



Invasive Crabs at Assateague Island National Seashore

Natural Resource Report NPS/ASIS/NRR—2023/2532



ON THE COVER

Two green crabs (*Carcinus maenas*) captured. Note variation of color between individuals.
NPS

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Natural Resource Report NPS/ASIS/NRR—2023/2532

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Executive Summary

An invasive crab inventory survey was performed to document the abundance and spatial distribution of the European green crab (*Carcinus maenas*) and the Japanese shore crab (*Hemigrapsus sanguineus*) at Assateague Island National Seashore (ASIS) which forms the eastern boundaries of Chincoteague and Sinepuxent Bays. Three habitat types (rocky, vegetated and unvegetated) are present within the Chincoteague and Sinepuxent Bays. Each habitat type was sampled to determine if different habitat types support different populations of these invasive crabs. Rocky habitat is known to be limited in these bays and there are only seven known locations of this habitat type. Crab traps were placed at randomly assigned stations where tidal elevations are within the known range and preferences of the invasive crabs.

Throughout two surveys representing July and September conditions, 15 species were collected and only one species was identified as an invasive crab. Only three *C. maenas* were captured throughout the project. These individuals were captured during the July survey at one of the rocky habitat stations. No invasive crab species were collected at either the vegetated or unvegetated habitats. Discrete water quality parameters that were measured during the initial deployment indicate that temperature and salinity at the survey stations may be at the extreme end of this species tolerance.

Introduction

The European green crab (*Carcinus maenas*) and Japanese shore crab (*Hemigrapsus sanguineus*) are invasive crabs that were introduced to the eastern United States likely through the ballast water of ships. *C. maenas* is native to the Atlantic coasts of Europe and northern Africa and is thought to have been introduced to the east coast of North America around 1857 (Carlton & Cohen, 2003). *C. maenas* have been found from Newfoundland to Virginia (USGS, 2021). This species can be found in a range of colors but is typically dark brown with green, brown, yellow, orange, or red mottling. They have four pairs of walking legs and a carapace that typically ranges from 5 to 9 cm (2 to 3.9 inches) in width with five spines along each side. *C. maenas* is primarily found in the mid to low intertidal to subtidal zones in mud, sand, and pebble substrates (Northeast Aquatic Nuisance Species Panel, 2019a). These crabs are commonly used as live fishing bait.

H. sanguineus is native to Russia, Korea, China, and Japan and is thought to be introduced to Cape May, New Jersey in 1988 (Northeast Aquatic Nuisance Species Panel, 2019b) and has been found from Maine to North Carolina (USGS, 2021). *H. sanguineus* is typically orange to brown with light and dark bands on legs, red spots on the claws, and a square-shaped carapace that ranges from 2 to 3 inches in width and has three spines on each side. *H. sanguineus* is primarily found in the mid to low intertidal zone typically in rocks and cobble, but it may also be found in soft sediments and other habitats (Northeast Aquatic Nuisance Species Panel, 2019b).

In Maryland, *C. maenas* is prohibited from being removed from the waters of one watershed and introduced into the waters of another watershed and prohibited from import, transport, sale, purchase, and possession (MD DNR, n.d.). The Code of Maryland Regulations Sec. 08.02.19.04 states that *C. maenas* and *H. sanguineus* may not be transported. The Code of Virginia Section 28.2-825. states that it is unlawful to import fish, shellfish or crustacea for introduction into waters of the Commonwealth; however, it is not prohibited which makes enforcement unclear.

Both invasive crabs have been documented in the Sinepuxent and Chincoteague Bays and are predators of several important commercial native species, including oysters, clams, scallops, fish, other crustaceans, and their larvae (MD DNR, 2016). These crabs have been identified as potential threats to commercial shellfish farms (ISSG, 2009; Young & Elliott, 2019). *C. maenas* has impacted the commercial soft-shelled clam (*Mya arenaria*) industry in New England where the lowest harvest totals are in areas with populations of *C. maenas* (Young & Elliott, 2019). *C. maenas* is also harmful to submerged aquatic vegetation (SAV) populations, including eelgrass. In New Hampshire, populations of *C. maenas* have been shown to damage eelgrass beds based on crab densities (Davis, Short, & Brudick, 2002). They have also been labeled as “ecosystem engineers” for their ability to adjust to the ecosystem where they live and have even been associated with mass mortalities of common eider ducks, *Somateria mollissima*, in the Wadden Sea due to transmission of a parasite, which *C. maenas* are the primary host (Young & Elliott, 2019).

Results from this survey may be used to assist the National Park Service (NPS) managers with management actions due to invasive species as well as in selection of suitable oyster and SAV

restoration areas. Additionally, results from this survey may be used to inform a regional shellfish restoration working group facilitated by the Maryland Coastal Bays National Estuary Program.

Permits

Three scientific collection permits were obtained from state and national agencies. Research and Collecting Permit number ASIS-2021-SCI-0009 was obtained using the National Park Service portal at <https://irma.nps.gov/RPRS> and was approved from July 8 to September 30, 2021. The Maryland Scientific Collection Permit SCP202128A was approved from May 21 (amended date) to December 31, 2021, and the Commonwealth of Virginia Marine Resources Commission Scientific Collection Permit 20-042 was approved from July 12 to September 30, 2021. These permits authorized the collection of crab in the intertidal and subtidal zones of Chincoteague and Sinepuxent Bays. Specific conditions and requirements of these permits can be found in each permit. Copies of these permits are available upon request.

Methods

Sample Design

The sample area from Chincoteague and Sinepuxent bays was divided into 0.49 km² (700 m x 700 m) polygons using R. All the polygons were individually numbered. *C. maenas* is known to travel up to 2 km in 6 hours so the plan was designed to provide sufficient scale to attract crabs in the sampling area (Young & Elliott, 2019). Sampling stations within the national seashore boundary were determined randomly using R. Sampling stations for known locations of rocky habitat outside the national seashore boundary were randomly determined using the *Create Random Points* tool in ArcMap, which were provided by NPS.

Using the seagrass polygon that was created from 2017 survey data (provided by NPS), the cells of the grids were further divided based on whether seagrass had been present or absent in 2017 (a buffer of 1 meter was included to smooth out some of the polygons). Following this, a weighted draw based on the area of the cell, was performed to select sample cells using R for both vegetated and unvegetated areas. Ten randomly placed points were then plotted in each selected cell using R.

Rocky habitat is a limiting factor in the seashore. NPS provided five locations of rocky habitat within the NPS boundary. All five of these habitats were surveyed. Additionally, NPS provided seven locations outside of the NPS boundary. Two of these were surveyed. Three stations were surveyed per location for a total of 21 traps located in rocky habitat. The grid cell that best represented the rocky habitat was determined and 10 randomly placed points were placed in these cells. Rocky habitat consisted of manmade structures associated with jetties or shoreline protection and hard bottom substrate created by dense oyster beds.

The 2017 vegetation survey data provided by the NPS was four years old, and the rocky habitat was not evenly distributed throughout a sample cell, therefore three primary and seven alternative stations were randomly selected for each sample cell. This was done to provide optional sampling station to place the plots within suitable habitat during the field effort. Seven additional cells for the vegetated and unvegetated areas were also provided as alternate cells in case field conditions are not suitable for sampling.

This resulted in 21 primary sampling stations located in each of the three habitat types (rocky, vegetated and unvegetated) for a total of 63 trap primary sampling stations. Seven alternative sampling stations are also provided for each cell. Actual sample stations are published and available at <https://irma.nps.gov/DataStore/Reference/Profile/2298888>. Alternative stations were selected based on order in the tables. Maps in Appendix A show the study area with actual sample stations.

Survey

The first survey was conducted from July 12 to 23, 2021, and the second from September 21 to 30, 2021 to provide a comparison between the beginning and the end of summer catches. A Carolina Skiff, which can run on water as shallow as 0.5 m in depth, was used to access traps. The survey crew planned access routes to each site with NPS input. All members of the field crew held boating safety and First Aid/CPR certifications.

Fukui style collapsible traps (approximately 61 x 46 x 20 cm (24 x 18 x 8 inches)) with a mesh size of 1.27 cm (0.5 inches) were used during both surveys. Fukui traps have been shown to efficiently capture *C. maenas* while reducing bycatch that might be collected using other techniques (Poirier, Flynn, Gehrels, & Quijon, 2020). These traps are able to collect both target invasive crab species as the mesh size is 1.27 cm.

The traps openings were modified to approximately 23 x 20 cm openings to minimize accidental trapping of mammals and turtles that may be attracted to the traps. The turtle, *Malaclemys terrapin*, was collected during the July survey and 1/3 of the turtles were found deceased. Turtle excluders were used during the September survey to further reduce the opening while allowing other animals to enter the traps. All traps were inspected for issues before deployment. Any issues observed with the traps were remedied before they were deployed. Each trap was marked with floats connected by lines and weighted. All traps were labeled with scientific collection permit numbers and contact information. *C. maenas* have demonstrated a feeding preference for mollusks (Young & Elliott, 2019). Each trap was baited with a commercially available mollusk based on availability. Stout razor clams (*Tagelus plebeius*) were used in all cases except from July 15 to 16 when they were unavailable. The northern quahog (*Mercenaria mercenaria*) was used as a substitute because it is a similar and preferred bait type.

All traps were deployed as quickly as possible to control against dynamic environmental conditions. Stations were located using a handheld GPS, Garmin Striker, or Garmin Navionics from a smart device based on coordinates obtained from mapped stations. If a station was determined to be unsampleable due to unexpected field conditions, an alternative station was selected from the table provided. Alternative stations were selected for V02 and V04 due to a lack of submerged aquatic vegetation, while alternative stations were selected for UV03 and UV04 because these stations were vegetated. Alternative stations were selected for R01, R03-03, and R06-01 due to dangerous boating conditions and severe currents that were dragging the traps. R07-01 and R07-03 were located on land that lacked rocky habitat, thus alternative station was selected. The only rocky habitat throughout the Sinepuxent and Chincoteague Bays is manmade and typical near bridge abutments and/or used to protect the shoreline from erosion. Traps were checked at approximately 24- and 48-hours following deployment (except when noted) and all captured specimens were enumerated. Invasive crabs were also sexed, and carapace width measured. All bycatch was released unharmed. Invasive crabs were euthanized by icing for several hours. Total trap deployment time was documented to be used in catch per unit effort (CPUE calculations).

SAV was documented within a 1 m² plot at each of the 21 vegetated sampling stations, including species observed, percent cover, and vigor. The Virginia Institute of Marine Sciences (VIMS) flies Sinepuxent and Chincoteague Bays annually to map SAV. According to the VIMS Interactive SAV Map, years of published data show primarily eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) were within the study area with over 90-percent of SAV occurring within 3-feet of depth in the water column (VIMS, 2021).

Macroalgae was documented and categorized as none, sparse, common, or abundant. Agarh's Red Weed (*Agardhiella tenera*) was the dominant species of red algae found while the Green Hair Algae

(*Chaetomorpha sp.*) was also found. Abundant macroalgae could outcompete SAV and create low dissolved oxygen through respiration and decomposition (Egerton, Mulholland, Sellner, & Wazniak, 2014).

Representative water quality parameters were measured at each sampling station using a YSI meter that measured temperature, dissolved oxygen, salinity, pH, and chlorophyll measured by Total Algae- Phycoerythrin (TAL-PE). Profile measurements were collected at 0.3 meter from bottom and at every 0.5-meter interval beginning at the surface. Measurements were not collected if within 0.2 meter from a depth already measured following the quality assurance plan from Maryland DNR (MD DNR, 2021). Water clarity was documented at each station using a Secchi disk. Representative photographs of each individual species were collected and are provided in Appendix B.

A NOAA tide station near Ocean City (8570283) records tidal and meteorological data (NOAA, n.d.). According to this station, the greatest tidal fluctuation during the July survey was 0.69 meter (2.26 feet) on July 23rd, 2021, while 0.56 meter (1.83 feet) was the greatest tidal fluctuation during the September survey on September 21st, 2021 (NOAA, n.d.). Weather conditions were acceptable during both surveys except for two small craft advisories that took place on July 12 and September 23 due to wind. The windy period also related to the only time that *C. maenas* were captured during these surveys demonstrating that the windy period likely didn't affect the ability to capture crabs during this period.

Data Management and Analysis

All organisms that were collected during these surveys were identified and enumerated from each trap and have been summarized in an MS Excel spreadsheet and tables published and available at <https://irma.nps.gov/DataStore/Reference/Profile/2298888>. The number of individuals captured during a soak for each species was adjusted to CPUE based on the deployment time (in hours) for each trap. Summary covariate data are provided in Section 6.4 and Section 6.5. Discrete water quality parameters were measured during deployment of the traps and have been summarized using boxplots organized by habitat type and survey. Sighting Report Forms were submitted to United States Geological Survey - Nonindigenous Aquatic Species Database for the invasive crabs collected during this survey.

Quality Control

The YSI ProDSS Multiparameter Water Quality Meter was calibrated according to manufacturer's instructions and using calibration standards prior to use. All field collected data was assessed for completion and accuracy by the field crew manager. Data sheets were scanned at the end of each field day. Species that were not confidently field identified were photographed for later identification. All (100%) hand entered data was checked for accuracy, and 10% of data that is cut and pasted was also assessed.

Results

Field Survey

Fukui style crab traps were deployed at 21 locations throughout the Chincoteague and Sinepuxent bays during two surveys (July and September 2021). One trap was placed at three predefined sampling stations within each location. Table 1 and Table 2 provide the deployment/recovery dates and the average soak time for traps placed at each location. On September 23rd a small craft advisory was in place that delayed the recovery of the traps that were deployed for 24 hours.

Table 1. July 2021 Survey Deployment and Recovery Information.

Location	Deployment Date	Recovery/ Deployment Date	Recovery Date	1 st Soak (Average hours)	2 nd Soak (Average hours)
R02	July 21, 2021	July 22, 2021	July 23, 2021	23.4	23.3
R03	July 21, 2021	July 22, 2021	July 23, 2021	23.5	23.7
R04	July 12, 2021	July 13, 2021	July 14, 2021	20.5	22.9
R05	July 12, 2021	July 13, 2021	July 14, 2021	20.6	22.6
R06	July 21, 2021	July 22, 2021	July 23, 2021	23.2	21.4
R07	July 21, 2021	July 22, 2021	July 23, 2021	23.1	21.7
R08	July 21, 2021	July 22, 2021	July 23, 2021	23.3	23.7
UV01	July 15, 2021	July 16, 2021	July 17, 2021	20.2	22.9
UV02	July 15, 2021	July 16, 2021	July 17, 2021	19.4	22.7
UV05	July 15, 2021	July 16, 2021	July 17, 2021	21.1	22.8
UV06	July 15, 2021	July 16, 2021	July 17, 2021	20.3	22.7
UV07	July 15, 2021	July 16, 2021	July 17, 2021	21.4	23.0
UV09	July 21, 2021	July 22, 2021	July 23, 2021	23.0	21.2
UV10	July 15, 2021	July 16, 2021	July 17, 2021	21.6	23.2
V01	July 12, 2021	July 13, 2021	July 14, 2021	20.7	22.7
V03	July 15, 2021	July 16, 2021	July 17, 2021	20.5	22.7
V04	July 13, 2021	July 14, 2021	July 15, 2021	19.4	19.7
V05*	July 12, 2021– July 13, 2021	July 13, 2021– July 14, 2021	July 14, 2021– July 15, 2021	21.0	24.4
V06	July 15, 2021	July 16, 2021	July 17, 2021	20.5	22.8
V07	July 12, 2021	July 13, 2021	July 14, 2021	21.2	24.2
V08	July 12, 2021	July 13, 2021	July 14, 2021	19.3	22.4

* The trap deployed at V05-01-PRI on July 12, 2021 was lost and a replacement trap was deployed on July 13, 2021.

Table 2. September 2021 Survey Deployment and Recovery Information.

Location	Deployment Date	Recovery / Deployment Date	Recovery Date	1st Soak (Average hours)	2nd Soak (Average hours)
R02	September 21, 2021	September 22, 2021	September 24, 2021	23.2	47.5*
R03	September 21, 2021	September 22, 2021	September 24, 2021	21.6	48.8*
R04	September 28, 2021	September 29, 2021	September 30, 2021	23.1	23.5
R05	September 28, 2021	September 29, 2021	September 30, 2021	23.6	24.0
R06	September 21, 2021	September 22, 2021	September 24, 2021	23.0	45.5*
R07	September 21, 2021	September 22, 2021	September 24, 2021	21.8	49.7*
R08	September 21, 2021	September 22, 2021	September 24, 2021	22.9	48.4*
UV01	September 25, 2021	September 26, 2021	September 27, 2021	22.9	23.8
UV02	September 25, 2021	September 26, 2021	September 27, 2021	22.7	23.5
UV05	September 25, 2021	September 26, 2021	September 27, 2021	22.7	22.7
UV06	September 25, 2021	September 26, 2021	September 27, 2021	22.7	23.9
UV07	September 25, 2021	September 26, 2021	September 27, 2021	21.9	22.3
UV09	September 21, 2021	September 22, 2021	September 24, 2021	22.5	48.8*
UV10	September 25, 2021	September 26, 2021	September 27, 2021	24.0	21.1
V01	September 25, 2021	September 26, 2021	September 27, 2021	23.1	21.1
V03	September 25, 2021	September 26, 2021	September 27, 2021	22.6	23.0
V04	September 28, 2021	September 29, 2021	September 30, 2021	21.7	22.5
V05	September 28, 2021	September 29, 2021	September 30, 2021	22.1	22.7
V06	September 25, 2021	September 26, 2021	September 27, 2021	22.6	22.5
V07	September 28, 2021	September 29, 2021	September 30, 2021	22.6	23.1
V08	September 28, 2021	September 29, 2021	September 30, 2021	22.5	23.0

* Traps were deployed for 48 hours due to storm conditions on recovery date.

Catch Results

During the July and September 2021 surveys 15 species were captured. Of these 15 species, five were crab, nine fish and one was a turtle (Table 3). The only species captured in traps from all habitat types during both surveys was the blue crab (*Callinectes sapidus*). *C. sapidus* were the most common species to be trapped with an average CPUE of 0.043 across both surveys relating to one crab per roughly 23 hours of trap deployment. A violin plot is provided (Figure 1) to compare CPUE from each species related to the habitat type averaged across both surveys. Some species were only collected from a single habitat; *Sphoeroides maculatus*, *Paralichthys dentatus*, *Libinia emarginata*, and *Carcinus maenas* were only captured from the rocky habitat, while *Hypsoblennius hentz* and *Dyspanopeus sayi* were only captured at vegetated habitat stations. A similar comparison by survey is provided in Figure 2 (July Survey) and Figure 3 (September Survey). Although the turtle, *Malaclemys terrapin*, was captured from each habitat type during the July survey, no turtles were captured in the September survey due to the installation of turtle excluders to prevent turtles from entering the traps. The turtle excluders used were shown to allow other animals to enter the trap while specifically excluding turtles. The CPUE results for the hermit crab *Pagurus* sp. were removed from Figure 1 through Figure 3 because the CPUE for this species was elevated at a couple stations which minimized the visibility of the other species.

Table 3. Average CPUE for all species captured (CPUE - hours). NC = not captured. Green Crab (*Carcinus maenas*) in bold.

Species	Common Name	Group	Rocky July	Rocky Sept.	Unvegetated July	Unvegetated Sept.	Vegetated July	Vegetated Sept.
<i>Archosargus probatocephalus</i>	Sheepshead	Fish	NC	0.0005	NC	0.0031	NC	NC
<i>Carcinus maenas</i>	Green Crab	Crab	0.0033	NC	NC	NC	NC	NC
<i>Callinectes sapidus</i>	Blue Crab	Crab	0.0500	0.0230	0.0440	0.0381	0.0567	0.0483
<i>Centropristis striata</i>	Bass	Fish	0.0022	0.0010	0.0063	0.0087	NC	NC
<i>Dyspanopeus sayi</i>	Mud Crab	Crab	NC	NC	NC	NC	NC	0.0096
<i>Fundulus heteroclitus</i>	Mummichog	Fish	0.0056	NC	0.0021	NC	NC	NC
<i>Hypsoblennius hentz</i>	Feather Blenny	Fish	NC	NC	NC	NC	NC	0.0021
<i>Leiostomus xanthurus</i>	Spot	Fish	0.0032	NC	0.0010	NC	0.0012	NC
<i>Libinia emarginata</i>	Spider Crab	Crab	NC	0.0010	NC	NC	NC	NC
<i>Malaclemys terrapin</i>	Diamondback terrapin	Turtle	0.0126	NC*	0.0020	NC*	0.0009	NC*
<i>Opsanus tau</i>	Oyster Toadfish	Fish	0.0011	0.0015	0.0011	NC	NC	NC
<i>Orthopristis chrysoptera</i>	Grunt	Fish	NC	NC	0.0010	0.0021	NC	0.0011
<i>Pagurus</i> sp.	Hermit Crab	Crab	0.0231	0.0575	0.0010	0.0011	NC	NC
<i>Paralichthys dentatus</i>	Summer Flounder	Fish	0.0044	0.0005	NC	NC	NC	NC
<i>Sphoeroides maculatus</i>	Northern Puffer	Fish	NC	0.0010	NC	NC	NC	NC

* Turtle excluders installed.

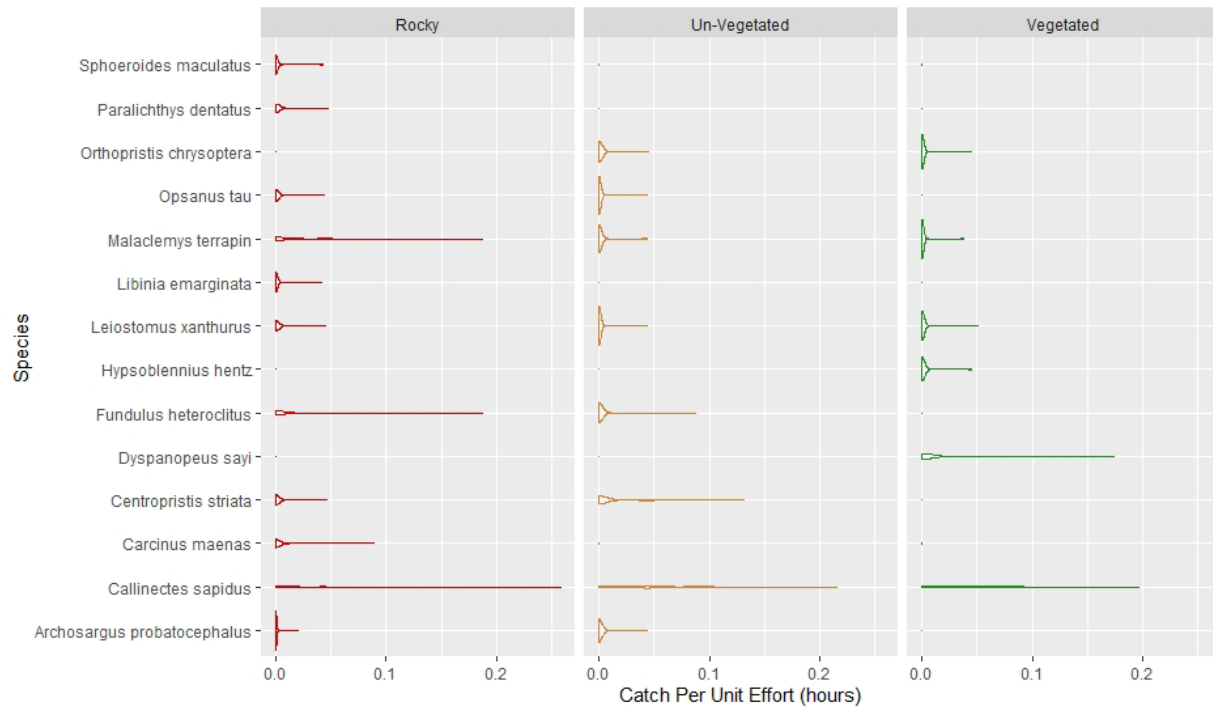


Figure 1. Catch per unit effort by habitat type. Violin plots provides a representation of the distribution of the catch per unit effort for each organism.

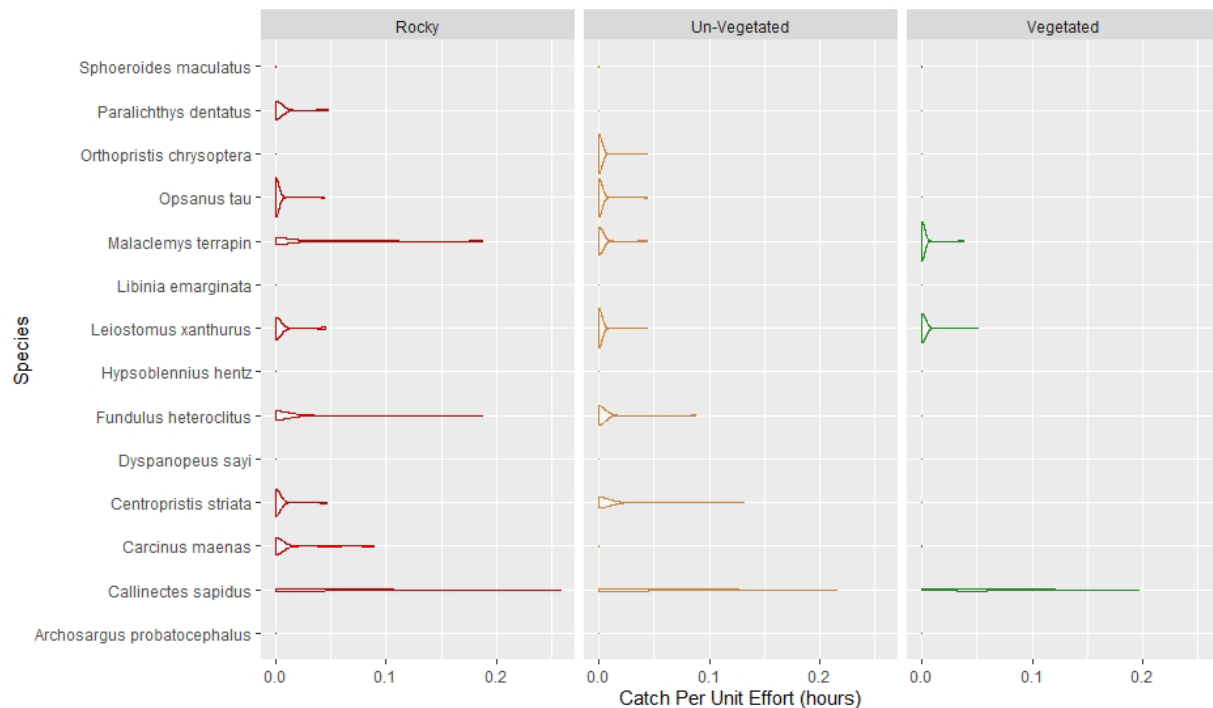


Figure 2. Catch per unit effort - July Survey. Violin plots provides a representation of the distribution of the catch per unit effort for each organism.

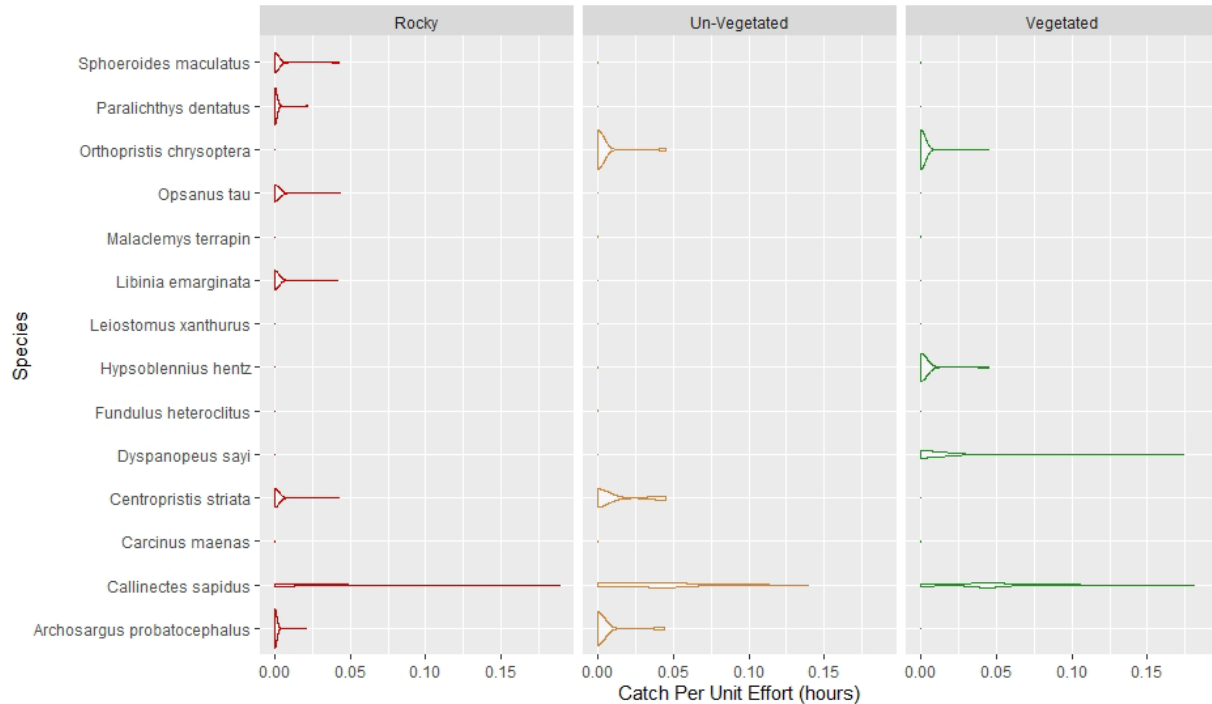


Figure 3. Catch per unit effort - September Survey. Violin plots provides a representation of the distribution of the catch per unit effort for each organism.

Invasive Crab Results

Only one species of invasive crab, green crab (*Carcinus maenas*), was collected during the 2021 surveys. Three individual *C. maenas* were collected at one station, R05-02-PRI, from within the rocky habitat during the July survey. One of these crabs was a non gravid female which measured 49-mm, and two were males which measured 60- and 65-mm. Carapace widths for sexual maturity of *C. maenas* has been reported to range from 28.66 to 42.7 mm for females and 21.3 to 34-mm for males for the northwestern Atlantic nonindigenous population (Young & Elliott, 2019). This would indicate that these three individuals were adults and were old enough to be reproductive. The site where these crabs were captured, R05-02-PRI, is located in a heavy boat traffic area with commercial and recreational fishing. This station is located along the southern edge of the Ocean City inlet jetty system consisting of Class III rip-rap which allows for *C. maenas* to hide in spaces between the rip-rap and avoid predation. Additionally, the Ocean City inlet is a popular spot for tautog fishing where green crabs are the common bait (OTW Staff, 2016). No *H. sanguineus* crabs were collected at any time during either of these surveys.

The CPUE for *C. maenas* at station R05-02-PRI was 0.0485 during the first 24 hours and 0.0890 during the next 24 hours (Figure 4). CPUE averaged across all rocky habitat sites during the July survey for this species was 0.0033, in hours (Table 3). This relates to one *C. maenas* captured for roughly every 305 hours of trap deployment at the rocky habitat during the July survey. No *C. maenas* were collected during the September survey or at the unvegetated and vegetated sites from both surveys.

The northwestern Atlantic population of *C. maenas* is potentially limited by the predatory blue crab (*C. sapidus*) (Young & Elliott, 2019). The CPUE for *C. sapidus* ranged from 0.000 at R04 in the rocky habitat during the September survey to 0.0989 at R03 in the rocky habitat during the July survey (Table 4). The CPUE for *C. sapidus* at R05-02-PRI was 0.0465 during the July survey, which was slightly above the average CPUE, 0.043, for *C. sapidus* throughout the surveys. If *C. sapidus* are preying on *C. maenas*, *C. maenas* are likely using the rocky habitat to avoid predation.

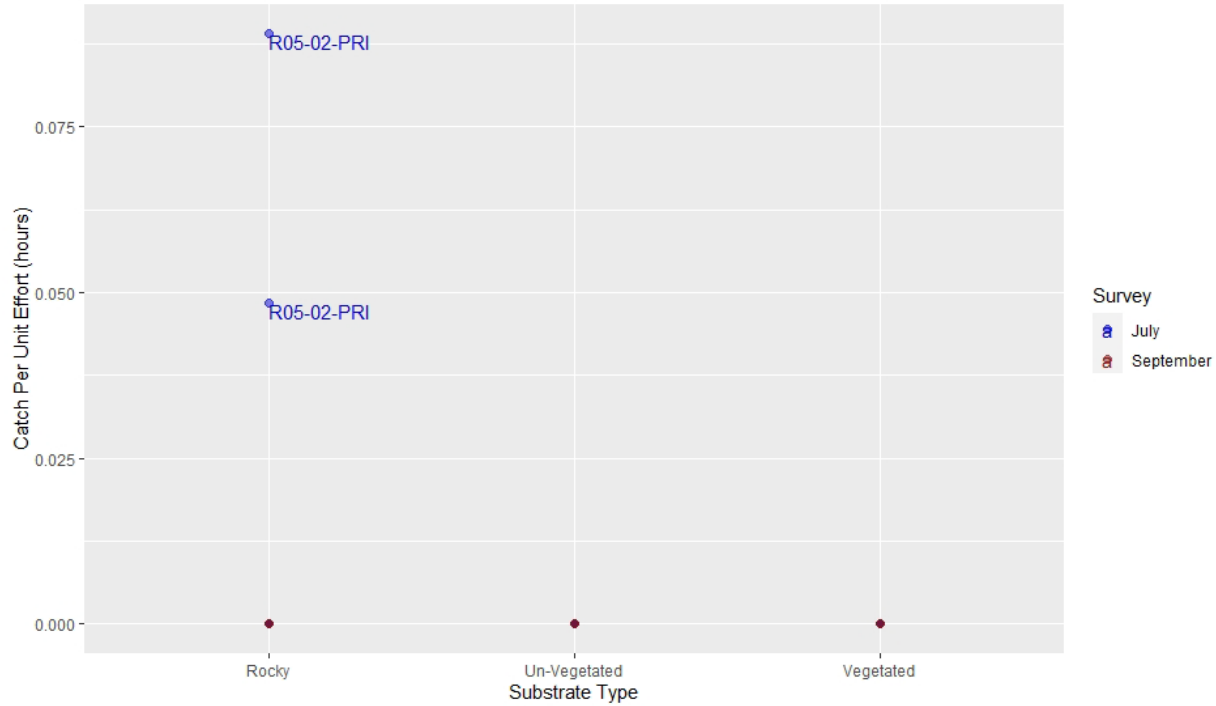


Figure 4. Catch per unit effort for Green Crab for individual stations.

Table 4. Catch per unit effort for predatory Blue Crab.

Habitat Type	Location	July	September
Rocky	R02	0.0761	0.0251
	R03	0.0989	0.0497
	R04	0.0631	0.0000
	R05	0.0155	0.0069
	R06	0.0223	0.0211
	R07	0.0145	0.0221
	R08	0.0477	0.0309
Unvegetated	UV01	0.0163	0.0360
	UV02	0.0284	0.0287
	UV05	0.0299	0.0221
	UV06	0.0313	0.0429
	UV07	0.0511	0.0458

Table 4 (continued). Catch per unit effort for predatory Blue Crab.

Habitat Type	Location	July	September
Unvegetated (continued)	UV09	0.0899	0.0290
	UV10	0.0445	0.0569
Vegetated	V01	0.0796	0.0724
	V03	0.0237	0.0375
	V04	0.0586	0.0532
	V05	0.0527	0.0522
	V06	0.0161	0.0295
	V07	0.0847	0.0500
	V08	0.0685	0.0369

Discrete Water Quality Measurements

Discrete water quality parameters were measured at each sample station at the beginning of the trap deployment. Figure 5 through Figure 10 provide boxplots for the individual water quality parameters organized by survey. The parameters measured at station R05-02-PRI during the July survey, the only station where *C. maenas* was captured, are indicated for each plot. In general, station R05-02-PRI did not have any water quality parameters that were measured outside of the range of the water quality parameters measured at other locations during the July survey.

Young and Elliot (2019) reported water quality tolerance ranges of *C. maenas* for temperature, salinity, and dissolved oxygen. They found that *C. maenas* can tolerate short-term exposures of temperature ranges between 0 and 33 – 35°C which is within the range of all temperature measurements collected during this survey. They also report that the maximum temperature that has been reported for breeding is 26°C. Average temperature measurement for the July survey was 29.4°C with the lowest specific habitat temperature average measured at the rocky habitat, 27.9°C. The maximum temperature measured during the September survey was 25.5°C which is below the reported breeding maximum temperature. The temperature measured at R05-02-PRI during the July survey was 29.5°C which would place this station within the range of temperature tolerance but above the reported maximum for a breeding population (Figure 8). Ovigerous females have been reported in Massachusetts from November to January (Young & Elliott, 2019). Based on this information, temperature may be restricting the breeding season for *C. maenas* in Chincoteague and Sinepuxent bays.

Young and Elliot (2019) reported the salinity minimum range for *C. maenas* survival to be between 4 and 11 ppt while reported maximum salinity for short-term exposure was 54 ppt. Laboratory studies reported preferred salinity range from 27 to 40 ppt but also reported that *C. maenas* are not typically found at salinities greater than 31 ppt (Young & Elliott, 2019). Measured salinities averaged 30.9 ppt in the July survey and 31.6 ppt in the September survey. The lowest salinities were recorded at the rocky habitat stations during both surveys. The salinity measured at R05-02-PRI during the July

survey was 28.8 ppt which would indicate that salinity at this station was within the preferred range for *C. maenas* (Figure 5).

Young and Elliot (2019) report that *C. maenas* are able to breath air and can survive out of water for at least 10 days. This species is highly tolerant to low dissolved oxygen events. Dissolved oxygen ranged from 4.1 to 11.8 during this survey and was measured at 7.9 mg/L at R05-02-PRI during the July survey (Figure 6). These ranges are not believed to be outside of the tolerance ranges for *C. maenas* and should not restrict the likelihood of collecting them in deployed traps.

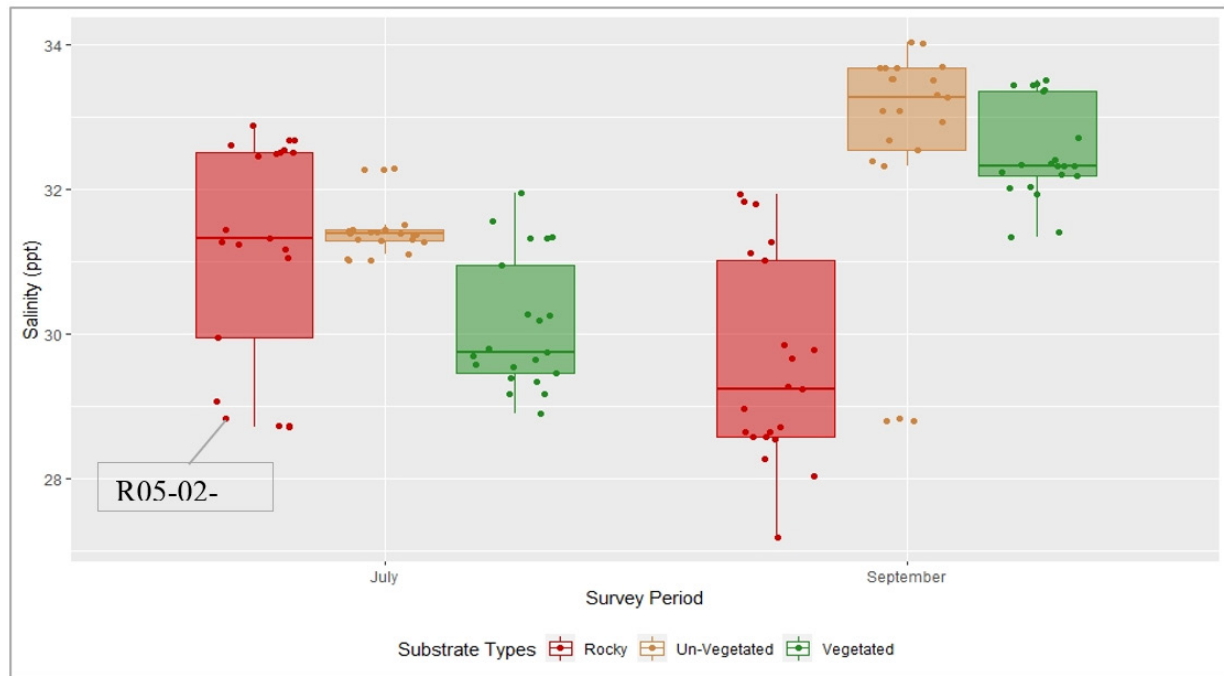


Figure 5. Salinity measurement by habitat type and survey. The box portion of the plot represents the 1st and 3rd quartiles which is divided by the median of the data.

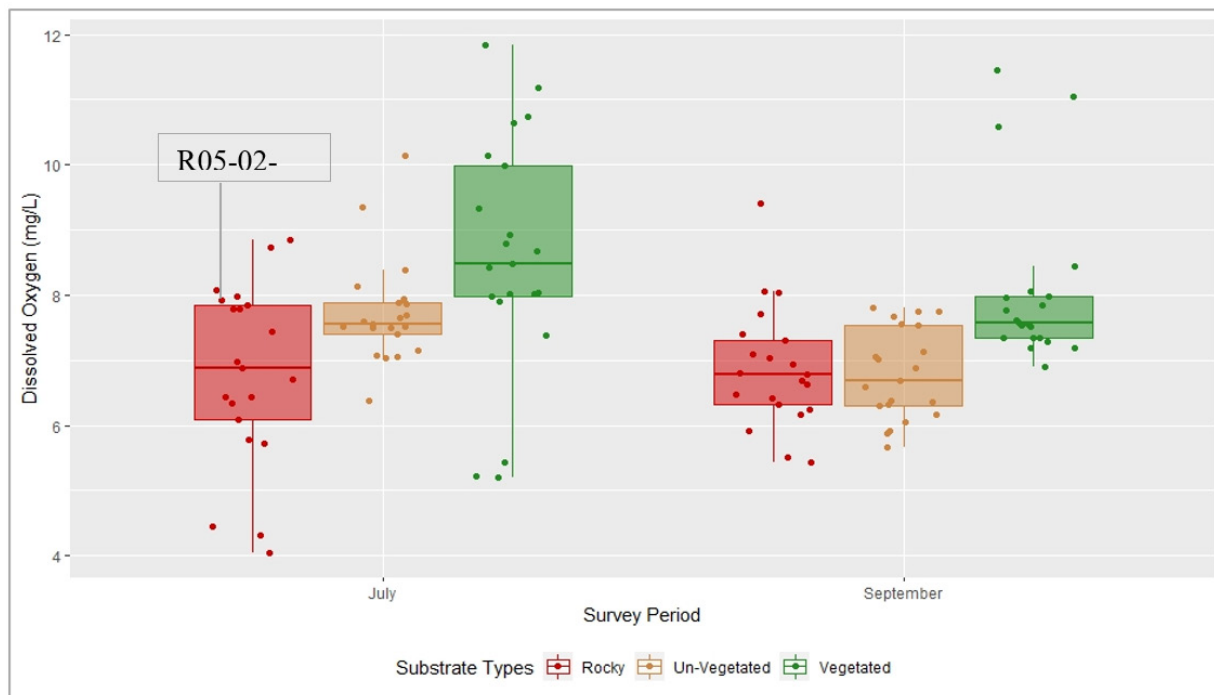


Figure 6. Dissolved oxygen measurements by habitat type and survey. The box portion of the plot represents the 1st and 3rd quartiles which is divided by the median of the data.

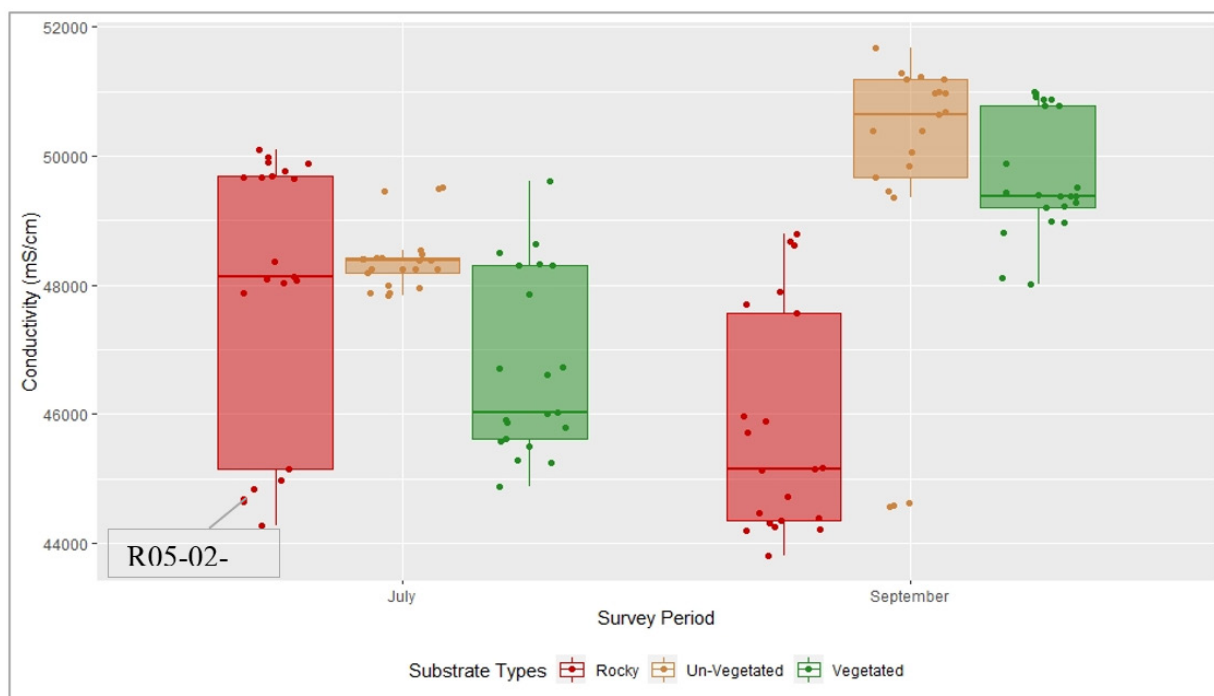


Figure 7. Conductivity measurement by habitat type and survey. The box portion of the plot represents the 1st and 3rd quartiles which is divided by the median of the data.

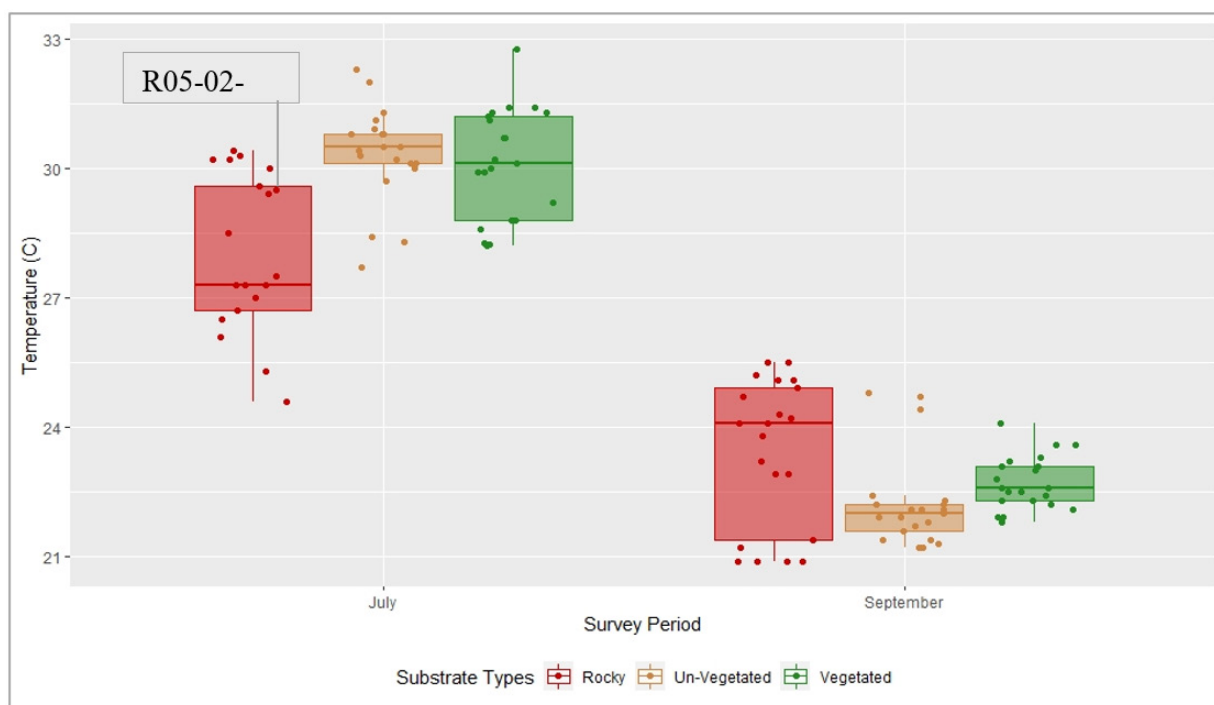


Figure 8. Temperature measurements by habitat type and survey . The box portion of the plot represents the 1st and 3rd quartiles which is divided by the median of the data.

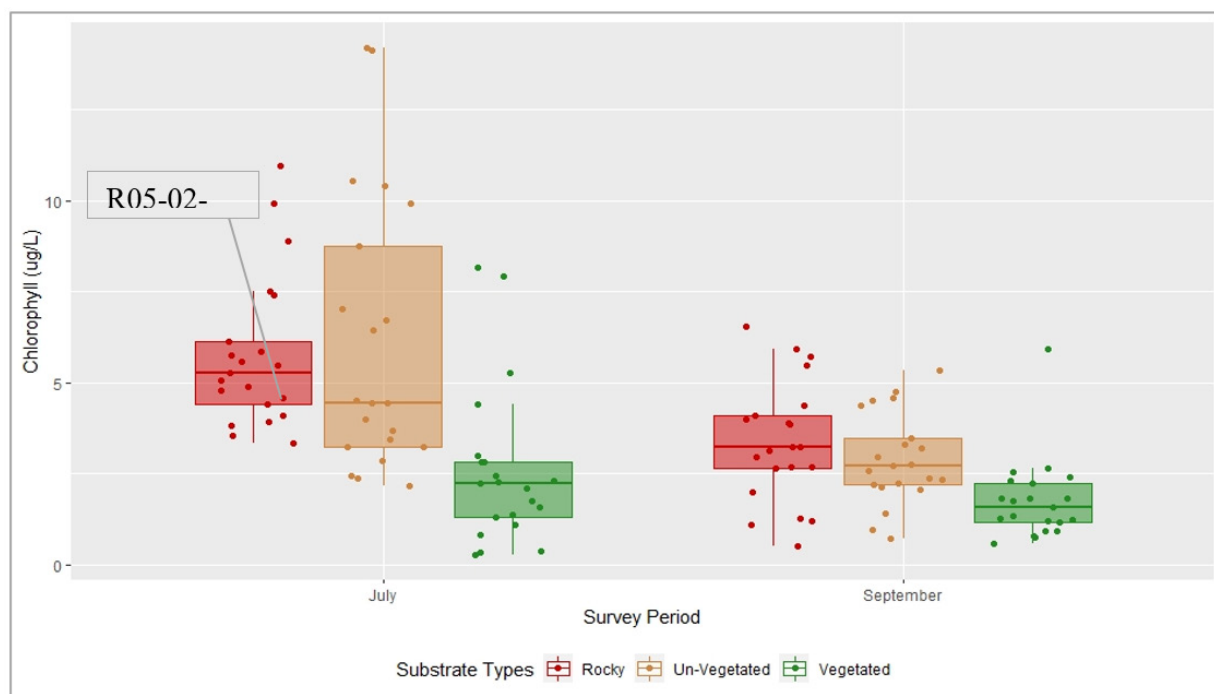


Figure 9. Chlorophyll measurements by habitat type and survey. The box portion of the plot represents the 1st and 3rd quartiles which is divided by the median of the data.



Figure 10. pH measurement by habitat type and survey. The box portion of the plot represents the 1st and 3rd quartiles which is divided by the median of the data.

Vegetation Survey Results

Sub-aquatic vegetation and macro algae presence was noted at all vegetated locations. *Zostera marina* was identified at all stations except 3 during the September survey and ranged from 3 to 95 percent coverage at locations where it was identified (Table 5). Two species of macro algae, *Agardhiella tenera* and *Chaetomorpha sp.* were identified at vegetated locations. *Agardhiella tenera* was the most common. Field observations indicate that water clarity to the west of Tingles Island was excellent and SAV was abundant.

Table 5. Vegetation survey results. SAV = submerged aquatic vegetation.

Station ID	Date	SAV Species	SAV Percent Cover	Macro Algae Species	Macro Algae Abundance
V01-01-PRI	7/12/2021	<i>Zostera marina</i>	15	<i>Agardhiella tenera</i>	Abundant
	9/25/2021	<i>Zostera marina</i>	95	<i>Agardhiella tenera</i>	Abundant
V01-02-PRI	7/12/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Abundant
	9/25/2021	<i>Zostera marina</i>	60	<i>Agardhiella tenera</i>	Abundant
V01-03-PRI	7/12/2021	<i>Zostera marina</i>	50	<i>Agardhiella tenera</i>	Abundant
	9/25/2021	<i>Zostera marina</i>	80	<i>Agardhiella tenera</i>	Abundant
V03-01-PRI	7/15/2021	<i>Zostera marina</i>	75	<i>Agardhiella tenera</i>	Common
	9/25/2021	<i>Zostera marina</i>	3	<i>Agardhiella tenera</i>	Sparse

Table 5 (continued). Vegetation survey results. SAV = submerged aquatic vegetation.

Station ID	Date	SAV Species	SAV Percent Cover	Macro Algae Species	Macro Algae Abundance
V03-02-PRI	7/15/2021	<i>Zostera marina</i>	85	<i>Agardhiella tenera</i>	Common
	9/25/2021	<i>Zostera marina</i>	30	<i>Agardhiella tenera</i>	Abundant
V03-03-PRI	7/15/2021	<i>Zostera marina</i>	80	<i>Agardhiella tenera</i>	Sparse
	9/25/2021	<i>Zostera marina</i>	3	<i>Agardhiella tenera</i>	Common
V04-06-ALT	7/15/2021	<i>Zostera marina</i>	15	<i>Agardhiella tenera</i>	Common
	9/28/2021	<i>Zostera marina</i>	10	<i>Agardhiella tenera</i>	Sparse
V04-08-ALT	7/15/2021	<i>Zostera marina</i>	10	<i>Agardhiella tenera</i>	Common
	9/28/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Sparse
V04-10-ALT	7/15/2021	<i>Zostera marina</i>	15	<i>Agardhiella tenera</i>	Sparse
	9/28/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Sparse
V05-01-PRI	7/12/2021	<i>Zostera marina</i>	5	–	None
	9/28/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Sparse
V05-02-PRI	7/12/2021	<i>Zostera marina</i>	80	<i>Agardhiella tenera</i>	Sparse
	9/28/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Sparse
V05-03-PRI	7/12/2021	<i>Zostera marina</i>	85	<i>Agardhiella tenera</i>	Common
	9/28/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Sparse
V06-01-PRI	7/15/2021	<i>Zostera marina</i>	8	<i>Agardhiella tenera</i>	Sparse
	9/25/2021	–	0	–	None
V06-02-PRI	7/15/2021	<i>Zostera marina</i>	5	–	None
	9/25/2021	–	0	–	None
V06-03-PRI	7/15/2021	<i>Zostera marina</i>	10	<i>Agardhiella tenera</i>	Common
	9/25/2021	–	0	–	None
V07-01-PRI	7/12/2021	<i>Zostera marina</i>	60	<i>Agardhiella tenera</i> , <i>Chaetomorpha</i> sp.	Common Abundant
	9/28/2021	<i>Zostera marina</i>	15	<i>Agardhiella tenera</i>	Sparse
V07-02-PRI	7/12/2021	<i>Zostera marina</i>	60	–	None
	9/28/2021	<i>Zostera marina</i>	40	<i>Agardhiella tenera</i>	Common
V07-03-PRI	7/12/2021	<i>Zostera marina</i>	10	–	None
	9/28/2021	<i>Zostera marina</i>	70	<i>Agardhiella tenera</i>	Abundant
V08-01-ALT	7/12/2021	<i>Zostera marina</i>	5	–	None
	9/28/2021	<i>Zostera marina</i>	10	<i>Agardhiella tenera</i>	Sparse
V08-02-ALT	7/12/2021	<i>Zostera marina</i>	3	–	None
	9/28/2021	<i>Zostera marina</i>	30	<i>Agardhiella tenera</i>	Common
V08-03-ALT	7/12/2021	<i>Zostera marina</i>	15	–	None
	9/28/2021	<i>Zostera marina</i>	5	<i>Agardhiella tenera</i>	Sparse

Discussion and Conclusions

Two surveys were performed during 2021, one in July and one in September, to determine the distribution of invasive crab in and adjacent to the Assateague Island National Seashore. Three crab traps were placed at seven locations representing three different habitat types, rocky, vegetated, and unvegetated. Of the 15 species that were collected during these surveys, only one species of invasive crab, *Carcinus maenas*, was captured. Three individual *C. maenas* (1 non gravid female, 2 males) were collected at one station from the rocky habitat during the July survey. All *C. maenas* were adults which with carapace widths measured above reported ranges for sexual maturity. The station where these crabs were captured is located in a popular tautog fishing spot where *C. maenas* are the primary bait. Furthermore, the Class III rip-rap of the jetties allow for *C. maenas* to hide from predators such as *Callinectes sapidus*.

Hemigrapsus sanguineus were not captured during this study. The USGS has reported established populations of *H. sanguineus* which are reproductive and expanding on the east coast of the United States from Maine to North Carolina (USGS, 2018). The traps used during this survey had mesh size of 1.27 cm (0.5 inches) which was small enough to retained adult *H. sanguineus* and the stout razor clam bait should have been attractive to these crabs which feed on bivalves (USGS, 2018). During these surveys, we captured *Dyspanopeus sayi*, a native mud crab, the smallest which was 5-mm and captured in the traps. It is recommended that future surveys include transects of the rocky habitat in addition to trapping as following our survey, we found anecdotal evidence that stated that *H. sanguineus* would not be effectively captured using traps. OTW (2016) reported that

“Asian shore crabs cannot be bought at bait shops and must be caught on your own. Due to the small size of these crabs and their tendency to live strictly in the intertidal zone, they are nearly impossible to trap with commercially available crab traps. The most effective means of acquiring a supply of Asian shore crabs is by flipping over rocks at low tide and catching them by hand (OTW Staff, 2016).”

Water quality parameters were measured during the initial deployment of the crab traps. Water quality measurements recorded during the surveys for salinity, temperature, and dissolved oxygen were within the reported tolerance limits for *C. maenas*. Although recorded temperatures were within the tolerance ranges, average temperatures recorded during the July survey were higher than the water temperature reported as necessary for reproduction. This indicates that summer temperatures within the Assateague Island National Seashore boundary could be a stressor to *C. maenas*. September temperature measurements were just below the reported temperature necessary for reproduction. The current population of *C. maenas* would likely have difficulty brooding during the warmer summer conditions.

Salinity measurements were also within the reported tolerance limits for *C. maenas* however, it was reported that they are rarely captured at salinities above 31 ppt. Average salinity measurements during the July survey was just under this level and was higher than 31 ppt during the September survey. Temperature and salinity could have a synergistic effect on *C. maenas* where an extreme

condition of one of the parameters could impact *C. maenas* ability to tolerate the other parameter (Young & Elliott, 2019).

Water quality collected during this study were discrete measurements while deploying the traps and only represent the water conditions at that time. Eyes on the Bay, a program managed by Maryland Department of Natural Resources, measures these parameters over longer periods of time. From 2001 to 2020 at the Isle of Wight Bay location, XDN2438, near Ocean City salinity ranged from 21.34 to 33.35 ppt (MDNR, n.d.). Temperature at this location ranged from 1.5 to 29.1°C (MDNR, n.d.). High temperatures at this site were measured above 26°C, which is the high temperature threshold for reproduction, from roughly July through September. The Chincoteague Bay station, XCM1562, indicated a slightly greater range in salinity over this same period from 20.2 to 36.22 ppt (MDNR, n.d.). Water temperatures at this station displayed a greater range of -1.5 to 30.2 °C. Throughout this time period, high temperature measurements at this location were above 26°C from June through September. These data seem to indicate periods of stress for *C. maenas* in the surveyed area. In addition, the presence of a natural predator, *Callinectes sapidus*, could be assisting with controlling the population of *C. maenas* near Assateague Island National Seashore.

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Appendix A – Sampling Station Maps

Maps A1 through A15 depict stations where sampling occurred.

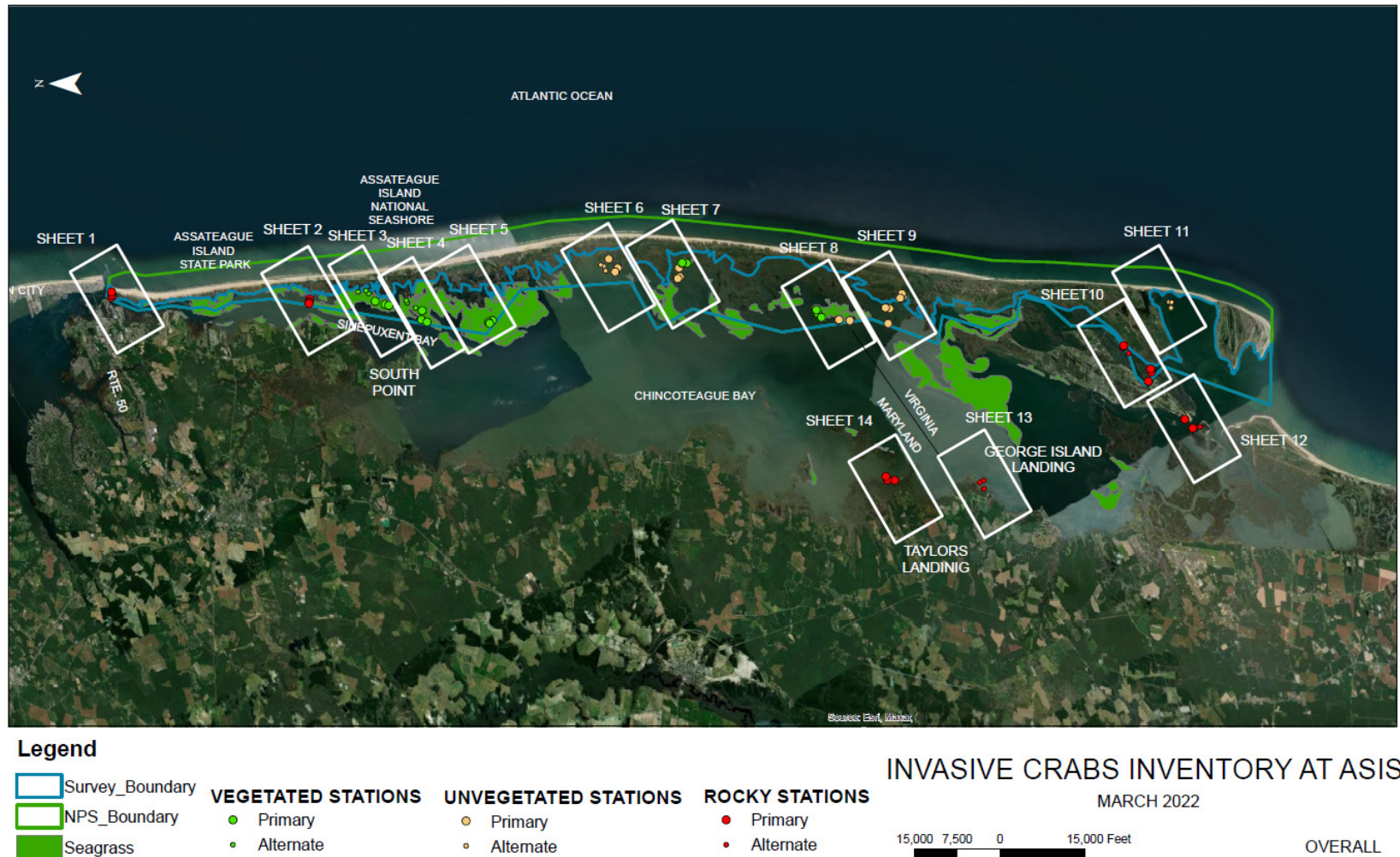


Figure A-1. Map showing sampling locations at vegetated (green), unvegetated (yellow), and rocky (red) stations at ASIS.



Legend

 Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
 NPS_Boundary	 Primary	 Primary	 Primary
 Seagrass	 Alternate	 Alternate	 Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 1

Figure A-2. Map showing a subset of sampling locations at ASIS.



Legend

Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
NPS_Boundary	Primary	Primary	Primary
Seagrass	Alternate	Alternate	Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 2

Figure A-3. Map showing a subset of sampling locations at ASIS near the Verrazano Bridge.



Figure A-4. Map showing a subset of sampling locations at ASIS.

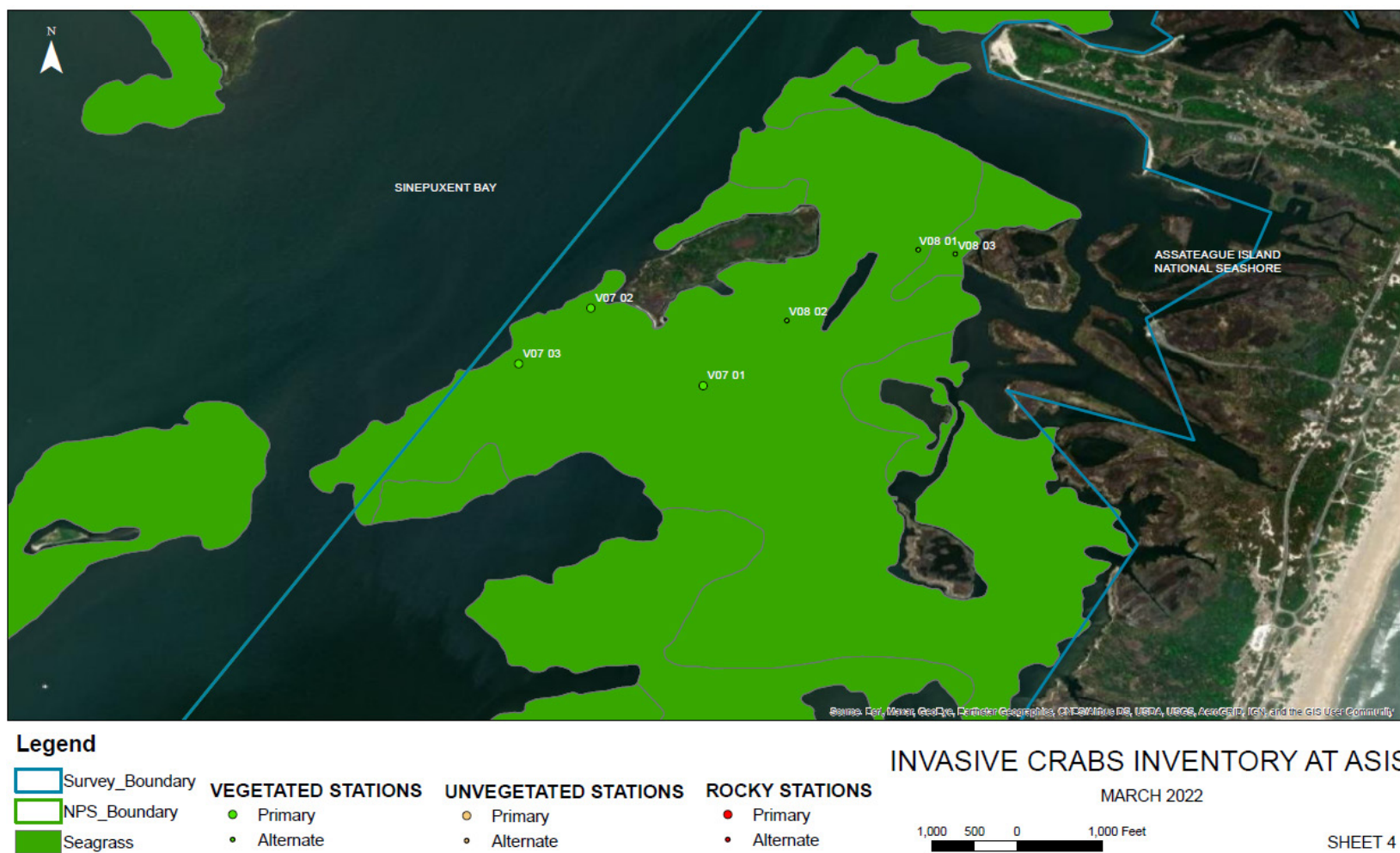


Figure A-5. Map showing a subset of sampling locations at ASIS.



Legend

Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
NPS_Boundary	Primary	Primary	Primary
Seagrass	Alternate	Alternate	Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 5

Figure A-6. Map showing a subset of sampling locations at ASIS.



Legend

Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
NPS_Boundary	Primary	Primary	Primary
Seagrass	Alternate	Alternate	Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 6

Figure A-7. Map showing a subset of sampling locations at ASIS.

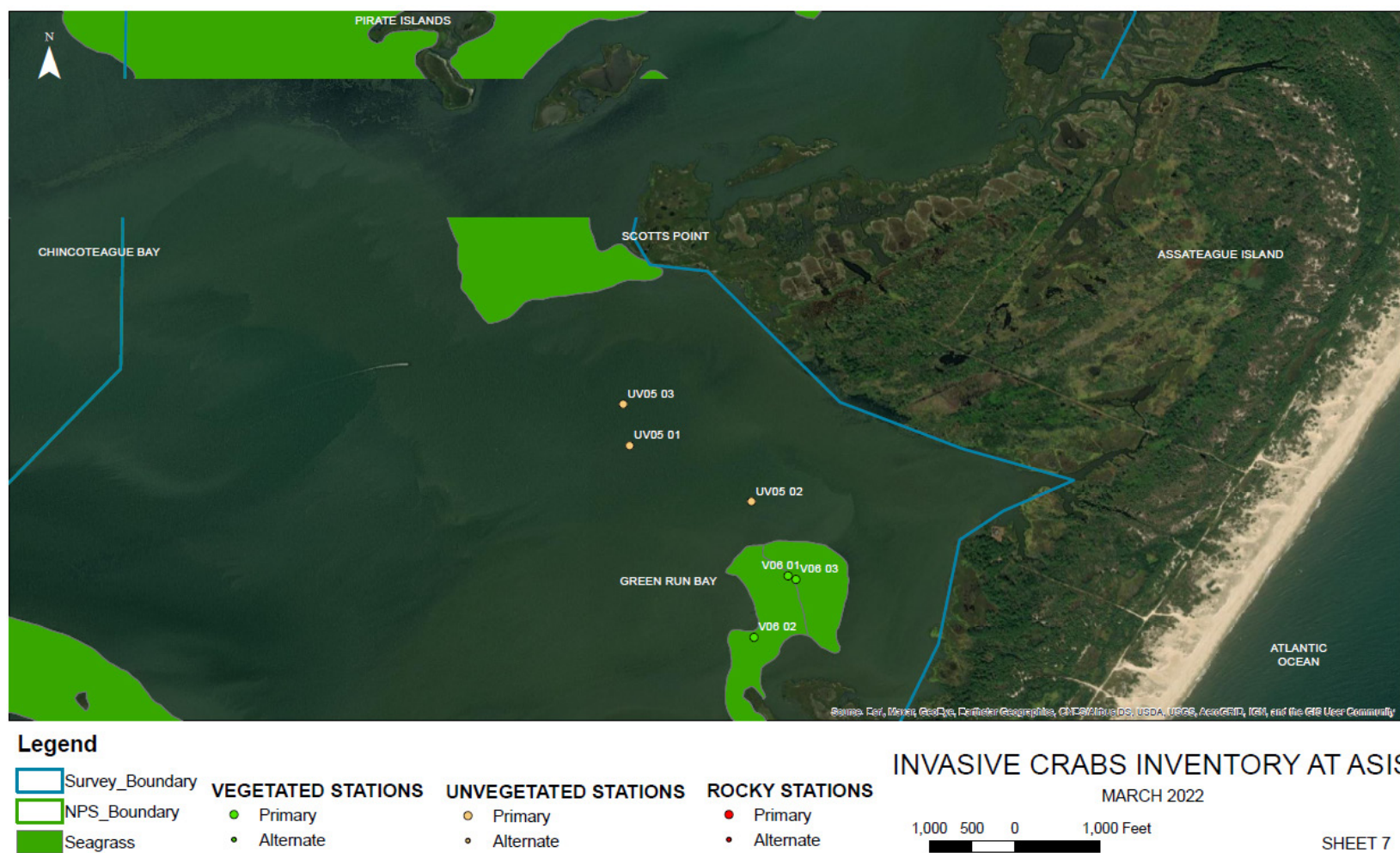


Figure A-8. Map showing a subset of sampling locations at ASIS.

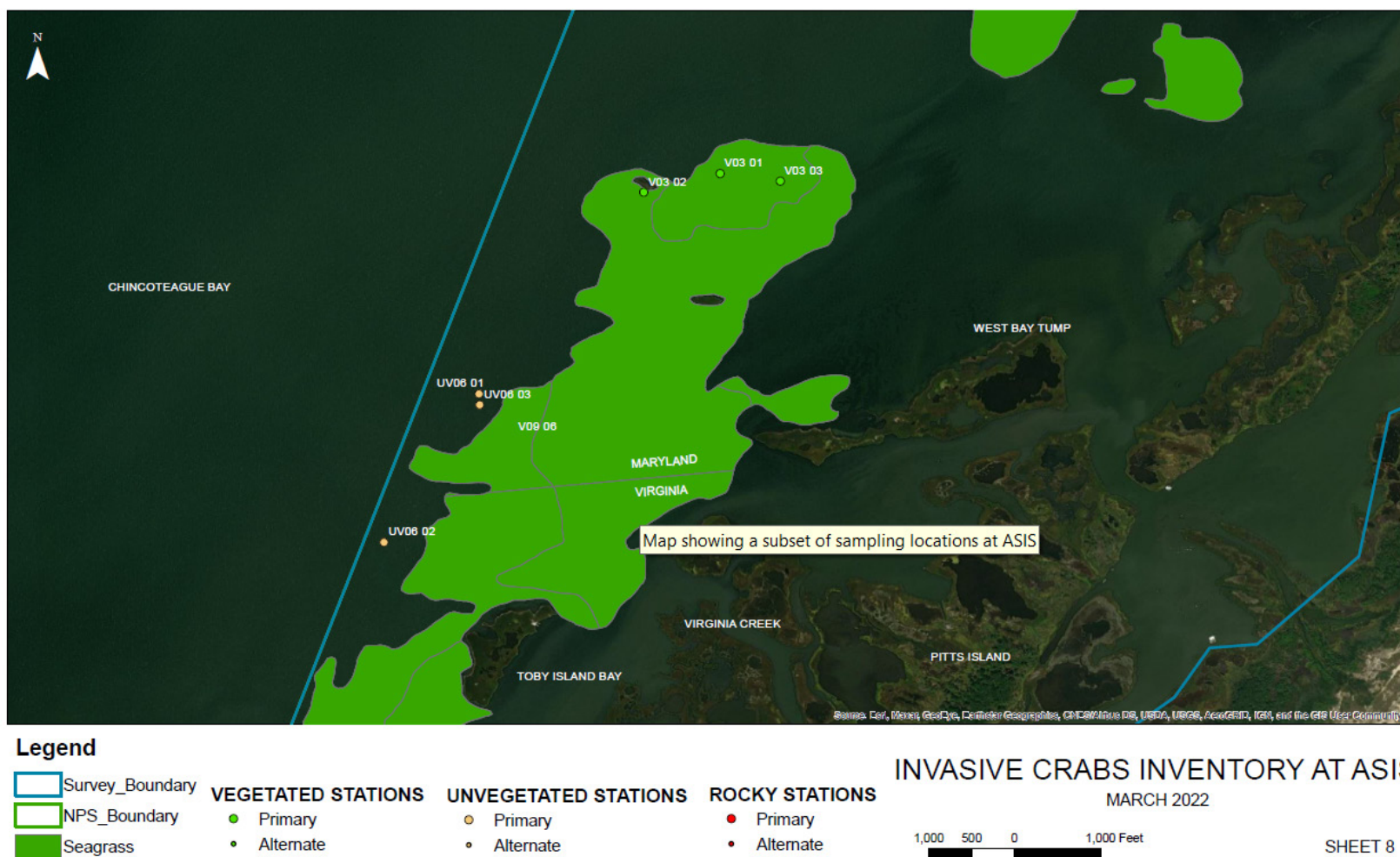


Figure A-9. Map showing a subset of sampling locations at ASIS.



Legend

Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
NPS_Boundary	Primary	Primary	Primary
Seagrass	Alternate	Alternate	Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 9

Figure A-10. Map showing a subset of sampling locations at ASIS.



Legend

Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
NPS_Boundary	Primary	Primary	Primary
Seagrass	Alternate	Alternate	Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 10

Figure A-11. Map showing a subset of sampling locations at ASIS.



Legend

 Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
 NPS_Boundary	 Primary	 Primary	 Primary
 Seagrass	 Alternate	 Alternate	 Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 11

Figure A-12. Map showing a subset of sampling locations at ASIS.



Legend

Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
NPS_Boundary	Primary	Primary	Primary
Seagrass	Alternate	Alternate	Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 12

Figure A-13. Map showing a subset of sampling locations at ASIS.



Legend

 Survey_Boundary	VEGETATED STATIONS	UNVEGETATED STATIONS	ROCKY STATIONS
 NPS_Boundary	 Primary	 Primary	 Primary
 Seagrass	 Alternate	 Alternate	 Alternate

INVASIVE CRABS INVENTORY AT ASIS

MARCH 2022

1,000 500 0 1,000 Feet

SHEET 13

Figure A-14. Map showing a subset of sampling locations at ASIS.



Figure A-15. Map showing a subset of sampling locations at ASIS.

Appendix B – Photographic Documentation

Figures B-1 through B-22 show representative photographs of each individual species collected and the equipment used in the study.



Figure B-1. Trap Example. September 2021. Station not applicable. Fukui style collapsible traps that are approximately 61 x 46 x 20 cm (24 x 18 x 8 inches) with a mesh size of 1.27 cm (0.5 inches) were used.



Figure B-2. ID MFB_6030. 2021-07-15. Station UV07-01-PRI. Typical deployment of trap featuring line, buoy, permit information, and station ID.



Figure B-3. ID IMG_20210930_100626. 2021-09-30. Assateague State Park. Boat used for field work was a Carolina Skiff. A low draft boat was necessary due to shallow water throughout the study area.



Figure B-4. The Carolina skiff backing near the boat launch at Assateague State Park.



Figure B-5. ID DSC01396. 2021-09-25. Station V01-03-PRI. Typical Vegetated site with high coverage. Vegetated sites were characterized by shallow depths (0–1 meter).



Figure B-6. 2 ID DSC01399. 2021-09-25. Station UV03-02-PRI. Typical Unvegetated site. Unvegetated sites were typically deeper than vegetated sites.



Figure B-7. ID MFB_5963. 2021-07-14. Station R05-02-PRI. Rocky habitat where green crabs were captured. Station located at Ocean City Inlet. Rocky habitat consists of Class III rip-rap jetties along intertidal zone.



Figure B-8. ID MFB_5701 2021-07-12. Station R05-01-PRI. Typical rocky habitat consisted of Class III rip-rap jetties and armoring.



Figure B-9. ID MFB_5786. 2021-07-13. Station R05-02-PRI. Female green crab (*Carcinus maenas*) captured.



Figure B-10. ID MFB_5947. 2021-07-14. Station R05-02-PRI. Two male green crabs (*Carcinus maenas*) captured. Note variation of color between individuals.



Figure B-11. ID MFB_5718. 2021-07-13. Station V01-02-PRI. Male blue crab (*Callinectes sapidus*).



Figure B-12. ID P1070706. 2021-09-29. Station V04-10-ALT. Say mud crab (*Dyspanopeus sayi*) captured. This is a small, native mud crab species.



Figure B-13. ID P1060299. 2021-07-21. Station UV05-01-PRI. Black sea bass (*Centropristis striata*).

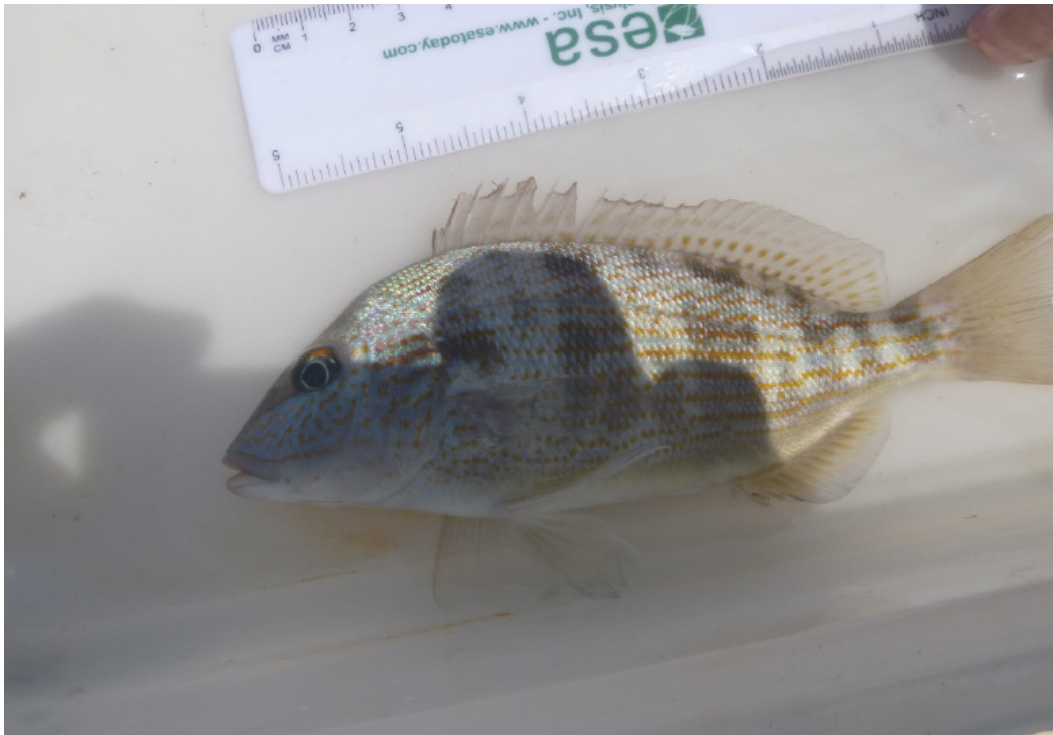


Figure B-14. ID P1060310. 2021-07-22. Station UV09-02-ALT. Pigfish (*Orthopristis chrysoptera*).



Figure B-15. ID P1070645. 2021-09-29. Station OCA-02. Northern puffer (*Sphoeroides maculatus*).



Figure B-16. ID MFB_5956. 2021-07-14. Station R05-02-PRI. Feathered blenny (*Hypsoblennius hentz*).



Figure B-17. ID MFB_5902. 2021-07-14. Station R04-03-PRI. Summer flounder (*Paralichthys dentatus*).



Figure B-18. ID MFB_5920. 2021-07-14. Station R04-02-PRI. Oyster toadfish (*Opsanus tau*).



Figure B-19. ID MFB_5896. 2021-07-14. Station R05-02-PRI. Spot (*Leiostomus xanthurus*).



Figure B-20. ID MFB_5859. 2021-07-14. Station V05-02-PRI. Terrapin (*Malaclemys terrapin*).



Figure B-21. ID MFB_5952. 2021-07-14. Station R05-02-PRI. Hermit crab (*Pagurus* sp.).



Figure B-22. ID P1070715. 2021-09-30. Station R05-03-PRI. Portly spider crab (*Libinia emarginata*).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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