The Catch of a Decade: A Report of University of Georgia Marine Extension and Georgia Sea Grant Trawl Records from 2012-2021

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Introduction

Figure 1: Satellite imagery of the Wassaw Sound estuary system, along the northern Georgia coast.

The University of Georgia Marine Extension and Georgia Sea Grant (MAREX-SG) is a unit of the University of Georgia's Office of Public Service and Outreach. As such, MAREX-SG staff and faculty throughout the state are dedicated to research, stewardship, and education concerning Georgia's unique coastline and its abundant coastal resources. One of the MAREX-SG facilities, the Marine Education Center and Aquarium (MECA) has the primary mission of education and outreach with PreKindergarten-12th grade and adult groups. Located on Skidaway Island, along the Georgia coast, MECA is equipped with a myriad of teaching spaces, including a public aquarium, where faculty and staff teach interactive lecture and laboratory classes. The facility is ideally situated on 700 acres of maritime forest and marsh habitat along the Skidaway River, making it perfectly suited for year-round field and boat experiences.

One such educational experience is carried out on a research vessel that is part of a small fleet at MECA. The R/V Sea Dawg, a 43' vessel equipped for research and field operations, allows visiting groups the opportunity to learn about estuarine communities and assist in data collection during educational trawling trips. These trips have multiple benefits, in that they are remarkable teaching opportunities as well as provide necessary resources for animal collections at the public aquarium operated within MECA. Authorized by scientific collecting permits from the US Fish & Wildlife Service and Georgia Department of Natural Resources (GADNR), MECA faculty and staff collect animals for use in aquarium displays in addition to collecting small schooling fish, shrimp, and squid as food for the aquarium inhabitants.

These trips are typically conducted within the Wassaw Sound estuary system: the Skidaway River, adjoining Wilmington River, and the Wassaw Sound, which is the inlet from the neighboring Atlantic Ocean (Figure 1). This is the northernmost of eight estuary systems along the Georgia coast, is dominated by tidal rivers and expansive salt marsh with limited freshwater input. With a diurnal tidal cycle and a typical tidal range of 2-3 m, large amounts of saltwater from the Atlantic Ocean are introduced to the system every six hours, with limited freshwater entering the system from the Savannah and Ogeechee Rivers after periods of heavy precipitation (Verity 2002). The Savannah River, to the north of Wassaw

Sound, drains a large area of Georgia's piedmont region and can introduce freshwater to the estuary via connections in the upper Wilmington River. South of the system, the Ogeechee River drains the coastal plains and can influence the salinity in the upper Skidaway River (Dame et al. 2000).

Considered a contiguous system from the Wassaw Sound through the Wilmington and Skidaway Rivers, this estuary can be classified as well-mixed (Verity 2002) due to its large tidal range and strong tidal mixing within the water column. Depths in the system range from -2.2-23 m (MLLW) with a mean depth of 4.3 m (Robinson et al. 2021). In the Wilmington River, where the majority of trawls were conducted, the mean depth of about 8 m (MLLW) (Robinson et al. 2021). While no depths were recorded for past trawl samples, the R/V Sea Dawg can only safely trawl in depths of 3 m or greater due to the shape and draft of the hull. Sediment composition along the estuary bottom depends on bathymetry, but is predominately sand, with small amounts of gravel, silt, and clay depending on the quiescence of locations within the system (Robinson et al. 2021). Coarser sediments are located in the open sound and major channels within the Wilmington River, and finer sediments like silt and clay are found in the upper reaches of some rivers (Robinson et al. 2021), tidal creeks, and surrounding salt marsh habitat.

This dynamic estuarine system, with its network of rivers, creeks, and marshes, is home to diverse benthic and pelagic communities of organisms. A number of fishes and invertebrates inhabiting the Wassaw Sound estuary are the target of commercial fisheries along the Georgia coast that are crucial to the local and regional economy. Otter trawling is the primary fishing method employed by commercial fishers targeting food shrimp and bait shrimp which yield two of the highest-ranked (by weight) commercial seafood landings in Georgia (GADNR 2020). Finfish, another top-ranked component of the commercial seafood industry (GADNR 2020), can also be targeted by trawling efforts, though it is not the sole method of fishing. In addition to commercial fishing operations, otter-trawling is a successful method of sampling benthic and benthopelagic communities of organisms for education and research applications.

The R/V Sea Dawg is equipped for otter trawling with a common configuration similar to others in the area. The trawl net is a conical shape, with the mouth of the net attached to a heavy, wooden, rectangular "door" on each side. Each door stands upright and slides along the estuary bottom on steel skids. A stainless-steel tickler chain is threaded across the bottom edge of the net's mouth to create a slight disturbance in the sediment for collecting benthic organisms. Spaced evenly across the top edge of the net, small, round floats provide buoyancy to keep the net open while travelling through the water. Organisms that are captured by the mouth of the net may be small enough to escape through the mesh of the net (roughly 1-1¼"), but any that are large enough to be trapped will travel through the length of the net to the cod end. This end is tied with a series of 3-4 slip knots for easy release of the catch once the net is brought onboard.

Sciaenid fishes are well-known for their ability to create drumming noises with the aid of their swim bladder and therefore have gained the common name of "drums", which will be used in the remainder of this report. Most drum species have a fusiform body shape and are adapted to a wide variety of habitats within estuarine and coastal environments in temperate and tropical waters worldwide (Sasaki 1989), with some species occurring in freshwater (ASMFC 2017). The marine Sciaenids are considered euryhaline, though many species have preferred salinity ranges depending on life stage (ASMFC 2017). While drums utilize a broad range of habitats throughout their life, estuaries are vital at all life stages of for uses such as spawning, nursery, and foraging (ASMFC 2017). With almost 20 species occurring in coastal waters along the Georgia coast, this family of fishes serves many ecosystem functions in the Wassaw Sound and similar estuary systems in the region. For example, through necropsies of stranded dolphins in similar estuarine systems in North and South Carolina, Atlantic croaker have been identified as the primary food source for bottlenose dolphin (*Tursiops truncatus*) (Gannon and Waples 2004). Drums are not only ecologically important, as they are also sought after by recreational and commercial fishers. For over 200 years, weakfish have been a large component of the mixed-stock fishery along the Atlantic coast of the United States (ASMFC website).

This study explores 10 years of trawl data collected from 2012-2021, with three goals: 1) summarize the 10 years of data 2) further focus on observations of the drum family of fishes, Sciaenidae as they relate to environmental and biological factors, and 3) examine potential weaknesses in the data collection process to create recommendations for improvement. Observations and conclusions about the seasonal patterns and diversity of trawl catch over time could be an important tool to maximize efficiency of future trawling trips. This could include collection of aquarium display species, aquarium food, and organisms for research purposes. A focus on Sciaenid species was chosen because they are abundant within the Wassaw Sound estuary system and can thus produce robust data sets to evaluate their seasonal or annual patterns and assess for any long-term trends. In addition, they are a recreationally, commercially, and ecologically important family of fishes that is diverse and abundant in Georgia's estuaries and beyond. The seven species of focus in this study are weakfish (*Cynoscion regalis*), Atlantic croaker (*Micropogonias undulatus*), star drum (*Stellifer lanceolatus*), silver perch (*Bairdiella chrysoura*), banded drum (*Larimus fasciatus*), spot (*Leiostomus xanthurus*), and southern kingfish, also known as whiting (*Menticirrhus americanus*).

Methods

Trawling

During trawling trips on the R/V Sea Dawg, one trawl sample is defined as a single drag of the trawl net for a maximum of 15 minutes along the estuary bottom. A power winch and A-frame on the deck lowers the cable and attached net into the water. Timing of the trawl begins when the net is fully open within the water column and the net is dragged along the estuary bottom for a maximum of 13 minutes, allowing two minutes for net retrieval. Often the net is retrieved after 10 minutes, although length of trawl time varies with environmental variables (depth, obstacles, etc). The cod end of the net is brought on board and the catch is deposited directly into a large, shallow tub filled with water from the sample site. During educational programs, MECA faculty and staff then gather the visiting group around the tub to highlight the organisms' natural history, form and function, predator/prey relationships, taxonomy, and more. Any organisms that are not needed for aquarium food, display, or education programs are given priority for live release so that there is minimal unnecessary mortality. Any organisms needed for live display are kept in an aerated live well with water from the sample site for transport back to the aquarium. In both of these cases, organisms removed from the catch tub are identified and tallied for final species counts, discussed later in this section. Remaining organisms needed for aquarium food or education programs are transferred to trays for sorting, identification, counting, then placed into gallon-size plastic zip-bags labeled with the date. These bags are kept on ice during travel back to the aquarium.

Data Collection

Trawl data was collected by MAREX-SG crew with the assistance of students, teachers, volunteers, interns, and general public in attendance during trawl trips. For each trawl sample, a single data sheet was completed. Environmental data included date, time, general location, coordinates (Degrees / Minutes / Seconds), water temperature (°C), salinity, and dissolved oxygen (mg/L). The time of the trawl was listed as time the trawl began, but the total soak time of the net was not recorded. The general location referred to the river or sound, and coordinates were copied from those listed on the Sea Dawg's GPS unit after net deployment was complete; the latitude and longitude were recorded in degrees, minutes, and seconds, but converted to decimal degrees in R. Dissolved oxygen (DO), water temperature, and salinity were obtained using a water sample from each trawl site in a 5-gallon bucket that was collected prior to dragging the net. A single, handheld water quality meter was used to measure DO and water temperature, with various types and brands utilized over time. The meters, however, have been notoriously unpredictable due to lack of maintenance and calibration of the probes. Often the meter gave erroneous measurements or was not operational, therefore leading to a considerable lack of DO measurements throughout the time series. Water temperature was also measured using the same handheld water quality meters but if the unit was not operational at the time, water temperature could be obtained from the GPS unit within the R/V Sea Dawg's wheelhouse instead. Salinity was measured using a refractometer and the same 5-gallon water sample.

Biological data included identification and counts of all species contained within the net. A general survey form that encompasses the most common species caught in the estuary is used (Supplemental materials, Figure S3), with space to write in any additional species caught that are not listed on the data sheet. Some organisms are compiled into a category or listed as their general family ("sea robins" or "crab – other portunid") due to the difficulty of distinguishing distinct species in the field, while most others are listed as the common name for their species. This format allows participants that are unfamiliar with species names or spelling, such as visiting students, to easily and efficiently assist with data recording. All paper copies of data sheets were transferred to Microsoft Excel spreadsheets annually and sent to GADNR per the requirements of MAREX-SG permits.

A portion of this project was dedicated to compiling and organizing the data from original data sheets and various digital files. For more than ten years, there has been no established system for organizing or storing this data for use by faculty, staff, or external researchers. While many years had data already in digital format, many files contained missing data and used different formatting. In addition, data before 2012 was very inconsistent, with some years only having a few months of data available to work with. Thus, beginning with January 2012 records (through December 2021), all data were transferred from paper and computer files to a single spreadsheet in Microsoft Excel, using a format suitable for easy import to computational programs. Additionally, beginning with the first sample date in 2012, each individual trawl was given a number which continued throughout the time series to be used for referencing those samples.

During data entry, a number of unforeseen issues were encountered. Many trawl samples (up to 20 per year) had species marked as present in a trawl, but lacked an abundance measurement. On the data sheet used in the field (Supplemental materials, Figure S3), there are boxes to mark the identified species and spaces to later record the count of each species present in the catch. If a species was marked as present but no abundance was recorded, the abundance was changed to "1" during the data organization process. Additionally, there were also instances of data recorders using a mixture of tally marks and cardinal numbers to count species, thus leading to confusion about the true counts. Tally marks can be helpful when sorting the catch, but a final count of the total number of each species is needed. When both tally marks and cardinal numbers are used on a single data sheet, two (in tally marks) and eleven are easily confused in addition to three (in tally marks) and 111. Therefore, care was taken to determine the best course of action for each discrepancy, based on how the remainder of the data sheet was written as well as the species in question.

Data Assessment

The compiled database from 2012-2021 was analyzed in R and Excel. Of 556 total trawl samples, only two samples were eliminated and only 554 samples were assessed for this report. One of the two eliminated samples combined data from multiple trawls in the Skidaway River, Wilmington River, and Wassaw Sound; this weakened the validity of the data and therefore was not used. The other eliminated sample was a paper data sheet with biological data (species and abundance values) but no date or environmental data was recorded. Although we can possibly assume it was from 2018, no other information is known and therefore it was considered invalid. With the remaining database of 554 trawl samples, I first found the distribution of trawls in each general location. If any samples had coordinates but no general location recorded, the coordinates were plotted online using Mission Manager website (http://missionmanager.net/Maps.php) to find and fill in the general location of the trawl (Skidaway River, Wilmington River, etc). Coordinates from each sample were also converted from DMS to decimal degrees in Excel and uploaded to Google Earth to visualize distribution of trawl samples on a satellite image of the Wassaw Sound estuary system.

Next, the total catch (number of individuals), mean catch, and catch frequency of each species per year and overall for the time series were calculated and plotted. Drum species were some of the most frequently caught fish and were consistently among the most abundant fish species in trawl catch throughout the 10 years. Thus, the robust data sets for the seven most commonly caught drum species were used to make further observations: star drum, spot, croaker, weakfish, whiting, silver perch, and banded drum. For these species, their catch in relation to both salinity and temperature was plotted for each year and overall.

Special Considerations

While using a "citizen science" approach to data collection can be an impactful educational tool, an introduced error can be expected. Data recorders were as young as 11 years old, most were not trained in data collection and/or were not knowledgeable in the field of marine science. Therefore misspelled names, misidentified species, and/or incorrect measurements (like coordinates) were common during the data collection process. Educators present on trawling trips are often able to correct the data sheets in the field, but there were still inaccuracies in the data that I encountered and had to rectify.

Results

Environmental Data

Throughout the study, trawls were conducted in at least eight months of each calendar year, with only 21 of the 120 total months of the study period not sampled. December, January, and February were the most commonly missed months due to holiday breaks, a lack of school programs, and lower abundance of catch during the coldest season of the year (thus fewer collecting trawls). In 2015, there were no trawls from October through December due to dock and boat damage from Hurricane Matthew in early October.

Of the total trawl samples, 393 occurred in the Wilmington River (70.9%), 85 in the Skidaway River (15.3%), and 67 in the Wassaw Sound (12.1%). The remaining 1.7% represented three trawls in the Burnside River, one trawl in Ossabaw Sound, and five trawls that were missing both the location and coordinate data. The coordinates of each sample were plotted using Google Earth to visualize distribution of trawl samples on a satellite image of the Wassaw Sound estuary system (Supplementary materials, Figure S1). Some coordinates were not recorded correctly, or lack of significant figures in the coordinates' values caused the points to be plotted at erroneous locations, such as in upland habitat or offshore regions. To plot properly within along waterways in the estuary system, coordinates need to be recorded with three to four figures after the decimal point. Any points not plotted within waters of the study area were ignored since there is no way to get a more specific location post facto. The remaining points were used to look at the most commonly trawled regions within the estuary system.

Areas with a high density of points were outlined with polygons and those areas were compared to a figure from a study by Robinson (2021), included in the supplemental materials (Figure S4), which shows the gradient of sediments found throughout the estuary*. The Wilmington-1 (W-1) polygon, in yellow, (Figure 2a and Supplementary Figure S2) shows one area of high trawl density found in the northern part of the Wilmington River. Trawls in the top half of this polygon were dragged in areas of medium to fine sand (orange and green, respectively, on the Figure 2b) while trawls in the bottom half of the polygon occurred in areas of coarse sand (red on Figure 2b). The Wilmington-2 (W-2) polygon, in green (Figure 2a), shows a second area of high trawl density in an area dominated by medium and fine sand. In addition to varying classes of sand and mud that are common in Georgia estuaries, there are a few areas of hard bottom habitat located in the Wilmington River. These rare habitats are host to a variety of benthic

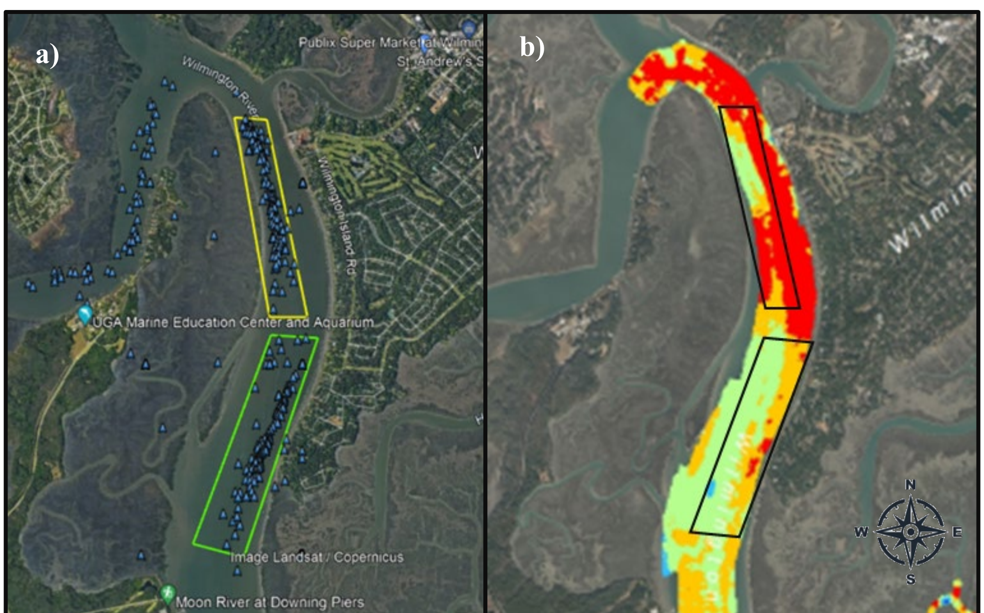

Figure 2b: Sediment gradient in the Wilmington River from a segment of Figure 6 in Robinson et al. 2021. The full figure can be found in the supplemental materials.

organisms that require harder, less mobile sediments to flourish (Robinson et al. 2021) and fall along the northern half of the W-1 polygon and just outside the southeastern edge of the W-2 polygon (Figure 2a).

Biological Data

The 554 trawl samples documented over 85 species of fish from 45 taxonomic families (attached separately). Of the 85 species, there were 13 elasmobranch species recorded: seven shark species, four ray species, clearnose skate, and Atlantic guitarfish. The remaining 72 teleost species represent a diverse group of benthic, benthopelagic, and pelagic fishes. Some species of fish were very rarely caught; only one red drum (*Sciaenops ocellatus*) and one spiny dogfish (*Squalus acanthias*) were documented in 10 years, while nine species had only two individuals documented during the study. In fact, more than half of the species identified (46) had less than 100 individuals recorded during this ten year study. Some of the most abundant fish species in trawls were members of the family Sciaenidae. The largest total catch was star drum (### individuals), followed by spot (### individuals) and then croaker (### individuals), but with bay anchovy (not a drum species) and weakfish not far behind in numbers, with ### and ### individuals, respectively. When catch frequency was assessed, each year, the most frequently caught fish was one of five drum species: spot, whiting, star drum, weakfish, and croaker. In addition, only three years had a species other than drum rank in the top three most frequently caught species; in 2015 and 2018 Atlantic stingray (*Dasyatis sabina*) ranked as third and in 2021 bay anchovy (*Anchoa mitchilli*) ranked as the second most frequently caught fish species.

Species of Interest

While rare and unexpected, there were four recorded of captures of an endangered species. Two samples documented the Atlantic sturgeon (*Acipenser oxyrinchus*) in a trawl: February 2013 in the Skidaway River and January 2016 in the Wilmington River. There were two recorded Kemp's ridley sea turtle (*Lepidochelys kempii*) in a trawl, in November 2018 and May 2019; both instances occurred in the Wilmington River. In all of these cases, the individuals were released unharmed and as soon as possible after capture.

Many other species found in trawls throughout the Wassaw Sound estuary are important for aquarium display and education. For the UGA Aquarium, trawling is the primary method of collecting fish and invertebrate species for display. Lookdown and Atlantic moonfish are two species of fish from the jack family, Carangidae, and are excellent specimens for display as they are visually pleasing with an interesting body shape. Because they occur more rarely in trawl catch, pinpointing the locations at which they have been caught most often could help to increase the possibility of capture by knowing where to trawl. Moonfish and lookdown were recorded on 30 and 31 trawls, respectively. About 60% of moonfish and 38% of lookdown were caught within the W-1 polygon (Figure 2a). A second species of interest which holds great value as an ambassador of its species in the UGA Aquarium is the Atlantic guitarfish (*Rhinobatos lentiginosus*). This species of elasmobranch is not as well-known as others (like stingrays and sharks) and is very popular with aquarium visitors. Atlantic guitarfish was only caught 6 times in 10 years and only within the W-1 and W-2 polygons.

Sciaenid Species

Fish from the family Sciaenidae are recorded in many trawls on the R/V *Sea Dawg* and were the most commonly caught throughout the time series. While not recorded in every trawl sample, drums were caught very frequently and typically had high abundance in trawl samples. Because they were caught so frequently and in high abundance, their datasets provide a robust set of information for further assessment.

Spot was the most frequently caught fish species during the 10-year time series and was recorded in 78.3% of trawls, totaling 23,324 individuals (second-highest total catch). This species' annual catch frequency does seem to exhibit an increasing trend from 2012-2021, with the exception of an outlier in 2017, when spot were only found in 54.9% of trawls (Figure 3); 2017 documented both the lowest frequency and the lowest total mean catch of all 10 years (Figure 4). Spot were recorded throughout the Wassaw Sound estuary and abundance in trawls was variable throughout each year with no discernable trend associating spot catch with temperature or salinity; they were recorded through virtually the entire range of temperatures and salinities that were documented during the study.

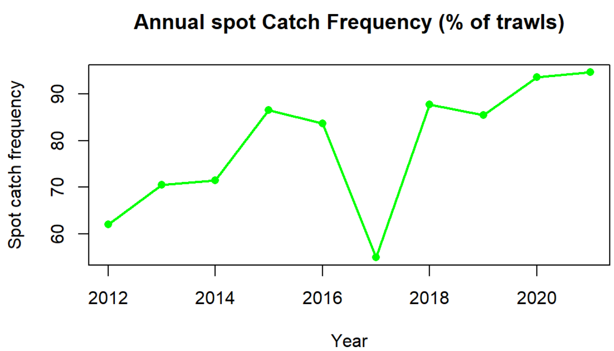

Figure 4: The percent of trawls in which spot were recorded every year from 2012-2021.

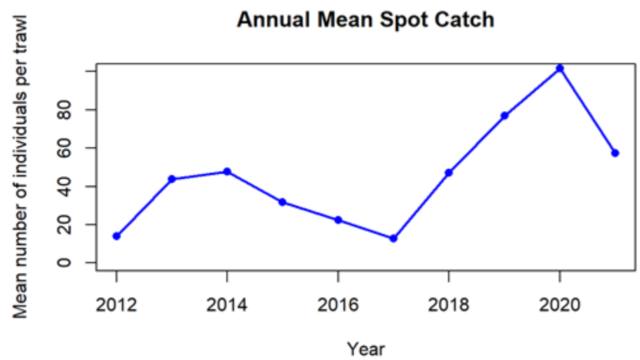

Figure 3: The mean number of spot per trawl that were recorded annually from 2012-2021.

Whiting was the second most frequently caught fish species and was documented in 72.4% of all trawls, but only totaled 3,415 individuals over 10 years. This is two orders of magnitude less than spot described above. With an early peak frequency in 2013, whiting then experienced a sharp decline the next year, with only 32 individuals caught in less than 50% of trawls in 2014. The next five years, 2015-2019, documented a gradual increase in frequency to the next peak in 2019, in which whiting were caught in 90.3% of trawls (Figure 5). Their catch frequency declined over the last two years of the study. Although found in varying numbers throughout the range of temperatures recorded, when whiting catch over the time series was plotted against salinity, the distribution appears somewhat close to a normal distribution, or approximate bell-shaped curve (Figure 6). In trawls with whiting present, those at the extreme salinities had lower counts of whiting, while trawls in intermediate salinities had higher whiting counts.

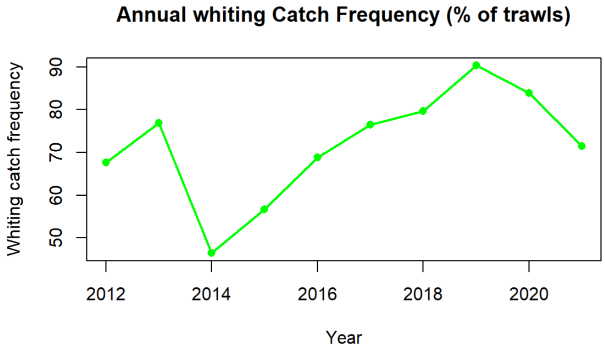

Figure 5: The percent of trawls in which whiting were recorded every year from 2012-2021.

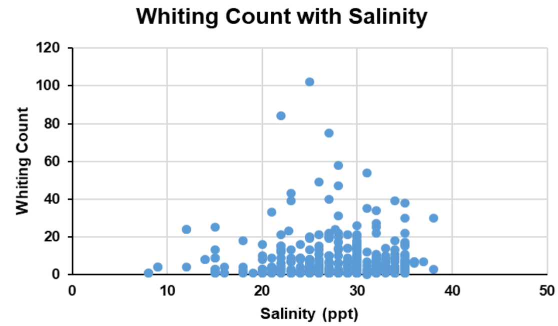

Figure 6: Count of whiting in trawl samples over the range of salinities recorded in the study.

The species with the highest number of recorded individuals was star drum; their total of 49,567 caught in 10 years is more than double the amount of spot (described above), the species with the second highest total catch. Star drum was only caught on 63.5% of trawls, and thus was the third most frequently caught species in this study. Their catch frequency spiked dramatically from 32% in 2012 to 73% in 2013, but remained more stable for the remainder of the study at an annual catch frequency between 61-78% (Figure 7). When their catch was plotted against recorded temperatures, star drum exhibits a left-skewed distribution; few individuals were caught in temperatures below 20 °C and the majority were caught between 25-30 °C with a peak centered around 27 °C (Figure 8). When plotted against recorded salinities, the number of star drum caught was variable, though it somewhat resembles the curve of a normal distribution, similar to whiting.

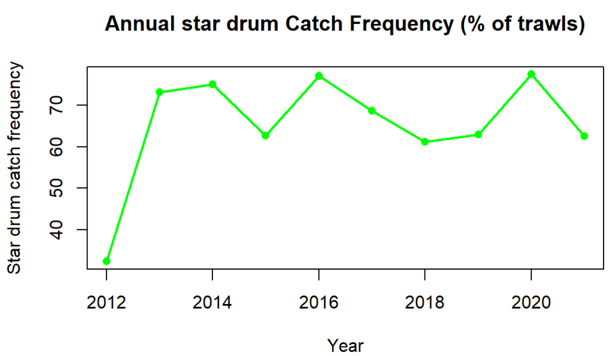

Figure 7: The percent of trawls in which star drum were recorded every year from 2012-2021.

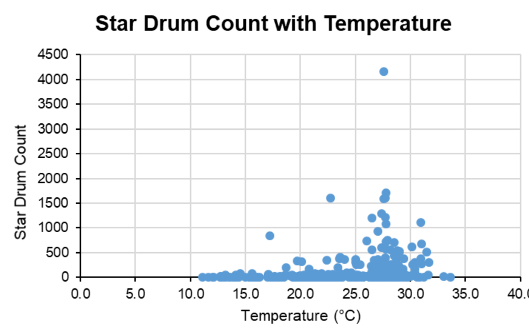

Figure 8: Count of star drum in trawl samples over the range of temperatures recorded in the study

Croaker ranked third in total catch, with 15,995 individuals recorded, but this species was only caught in 57% of all trawls over 10 years. Despite some yearly fluctuation, both the frequency at which croaker were caught and their annual mean catch exhibited a general upward trend over the time series (Figures 9 & 10). Croaker is another species that, like star drum (described above), exhibits a left-skewed distribution of individuals when plotted against temperature; fewer croaker were caught below 20 °C with the majority caught between 25-30 °C and a peak centered around 27 °C (Figure 11). The number of croaker caught over a range of salinities was not remarkable, though few individuals were recorded at salinities less than 18.

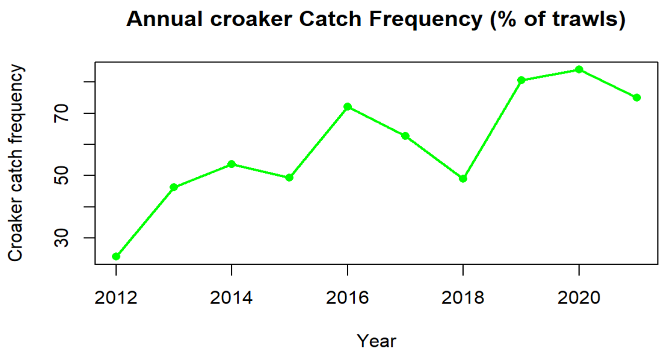

Figure 9: The percent of trawls in which croaker were recorded every year from 2012-2021.

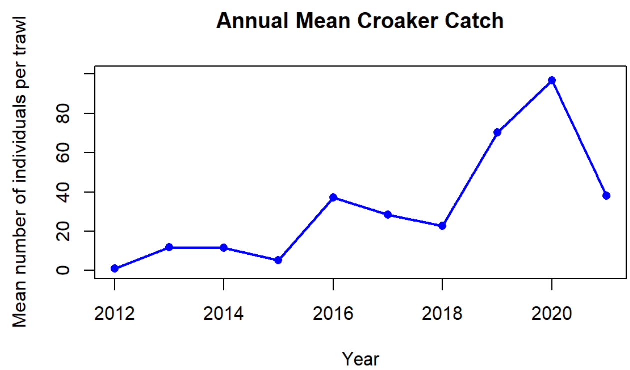

Figure 10: The annual total of croaker that were recorded annually from 2012-2021.

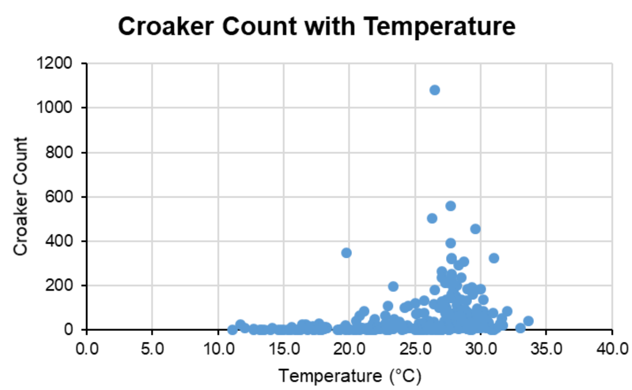

Figure 11: Count of croaker in trawl samples over the range of temperatures recorded in the study.

Weakfish were found in 61.6% of trawls over the time series, totaling 13,840 individuals. Their catch frequency exhibits large oscillations between lower and higher frequencies through most of the study, changing as much as 25% over a single year, from 2017-2018 (Figure 12). The annual mean catch of weakfish exhibits a gradual increase from 2012-2020 but has a somewhat drastic decrease from 2020-2021 (Figure 13). Though this species exhibits much variability when catch is plotted against salinity, they are another example of a left-skewed distribution of weakfish catch with temperature (Figure 14). As with star drum and croaker, fewer weakfish were caught below 20 °C with the majority caught between 25-30 °C and a peak centered around 27 °C.

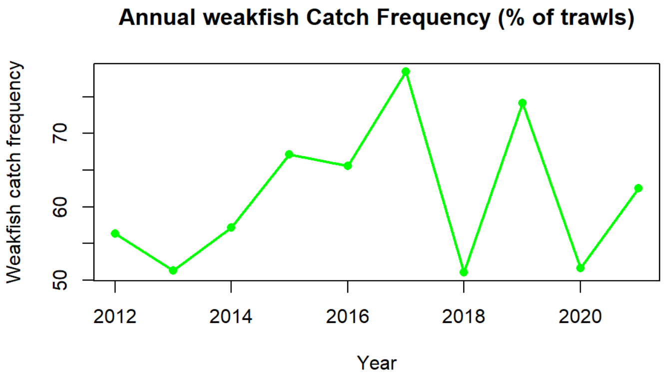

Figure 12: The percent of trawls in which weakfish were recorded annually from 2012-2021.

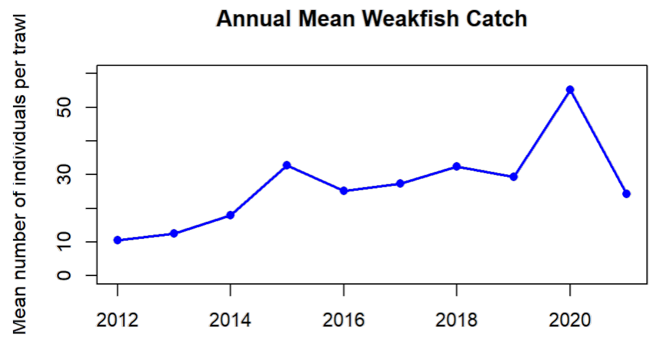

Figure 13: The annual mean croaker catch that was recorded annually from 2012-2021.

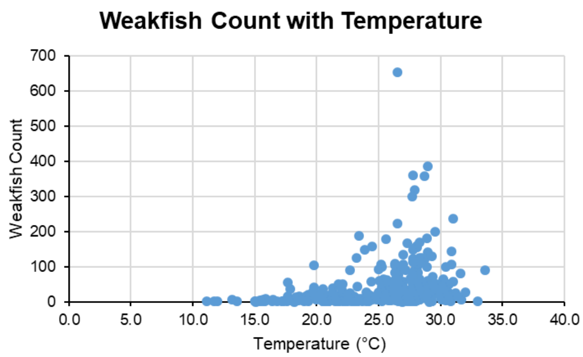

Figure 14: Count of croaker in trawl samples over the range of temperatures recorded in the study.

Banded drum and silver perch are two drum species that were less commonly caught during this study. Over 10 years, 2,295 banded drum were recorded (Figure 15a) in 17.2% of all trawls (Figure 15b). While it was difficult to assess for patterns of banded drum catch over a range of temperatures and salinities due to their low frequency and total numbers caught, we do know that banded drum were only recorded in the Wilmington River and Wassaw Sound. Silver perch were recorded at about the same frequency, in 15.5%

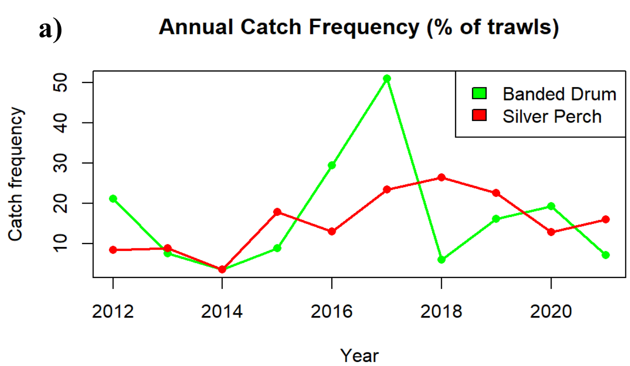

Figure 15a: The percent of trawls in which banded drum (green) and silver perch (red) were recorded every year from 2012-2021.

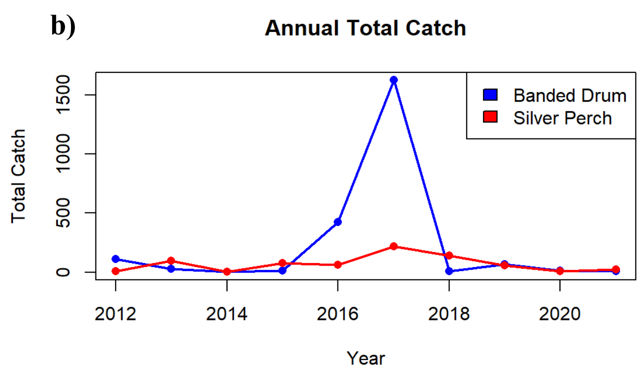

Figure 15b: The annual total of banded drum (blue) and silver perch (red) that were recorded annually from 2012-2021.

of all trawls (Figure 14a), but only 690 individuals were recorded in 10 years (Figure 14b). This species was found distributed throughout the study area, but there appeared to be no relationship to temperature or salinity, possibly due to their relatively low abundances during the study. Another drum species with relatively low abundance, silver seatrout (*Cynoscion nothus*), had a total catch similar to silver perch, with 769 individuals recorded during the study, but was only recorded in a mere 4.5% of trawls. There are a few inconsistencies surrounding records of this species and thus it may have actually been caught more often and possibly in larger numbers than what was recorded, which will be discussed later.

Discussion

Over the past 10 years, these trawling trips have proven to be an effective tool for sampling benthic, benthopelagic, and pelagic species of fish in the Wassaw Sound estuary system over multiple sediment types, through all seasons of the year. As the majority of trawls each year were conducted in the Wilmington River, however, the observations are biased and statements about fish species in regards to general location are difficult to make. The Skidaway River and Wassaw Sound have approximately equal number of trawls and therefore data from these samples could be used to compare trends in catch. The Wilmington River, however, was sampled about four times more than the other locations. In the future, approximately equal numbers of trawl samples from each area of the estuary system (Wassaw Sound, Wilmington River and Skidaway River) would allow for comparison of catch in different general locations. By plotting coordinates of trawl samples on a satellite image of the Wassaw Sound estuary system (Figure 2a), we see that polygons W-1 and W-2 show areas of high trawl density. This is due to experiential and anecdotal evidence from past captains and crew who have experienced great success in high diversity and abundance of trawl catch in those areas consistently overt time. That knowledge, passed down by individuals over many years, has led to a majority of trawls occurring at and around those areas. In addition, for educational trawls when time may be limited, those sample sites are fairly close to the dock with little travel time and provide ample catch for education. When polygons W-1 and W-2 are compared to a figure from Robinson (2021) we see that they cover a gradient of sediments from fine sand to coarse sand (Figure 2b) which may help to increase diversity of trawl catch dragged within these polygons. Many benthic and benthopelagic species exhibit preference in sediment type due to their foraging and/or predation behavior as well as resting habits. By trawling over areas with multiple sediment types, we may be able to sample a wider variety of fish species when compared to trawls that cover only one sediment type.

The 72 bony fish species identified in these 10 years of trawl records might be a slightly conservative number due to a few discrepancies. First, in some instances, a group of fish was not identified to the species level and simply written on the data sheet as “flounder”, “trout”, or “puffer” without any species identifier. This lack of specificity makes those pieces of data unusable for most analyses, unless one is looking at larger groups of species such as flounders, drums, or flatfishes. Second, on the data sheet used in this study, there are multiple instances of a family or genus of fishes (i.e. sea robin, goby, and pipefish) used on the checklist for recording purposes (Supplementary materials, Figure S3), that is actually comprised of multiple species known to reside within the Wassaw Sound estuary. For example, multiple species of sea robin can be found throughout coastal Georgia, but they can be hard to distinguish in the field and therefore are listed on the data sheet as simply “sea robin”, without a species identifier. So, while we know that sea robins were recorded frequently, there is uncertainty as to how many individual species were caught and the total count for each. In the UGA Aquarium, when live sea robins were caught and kept for display, only two of the distinct species were positively identified: bighead sea robin (*Prionotus tribulus*) and northern sea robin (*Prionotus carolinus*). In addition, there are pairs of species within the same genus that can be hard to distinguish from each other and, although they appear separately on the data sheet, may get confused for one another and therefore misidentified. Notable examples include harvestfish and butterfish (*Peprilus paru* and *Peprilus triacanthus*), Spanish mackerel and king mackerel (*Scomboromorus maculatus* and *Scomboromorus cavalla*), and Atlantic moonfish and lookdown (*Selene setapinnis* and *Selene vomer*).

Two endangered species have been documented in R/V Sea Dawg trawl samples: Kemp's ridley sea turtle and Atlantic sturgeon. While these species are listed as endangered at the state level and protected under Georgia law, MAREX-SG trawling activities have posed no threat to any individuals captured and all were released alive and unharmed. Data gathered about these individuals, however, can be useful information to convey to appropriate parties involved in research and conservation efforts.

Atlantic sturgeon are found along the east coast of the United States where they utilize freshwater rivers, estuaries, and nearshore habitats at different stages of their life (Bahr & Peterson 2016). Their populations along the east coast of the U.S. are divided into five Distinct Population Segments (DPSs) and the South Atlantic DPS includes approximately 2,883 km of critical habitat in nine rivers along South Carolina, Georgia, and Florida (Department of Commerce 2017). Of these rivers in the South Atlantic DPS, the Altamaha River in Georgia is known to have the healthiest population of Atlantic sturgeon (Bahr & Peterson 2016). Less is known about their population dynamics within the Savannah River system, which also has designated critical habitat for Atlantic sturgeon (Department of Commerce 2017), though there have been multiple studies over the past 10 years as river dredging and port changes have increased anthropogenic threats. While there is little evidence of an established Atlantic sturgeon population residing in the Wassaw Sound estuary system, individuals may be moving through the estuary. The upper reaches of the Wilmington River connect to the Savannah River with its known Atlantic sturgeon population and the upper reaches of the Skidaway River connect to the Ossabaw Sound estuary system where there is a struggling population of Atlantic sturgeon (Sheldon & Alber 2013).

Turtle Excluder Devices are a type of Bycatch Reduction Device that aims to eliminate endangered sea turtles from trawl nets. They are a crucial element in reducing bycatch like sea turtles, sturgeon, sharks, rays, and large cannonball jellies during commercial shrimp trawling. They were developed and tested by many organizations from 1976 through 2000, though research has continued after that time to improve the efficacy of TEDs (Jenkins 2012). TEDs are currently required on commercial trawling vessels in the Atlantic Area or Gulf Area (defined by the Code of Federal Regulations) with some exceptions based on the type of gear, length of tow, and specific trawling location (Code of Federal Regulations 2022). Due to the small net size and short drag time of the trawls conducted on the R/V Sea Dawg, however, installation of a Turtle Excluder Device (TED) in the trawl net has never been required. The lack of a TED in the R/V Sea Dawg's net allows for routine catch of larger vertebrates like bonnethead shark (*Sphyrna tiburo*) and southern stingray (*Dasyatis americana*) for educational value and aquarium display, but with little to no mortality of these charismatic megafauna, due to the crew's priority of live release of these individuals as soon as possible after capture. During the rare sea turtle capture during R/V Sea Dawg trawls, the species name, curved carapace length and width, and any presence of tags or injuries is recorded. This, paired with the environmental data for the study site and a photograph are sent to GADNR's Georgia Sea Turtle Cooperative Network. As there are not a great number of inwater research projects investigating sea turtle ecology throughout the Wassaw Sound estuary, even occasional data from projects such as this can prove useful.

Drums are a more commonly caught species than those previously discussed, and could be considered ubiquitous within the Wassaw Sound estuary system; they have been documented often and in large numbers throughout this study period and most are known to tolerate a large range of temperatures, salinities, and DO (ASMFC 2017). When assessing for trends of drum catch over the full range of temperature recorded in this study (7-33.6°C), croaker, star drum and weakfish were the three species to exhibit a left-skewed distribution of catch. For these species, temperature could be considered a driving factor for the number of individuals recorded in trawl catch. While none of the drum species discussed here exhibited a notable distribution of catch over the recorded range of salinity (8-39), only spot, whiting, and croaker were found at salinities less than 12 and the samples that documented those species were few. Lower salinities are required for larval croaker settlement, though whiting generally inhabit higher salinities that are typically found closer to inlets (ASMFC 2017). However, drums, as a euryhaline species, generally tolerate a large range of salinities.

Some patterns of drum catch over the time series were apparent with this initial assessment. While it did not exhibit a minimum for all drum species, in 2012 we saw generally low catch frequencies for six of the seven species of drum assessed here (all but whiting), although we had a large sample size of 71 trawls. In contrast, 2020 only had 31 trawls but exhibited some of the highest catch frequencies for spot, croaker, star drum and whiting. For the large sample size in 2012, that year also had one of the lowest mean catch for all drum species. The small sample size in 2020 actually had some of the highest mean catch numbers for weakfish, spot, croaker, and star drum. This indicates that sample size does not necessarily indicate the number of or the frequency at which these fish are caught, and that other factors affect variation in catch frequency and mean catch. Further investigation into details each sampling year (locations, sediment type, average temperature, etc) would be needed for further assessment of patterns.

The seven species of drum assessed in this study are the most frequently caught species overall in trawls as well as those caught in high abundance. They are also some of the smaller drum species found in the Wassaw Sound estuary system and those inhabit areas frequently trawled. However, larger species of drum such as red drum (*Sciaenops ocellatus*) and black drum (*Pogonias cromis*) are extremely rare in otter trawls on the R/V Sea Dawg but commonly caught throughout the Wassaw Sound estuary system using other methods of fishing, such as hook and line. The larger drum species are part of an important recreational fishery in the South Atlantic Bight, both in estuaries and nearshore habitats. Red drum are likely not caught in trawl nets due to their preference for living and foraging around habitat edges and areas with structure, such as oyster reefs, seagrass beds, and salt marsh edges (Dance and Rooker 2015). Thus, red drums are not inhabiting areas suitable for otter trawling and are unlikely to be caught in trawl nets. The same could be said for black drum, of which only four individuals were caught in 10 years. This species, as juveniles and adults, typically prefers mud bottoms and areas with shell rubble or oyster reef habitat (ASMFC 2017) which are not typically suitable trawl locations. Although some trawls can occur over mud bottoms, this sediment is typically found in tidal creeks and salt marshes where trawling vessels are not able to navigate. A third popular sportfish in the drum family, the spotted sea trout (*Cynoscion* *nebulosus)* was more frequently caught, in 8.1% of all trawls from 2012-2021. While juveniles prefer seagrass beds and tidal salt marsh habitat, as they mature they begin to utilize a wider range of habitats found throughout estuaries, which could explain why this species is caught more frequently in trawls than the other drum species that grow to be larger than the seven assessed in this study.

Silver seatrout is a species that was caught infrequently but in similar numbers to silver perch. This species, however, is difficult to distinguish from weakfish as they look almost identical except for a lack of vague patterning above the midline of the body. For many years, they were misidentified as weakfish but in later years were recorded separately. Those later recordings, however, labeled the species incorrectly as summer trout and sand trout, which may other regional common names for the true species of silver seatrout (*Cynoscion nothus)*. This will be corrected beginning in all records from 2022, but in previous years, any records of summer trout and sand trout were considered to be silver seatrout. It is unknown, though, to what extent misidentification could have affected counts of other drum species.

Many factors not recorded in this study could help explain patterns of drum catch as well as other commonly caught species. First, tidal influence is not considered in this study. While many of the species found in the Wassaw Sound estuary system are tolerant of fluctuations in salinity and temperature, movements of animals throughout the estuary in response to tidal cycle cannot be ruled out. Some species may move in and out of small tidal creeks with the tide to follow ideal salinity, temperature, DO, or water depth. Depending on the location of the trawls in relation to nearby habitat, this could affect what species are directly inhabiting the study site at that time of the trawl. Second, the physical size of the trawl net has changed over time. There have been multiple trawl nets used on the R/V Sea Dawg throughout the study period; nets with a larger mouth can drag over a larger area and thus collect more individuals and possibly a greater diversity of species. Records of the size of the net during different time frames are not immediately available. In the future, this should always be recorded in the ship's log for reference and be considered when comparing catch.

Areas of Improvement

The largest opportunity to improve this ongoing trawl research revolves around data collection. Until now, the minimum data needed to submit to GADNR was collected (date, location/coordinates, temperature, salinity, DO, and presence/abundance of species). There are a number of other key pieces of information, however, that would be beneficial to include in a data sheet for future trawl samples. For example, GADNR's Ecological Monitoring Trawl Survey (EMTS) program has been operating for 56 years at present, and includes tow duration, tow speed, depth, and tide information for each trawl sample conducted (GADNR website, 2020). This information could easily be recorded during future sampling on the R/V Sea Dawg and would expand the potential for future analysis and research applications. The EMTS program combines tow duration and catch data to calculate catch-per-unit-effort, or CPUE, measurements; these values are common in fisheries research and important for comparing certain aspects of samples or sample period to one another. It is also used to evaluate stock status, species abundance, and construct biomass indices (GADNR website 2020 and Dunn et al. 2000).

For future trawls, it is recommended to use an improved data sheet that would include additional elements to data collection. Tow duration, tow speed, depth (start/end), found on the GPS unit, could be incorporated as well as tide stage. In addition, more species names should be added to the general checklist of commonly caught species to make it easier for citizen scientists to record data. Some species are recorded often in the "other vertebrates" section of the data sheet and thus should be moved to the general checklist as this is easier for citizen scientists to follow. Lastly, a few species already listed on the data sheet but never caught during the study could be removed.

For the data collection process, a dedicated crew member should be responsible for quality control of the data sheet when individuals other than trained staff are recording trawl data. This person would work closely with the data recorder to correct mistakes and thoroughly review each data sheet before filing. Eliminating discrepancies before filing the data is key to smoother data analysis. One recommendation to improve species data would be to include a standard for species identification. Any fish not listed to the species level on the data sheet should be saved for later identification. This could happen by bringing the individual back alive if there is interest in keeping it for aquarium display, or for identification and subsequent release. Alternately, if it is a suitable food fish, it can be bagged and marked for identification or verification of species. A second option would be to take clear photos of the front and side of each fish for later identification, being careful to include identifying features in clear detail.

Although some areas are known to be less suitable for otter trawling due to bottom topography or physical obstructions, having a larger spread of trawls, particularly in the Wassaw Sound, would allow for greater knowledge about the diversity and abundance of species inhabiting the estuary. While most of the remaining rivers and creeks are too small or shallow for conducting trawls, there is the possibility in sampling the southern portion of the Bull River, which stems from the north edge of Wassaw Sound, behind Tybee and Little Tybee Islands. This area may produce data very similar to trawl samples from the mouth of the Wilmington River, to which it is similar in a few ways. First, both areas are known to have a mixture of medium to coarse sand in the mouth and main channel of the river, with some fine sediments along the edge and further up the river; additionally, bottom topography studies show that the lower reaches of both rivers have the presences of megaripples in the sediments along the main channel and are similar depths (Robinson et al. 2021). As the two rivers both stem from the Wassaw Sound, we can assume that salinity and temperature fluctuations would be similar throughout the year as well. However, despite these similarities, there could be variation in plant and animal communities due to differences in surrounding habitat, anthropogenic impacts, and predator-prey relationships in the different locales.

Future Work

The remainder of all trawl data 2012 should also be added to the database in its entirety. Although the goal for this study was just to look at the past ten years that have the most frequent sampling and therefore most consistent data set, there are years before 2012 that could be assessed as well. Additionally, for the study period of 2012-2021, there is also invertebrate catch data that has yet to be investigated. A future area of study would involve summarizing the invertebrate catch data in a similar fashion. Invertebrates of particular interest would be white shrimp (*Litopenaeus setiferus*), blue crab (*Callinectes sapidus*), and squid (*Lolliguncula brevis*). Shrimp and squid are sought after for aquarium food, and blue crab are important animals for aquarium display and education programs. In addition, shrimp, squid, and other invertebrates recorded in trawl catch are common food items for fish species discussed here and could be used to evaluate predator/prey relationships.

While only a few species were assessed for their specific catch locations within the study area, the same examination could be carried out for many species of interest that are caught infrequently but valued as aquarium specimens. Operations on the R/V Sea Dawg can be costly and trawling requires a minimum of three crew members for at least two hours to complete a single trawl trip, from launching to docking. Often, multiple trawls are conducted on a single trip to increase catch for aquarium food and display species, but this also extends the time commitment. By knowing the specific locations at which species of interest are typically caught throughout the year, MAREX-SG staff can maximize potential expected catch with minimal time, crew, and funding commitments.

Conclusion

This study had two main components for the current research project, but will be a continuing research endeavor. First, it was a dedicated effort to compile and organize many years of trawl data into a single database that is easily accessible to all faculty and staff within MAREX-SG. Second, this novel investigation assesses and summarizes the last decade of vertebrate trawl catch data collected by MAREX-SG and identifies ways to improve future data sets for internal and external research purposes. Additionally, any observed seasonal or spatial patterns may provide useful information for targeted trawling trips. As drums make up the majority of food fish used for the UGA Aquarium, maximizing future catch of these species based on past data would be an efficient use of time and mindful use of funds used for operating the R/V Sea Dawg.

As there is ten years of data for 85 species of fish and one species of sea turtle, this study merely scratches the surface of possible analyses but provides an initial report of useful findings to build on in the future. Faculty and staff with MAREX-SG are often involved in local and regional research endeavors and are always seeking to support fellow scientists with their work. For that reason, having a full database of information on a large group of species within the Wassaw Sound estuary system would be extremely beneficial for internal and external research programs.

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Supplementary Materials

Figure S1: Satellite imagery of the Wassaw Sound estuary system including individual trawl samples shown as blue triangles.

Figure S2: Satellite imagery from Figure S1 with added polygons for areas of high trawl density. The yellow polygon is Wilmington-1 (W-1), the green polygon is Wilmington-2 (W-2) and the white polygon in Wassaw Sound is Dead Man's Hammock.

R/V Sea Dawg Trawl Data *rev 6-11-08*

GROUP NAME	DATE	TIME
GENERAL LOCATION	LATITUDE	LONGITUDE
WATER TEMP	SALINITY (ppt)	DO_2

VERTEBRATES						INVERTEBRATES		
SPECIES	x	#	SPECIES	x	#	SPECIES	x	#
AMERICAN EEL			SOUTHERN STINGRAY			ANENOME		
ANCHOVY - BAY			SPADEFISH			BRITTLE STAR		
ANCHOVY – STRIPED			SPANISH MACKERAL			COMB JELLY		
ATLANTIC STINGRAY			SPOT			CRAB – ARROW		
BANDED DRUM			STARDRUM			CRAB – BLUE		
BATFISH			STAR GAZER			CRAB – CALICO		
BLACK SEA BASS			STRIPED BURRFISH			CRAB – ELBOW		
BLENNY			SUMMER FLOUNDER			CRAB – HERMIT		
BLUEFISH			THREAD HERRING			CRAB—HORSESHOE		
BONNETHEAD SHARK			TONGUE FISH			CRAB – MUD		
BUMPER			WEAKFISH/SEA TROUT			CRAB – OTHER PORTUNID		
BUTTERFISH			WHITING (SOUTHERN KINGFISH)			CRAB – PORCELAIN		
BUTTERFLY RAY						CRAB – SPIDER		
CATFISH						CRAB – STONE		
CLEARNOSE SKATE			↓OTHER VERTEBRATES↓			DOVE SNAIL		
CLINGFISH						LEMONDROP		
COWNOSE RAY						MOON SNAIL		
CROAKER						OCTOPUS		
CUSK EEL						SAND DOLLAR		
CUTLASSFISH						SEA CUCUMBER		
FILEFISH						SEA JELLY -- CANNONBALL		
FINETOOTH SHARK						SEA JELLY – OTHER		
GOBY						SEA PANSY		
GUITARFISH						SEA SPIDER		
HAKE						SEA STAR – COMMON -- *LUIDIA*		
HARVESTFISH						SEA STAR -- *ASTERIAS*		
HOGCHOKER						SHRIMP – BROWN		
KEMPS RIDLEY TURTLE						SHRIMP – GRASS		
KING MACKERAL						SHRIMP – MANTIS		
LIZARDFISH						SHRIMP – ROCK		
LOGGERHEAD TURTLE						SHRIMP – PEPPERMINT		
LOOKDOWN						SHRIMP -- SNAPPING		
MENHADEN						SHRIMP – WHITE		
MOONFISH						SQUID		
MULLET						WHELK – CHANNELED		
NORTHERN (SMOOTH) PUFFER						WHELK – KNOBBED		
OCELLATED FLOUNDER						↓CHECK ONLY IF PRESENT – DO NOT COUNT↓		
OYSTER TOADFISH						BRYOZOAN		
PIGFISH						ISOPOD		
PINFISH						SEA PORK		
PIPEFISH						SEA SQUIRT		
RED DRUM						SEA WHIP		
SEA ROBIN						SPONGE		
SEAHORSE						↓↓OTHER INVERTEBRATES↓↓		
SEA TROUT/WEAKFISH								
SENNET								
SHAD								
SHARPNOSE SHARK								
SILVER PERCH								
SOUTHERN FLOUNDER								

Figure S3: Example of the trawl data sheet. This form was used for every individual trawl sampled conducted from 2012-2021.

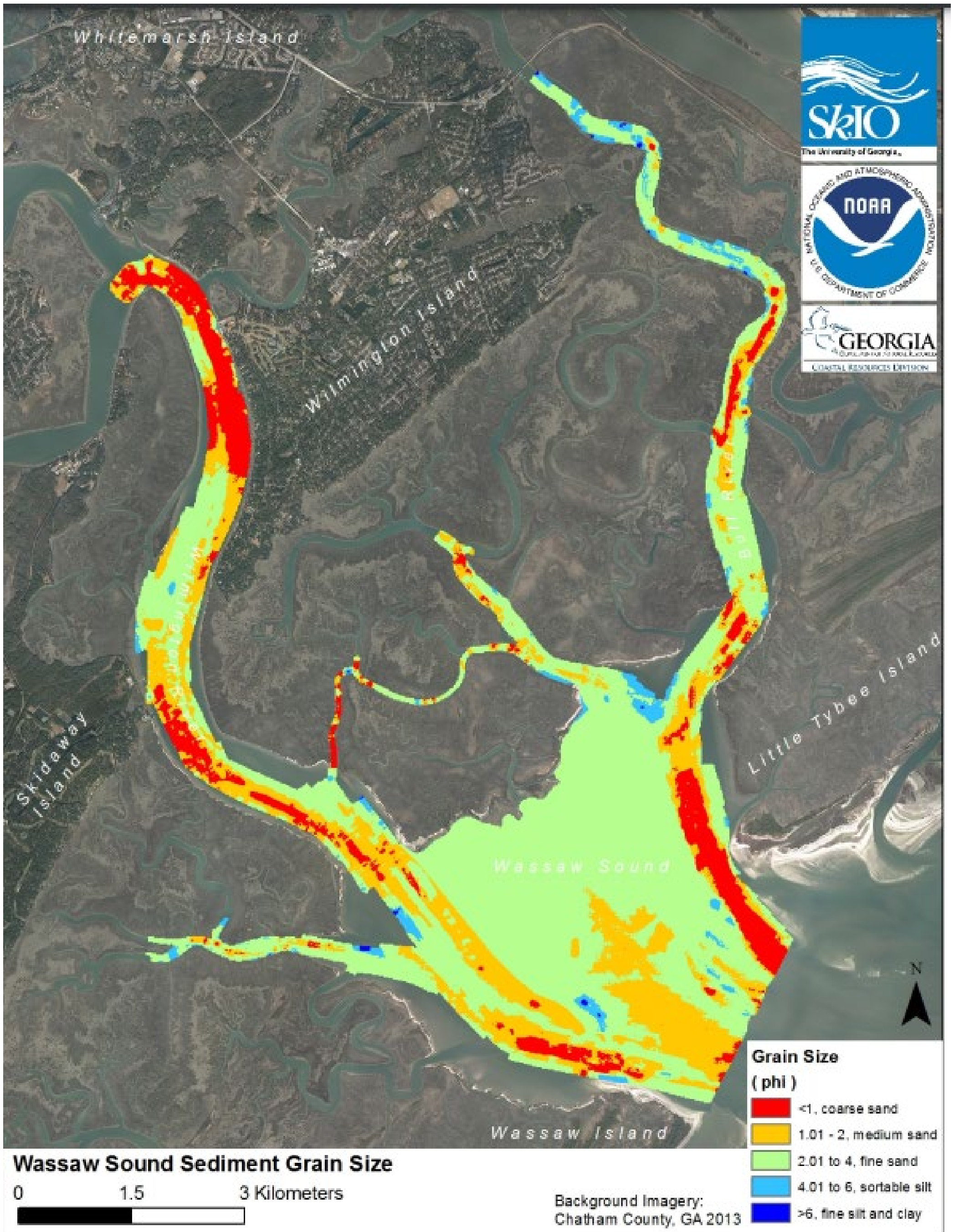

Figure S4: Gradient of sediment grain size in the Wassaw Sound estuary system

Source: Robinson et al., 2014 in works cited.