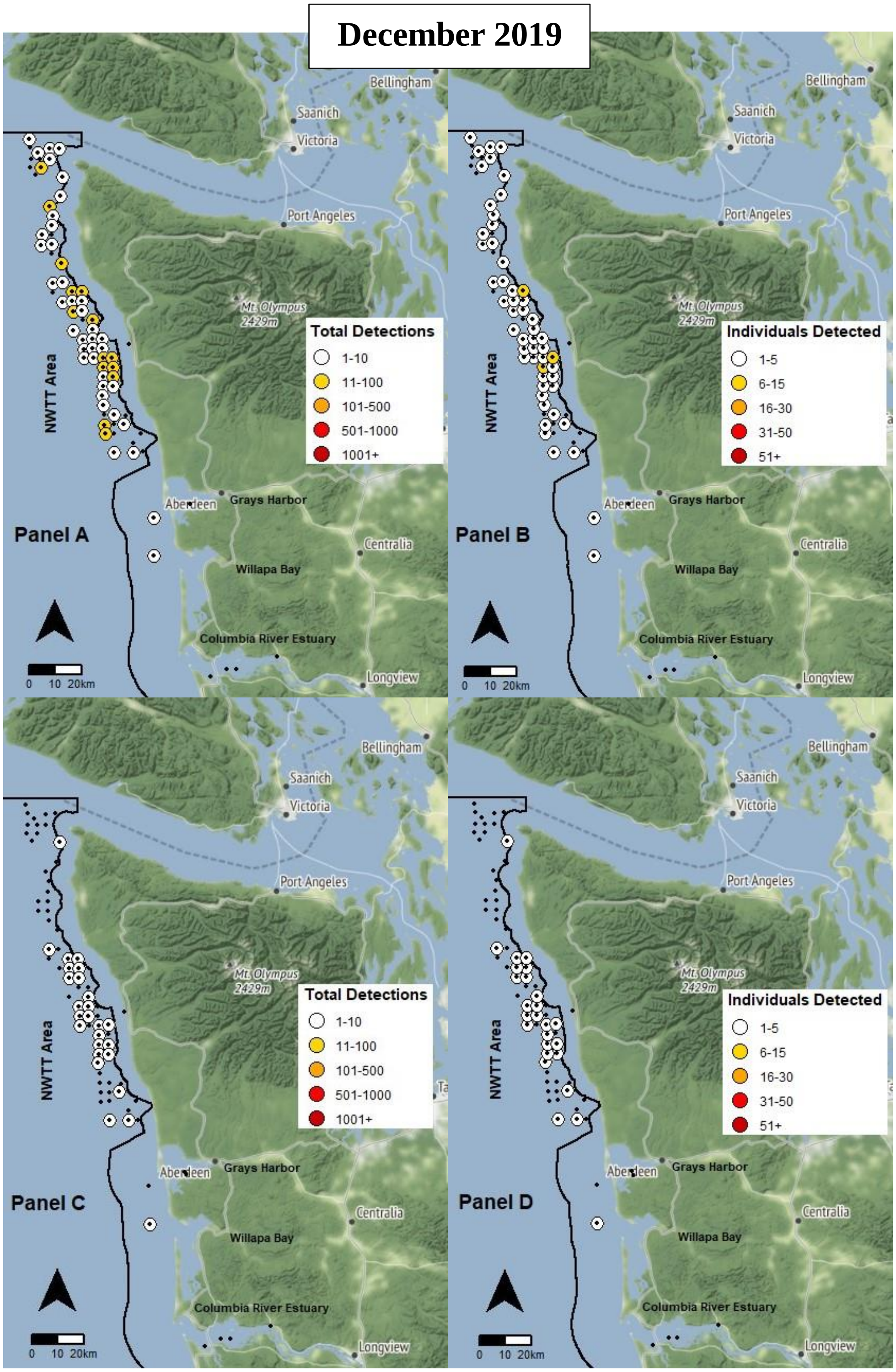


**Figure A- 8.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during December 2019. Black points represent receiver locations during this month. A total of seven sDPS green sturgeon and 38 unique individuals were detected during this period.

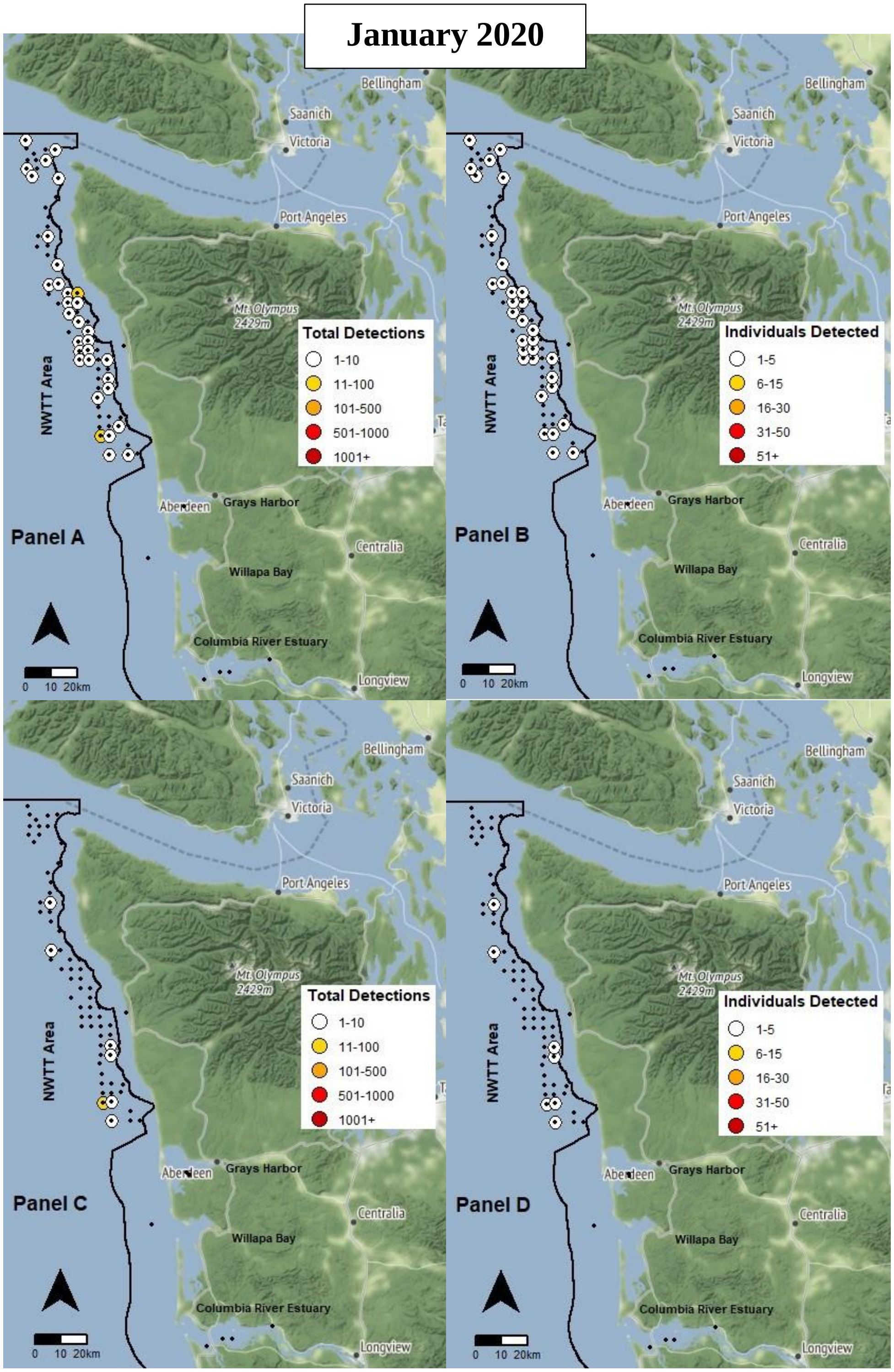


**Figure A- 9.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during January 2020. Black points represent receiver locations during this month. A total of three sDPS green sturgeon and 18 unique individuals were detected during this period.

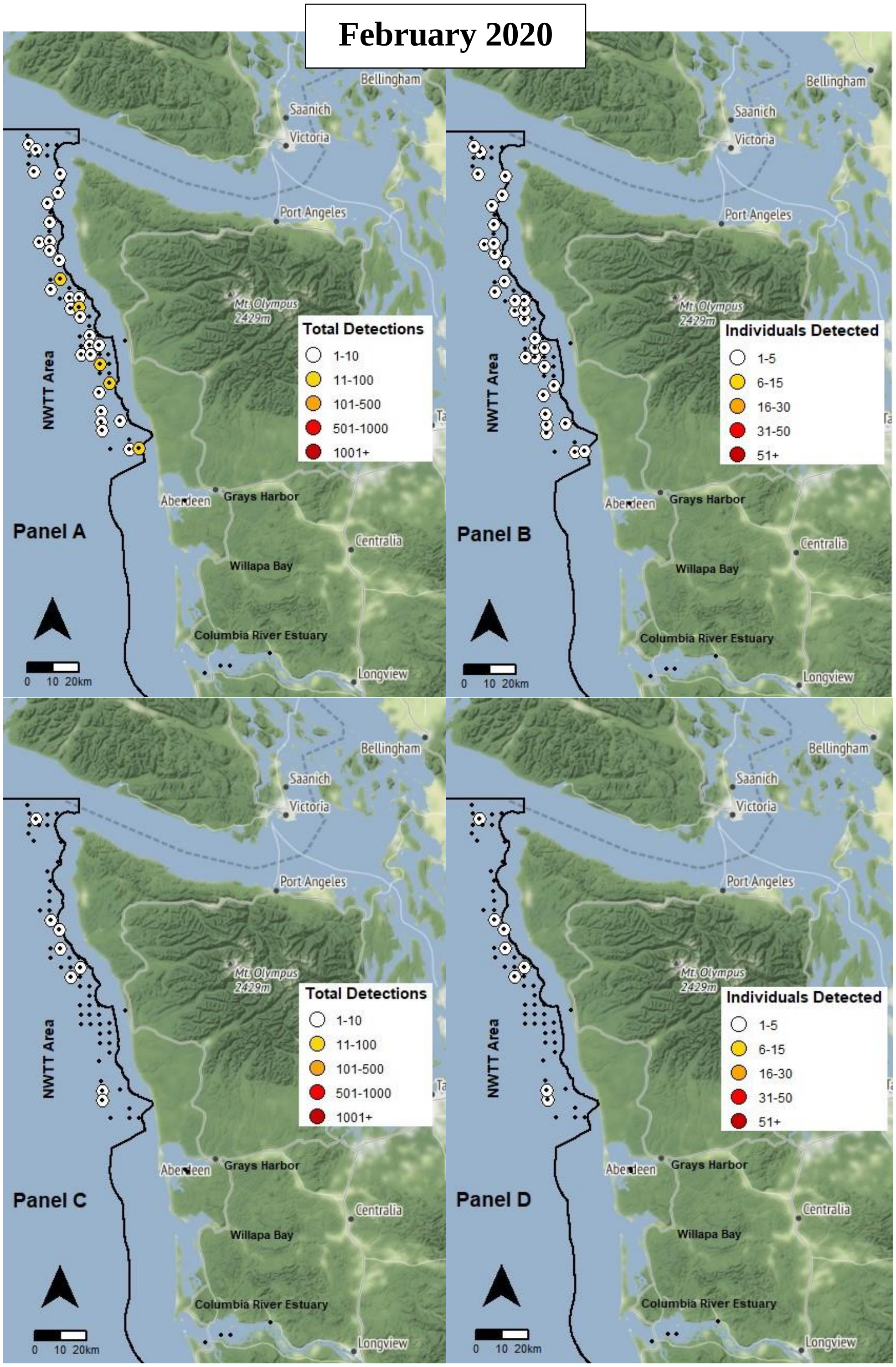


**Figure A- 10.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during February 2020. Black points represent receiver locations during this month. A total of four sDPS green sturgeon and 21 unique individuals were detected during this period.

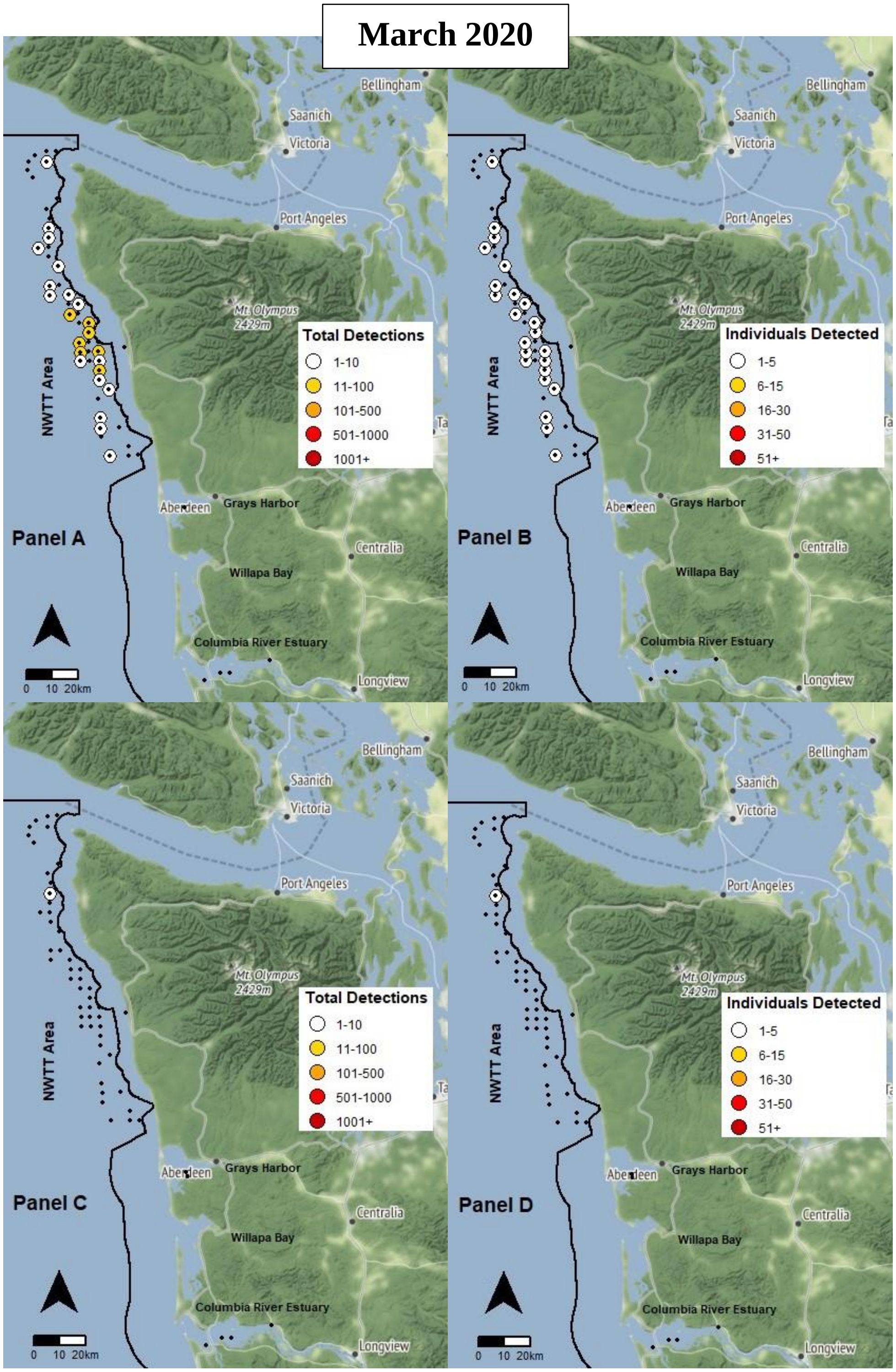


**Figure A- 11.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during March 2020. Black points represent receiver locations during this month. A total of one sDPS green sturgeon and 11 unique individuals were detected during this period.

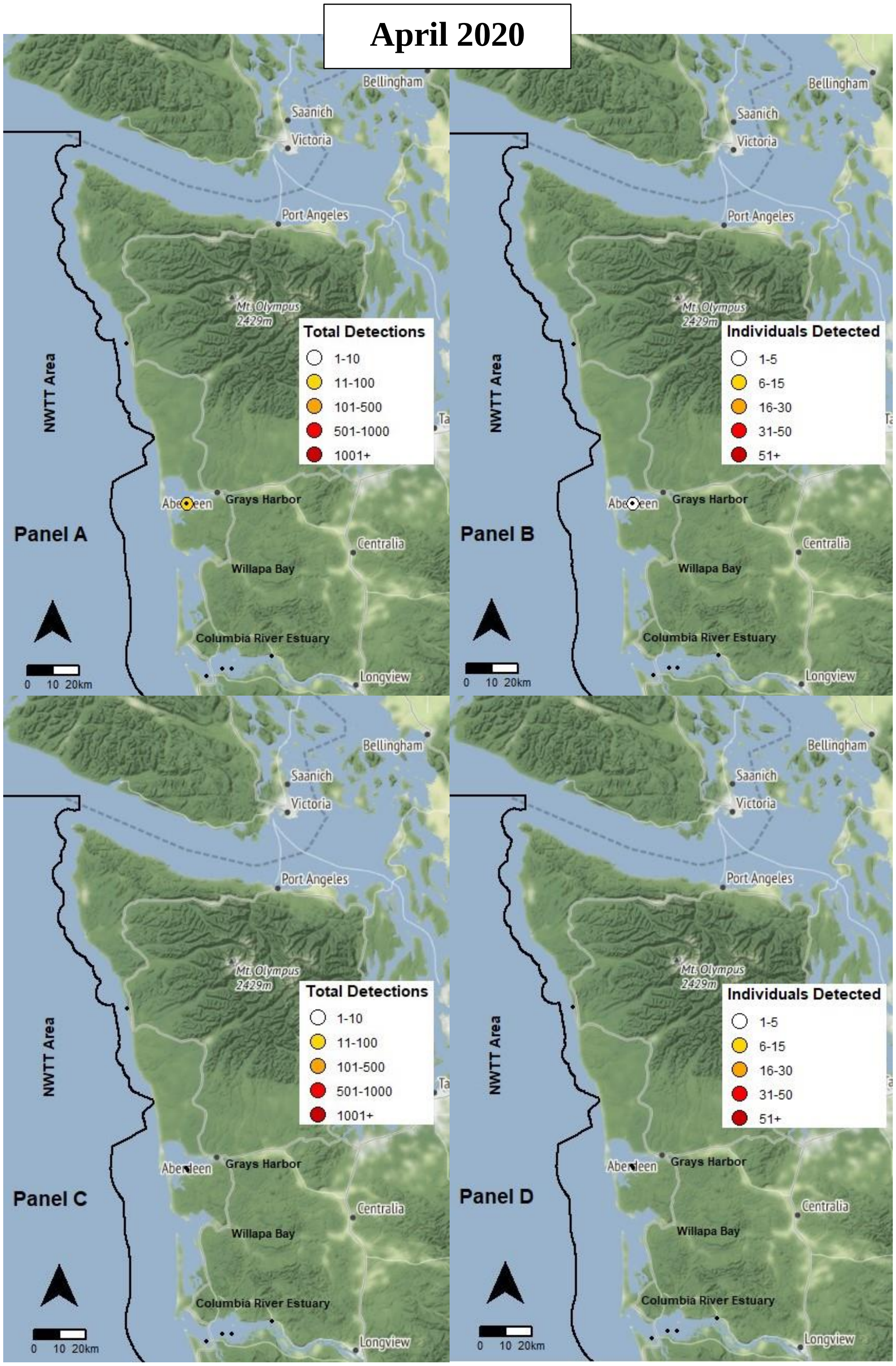


**Figure A- 12.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during April 2020. Black points represent receiver locations during this month. There were no sDPS green sturgeon and three unique individuals were detected during this period.

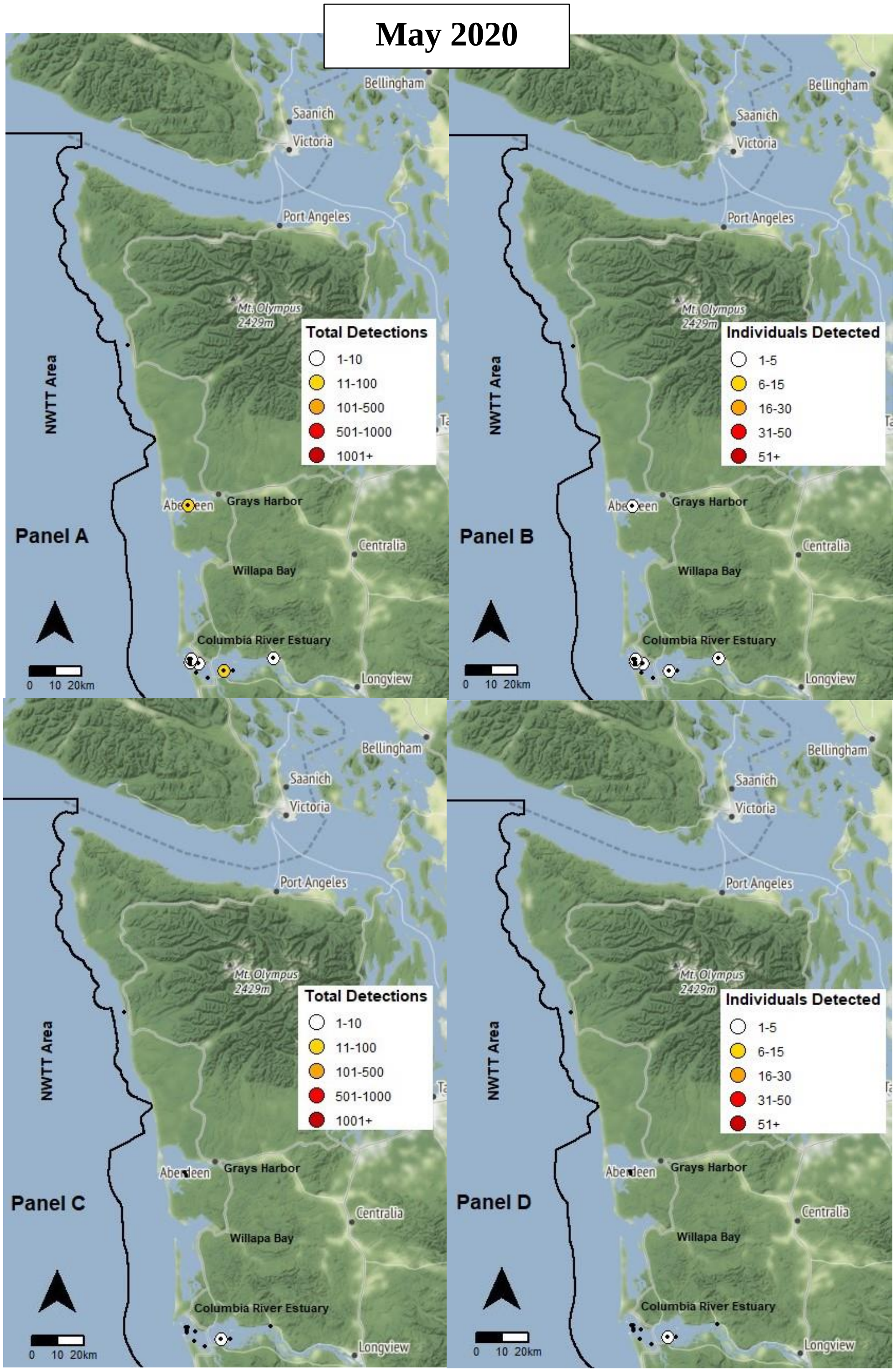


**Figure A- 13**. The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during May 2020. Black points represent receiver locations during this month. A total of one sDPS green sturgeon and 10 unique individuals were detected during this period.

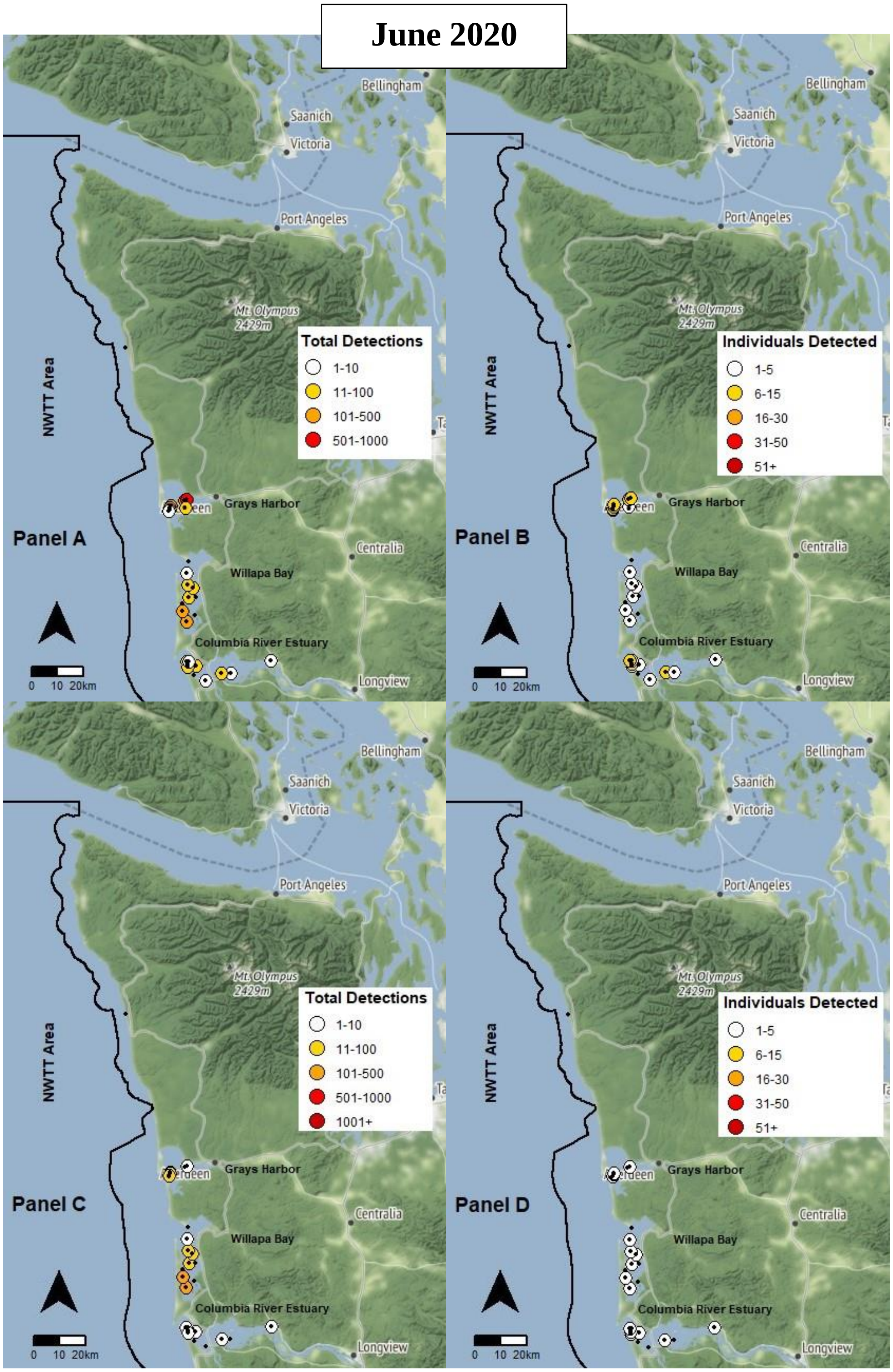


**Figure A- 14.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during June 2020. A total of 15 sDPS green sturgeon and 52 unique individuals were detected during this period.

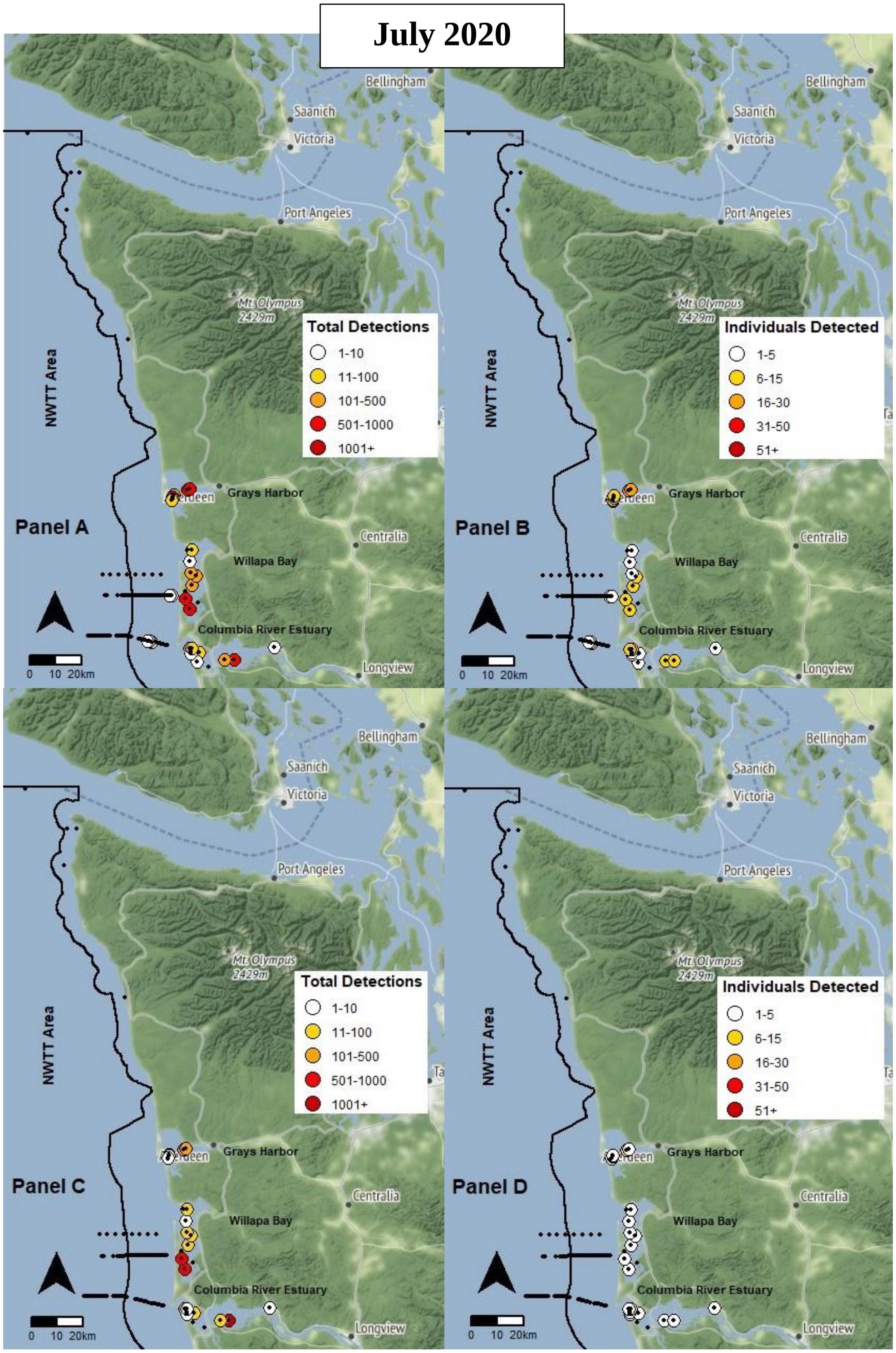


**Figure A- 15.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during July 2020. A total of 17 sDPS green sturgeon and 62 unique individuals were detected during this period.

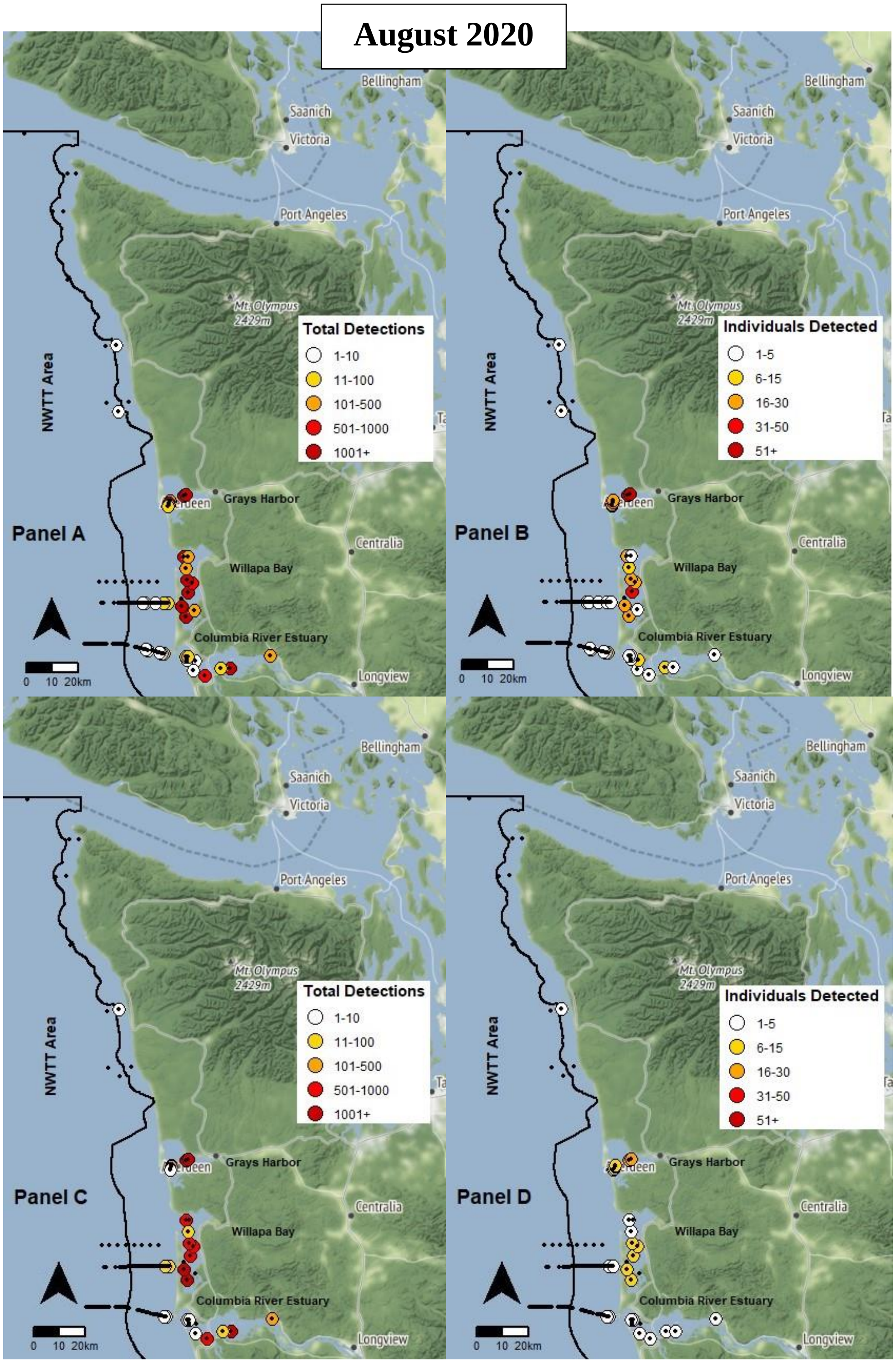


**Figure A- 16.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during August 2020. A total of 34 sDPS green sturgeon and 130 unique individuals were detected during this period.

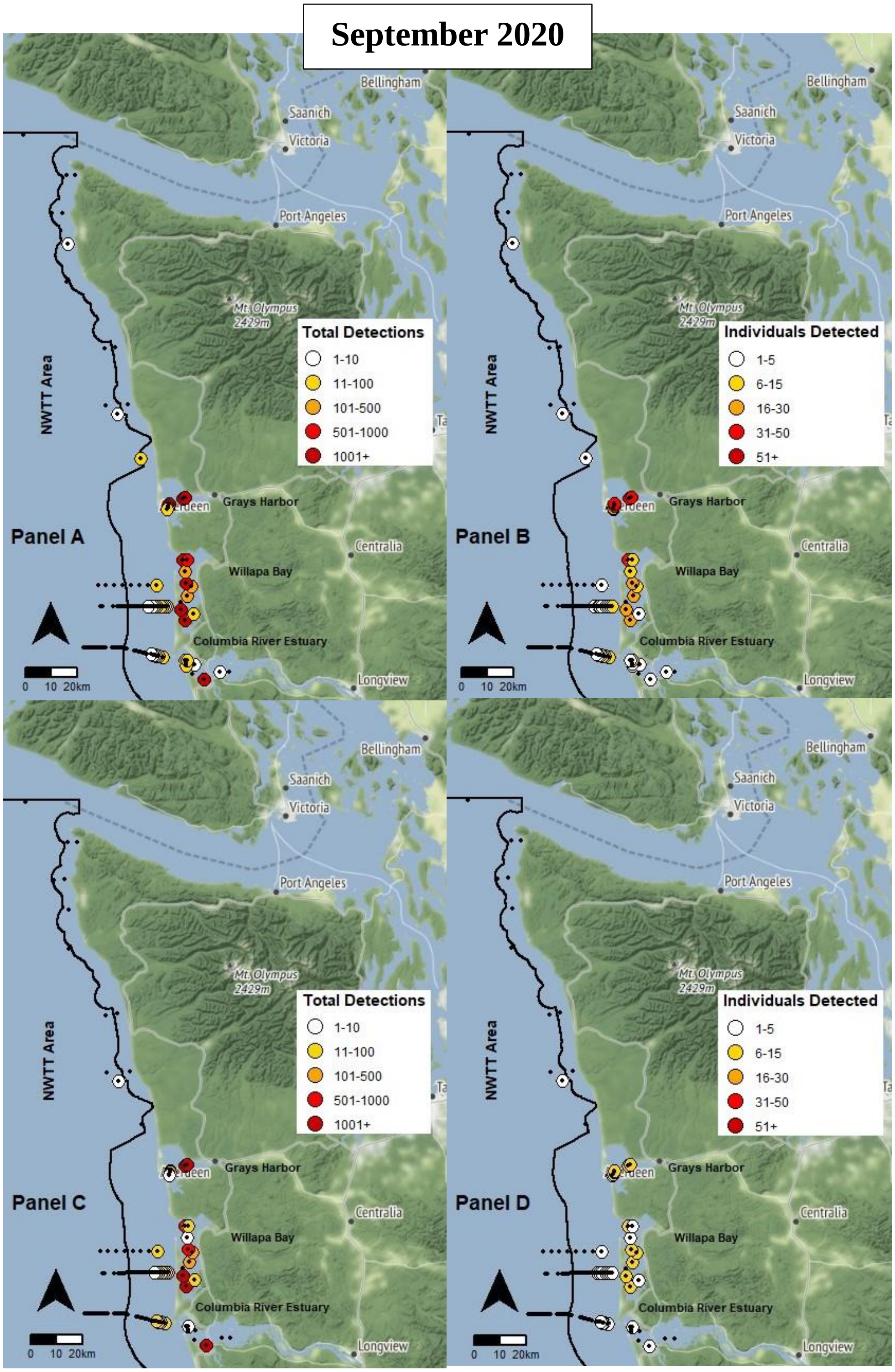


**Figure A- 17.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during September 2020. A total of 34 sDPS green sturgeon and 114 unique individuals were detected during this period.

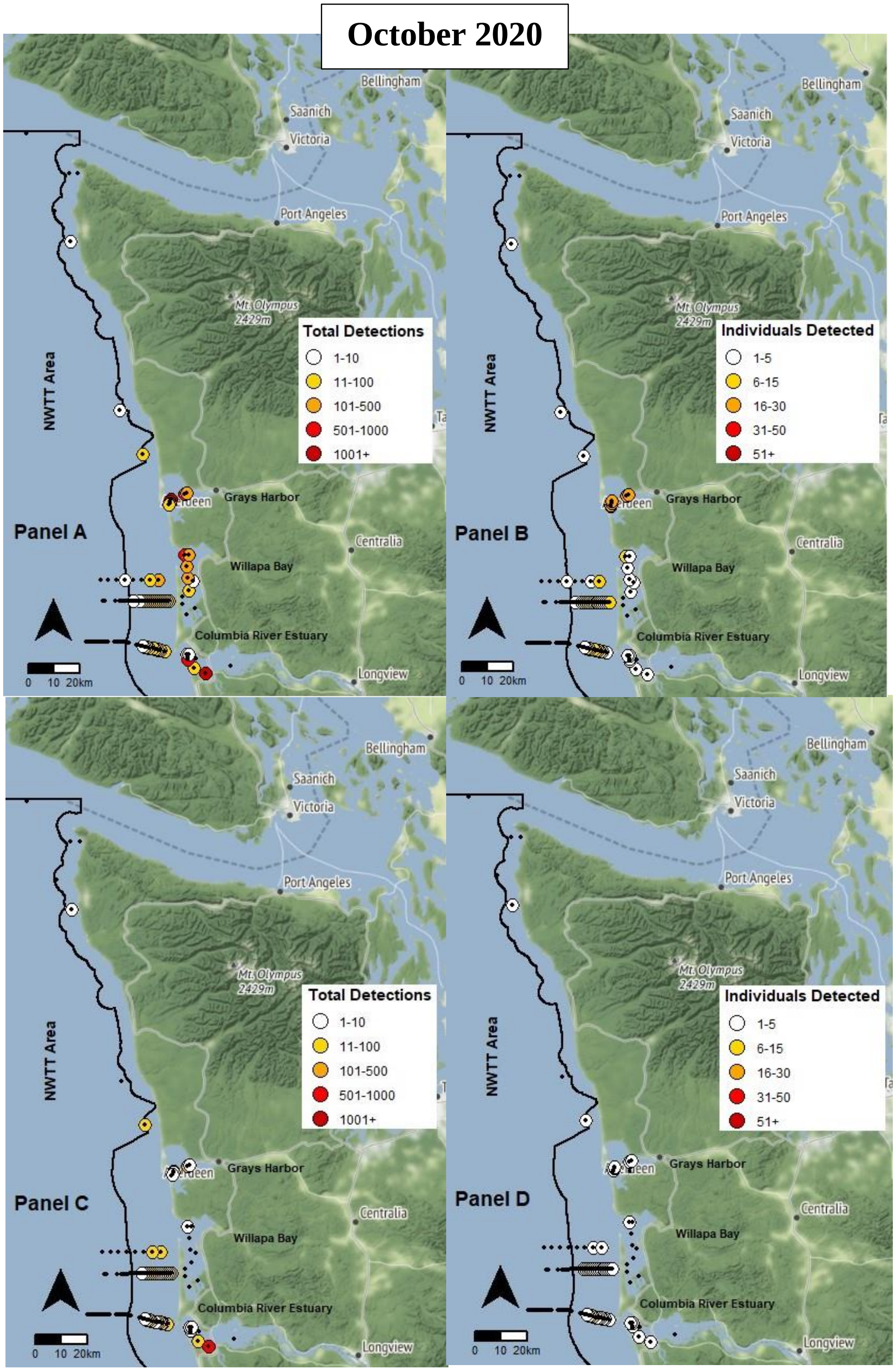


**Figure A- 18.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during October 2020. A total of 25 sDPS green sturgeon and 83 unique individuals were detected during this period.

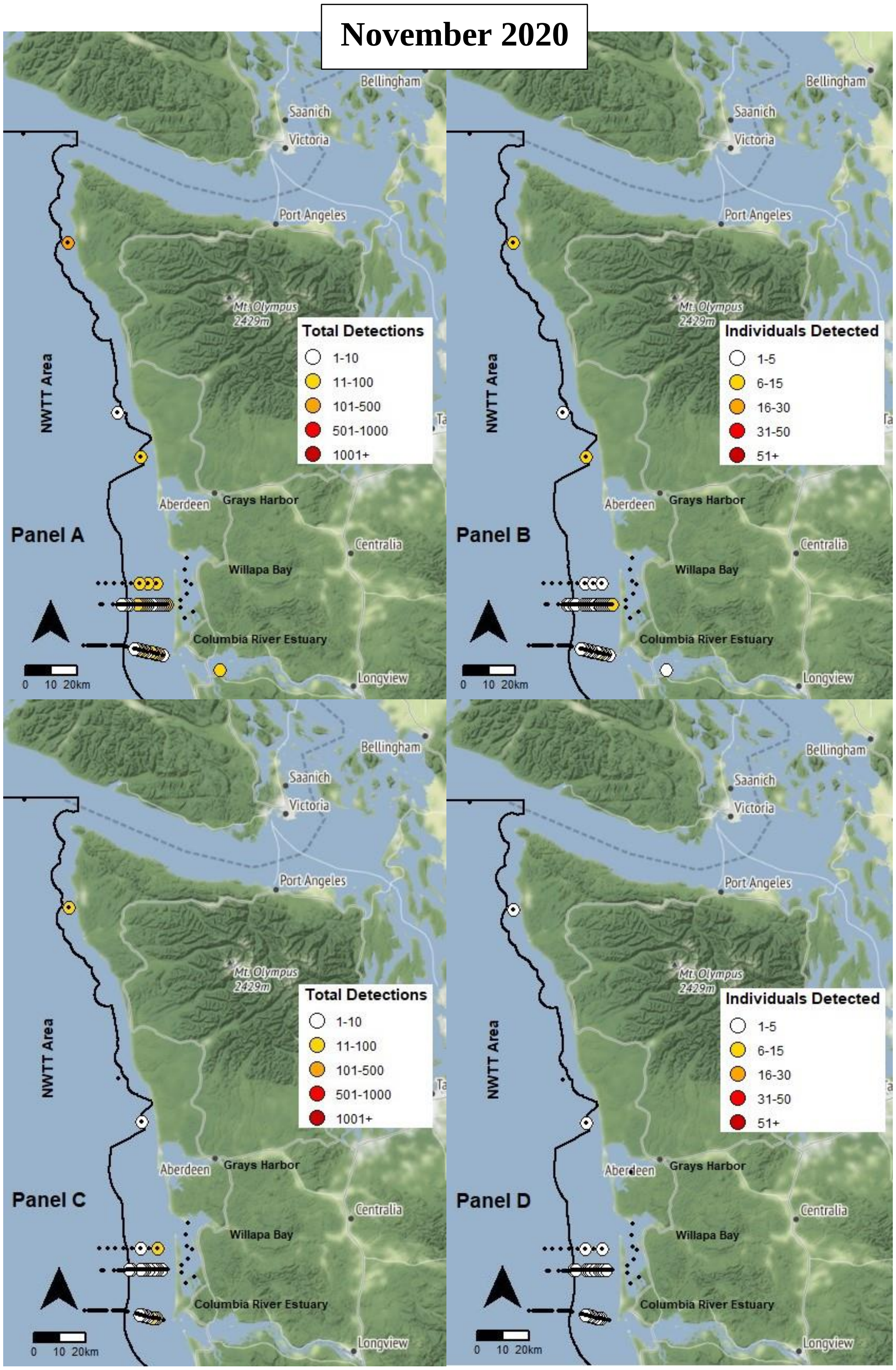


**Figure A- 19.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during November 2020. A total of 13 sDPS green sturgeon and 43 unique individuals were detected during this period.

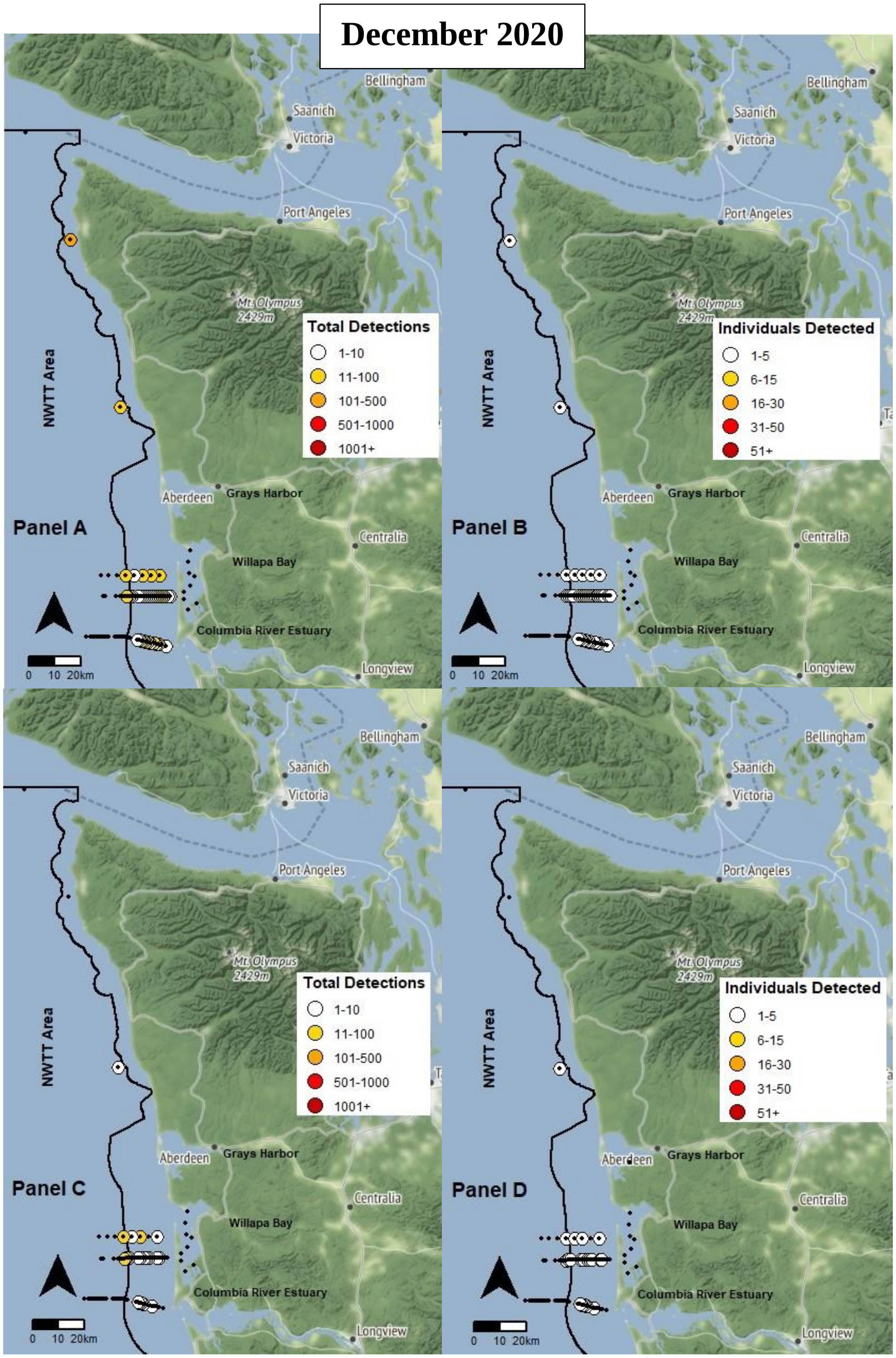


**Figure A- 20.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during December 2020. A total of five sDPS green sturgeon and 22 unique individuals were detected during this period.

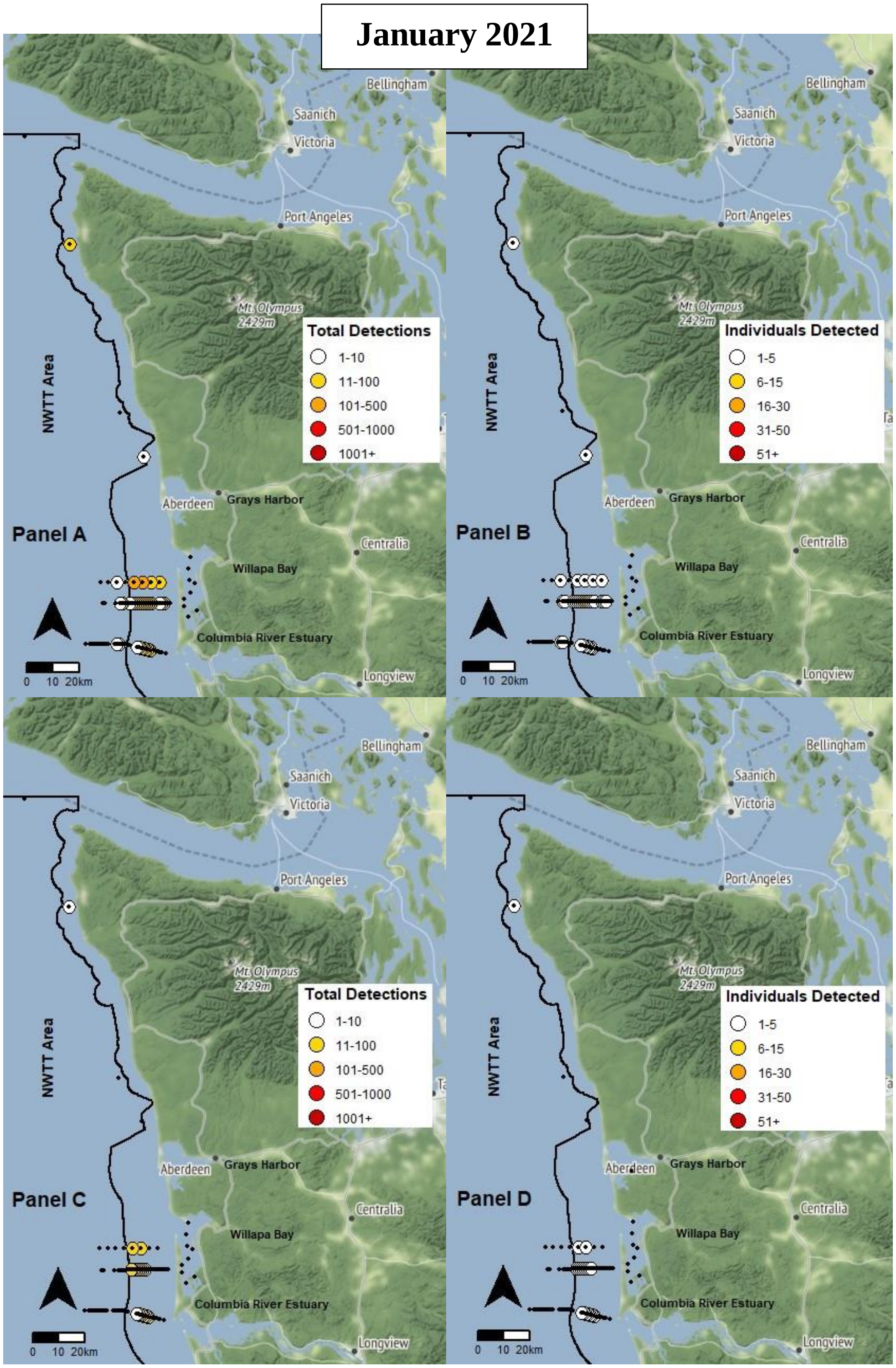


**Figure A- 21.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during January 2021. A total of seven sDPS green sturgeon and 25 unique individuals were detected during this period.

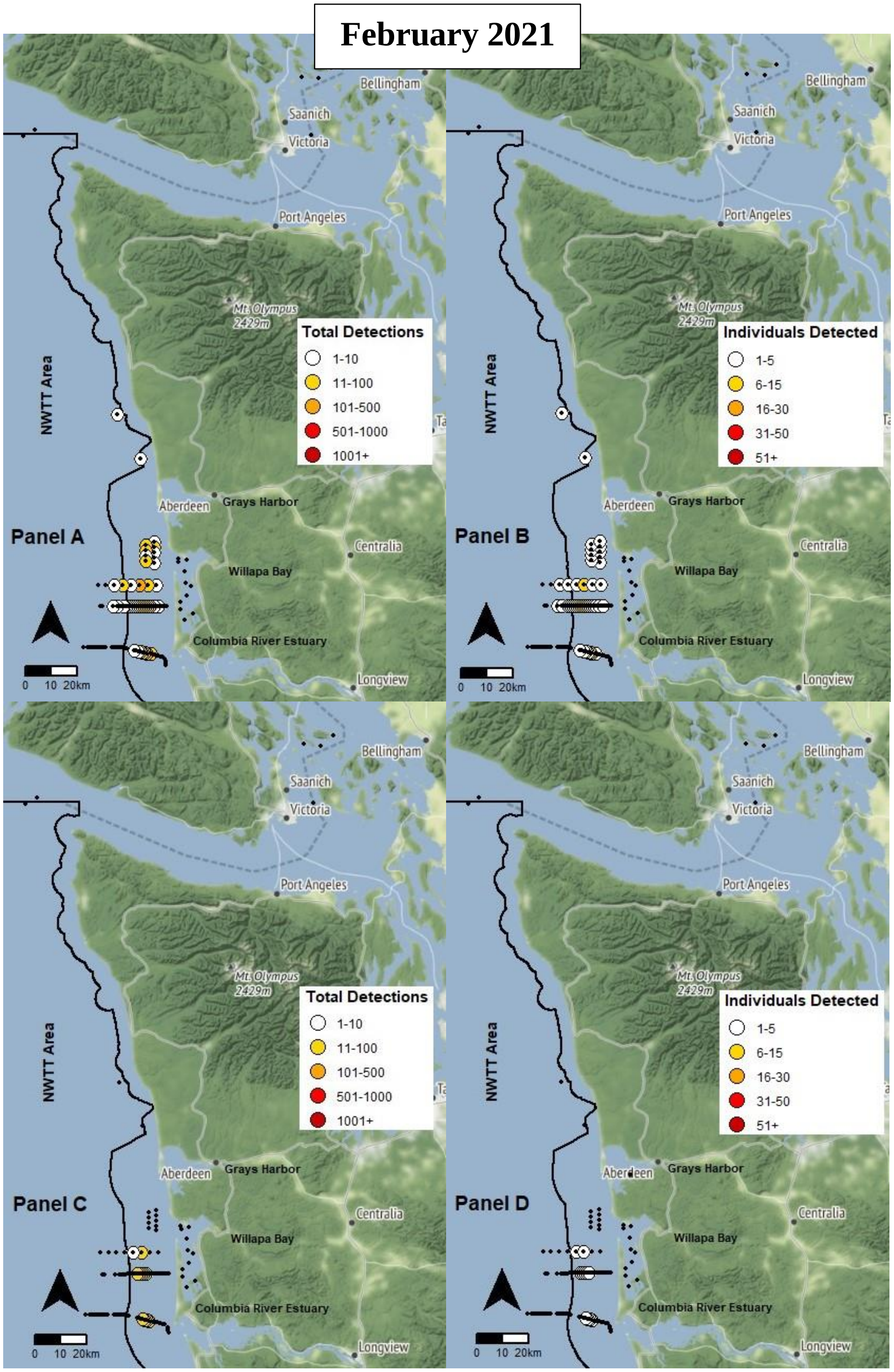


**Figure A- 22.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during February 2021. A total of six sDPS green sturgeon and 34 unique individuals were detected during this period.

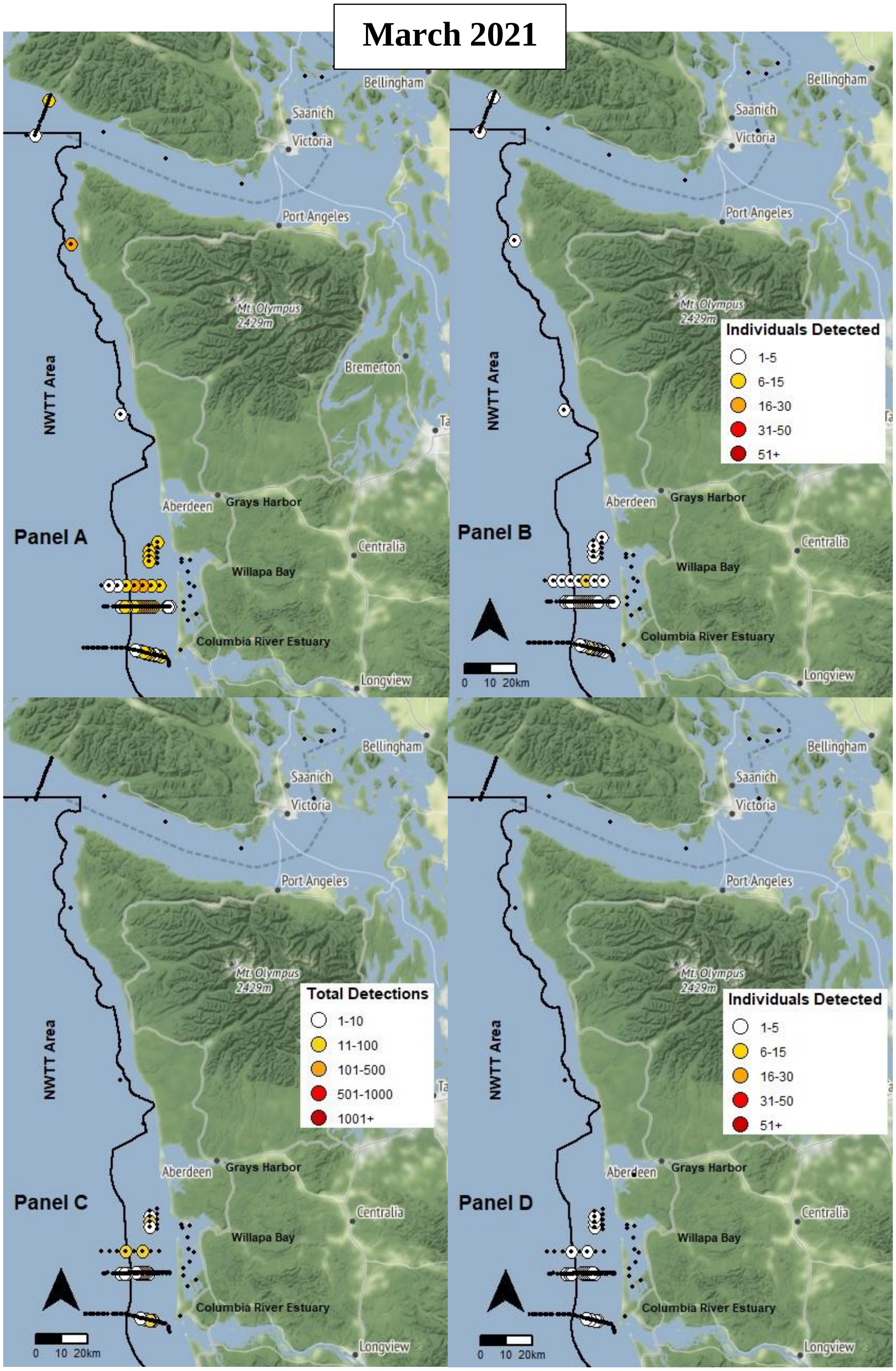


**Figure A- 23.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during March 2021. A total of nine sDPS green sturgeon and 31 unique individuals were detected during this period.

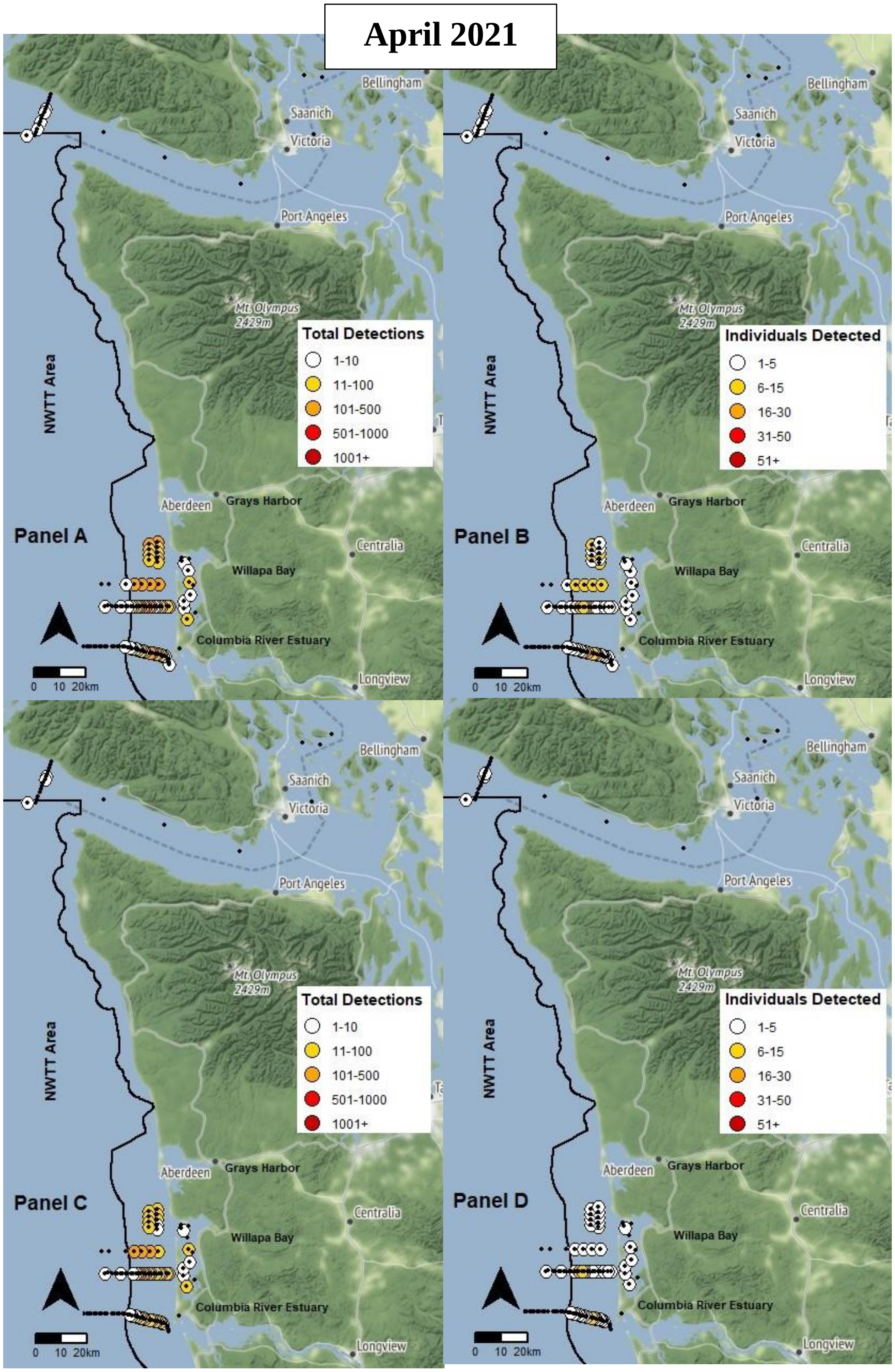


**Figure A- 24.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during April 2021. A total of 28 sDPS green sturgeon and 76 unique individuals were detected during this period.

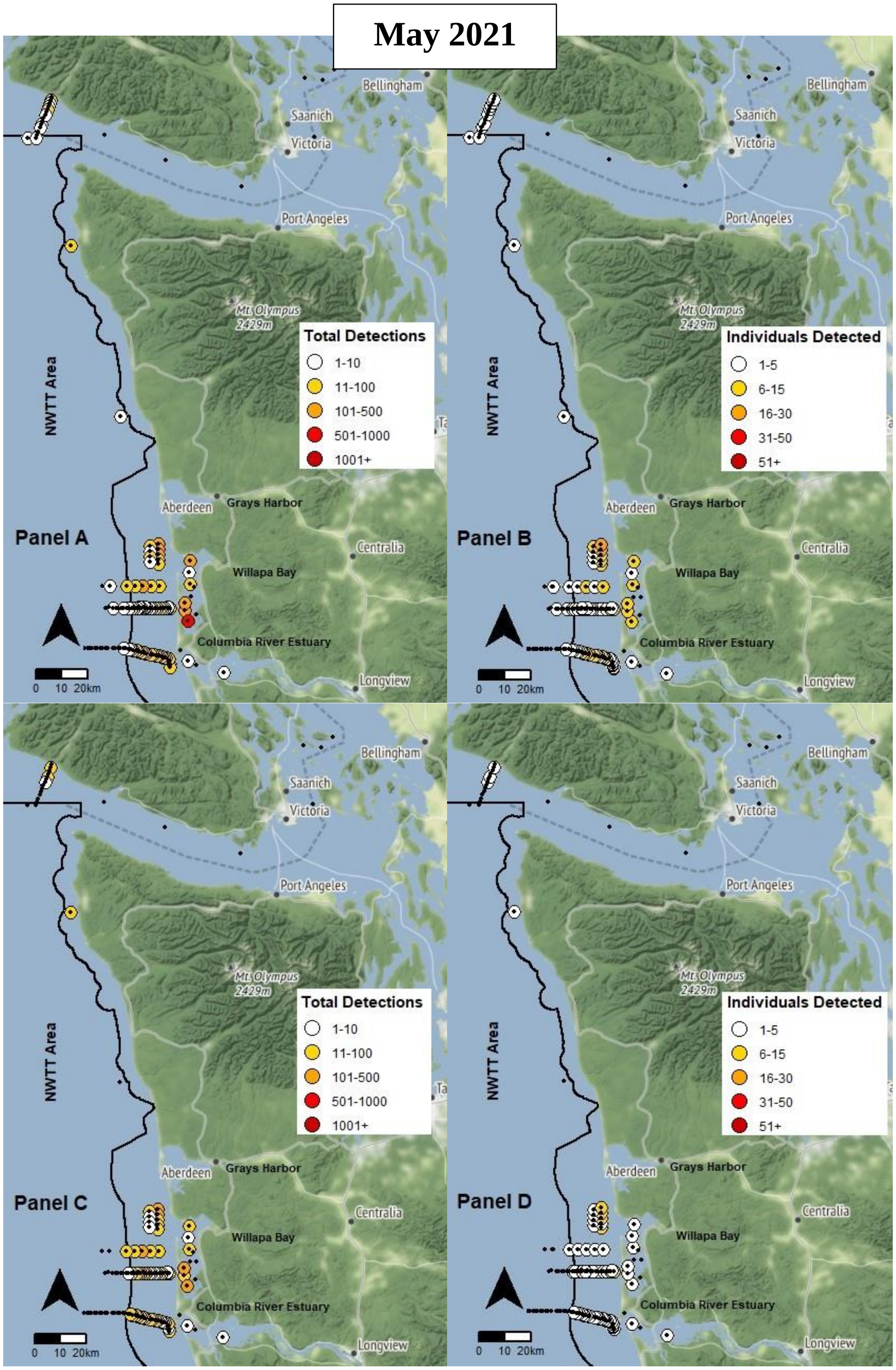


**Figure A- 25**. The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during May 2021. A total of 27 sDPS green sturgeon and 81 unique individuals were detected during this period.

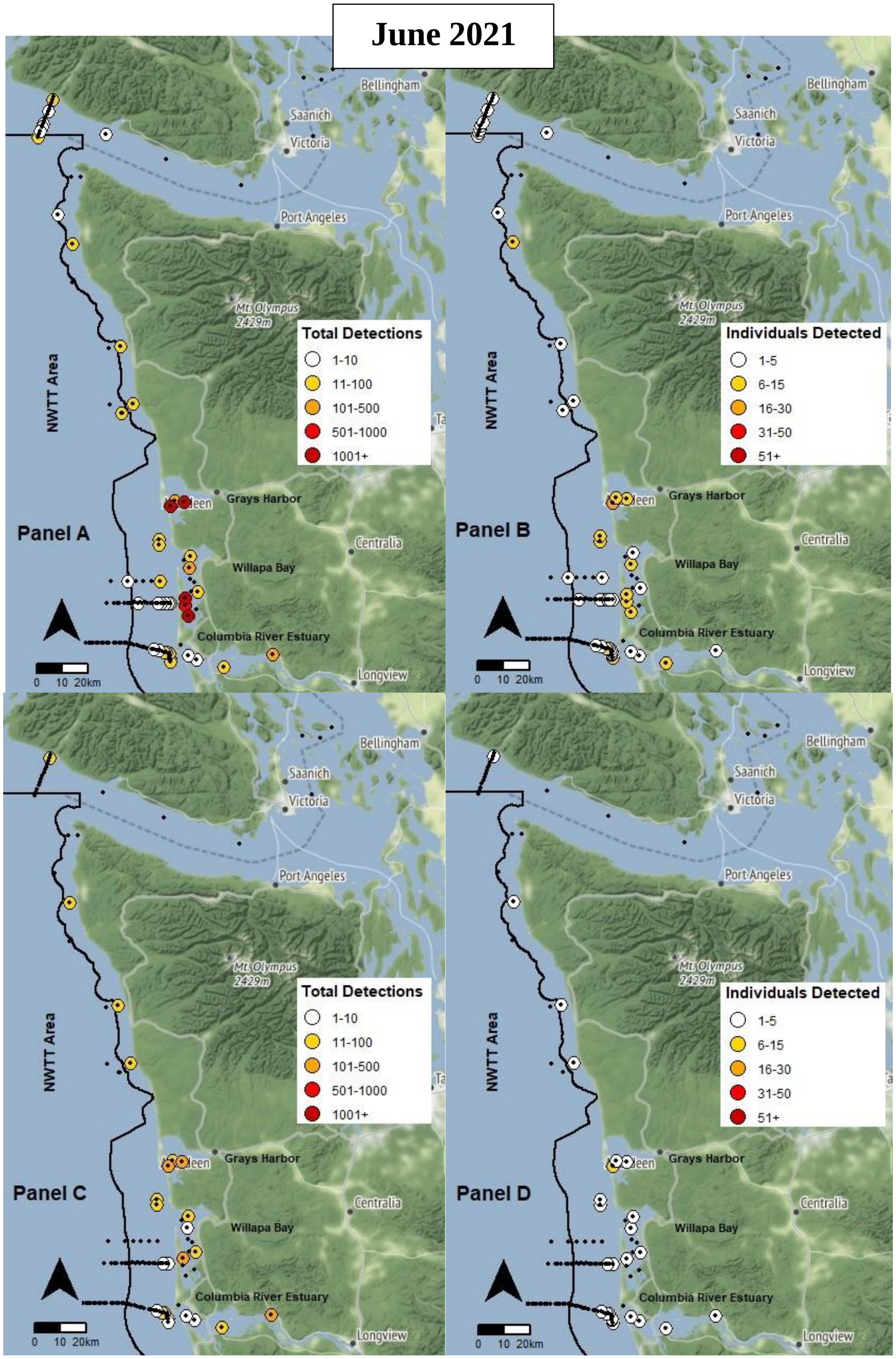


**Figure A- 26.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during June 2021. A total of 23 sDPS green sturgeon and 89 unique individuals were detected during this period.

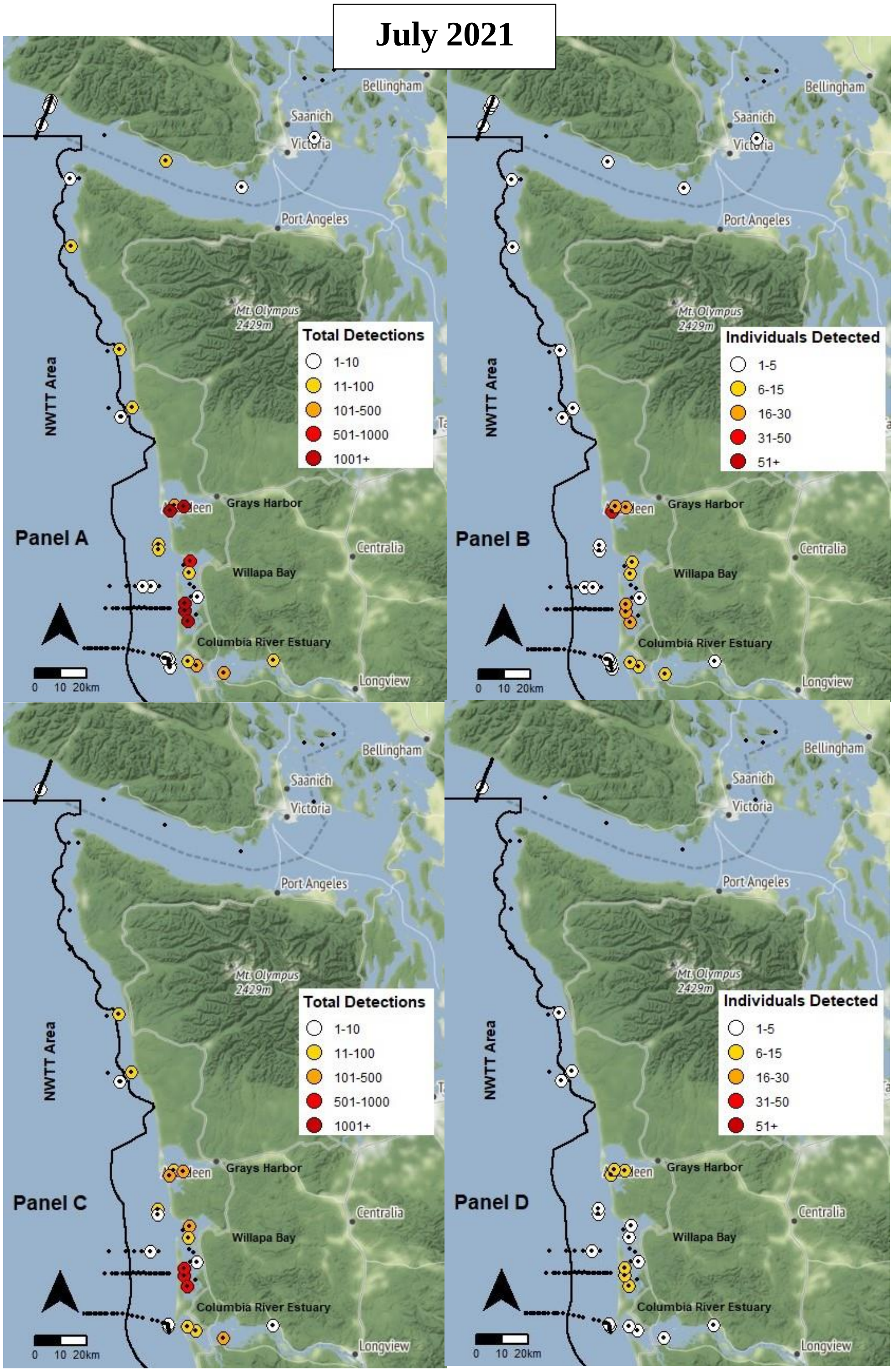


**Figure A- 27**. The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during July 2021. A total of 32 sDPS green sturgeon and 101 unique individuals were detected during this period.

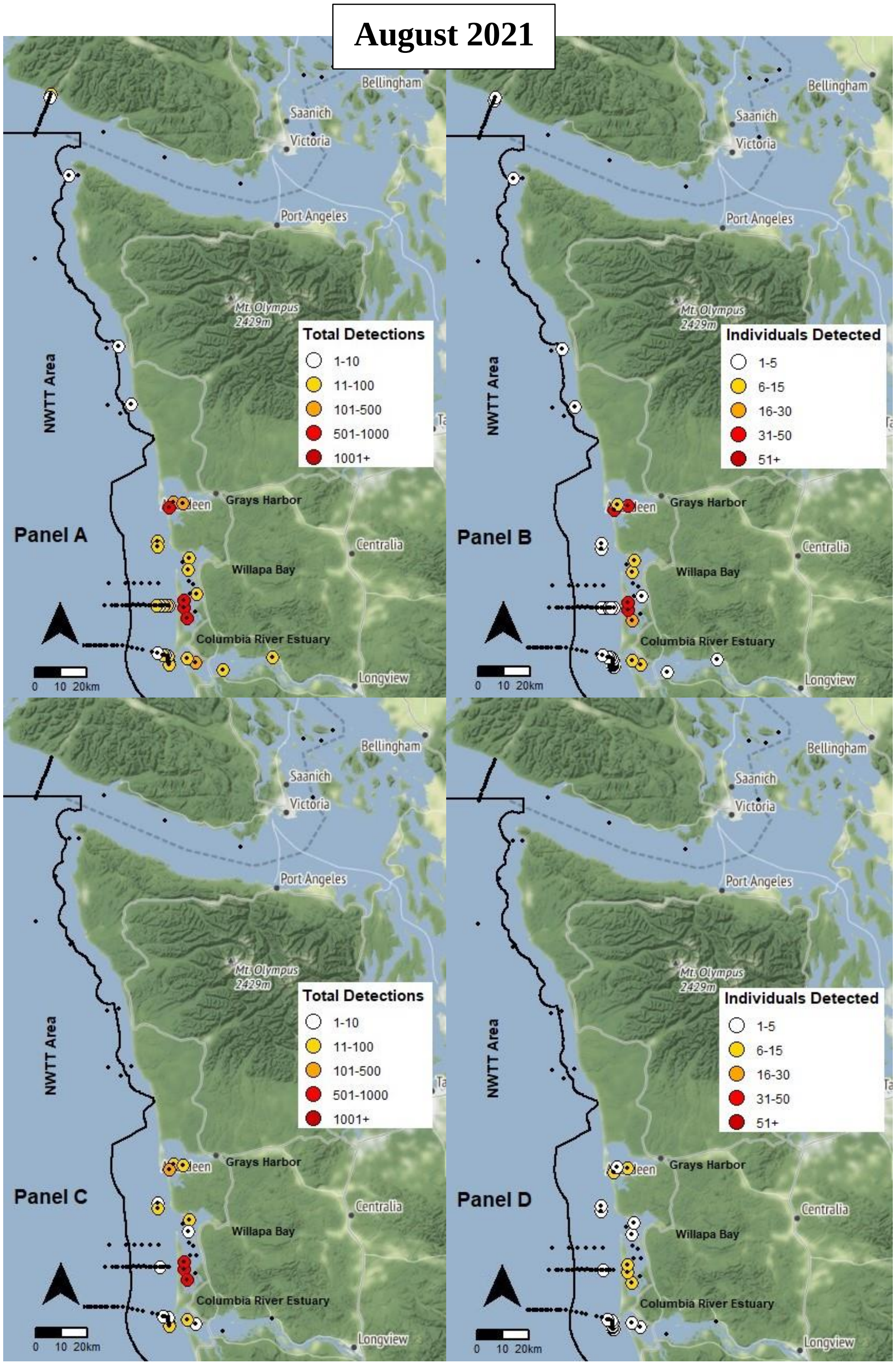


**Figure A- 28.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during July 2021. A total of 25 sDPS green sturgeon and 100 unique individuals were detected during this period.

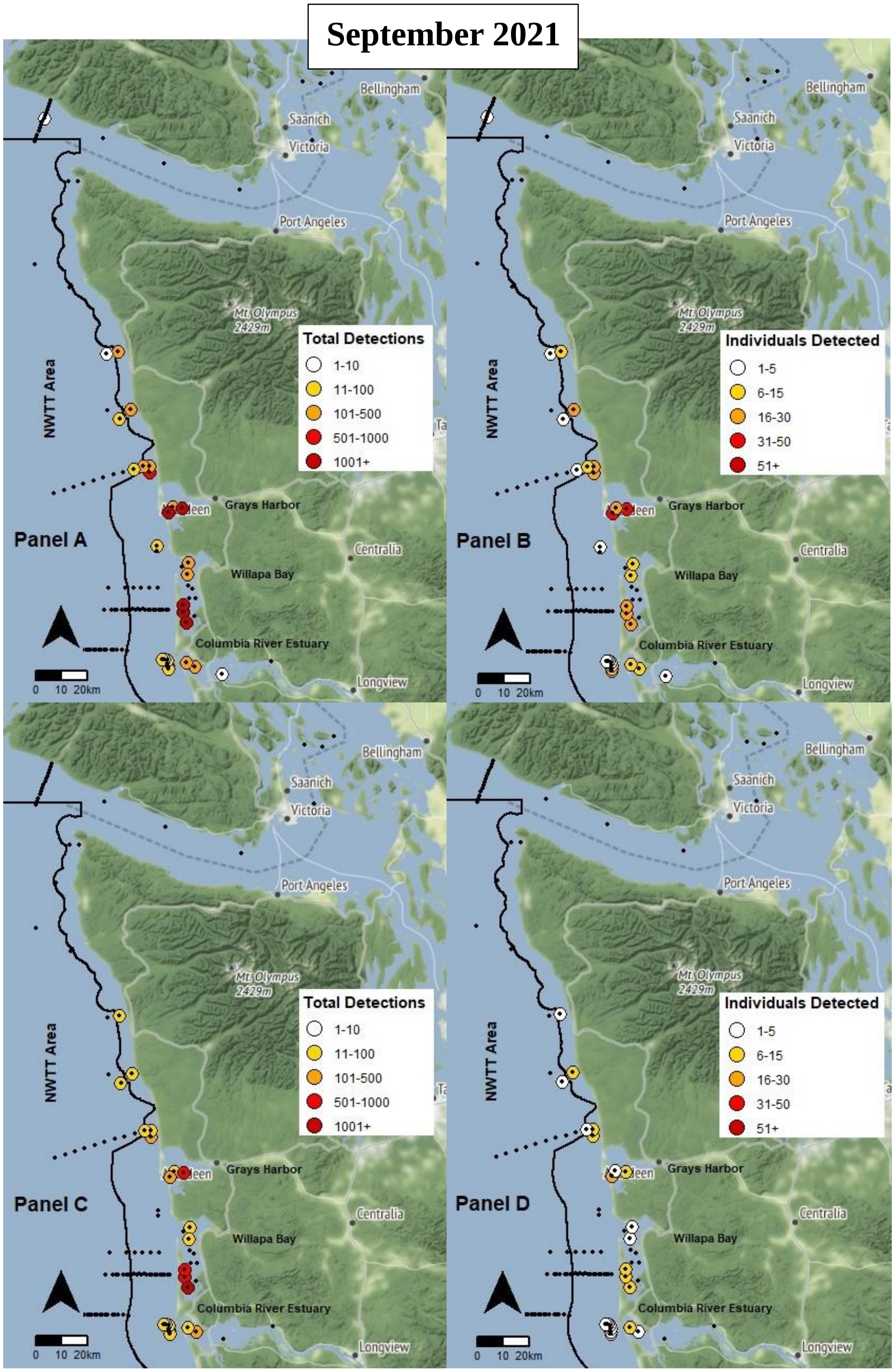


**Figure A- 29.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during September 2021. A total of 40 sDPS green sturgeon and 147 unique individuals were detected during this period.

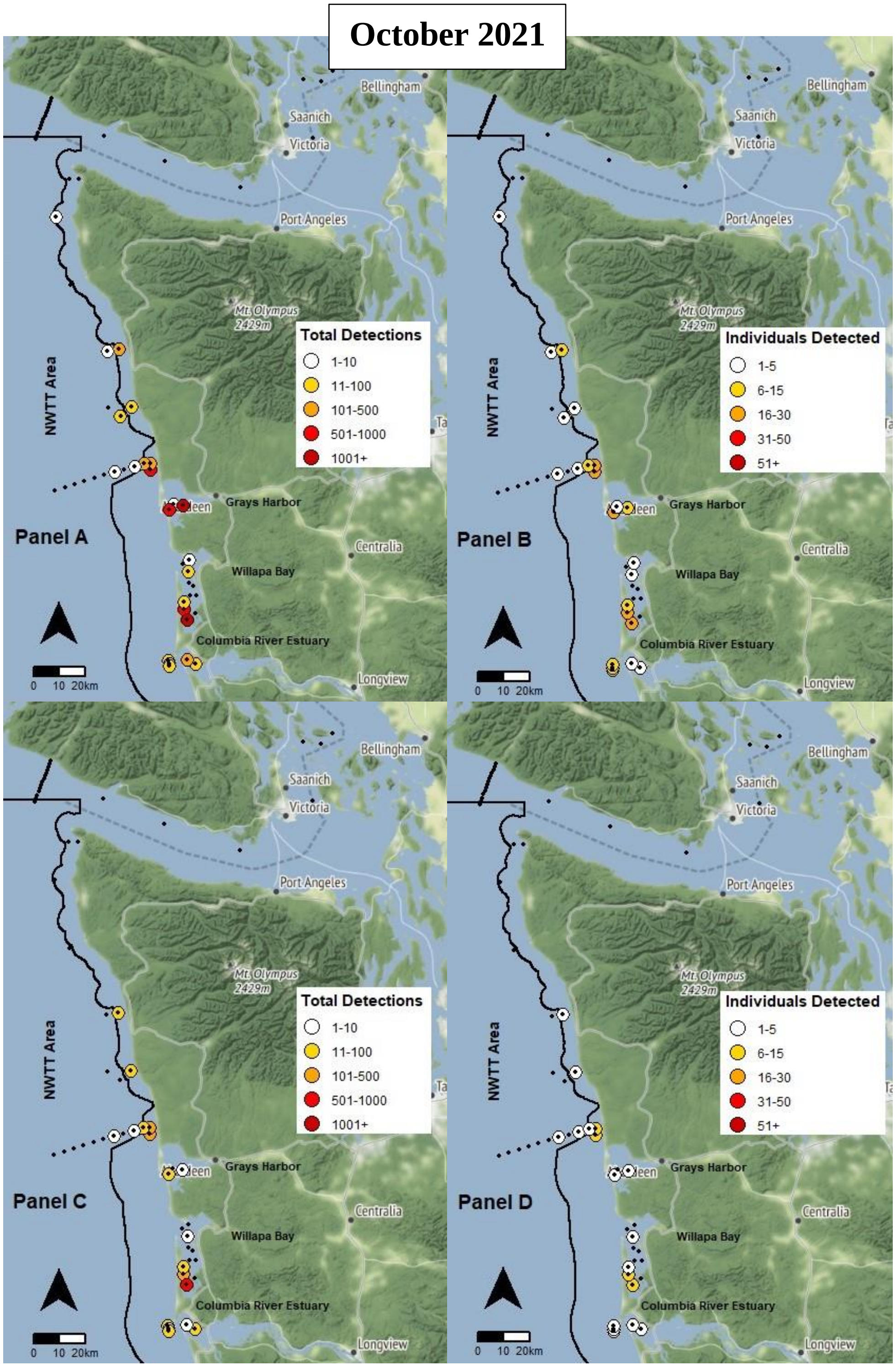


**Figure A- 30.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during October 2021. A total of 26 sDPS green sturgeon and 101 unique individuals were detected during this period.

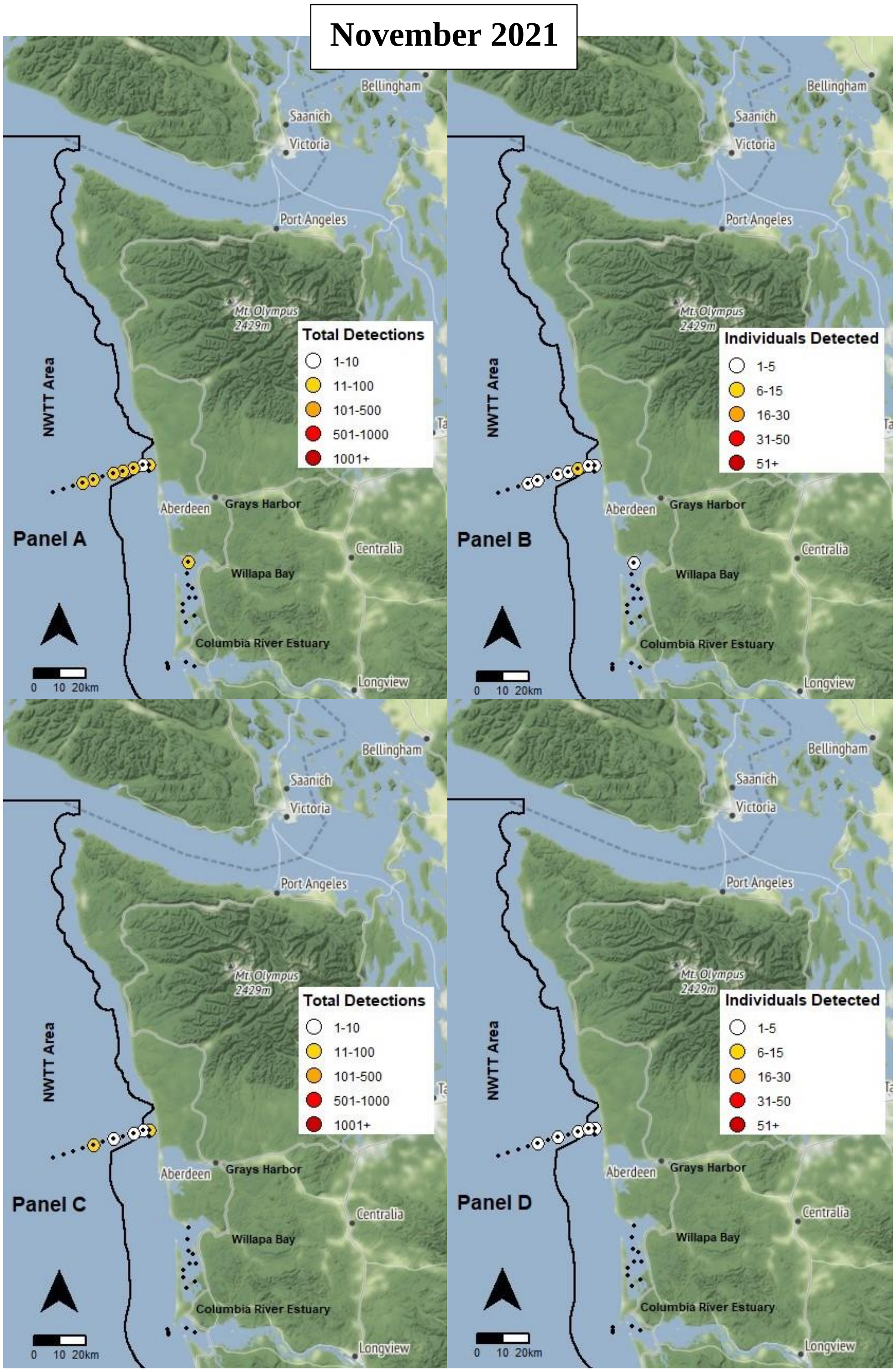


**Figure A- 31.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during November 2021. A total of six sDPS green sturgeon and 18 unique individuals were detected during this period.

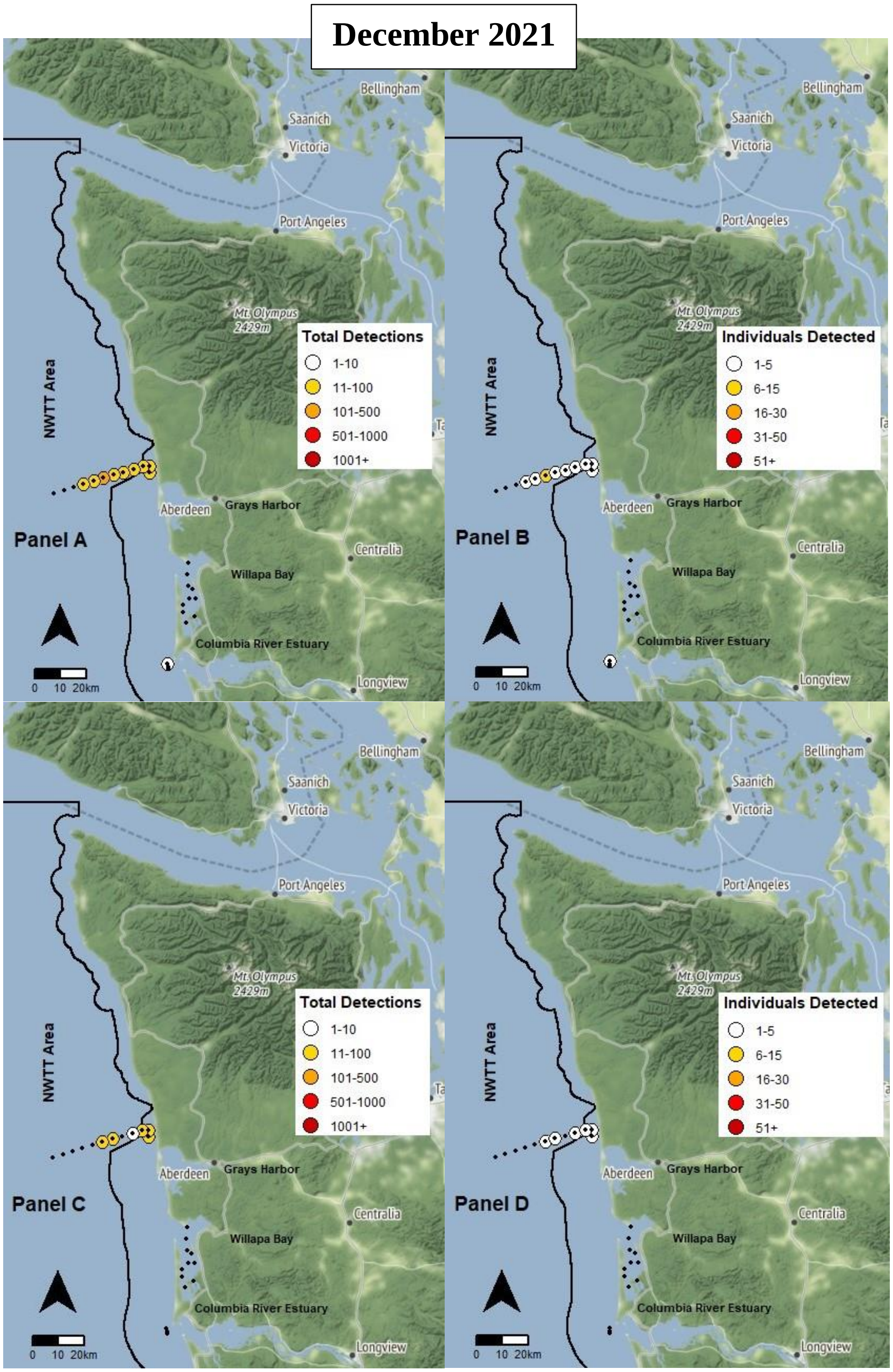


**Figure A- 32.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during December 2021. A total of five sDPS green sturgeon and 27 unique individuals detected during this period.

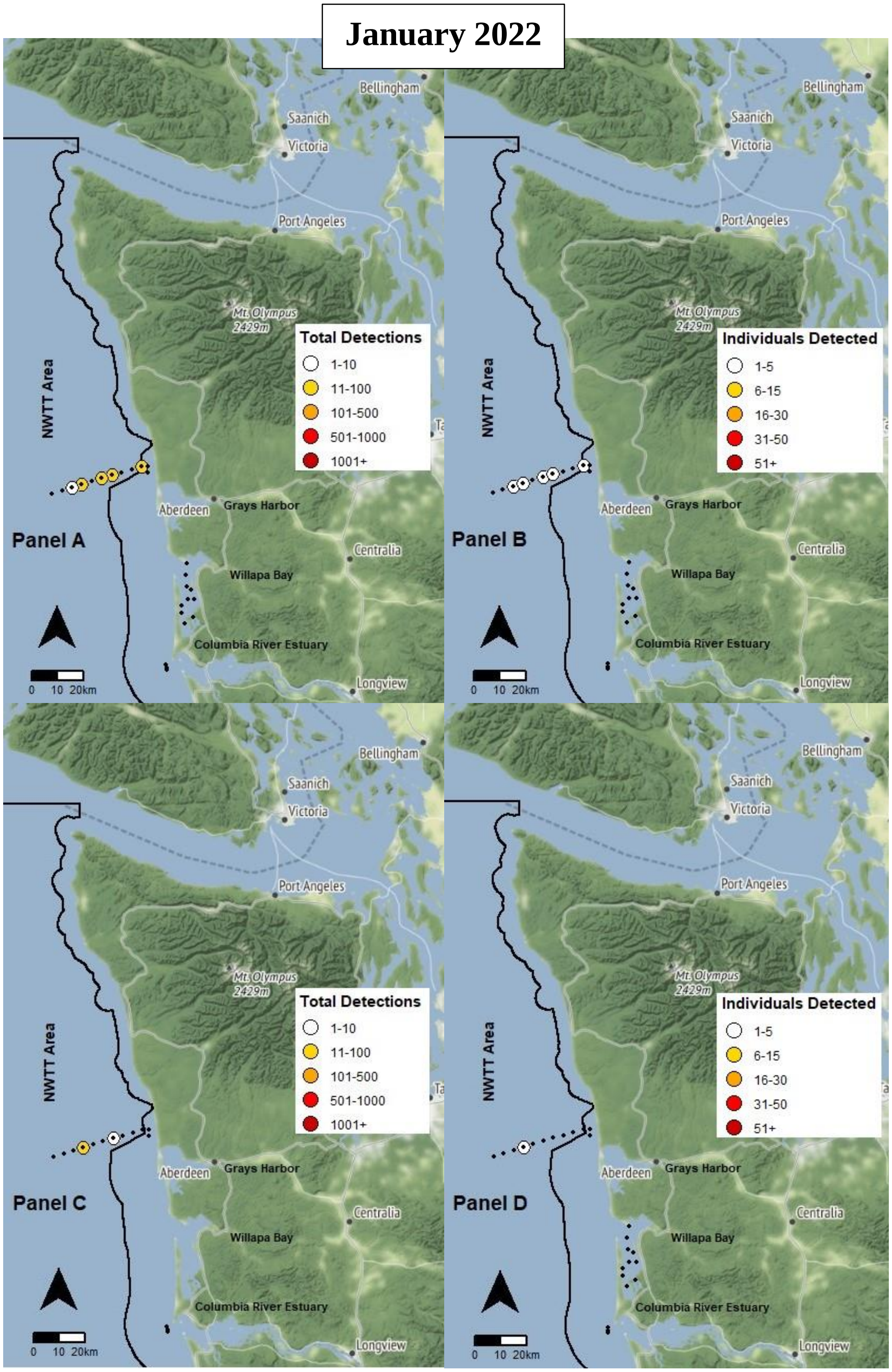


**Figure A- 33.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during January 2022. A total of one sDPS green sturgeon and 19 unique individuals detected during this period.

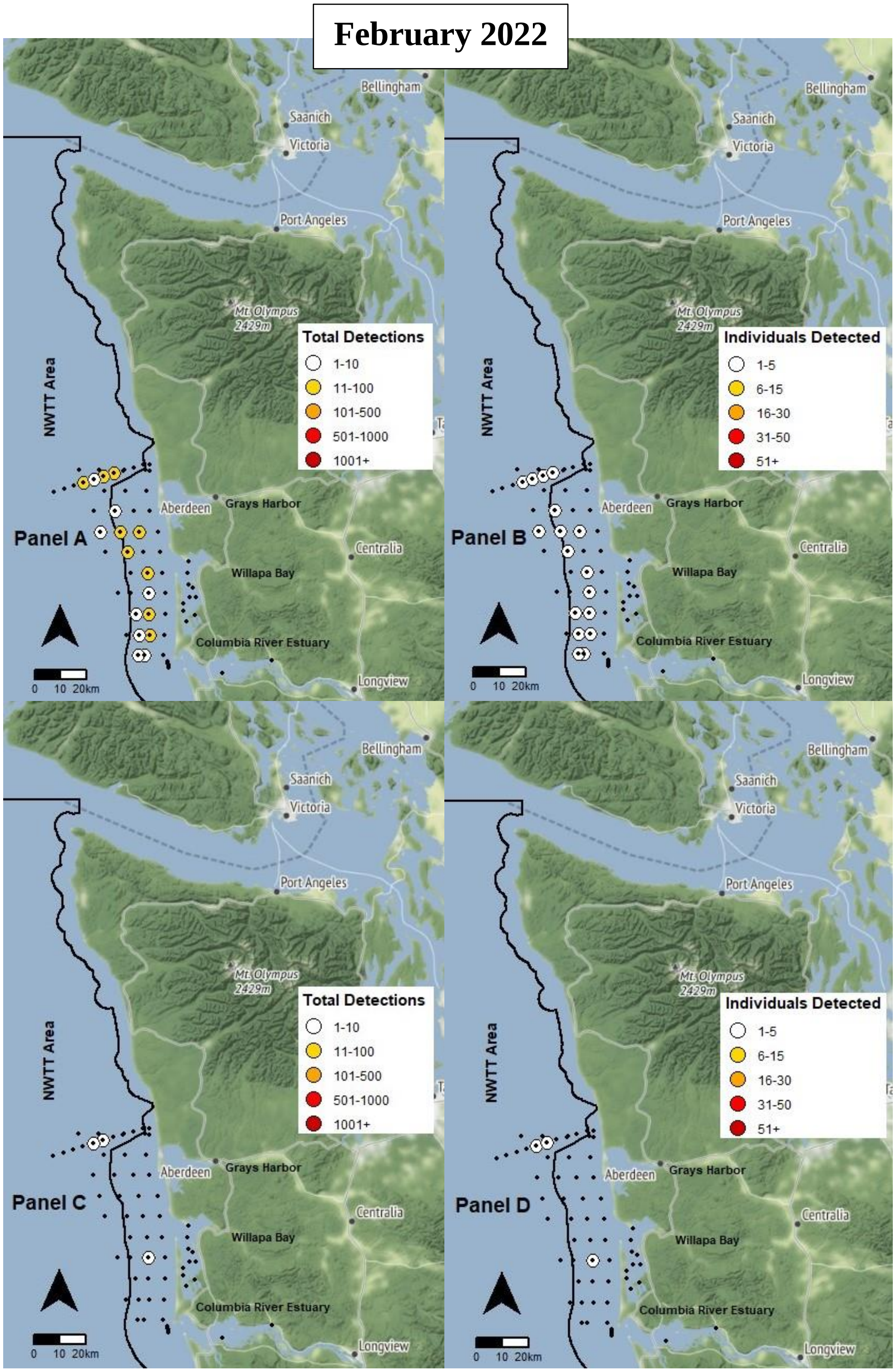


**Figure A- 34.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during February 2022. A total of three sDPS green sturgeon and 21 unique individuals detected during this period.

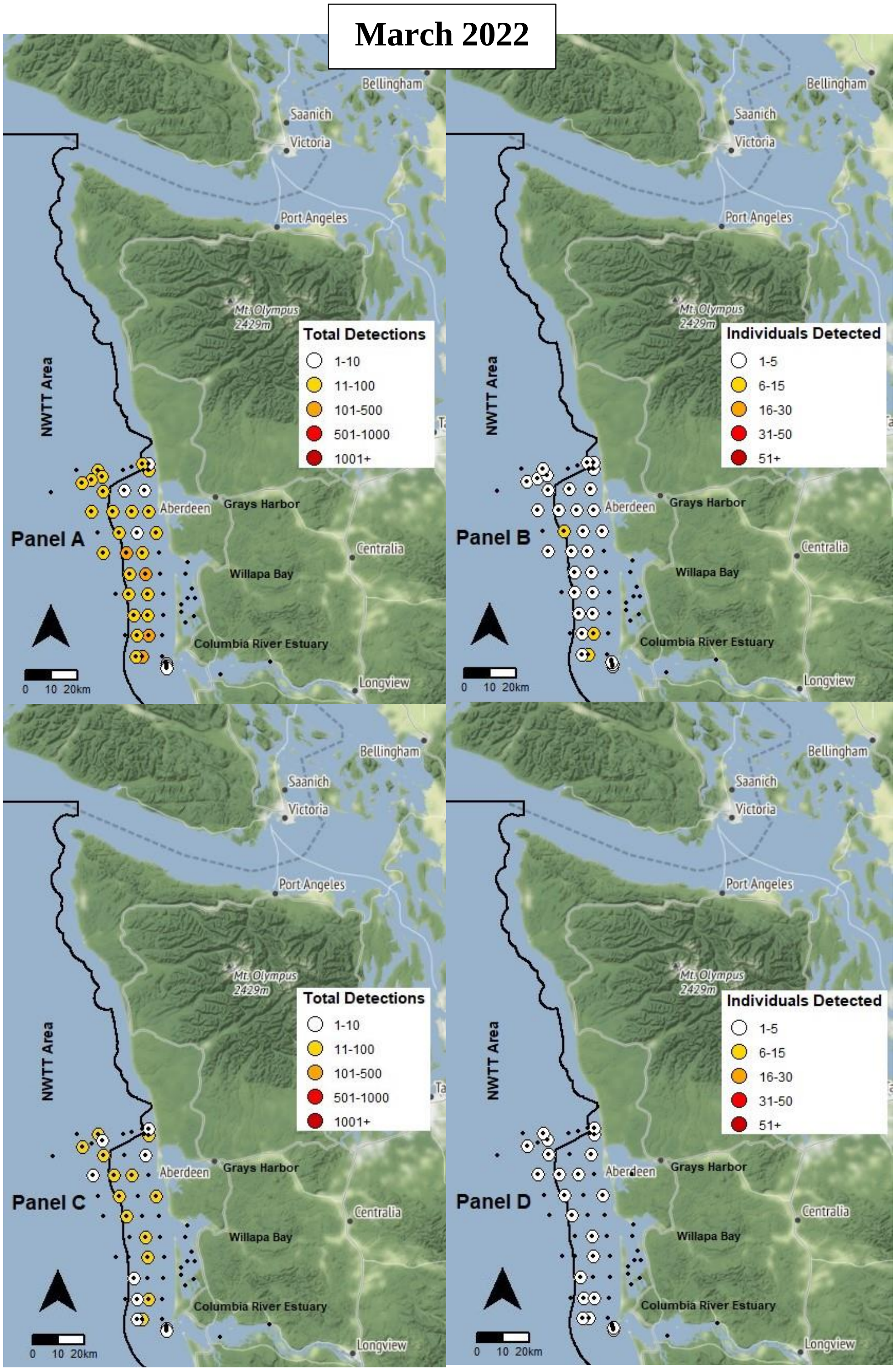


**Figure A- 35**. The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during March 2022. A total of nine sDPS green sturgeon and 31 unique individuals were detected during this period.

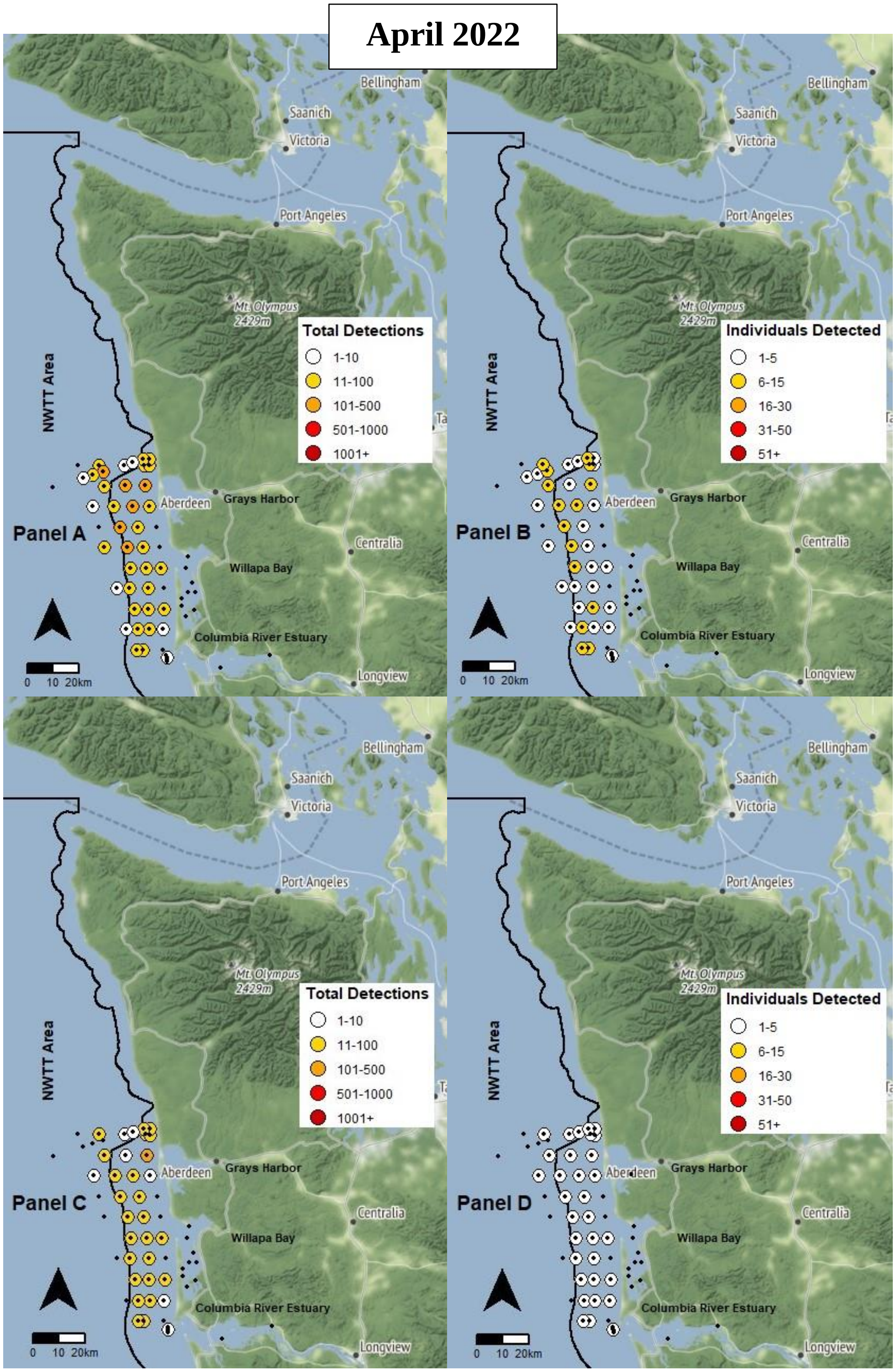


**Figure A- 36.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during April 2022. A total of 24 sDPS green sturgeon and 62 unique individuals were detected during this period.

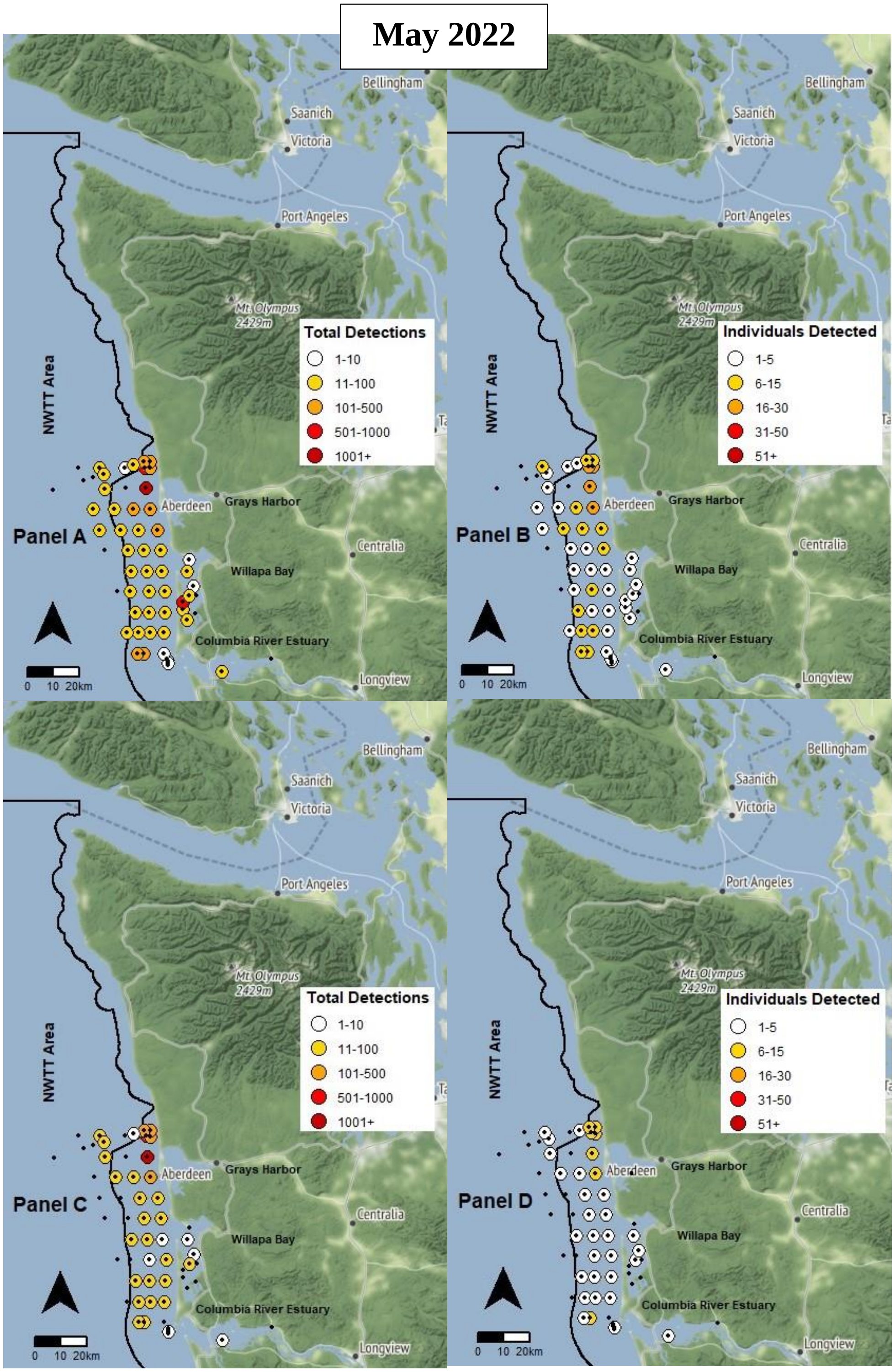


**Figure A- 37.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during May 2022. A total of 27 sDPS green sturgeon and 87 unique individuals were detected during this period.

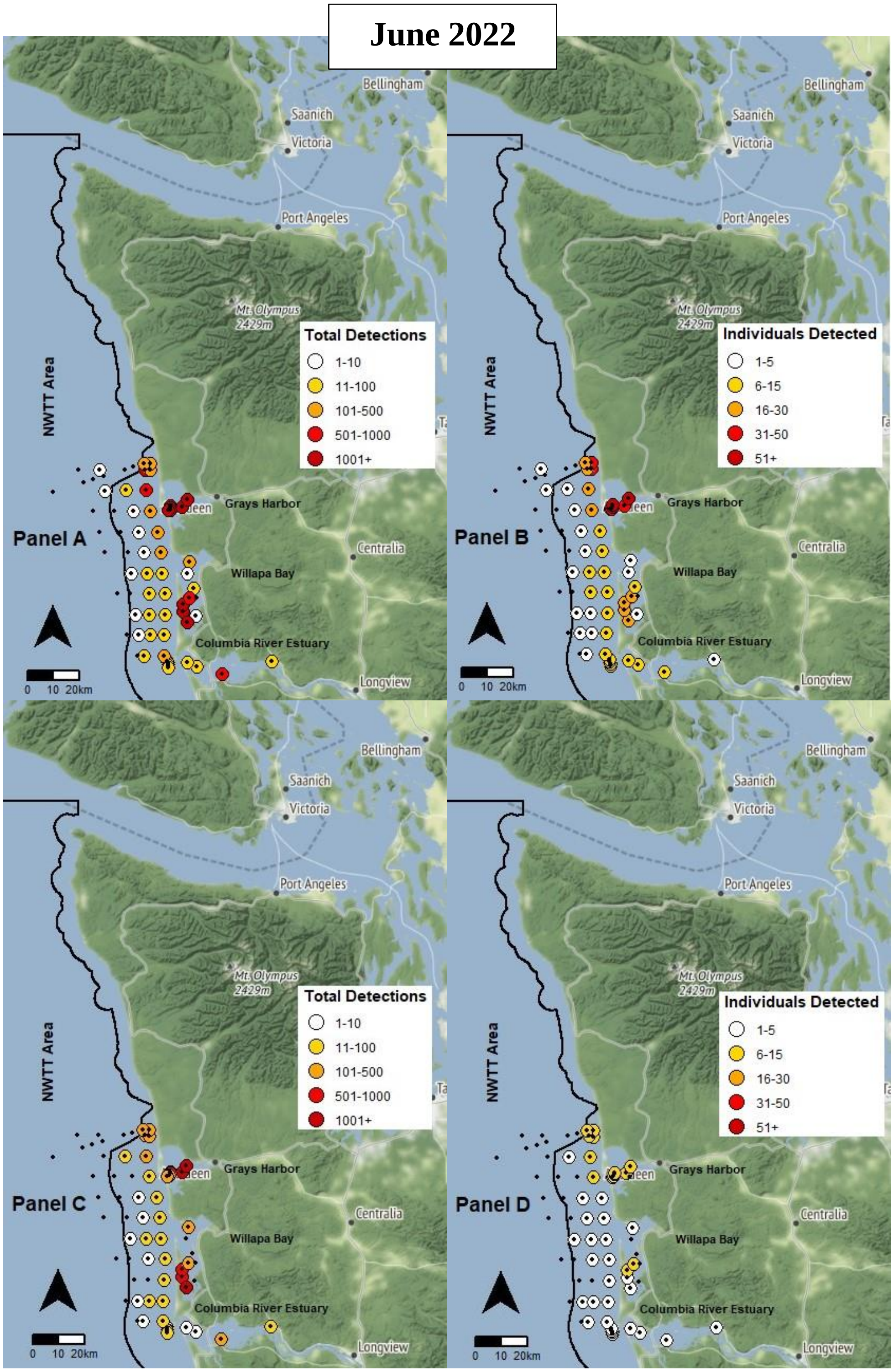


**Figure A- 38.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during June 2022. A total of 37 sDPS green sturgeon and 135 unique individuals were detected during this period.

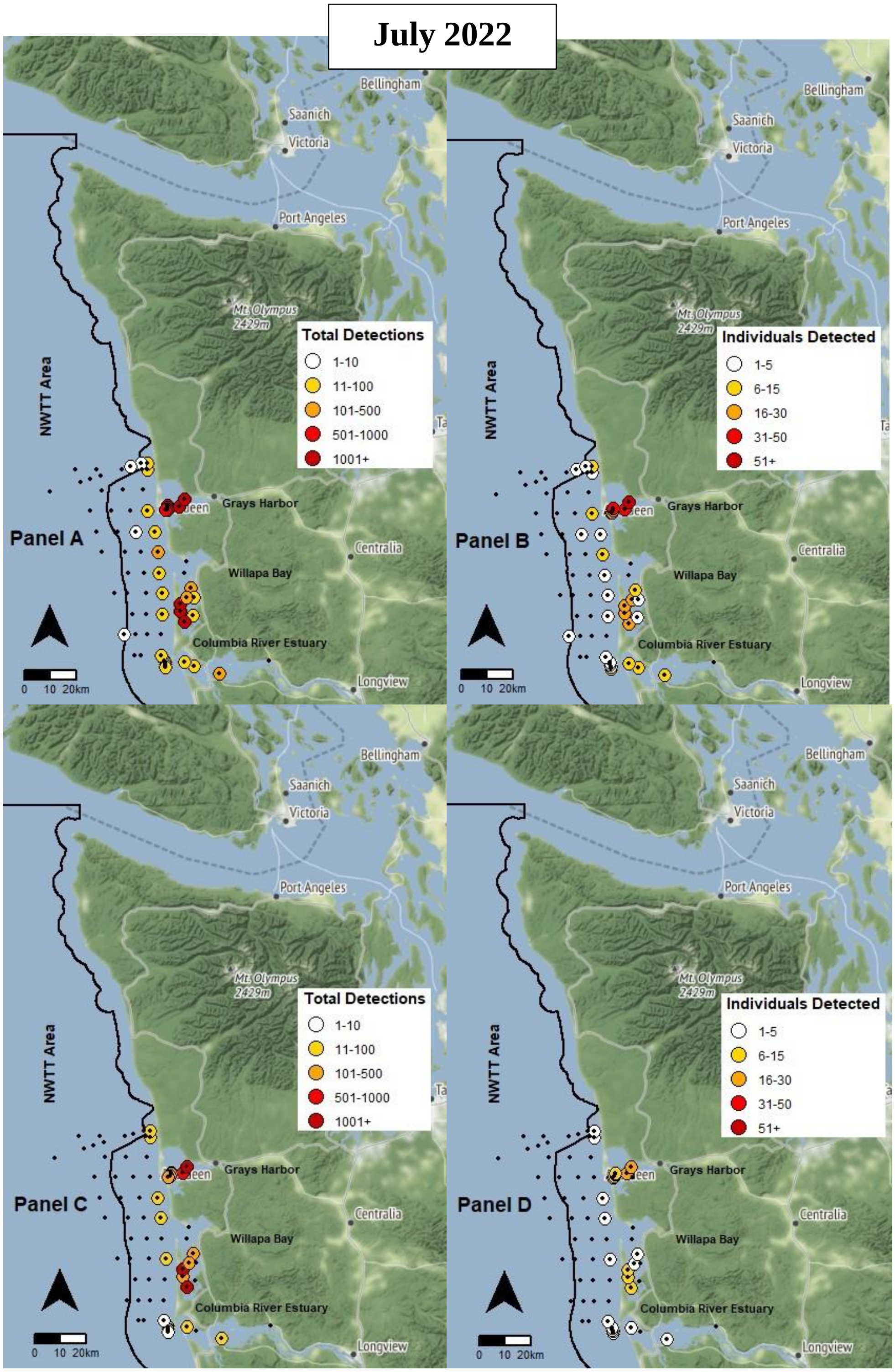


**Figure A- 39.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during July 2022. A total of 35 sDPS green sturgeon and 125 unique individuals were detected during this period.

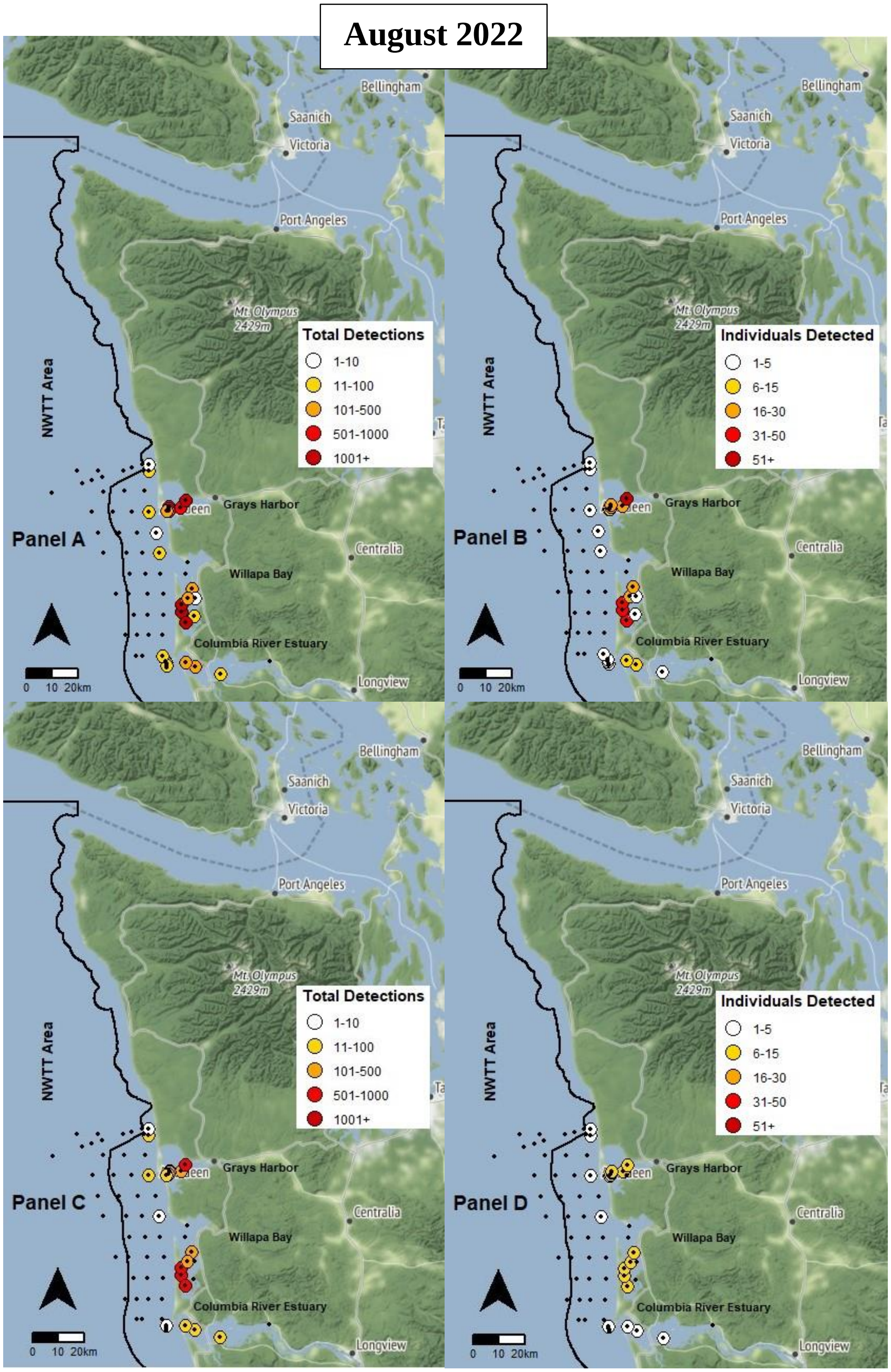


**Figure A- 40.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during August 2022. A total of 34 sDPS green sturgeon and 118 unique individuals were detected during this period.

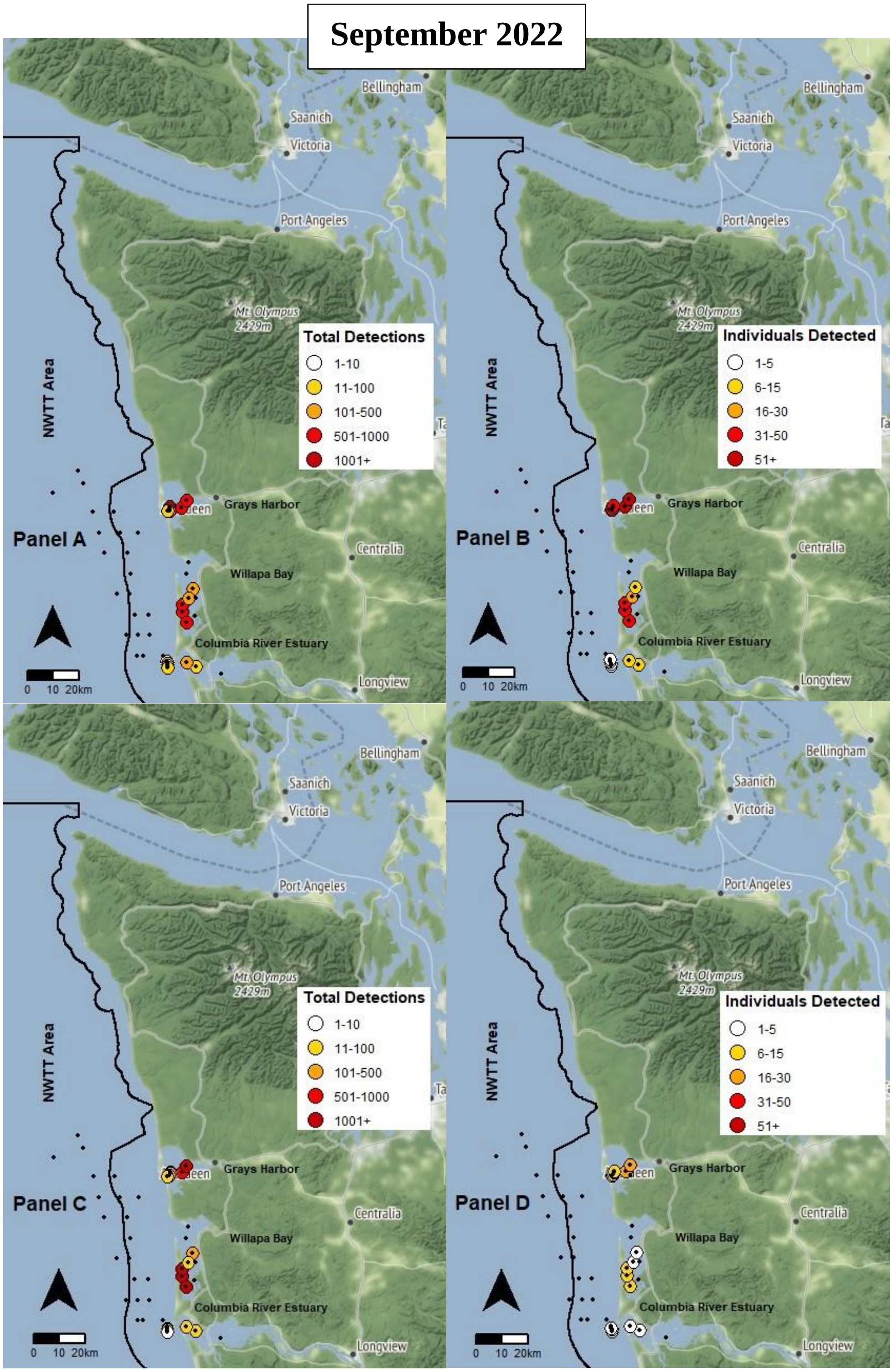


**Figure A- 41.** The total number of green sturgeon detections including fish of sDPS, nDPS, and unknown DPS (Panel A.), the number of individual green sturgeon detected (Panel B.), the total number of sDPS green sturgeon detections (Panel C.), and the number of individual sDPS green sturgeon detected (Panel D.) on acoustic receivers during September 2022. A total of 37 sDPS green sturgeon and 137 unique individuals were detected during this period.