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Substrate Utilization in Summer Flounder, *Paralichthys dentatus*, in the Barnegat Bay, New Jersey

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ABSTRACT

The substrate utilization of Summer Flounder, *Paralichthys dentatus*, is observed in the Barnegat Bay, New Jersey. Previous studies about Summer Flounder in the Barnegat Bay claimed that they prefer sand, but only collected data from mud substrate and had little fishing success. In this study fishing occurred from two primary locations, one with sand substrate and one with mud. This species has the ability to change its coloration to match its surroundings, so other factors besides substrate may be used when it determines its habitat. Data were collected on the chemical and physical conditions of the two sites including dissolved oxygen, temperature, salinity, and clarity to examine this. Morphometric data on Summer Flounder and other by-catch species were also taken. This study suggests that there is no significant difference in substrate utilization for this population of Summer Flounder (χ^2 test, $p = 0.323$). However, this study did find a positive relationship between flounder capture numbers and water temperature. Flounder captures were greater when using whole fish baits such as Atlantic Silverside (*Menidia menidia*) than when using diced baits (i.e. Atlantic Menhaden, *Brevoortia tyrannus*). Bluefish (*Pomatomus saltatrix*), a by-catch in this study, showed a negative correlation to water temperatures. Additionally, smaller Bluefish were captured more often on mud substrate than in sand substrate (χ^2 test, $p = 0.323$).

Keywords: ecology, flatfish, benthic, overfishing, fisheries, habitat

Habitat utilization is important in showing how an animal uses its environment. It can show how environment and behavior are linked, which can provide information about the ecology of the animal. Descriptions of habitat primarily based on coordinates can be useful in conservation and management of the species (Kie et al. 2010). By learning what is avoided or important to an animal, inferences can be made about how the animal perceives and uses its environment. Additionally, knowing how certain areas are utilized can help to prevent habitat loss and promote habitat protection in commercially important species, like *P. dentatus*. Habitat utilization is important to understand in *P. dentatus* because at the time this study was conducted, they were being overfished and the information found in this study may be important for conservation efforts in the future, if needed. In 2017, NOAA fisheries drastically cut the commercial and recreational quotas by 30% from 2016 (NOAA Fisheries, 2019). The 2017 quotas declined by more than 50% since 2013; the commercial quota declining from 11.44 million pounds in 2013 to 5.66 million pounds in 2017 (NOAA Fisheries, 2019). Fortunately, this species has a very well-regulated fishery, but drastic measures such as slashing the quotas and potentially putting a moratorium on the species (a recreational moratorium was considered in 2017 but did not go into effect) have wide reaching effects on local fishermen (NOAA Fisheries 2019). It is important to examine the behavioral ecology of a species while the stock is still robust, and an appropriate sample size can be more easily obtained. Since this study has taken place, the commercial and recreational quotas have increased since their 2017 levels, but another rise in illegal fishing could pose a significant threat on this species (NOAA Fisheries 2019).

Summer Flounder (*Paralichthys dentatus*) is an important commercial and recreational fish species found along the North Atlantic coast (NOAA Fisheries, 2019). It occurs in a variety of environments, including sand and mud substrates. Sand substrate is defined as being finer than gravel and coarser than silt and is primarily composed of silica, whereas mud is a fine-grained material composed of a mixture of water and many different soils including silt or clay (Glossary of Soil Science, 1976). Previous work reported that adult *P. dentatus* prefer to live on sand instead of mud throughout their range (Bigelow and Schroeder 1953; Schwartz 1964; Smith 1969). However, since adults can camouflage themselves using pigment changes in order to blend into their substrate (Mast 1916), they can be found in a variety of habitats. In the Barnegat Bay, Vouglitois (1983) claimed that flounder had a preference for sand because they were not readily found on mud substrate, even though they did not directly survey both substrate types in their study.

This study will examine the substrate utilization of *P. dentatus* in Barnegat Bay, New Jersey by examining both sand and mud substrate sites. Due to the species ability to change its coloration to match its substrate it should not use one substrate over another unless there are other advantages to this action, including a higher availability of food, protection from predation, or more favorable water chemistry. Environmental conditions were observed to look for preference, including water chemistry and temperature. Deploying various types of bait and were used to indicate if *P. dentatus* have preferred prey within the Barnegat Bay or if this changes with location. Moreover, *P. dentatus* that can be kept with a recreational permit will be dissected to determine what they have been eating in the wild to look for differences between sampling locations. By-catch species are also be examined similarly.

METHODS

Sampling occurred on both mud and sand substrate in the Barnegat Bay. Figure 1 shows where sampling took place in the bay. The locations that were sampled are marked with circles. There are two different sapling locations, labeled A and B. Site A consisted of primarily mud substrate and is near a research buoy called B1. The buoy logs information about water conditions and serves as a landmark for fishermen. It is a popular spot for recreational flounder fishing, which is why this site was chosen. Site B consisted of sand substrate and was close to the Barnegat Lighthouse. Site B is also a popular spot for fishing, which is why it was chosen.

Figure 1. Aerial photograph of the study area. The two sampling sites where data collection took place are labeled in white. Site A contains mostly mud substrate with few sand substrate areas while Site B contains only sand substrate.

The study had originally planned to survey more locations, but circumstances prevented all sites from being surveyed. During the first half of the study, only four fish were caught. The committee funding the research expressed concerns over the initial lack of data, which prompted the use of sampling sites where fishing had been recently reported by local fishers as having an abundance of *P. dentatus* and to collect more catch data by counting the number of fish caught on nearby boats during normal sampling. A rental boat was needed for sampling on 7/1, 7/4, 7/8, and 7/9 because the primary research boat needed repair. Due to these issues, sampling only occurred at Site B during the duration of the use of the rental boat. By only being able to sample at Site B, there was a disparity in time spent fishing in the two sample locations; this was accounted for in the statistics used.

Fishing was conducted on rod and reel. There were two to three people on the boat when fishing took place and all were fishing. Data collection took place primarily on weekends from May 27 until July 27, 2017. Fishing occurred in early morning, typically from around 6AM to 11AM. Drift fishing was used, which entails not dropping the anchor and allowing the boat to drift. This allowed for the boat to move to the fish, instead of waiting for the fish to come toward the boat. Four different baits were used: Atlantic menhaden (*Brevoortia tyrannus;* a.k.a. 'bunker'), Atlantic silverside (*Menidia;* a.k.a. 'spearing'), Bluefish (*Pomatomus saltatrix*) and squid strips (*Loligo sp.*). Squid strips were abandoned early in the study because they were ineffective. *P. saltatrix* was used later in the study, after small bluefish were caught and used opportunistically (within legal harvest limits) as bait. All undersized fish, including flounder, were released. All fish caught in this study were immediately released with the exception of *P. dentatus* that met the minimum length of 46 cm and bait bluefish. *P. dentatus* that met the minimum length requirement were dissected to see what they had eaten. The flounder rigs used had two different hooks, one above the sinker and one below, designed to position the hooks just above the bottom. When a fish was caught within the vicinity on another boat it was also recorded and added to the total catch for the substrate. When a fish was caught, the total length was measured in centimeters. The coordinates of each catch were recorded, along with the depth at which it was caught, the bait on which it was caught, and any physical characteristics about the fish. The coordinates were used to determine the type of substrate for the catch by entering them into SoilWeb, an online Google Earth extension where a pin can be dropped on a location and the substrate type will be displayed (Web Soil Survey, 2017).

Before sampling, the water parameters of each location were measured. Water samples were collected using a LaMotte dissolved oxygen sampling chamber. The container with the bottle in it was dropped to the bottom to collect a water sample. The bottle was then sealed at the surface to ensure that there was no contamination and tested later in the lab for the dissolved oxygen content. The weighted container was deployed again to collect water from the bottom of the water column without the bottle and brought back to the surface and the temperature (in degrees Celsius) and salinity (in ppt), was measured with a YSI probe. The pH of this water sample was measured with a separate pH probe. To observe water clarity, a Secci disk was deployed over the shadowed side of the boat. The depth at which the disk was no longer visible was recorded along with the depth at which the disk reappeared. This was used to get a range of water clarity.

To examine whether *P. dentatus* used one substrate over another a Chi Square analysis was performed. The expected frequency was standardized for time spent fishing in each location by dividing the total time spent in the area (either sand or mud) by the total time, then multiplying by the total number of fish caught. The same standardization was used in calculations for substrate preference of by-catch species and in calculations for bait preference. A t-test was performed when comparing length of fish and substrate, which was also standardized for time. A Chi Square calculation was performed to determine if the two sampling locations had different water chemistry. When comparing length of fish and temperature, a Pearson's R correlation was performed. Social Science Statistics was used for all statistical calculations (Social Science Statistics, 2019).

RESULTS

During our surveys, a total of 52 flounder were caught; 36 were caught on sand and 16 on mud. Forty-nine of these fish were undersized and did not meet the minimum length requirement of 46 cm in total length, with the overall mean length of 32.5 cm (Table 1). Only three specimens exceeded or were at least the minimum length requirement and could be kept for stomach analysis. Most *P. dentatus* were caught in the range of 16-26 degrees Celsius. Additionally, 23 Bluefish (*Pomatomus saltatrix*) and 9 Clearnose Skate (*Raja eglanteria*) were also caught (Tables 2 and 3, respectfully). The difference in the chemical water parameters between the two sampling locations is listed on Table 4. The mean value for salinity, temperature, pH, clarity, and dissolved oxygen is presented along with the range. There is no statistical difference in water chemistry for the two locations.

Table 1. Summer Flounder, *Paralichthys dentatus*, occurrence on mud and sand substrate in Barnegat Bay.

	Mud Substrate	Sand Substrate	Total
Flounder Observed	16	36	52
Caught on Bait	5 bunker 7 spear 1 bluefish	9 bunker 16 spear	14 bunker 23 spear 1 bluefish
Stomach content	1 sampled shrimp tail	2 sampled shrimp tail, legs, common periwinkle shell	3 sampled shrimp tail. Legs, common periwinkle shell
Mean Length	31.5	34	32.5
Range	15.2-45.7	22.9-45.7	15.2-45.7

Note: The type of bait, stomach contents of legally kept specimens, the mean and range of the total lengths, and the median and range of depth the fish were caught is also provided.

Table 2. Occurrence of Bluefish, *Pomatomus saltatrix*, on mud and sand substrate in Barnegat Bay.

	Mud Substrate	Sand Substrate
Bluefish Caught	17	6
Caught on Bait	8 bunker 7 spear 3 bluefish	3 bunker 3 spear
Mean Length	20	41.91
Range	15.2-48.3	12.7-50.8

Note: The type of bait used, mean total length and range, and mean and range of depth is also provided

Table 3. Occurrence of Clearnose Skate, *Raja eglanteria*, on mud and sand substrate in Barnegat Bay.

	Sand Substrate
Clearnose Skate Caught	9
Caught on Bait	7 bunker 2 spear
Mean Length	61.2
Range	50.8-68.6
Gender	9 male, 0 female

Note: The type of bait used, mean total length and range, and mean and range of depth is also provided

Table 4. Comparison of water chemistry characteristics between Site A and Site B.

	Site A	Site B
Salinity (ppt)	22.4	27.5
Temp. (C)	21.2	20.9
pH	7.38	7.46
Clarity (M)	1.9-2.3	1.8-2.3
Oxygen (ppm)	4.9	4.9

Note: The mean and range are shown for each.

DISCUSSION

After almost two months of weekend samplings, we determined that *P. dentatus* sand and mud utilization did not differ significantly (χ^2 test, p = 0.323). This finding might suggest that the population of *P. dentatus,* at least in Barnegat Bay, does not show a preference for mud or sand substrate. Further research would be necessary in order to confirm if *P. dentatus* have a preference also for a particular type of sand or mud substrate in the Barnegat Bay. Three different types of sand substrate were sampled, and two different types of mud substrate were sampled. This study was unable to accurately time how long fishing occurred on each type of sand or mud substrate and could only time how long fishing occurred on sand or mud substrate in total. This is the first study of adult *P. dentatus* to report no substrate preference instead of a sand substrate preference, which suggests that the substrate preference for the fish should be reevaluated in small, estuarine areas like the Barnegat Bay. There was also no difference between the total length of the fish caught on sand or mud substrate (t-test, p=0.0807).

Along with substrate preference and size compared to substrate, the preference of bait was also examined in Summer Flounder. The total catch number represents only the fish caught by the researcher and not fish caught by other boats which were observed by the researcher. There was a strong preference for spearing as bait when compared to bluefish and bunker (χ^2 test, p = 0.000043). This may be because flounder are predators and not scavengers and spearing more accurately mimics a live fish. Bunker is cut up into pieces and therefore does not look like a live fish to chase. Although only three fish were dissected, the stomach content of all three found crustacean exoskeletal remains, suggesting that in the wild flounder are predators on crustaceans. The exoskeletal pieces were digested so the species could not be easily identified. However, since flounder are known to hunt around eel grass beds (Lascara 1981), grass shrimp (*Palaemonetes pugio*) may be one possible prey species. If so, flounder might play an important role in grass shrimp ecology in the Barnegat Bay. A relatively intact common periwinkle shell (*Littorina littorea*) was found in the stomach of one fish. This suggests that *P. dentatus* have a varied diet that includes fish, crustaceans, and mollusks. Further research should be conducted to examine the role of Summer Flounder in the overall trophic ecology of the Barnegat Bay by examining the stomach contents over several years.

Although the two different sample sites did not have statistically different water chemistry data, the temperature preference of *P. dentatus* was examined without the factor of substrate. The temperature at which each flounder was caught and how many were caught at each temperature is shown in Figure 2. The correlation value (R = 0.5261) indicates a moderate positive correlation between temperature and number of fish caught, showing that more fish were caught at higher temperatures. Although this does not prove more fish were present in areas of higher temperature, it does suggest that *P. dentatus* were more active at higher temperatures and were therefore caught more frequently.

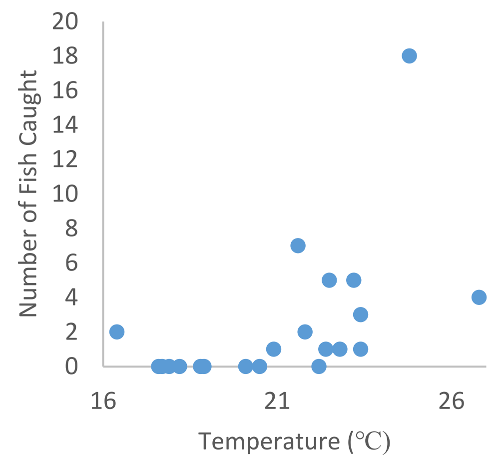

Figure 2. The relation between number of Summer Flounder, Paralichthys dentatus, caught and temperature is shown. The correlation is calculated using the R value

Along with *P. dentatus*, substrate preference was examined for *Raja eglanteria*, which showed a preference for sand substrate (χ^2 test, p =0.020). This species has been known to occur on mud and sand substrate, similar to *P. dentatus* (Packer, Zetlin, Vitaliano, 2003). However, they are also known to prefer waters with a higher salinity, typically higher than 22 ppt (Packer, Zetlin, Vitaliano, 2003). Although both sampling sites had statistically similar salinity, Site B was closer to the ocean and likely has salinity more consistent with the fishes' preference. Site A often dropped below the salinity preference of *R. eglanteria*, which may cause the apparent preference for sand substrate in the area sampled.

Size of *Pomatomas saltatrix* compared to substrate was also examined, showing that smaller *P. saltatrix* prefer sand substrate (t-test, p=0.0083). Although *P. saltatrix* are a pelagic species and do not settle on substrate, mud substrate is further from the ocean in the Barnegat Bay (see Figure 1). If smaller fish are further from the ocean then they are more protected against predation, giving them a better chance of survival. Total length in relation to temperature was also examined in P. saltatrix (Figure 3). The fish were caught between 16-25 degrees Celsius. The r value of

-0.5835 suggests a moderate negative correlation, meaning that larger *P. saltatrix* prefer colder temperatures while smaller fish prefer warmer temperatures. This species is known to migrate based on temperature (Olla and Studholme, 1971; Wilk 1977). In laboratory studies, fish smaller than 9.8 inches required higher temperatures to survive than larger *P. saltatrix* (Lund and Maltezos 1970; Wilk 1977). However, temperature preference related to size has not yet been observed in this species in the wild.

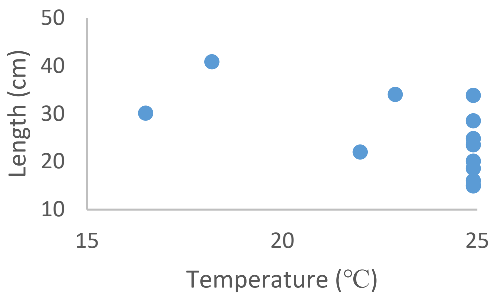

Figure 3. The relation between size of Bluefish, Pomatomus saltatrix, caught and temperature is shown. The correlation is calculated using the R value

In summary, *P. dentatus* caught in the Barnegat Bay do not have a substrate preference for sand or mud. This suggests that the preference may have changed over time and should be reevaluated. Further research should be done in order to determine if Summer Flounder prefer one type of sand or mud substrate over another in the Barnegat Bay. Additionally, there is no difference in the size of the flounder caught on sand or mud. *P. dentatus* do show a preference for warmer water temperature and for spearing bait. *R. eglanteria* show a preference for sand, possibly because Site B had a salinity more consistent with the preferred salinity of the species although both locations surveyed had statistically the same salinity. Small *P. saltatrix* show a preference for mud substrate, which is likely for protection against predation, and a preference for warmer water temperature. Larger *P. saltatrix*, in contrast, prefer colder water.

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