PREY SELECTIVITY OF THE FISHES STEPHANOLEPIS HISPIDUS AND HISTRIO HISTRIO ON THE SARGASSUM SHRIMPS LATREUTES FUCORUM AND LEANDER TENUICORNIS

KIMBERLY A. HUTCHINSON

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by

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The thesis was prepared under the direction of the candidate's thesis advisor, Dr. W. Randy Brooks, Department of Biological Sciences, and has been approved by the members of her supervisory committee. It was submitted to the faculty of Charles E. Schmidt College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Author: Kimberly A. Hutchinson

Title: Prey selectivity of the fishes *Stephanolepis hispidus* and *Histrio histrio* on the *Sargassum* shrimps *Latreutes fucorum* and *Leander tenuicornis*

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Predator-prey relationships were studied between the shrimps *Latreutes fucorum* and *Leander tenuicornis* and the predatory fishes *Stephanolepis hispidus* and *Histrio histrio*, all found within pelagic *Sargassum* communities. Average survival times of shrimps were compared in species, size/density, and habitat selection studies. The results showed that *S. hispidus* had a preference for prey species while *H. histrio* did not. 30 mm shrimp survived longer than the 10 mm shrimp for both *S. hispidus* and *H. histrio*. Density was a factor in the survival times of the 20 mm shrimps with *S. hispidus* only. *L. tenuicornis* survived longer in artificial *Sargassum* habitats with *H. histrio*. The larger shrimps survived longer in the artificial habitats than the smaller shrimps with *S. hispidus*. Both fish predators employ optimal foraging strategies with similarities and differences, the latter of which are likely related to behavioral differences in the these predator and prey.

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INTRODUCTION

The pelagic *Sargassum* community in the western North Atlantic is extremely diverse, possessing macro- and micro-epiphytes, fungi, over 100 species of both invertebrates and fishes, and four species of turtles. This small, complex community represents an excellent natural system for studying ecological interactions, such as predator-prey relationships and associated ecological models, including optimal foraging theory.

This ecological model suggests foraging behaviors by predators should be profit-driven, by maximizing energy intake and minimizing energy expenditure (Pyke et al., 1977; Hughes, 1980). Profitability equals energy from food divided by handling time. Parameters for assessing profitability can involve the following choices by predators: habitat patches for foraging, searching methods, and encountered prey items for consumption (Hughes, 1980). Many studies have focused on the last factor by looking at predator preferences for prey.

One example includes a study on fringed filefish, *Monacanthus ciliatus*, to determine if predator preferences for prey existed (Clements and Livingston, 1984). Specifically, *M. ciliatus* and three abundant amphipod prey species were collected from a seagrass community in Florida. Filefish were initially given a choice of each prey species in equal numbers and sizes and subsequently selected one type over the other two species. Next, prey species ratio was imbalanced resulting in random feeding behavior. Finally, vegetation used for cover was increased in aquaria, which inhibited the ability of filefish to capture these prey. However, even with increased cover, *M. ciliatus* still showed preference for one species of amphipod. Based on these results, Clements and Livingston (1984) hypothesized that preference for prey by these fish was primarily a function of differences in unique patterns of pigmentation among the amphipods.

In Wisconsin lakes, smallmouth bass have diets dominated by crayfish. Stein (1977) presented these bass with crayfish of different sizes to evaluate cost/benefit ratios of predator selection. Specifically, fish were given a choice of crayfish in four sizes (body length) on two different substrates (sand and pebble). On sand, bass chose smaller crayfish first. However, on pebble substrate, bass initially chose intermediate sizes. In a prior study, Stein (1976) discovered that smallmouth bass given only one size of crayfish on sand consumed animals based on differences in chela size (which did vary with similar-sized body lengths). Overall, Stein concluded that smallmouth bass, via selective predation, are optimal foragers. Obviously, larger crayfish or those with larger chelae potentially increase the costs of procuring prey. Thus, these fish likely select the largest, "safest" prey they can easily locate depending on the background substrate. In most cases, this translated into selecting smaller individuals or those with smaller chelae.

Main (1985) also conducted size preference experiments using pinfish and pipefish, which consume shrimp in a seagrass community in the Gulf of Mexico. Fish were presented two sizes of shrimp and first and second strikes on the shrimp by the fish were recorded. She found a significant preference by both fish for larger shrimp on the first strike, but no significant difference for prey size on second strikes. Main concluded that when given equal access to prey of different sizes, both pinfish and pipefish selected larger, more motile prey. This conclusion supports the optimal foraging model.

Werner and Hall (1974) conducted size-selection experiments using bluegill sunfish and *Daphnia* from freshwater lakes in Michigan. Specifically, their research goals looked for correlations between diet breadth and search time in different relative densities of prey. They found that in low prey densities, fish ate *Daphnia* as they were encountered, and size was not a factor. In high prey densities, however, fish ate larger *Daphnia* more than smaller sizes. Werner and Hall concluded that changes in prey selection maximize profitability with respect to time spent foraging.

Mikheev and Wanzenböck (1999) conducted size-selection experiments using naïve juvenile roach fish obtained via artificial fertilization of eggs from wild fish from a lake in Austria. Feeding rates and behavior of fish were observed when given access to two sizes of *Daphnia.* Selection of prey was related to satiation levels of the fish. Specifically, larger fish fed almost exclusively on larger prey until about 1% of the fish's body weight had been ingested. Subsequently, fish then fed on smaller prey.

Habitat choice and prey accessibility also have been studied in relation to optimal foraging theory. Many prey species mimic patterns of their background habitat, presumably increasing foraging time by predators and minimizing energy intake. In areas of high predation pressure, being cryptic can be beneficial (Endler, 1978). Experiments by Clements and Livingston (1984), reviewed above, found that increasing habitat structure and availability inhibited predation. Again, the *Sargassum* seaweed community, which is highly structured with numerous inhabitants in close proximity, could provide opportunities to test aspects of optimal foraging theory.

Sargassum community description

Sargassum (Figure 1a) is a brown alga commonly called gulf weed and consists of long branching stems with leaf-like extensions and stalked air bladders, for floatation (Weis, 1968). Colors vary from yellow to brown to black (Hacker and Madin, 1991). Two species are common in the western North Atlantic: *Sargassum natans* and *S. fluitans* (Coston-Clements et al., 1991). Specifically, both varieties circulate between 20° and 40° N latitude and 30° W longitude and the western edge of the Florida Current/Gulf Stream (Dooley, 1972; Coston-Clements et al., 1991). The Gulf Stream and wave action break apart the *Sargassum* and distribute it throughout the Atlantic Ocean forming floating clumps, which provide shelter, food, and substrate to numerous organisms (Weis, 1968; Dooley, 1972; Stoner and Greening, 1984; Coston-Clements et al., 1991).

One abundant shrimp species in this community is *Latreutes fucorum* (Figure 1 b), which occurs in numerous tints and color patterns with stripes and bars resembling *Sargassum* fronds (Brown, 1939). A second highly abundant, endemic shrimp species, *Leander tenuicornis* (Figure 1 c), also occurs in various color patterns with spots that resemble *Sargassum*. This latter shrimp species, although common in *Sargassum* is less abundant than *Latreutes fucorum* (Stoner and Greening, 1984).

Many fishes also inhabit the *Sargassum* community. Two in particular are the planehead filefish *Stephanolepis hispidus* (Figure 1d), and the Sargassum fish *Histrio histrio* (Figure 1 e). *Stephanolepis hispidus* is an abundant predatory fish found within this community (Fine, 1970; Dooley, 1972; Bortone et al., 1977; Stoner and Greening, 1984; Fedoryako, 1989). Especially during summer months, *S. hispidus* is numerous and of small size (indicating recent recruitment to the seaweed community) (Bortone et al., 1977). Dooley (1972) suggests these filefish feed mainly on hydroids and encrusting bryozoans; secondarily feeding on *Sargassum* shrimps.

Histrio histrio, an endemic species in *Sargassum* communities (circumtropically) (Adams, 1960), is best known for its intricate mimicry, resembling *Sargassum* weed with patterns of yellow, brown and olive (De Loach 1999). *Histrio histrio* is a highly sedentary, lie-in-wait predator spending most of its time clinging to *Sargassum* fronds due to poor swimming abilities. Distinguishing features include a large mouth and fleshy tabs or appendages on the body which have a weed-like appearance (Adams, 1960; De Loach 1999). The enormous mouth and distensible stomach make *H. histrio* a voracious predator, and gut analyses confirm that *Sargassum* shrimps are among prey types consumed frequently (Dooley, 1972).

Research questions

The following questions on prey selectivity by predatory fishes on the *Sargassum* shrimps were addressed: 1) Do *S. hispidus* and *H. histrio* have preferences for shrimp species? 2) Do *S. hispidus* and *H. histrio* have preferences for prey size? 3) Is camouflage by *Sargassum* shrimps an effective deterrent against predation by *S.*

hispidus and *H. histrio*? It is suggested that the predatory fishes, *S. hispidus* and *H. histrio*, may have a preference for species of shrimp. Size and prey density may also influence prey selection. According to optimal foraging theory, fish should choose larger shrimp because they provide the most nutritional value unless capturing expends too much energy. The shrimp's camouflage may also be effective in deterring predation by *S. hispidus* and *H. histrio*. However, differences in color patterns among these shrimp (e.g., stripe and bar patterns on *L. fucorum* versus spots on *L. tenuicornis*) might influence the outcome.

MATERIALS AND METHODS

Collection and maintenance of specimens

Floating clumps of *Sargassum natans* and *Sargassum fluitans* were collected via boat 1.5-3.5 km off the southeast coast of Florida using a fine mesh dip net. Clumps were shaken over a cooler containing a portable air pump to remove fishes and shrimp. Small clumps of *S. natans* or *S. fluitans* were placed in the container to provide a temporary refuge for fishes and shrimp while in transport. Animals were kept in laboratory aquaria (38-75 L in size) at Florida Atlantic University.

Total length of fish was measured (to nearest mm) from snout tip to caudal fin then placed in individual aquaria. Shrimp were separated by species and measured (to nearest mm) from rostrum tip to end of telson, then segregated in aquaria by the following size classes: 10±5, 20±5, and 30±5 mm. Fish and shrimp were acclimated to their environment for at least two days prior to experimentation. Fish were fed commercial flake food, but starved for 36 hours prior to predation trials. Shrimp were fed live brine shrimp three times a week. Animals were maintained in aquaria using seawater (32-35 ppt) from Gumbo Limbo Environmental Complex. All animals were exposed to a 12L:12D photoperiod.

Fish prey species selection

Both species of fish were tested in separate trials involving the following protocol. Ten individuals of both species of shrimp, each the same size (10±5 mm), were placed for ten minutes in an aquarium (9.5 L). An individual fish (35-105 mm in length for *S. hispidus* and 22-91 mm for *H. histrio*), starved for 36 hours, was placed into the tank. The fish was allowed to feed for thirty minutes before being removed. Feeding sequence (i.e., which shrimp species eaten) and survival times of the shrimp were recorded. The experiment was replicated nine times using different fish.

Fish prey size selection

Both species of fish were tested in separate trials involving the following protocol. One individual shrimp of each of the following size classes (10±5, 20±5, and 30±5 mm), holding species constant, were placed for ten minutes in an aquarium (9.5 L). Only the shrimp species *L. tenuicornis* was used in these trials because it was found in all 3 size classes in the collections, while *L. fucorum* was only found in one size (10±5 mm). An individual fish (26-105 mm in length for *S. hispidus* and 29-91 mm for *H. histrio*), starved for 36 hours, was placed into the tank. The fish was allowed to feed for thirty minutes before being removed. Feeding sequence (i.e., which shrimp size eaten) and survival times of the shrimp were recorded. The experiment was replicated nine times using different fish. Using the same protocol above, two more sets of trials were conducted increasing the shrimp density of each size class to 5 and then 10, respectively.

Camouflage effectiveness in species selection

Both species of fish were tested in separate trials involving the following protocol. Ten individuals of both species of shrimp, each the same size (10±5 mm), were placed for ten minutes in an aquarium (9.5 L) containing one of the following habitat choices:

-Experiment 1: Natural *Sargassum fluitans* plant light brown in color.

-Experiment 2: Artificial *Sargassum fluitans* plant red in color.

-Experiment 3: Artificial *Sargassum fluitans* plant light green in color.

An individual fish (26-62 mm in length for *S. hispidus* and 22-91 mm for *H. histrio*), starved for 36 hours, was placed into the tank. The fish was allowed to feed for thirty minutes before being removed. Feeding sequence (i.e., which shrimp species eaten) and survival times of the shrimp were recorded. The experiment was replicated four times using different fish. The same protocol was followed using the other 2 habitat choices. Additionally, I repeated the experiments above, but this time allowing *H. histrio* to acclimate for ten minutes instead of the shrimp because *H. histrio* is an ambush predator and may be more likely to consume prey when it has established a position in the habitat.

Camouflage effectiveness in size selection

Both species of fish were tested in separate trials involving the following protocol. Five individuals of each of the following size classes of shrimp (10±5, 20±5, and 30±5 mm), holding species constant, were placed for ten minutes in an aquarium (9.5 L) containing one of the following habitat choices. Only the shrimp species *L. tenuicornis* was used in these trials because it was found in all 3 size classes in the collections while *L. fucorum* was only found in one size (10±5 mm). The habitat choices were as follows:

-Experiment 1: Natural *Sargassum fluitans* plant light brown in color.

-Experiment 2: Artificial *Sargassum fluitans* plant red in color.

-Experiment 3: Artificial *Sargassum fluitans* plant light green in color.

An individual fish (26-62 mm in length for *S. hispidus* and 22-91 mm for *H. histrio*), starved for 36 hours, was placed into the tank. The fish was allowed to feed for thirty minutes before being removed. Feeding sequence (i.e., which shrimp size eaten) and survival times of the shrimp were recorded. The experiment was replicated four times using different fish. The same protocol was followed using the other 2 habitat choices. Again, the experiment was also performed allowing *H. histrio* to acclimate for ten minutes instead of the shrimp.

Statistical analysis

All statistical analyses and reports (appendices) were done using SigmaStat® (Version 3.2). Species selection experiments were analyzed using a Mann-Whitney rank sum test when they failed the assumptions of normality. Otherwise, a t-test was used. Size selection and habitat complexity experiments were analyzed using either one-way or two-way ANOVA. Multiple comparison tests (Tukey post-hoc for parametric measures or Bonferroni t-test for non-parametric measures) were performed when overall treatment effects were found.

RESULTS

General behavior of fishes and shrimp during predation

Stephanolepis hispidus would attack the 10 mm shrimp from the side and try to take a bite out of its abdomen. It would continue taking bites out of the abdomen until it stopped moving. Then it would eat the rest of the shrimp. *S. hispidus* would face the 20 and 30 mm shrimps and then it would try to attack the abdomen from all sides. It would also try to pull the chelae off the shrimp. Once a bite was successfully taken out of the abdomen, it would continue pursuing it and taking bites. The rostrum was often discarded.

Histrio histrio would mostly wait for the fish to pass its field of view before attacking. It would then swallow the shrimp whole no matter what size it was. *H. histrio* would sometimes use its hand-like appendages to move around the different habitat types apparently in a very slow pursuit of prey. The 91 mm *H. histrio*, would sometimes appear to use its dorsal spine as a lure to attract the larger shrimp before an attack.

Both species of 10 mm shrimp would try to flee from the predatory fishes. At times these smaller shrimp would appear to hide beside larger shrimp. The 20 mm shrimp would either try to flee or snap their chelae at the fish. There were a few instances where the shrimp clung on to the attacking fish with its chelae. The fish would try to get the shrimp off or it would keep looking for other prey. The 30 mm shrimp would mostly snap their chelae at the fish. During an attack, these larger shrimp would also occasionally spread their lateral rostrum.

Species selection

Leander tenuicornis survived significantly longer than *Latreutes fucorum* with the fish predator *Stephanolepis hispidus* ($p = 0.002$, Mann-Whitney Rank Sum test; Figure 2). However, survival times of both shrimp species did not differ with the fish predator *Histrio histrio* ($p = 0.656$, t-test; Figure 3).

Size selection by Stephanolepis hispidus

Overall, significant effects of *L. tenuicornis* shrimp size ($F = 35.340$, $p < 0.001$) and density ($F = 3.280$, $p = 0.044$) existed.

Specifically, average survival times were greater for 30 mm shrimps than either 10 or 20 mm shrimps when fish were given only 1 shrimp of each size ($p < 0.05$, Bonferroni t-test multiple comparison; Figure 4). There was no significant difference in survival times of 10 and 20 mm shrimps under the same conditions.

Average survival times of 20 and 30 mm shrimps were statistically similar, but both were significantly greater than survival times of 10 mm shrimp when there was a choice of 5 shrimp of each size ($p < 0.05$, Bonferroni t-test multiple comparison; Figure 4).

Average survival times of the 20 and 30 mm shrimps were also statistically similar, but both greater than 10 mm shrimps when there was a choice of 10 shrimp of each size ($p < 0.05$, Bonferroni t-test multiple comparison; Figure 4).

Although 10 and 30 mm shrimps survived equally in these density trials, 20 mm shrimp survived longer in densities of 10 than when 1 or 5 shrimp of each size was present ($p < 0.05$; Bonferroni t-test multiple comparison; Figure 5). There was no significant difference between average survival times of 10 mm or 30 mm shrimps at the 1, 5, or 10 densities.

Size selection by Histrio histrio

Overall, significant effects of *L. tenuicornis* shrimp size ($F = 16.933$, $p < 0.001$) existed. However, significant effects of *L. tenuicornis* shrimp density ($F = 2.304$, $p = 0.106$) did not exist.

Average survival times were greater for 30 mm shrimps compared to 10 mm shrimps when fish were given 1 shrimp of each size ($p < 0.005$, Bonferroni t-test multiple comparison; Figure 6). However, no significant difference existed between average survival times of the 30 versus 20 mm and 20 versus 10 mm shrimps.

Similar results to those in the 1-shrimp density trials were observed in trials with 5 shrimp of each size, with the largest shrimp surviving the longest ($p < 0.05$, Bonferroni t-test multiple comparison; Figure 6).

Average survival times were greater for 20 and 30 mm shrimps compared to 10 mm shrimps when fish were given 10 shrimp of each size ($p < 0.005$, Bonferroni t-test multiple comparison; Figure 6). However, no significant difference existed between average survival times of the 30 versus 20 mm shrimps.

Camouflage effectiveness in species selection

Overall, habitat type did not significantly affect survival times of the two shrimp species when shrimp were allowed to acclimate 10 minutes prior to the addition of either fish predator. However, when the fish *H. histrio* was allowed to acclimate for 10 minutes prior to adding shrimp, habitat type did significantly influence survival of one shrimp species. Specifically, average survival times of *L. tenuicornis* were greater in the artificial green and artificial red habitats than the natural *Sargassum* habitat ($p < 0.05$, Tukey post-hoc multiple comparison; Figure 7). Survival times in both artificial habitats were statistically similar.

Only the artificial green habitat was associated with differential survival of shrimp species, with *L. tenuicornis* having greater survival times than *L. fucorum* with the fish *H. histrio* ($p < 0.05$, Tukey post-hoc multiple comparison; Figure 8).

Camouflage effectiveness in size selection

Because of limitations in the numbers of sizes of *L. fucorum*, only *L. tenuicornis* was tested in these trials. Overall, prey selection by the fish *S. hispidus* was significantly affected by habitat ($F = 7.060$, $p = 0.003$) and size ($F = 5.897$, $p = 0.006$). Specifically, average survival times of 10 mm shrimps were greater in the artificial green and red habitats than in natural *Sargassum* habitat ($p < 0.05$, Tukey post-hoc multiple comparison; Figure 9). The only other significant effect with this fish predator involved 20 and 30 mm shrimps, which survived longer than 10 mm shrimp in natural *Sargassum* habitat ($p < 0.05$, Tukey post-hoc multiple comparison; Figure 10).

Prey size selection by the fish *H. histrio* was not significantly affected by habitat type, regardless of whether the shrimp or fish was acclimated for 10 minutes in the test arena first.

Camouflage effectiveness summary

Data were pooled from previous trials to estimate the overall effect of habitat cover versus no cover on predation of shrimp by both fish predators. Specifically, survival times for both species of shrimp (10 ± 5 mm in size for *L. tenuicornis* and 10 ± 5 mm in size for *L. fucorum*) with and without habitat were compared. Overall, shrimp survived significantly longer when habitat was available with the fishes *S. hispidus* ($p < 0.001$, Mann-Whitney Rank Sum Test) and *H. histrio* ($p = 0.009$, Mann-Whitney Rank Sum Test; Figure 11).

Effect of predator and prey size on feeding rates

Data from size selection trials (discussed previously above) were analyzed to examine whether fish size affected the size and number of shrimp consumed. This analysis is especially critical in determining if eating large shrimp reduced the total number of shrimp consumed in these time-limited trials. That is, eating one large shrimp may be nearly quantitatively (and qualitatively) equivalent to consuming several smaller shrimp.

Fish sizes were grouped into two major categories: large (48-105 mm for *S. hispidus* and 46-91 mm for *H. histrio*), and small (35-44 mm for *S. hispidus* and 29-36 mm for *H. histrio*). No significant differences in consumption rates by large versus small fishes existed for either predator in both 5 (*S. hispidus,* p=0.065, Mann-Whitney Rank Sum Test; and *H. histrio,* p=0.093, Mann-Whitney Rank Sum Test) and 10 density trials (*S. hispidus,* p=0.333, Mann-Whitney Rank Sum Test; and *H. histrio,* p=0.282, Mann-Whitney Rank Sum Test).

Consumption rates were statistically similar between trials for both fish species in which a 30 mm shrimp was consumed versus those trials in which no 30 mm shrimp was consumed (*S. hispidus,* p=0.384, Mann-Whitney Rank Sum Test; and *H. histrio,* p=0.055, Mann-Whitney Rank Sum Test).

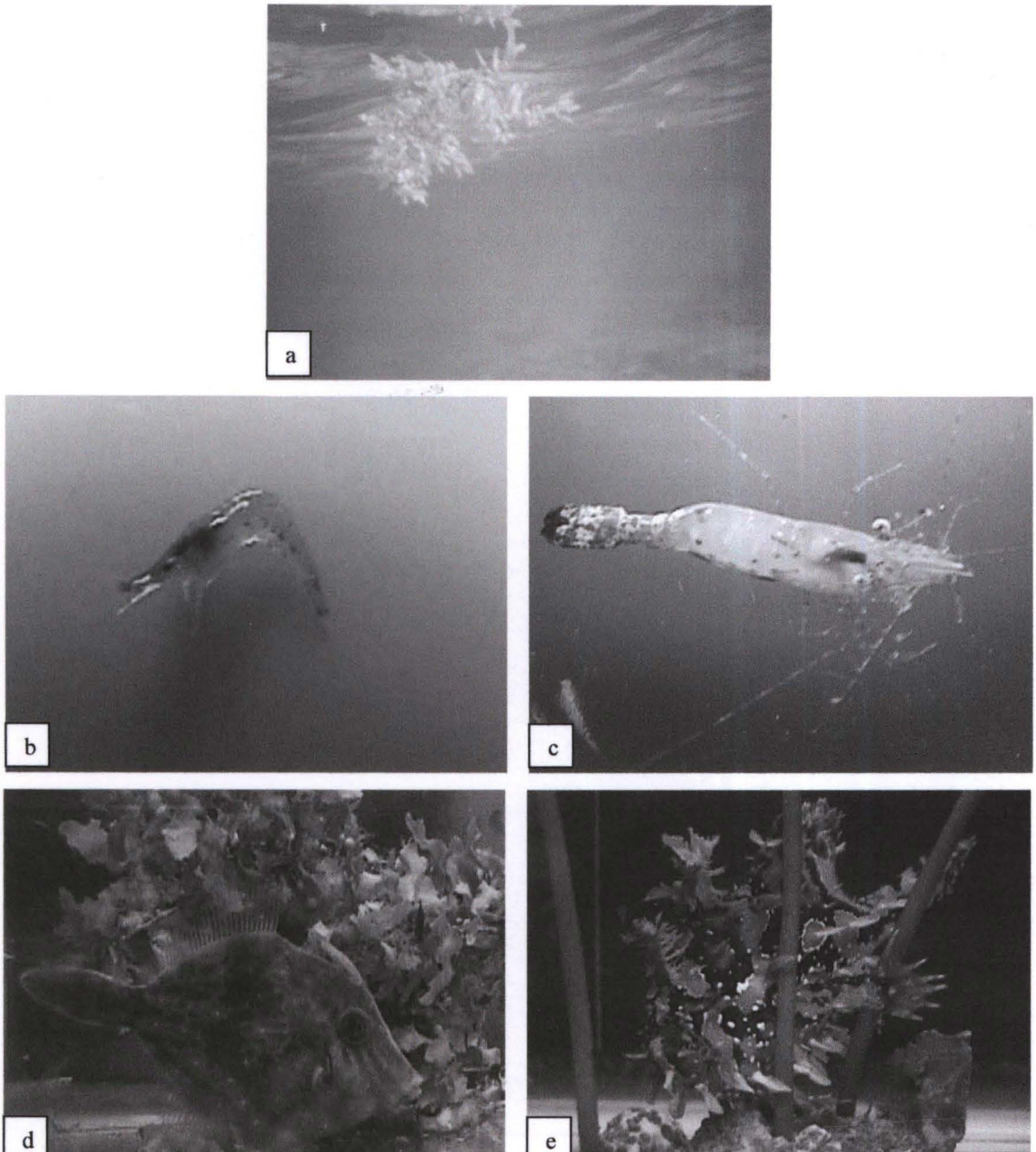


Figure 1. Organisms of the *Sargassum* community. a) *Sargassum sp.* b) *Latreutes fucorum* (10 mm). c) *Leander tenuicornis* (30 mm). d) *Stephanolepis hispidus* (54 mm). e) *Histrio histrio* (91 mm).

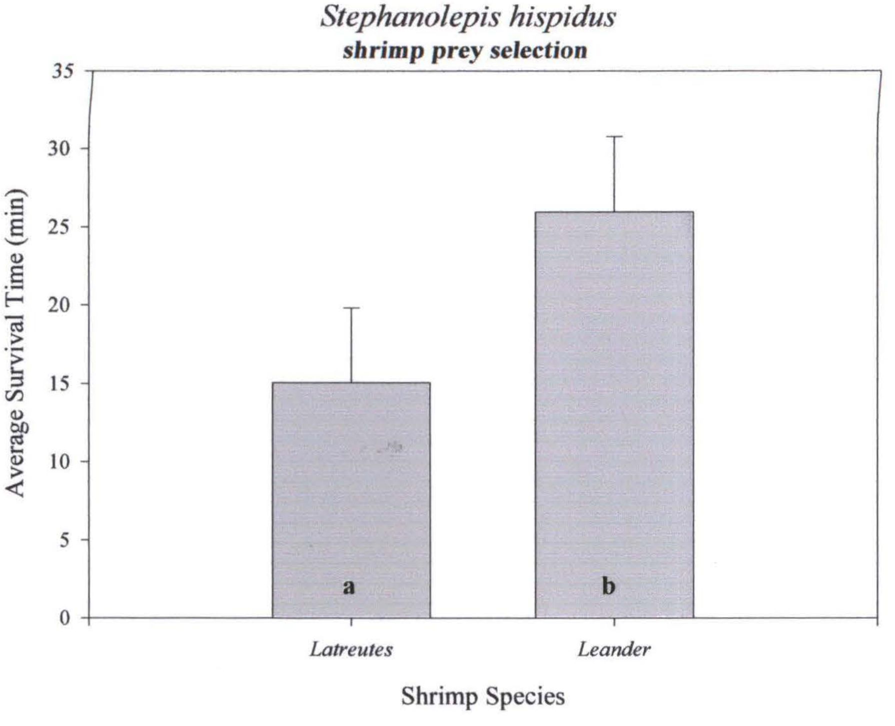


Figure 2. Shrimp species prey selection by the fish *Stephanolepis hispidus*. *Leander tenuicornis* survived significantly longer than *Latreutes fucorum* ($p < 0.05$, Mann-Whitney Rank Sum Test) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

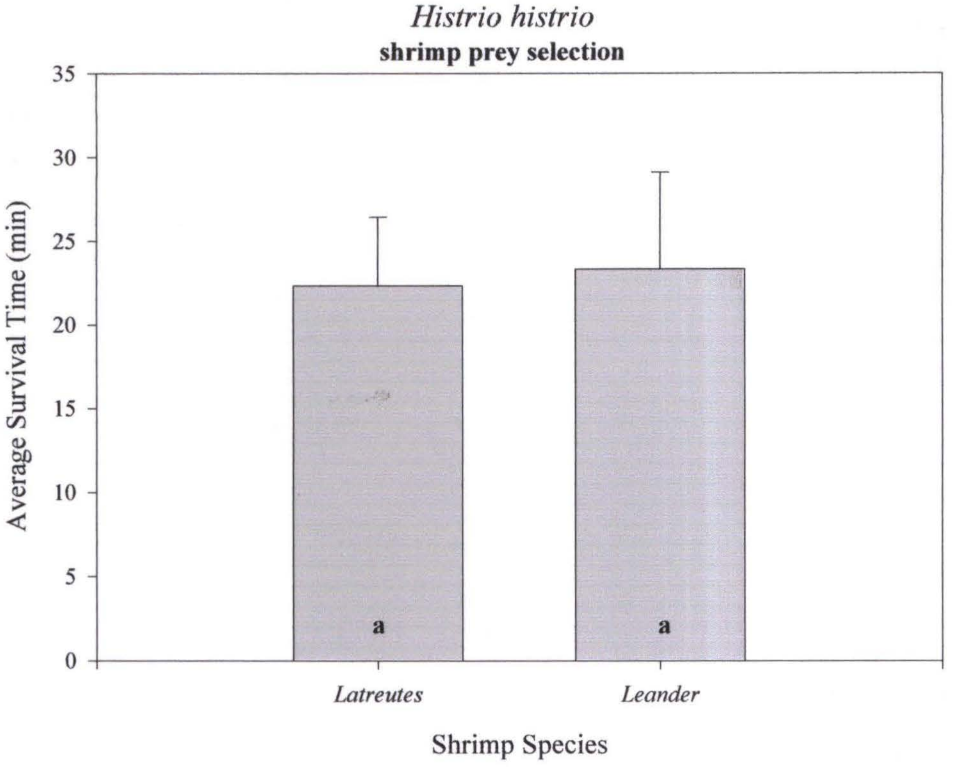


Figure 3. Shrimp species prey selection by the fish *Histrio histrio*. No difference in survival times existed ($p = 0.656$, t-test) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

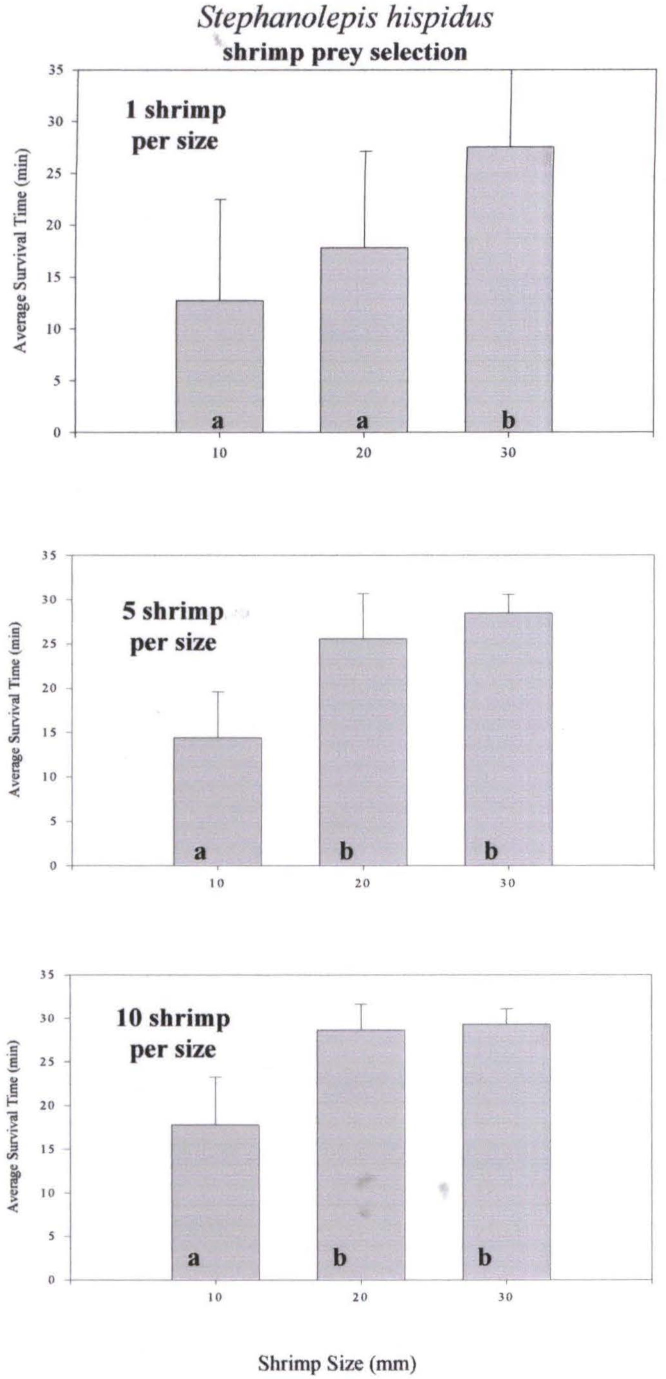


Figure 4. Shrimp (*Leander tenuicornis*) size selection by the fish *Stephanolepis hispidus* in densities of 1, 5 and 10 of each shrimp size. Significant differences exist in survival times of shrimp in each density trial ($p < 0.05$, Bonferroni t-test multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

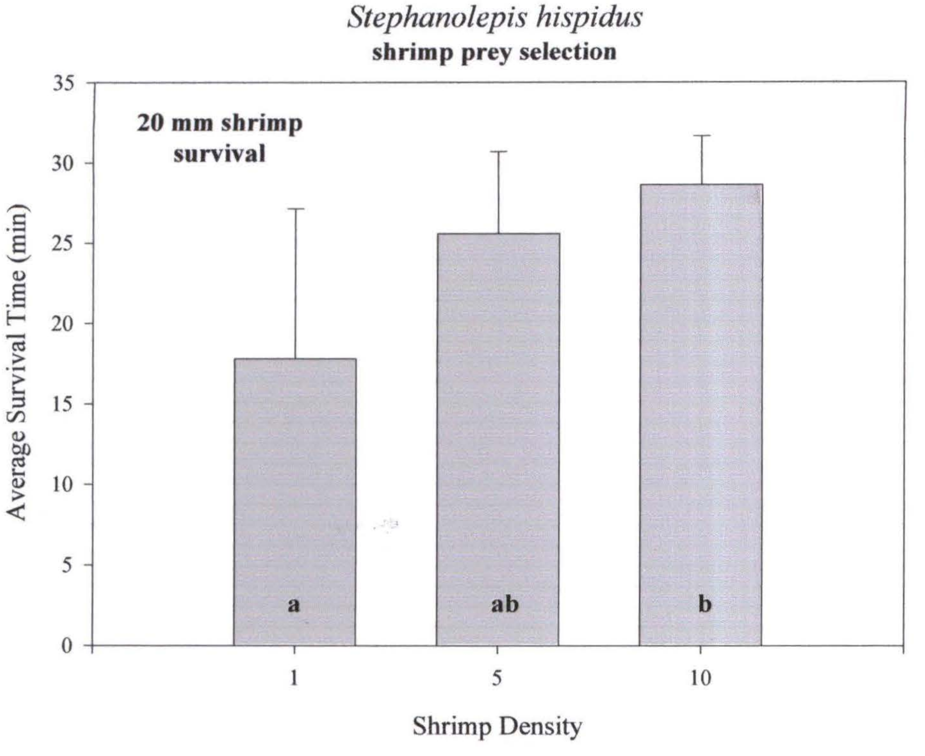


Figure 5. Effect of prey density on predation of 20 mm shrimp (*Leander tenuicornis*) by the fish *Stephanolepis hispidus*. Shrimp of this size class survived longer when more shrimp were present ($p < 0.05$, Bonferroni t-test multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

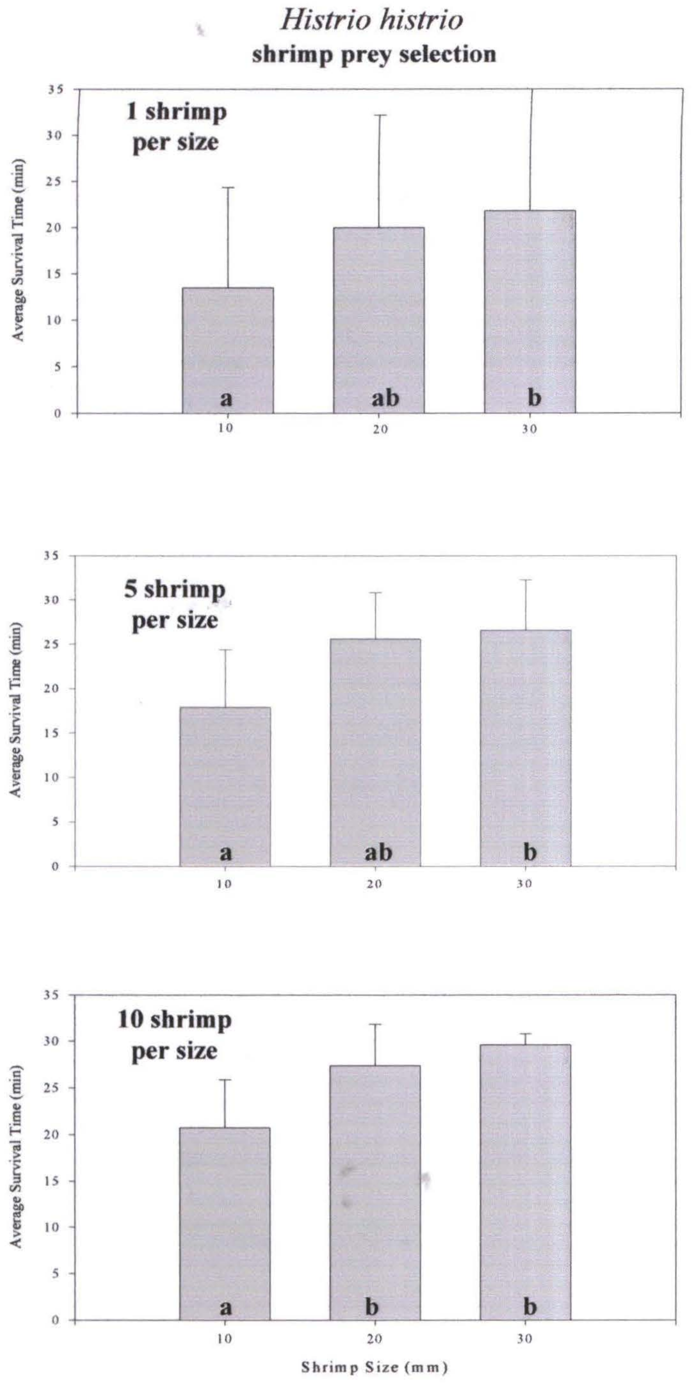


Figure 6. Shrimp (*Leander tenuicornis*) size selection by the fish *Histrio histrio* in densities of 1, 5 and 10 of each shrimp size. Significant differences exist in survival times of shrimp in trials with densities of 1, 5 and 10 shrimp ($p < 0.05$, Bonferroni t-test multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

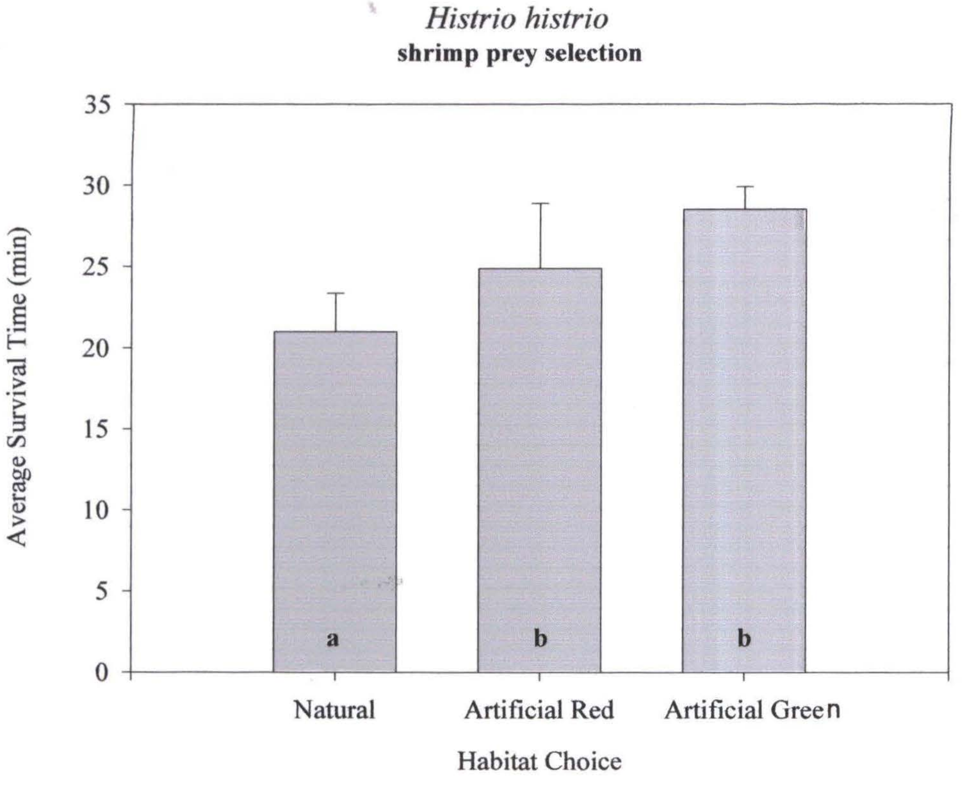


Figure 7. Shrimp (*Leander tenuicornis*) prey selection by the fish *Histrio histrio* in 3 habitat types. Artificial habitats provided significantly better protection for shrimp than did *Sargassum* (natural) habitat ($p < 0.05$, Tukey post-hoc multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

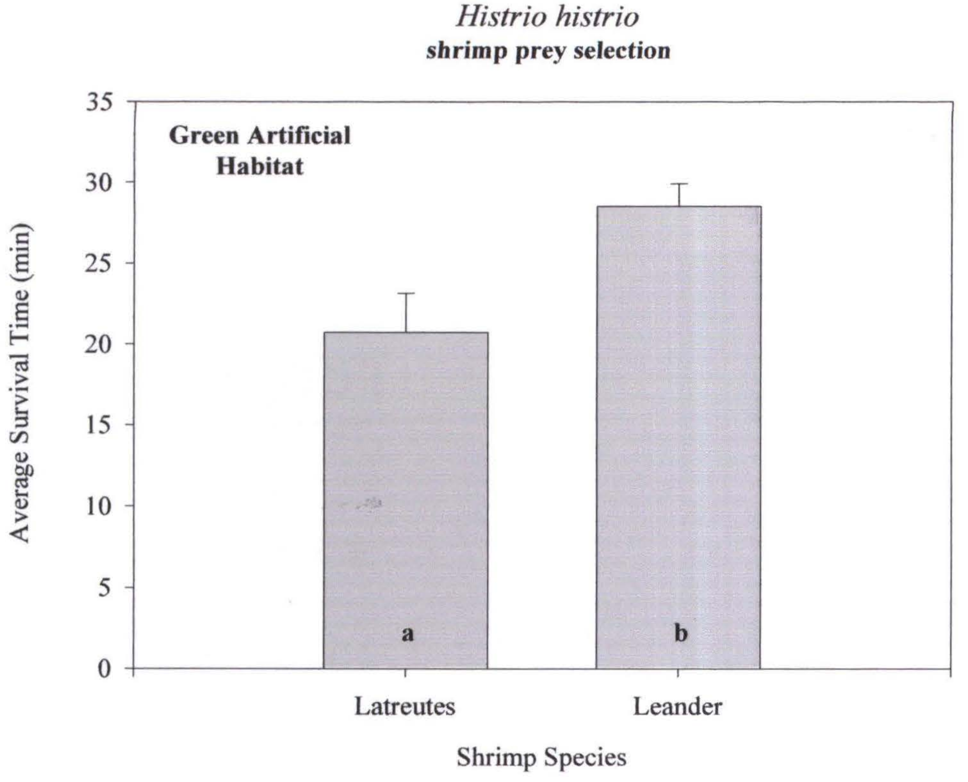


Figure 8. Shrimp species prey selection by the fish *Histrio histrio* in green artificial habitat. *Leander tenuicornis* survived significantly longer than *Latreutes fucorum* in this habitat ($p < 0.05$, Tukey post-hoc multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

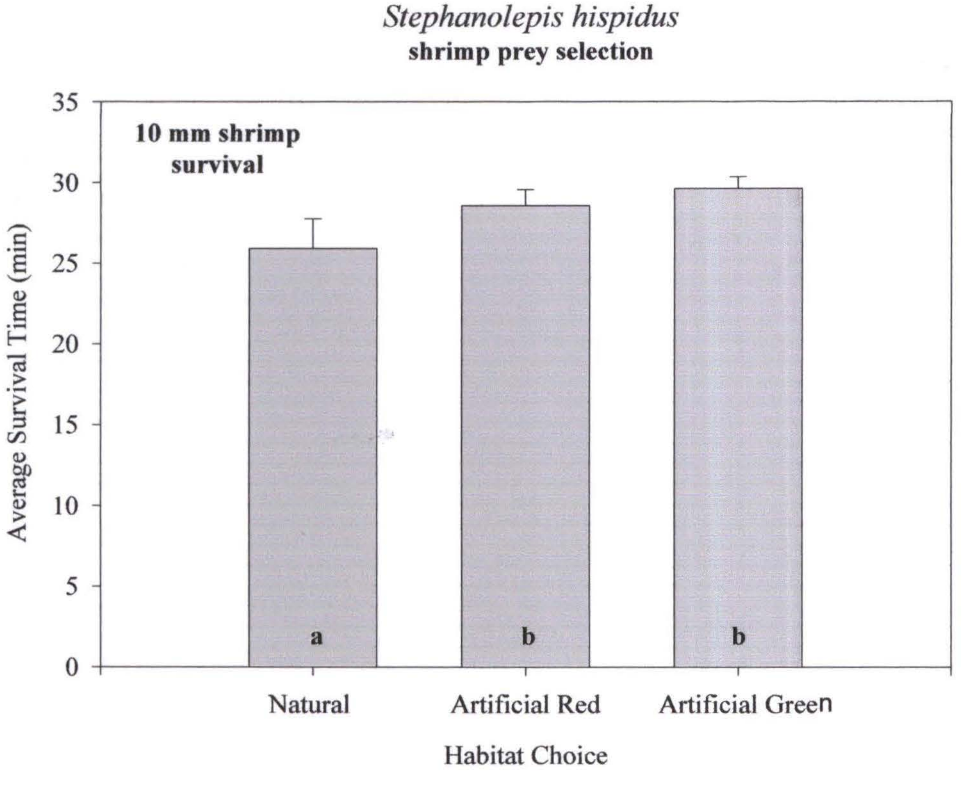


Figure 9. Effect of habitat type on predation of 10 mm shrimp (*Leander tenuicornis*) by the fish *Stephanolepis hispidus*. Shrimp of this size class survived significantly longer in both artificial habitats than in natural *Sargassum* ($p < 0.05$, Tukey post-hoc multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

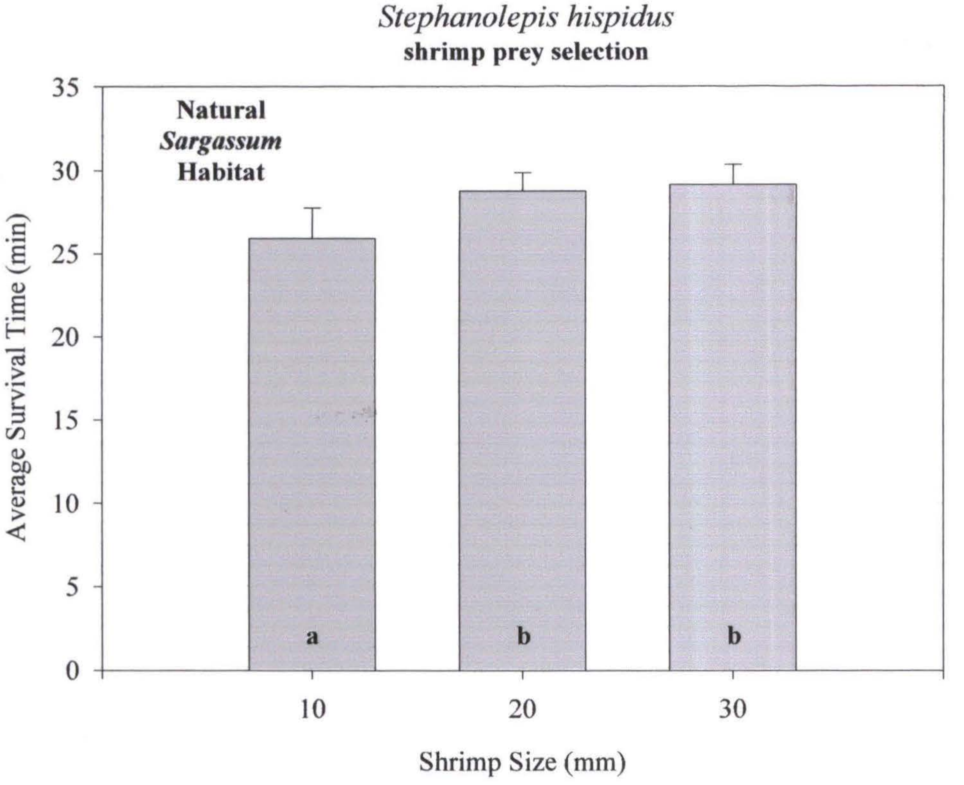
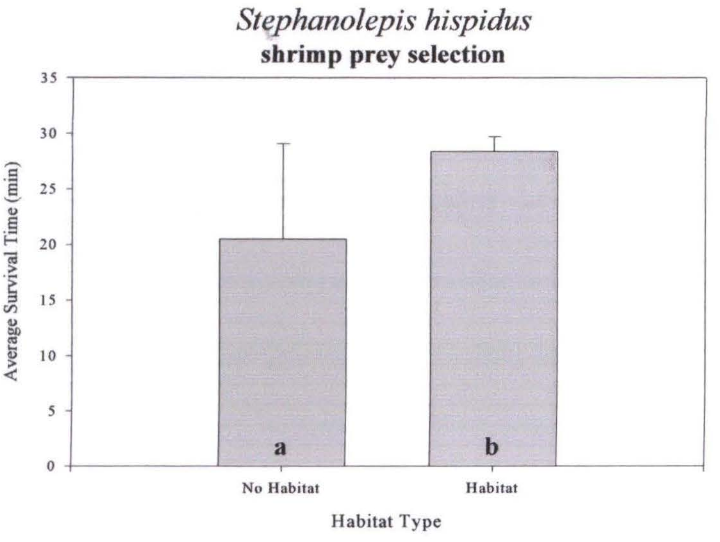


Figure 10. Effect of natural *Sargassum* habitat on shrimp size selection by the fish *Stephanolepis hispidus*. Larger shrimps survived significantly longer in natural *Sargassum* than did 10 mm shrimp ($p < 0.05$, Tukey post-hoc multiple comparison) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).



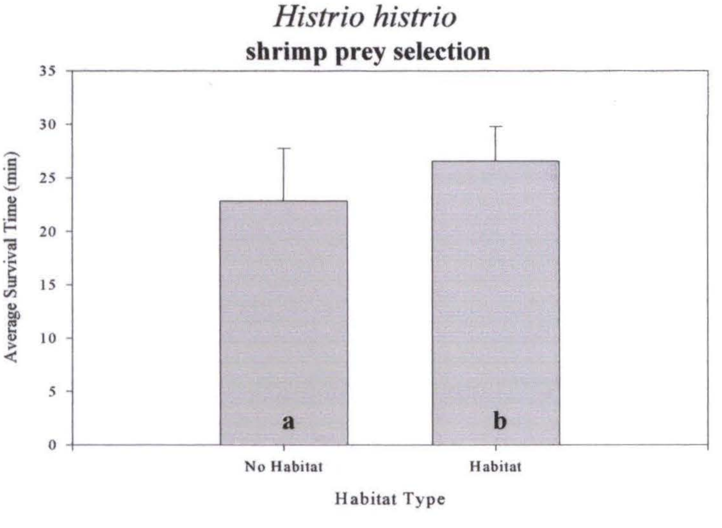


Figure 11. Effect of habitat cover on survival of shrimp species with fish predators. Pooled data from previous trials showed that shrimp (both species) survival times increased significantly with habitat with the fishes *Stephanolepis hispidus* ($p < 0.001$, Mann-Whitney Rank Sum Test) and *Histrio histrio* ($p = 0.009$, Mann-Whitney Rank Sum Test) (letters on histograms indicate statistical groupings) (bars indicate standard deviations).

DISCUSSION

The present *Sargassum* community predator/prey study compares survival times of the shrimps *Leander tenuicornis* and *Latreutes fucorum* in the presence of predatory fishes, *Stephanolepis hispidus* and *Histrio histrio,* under various experimental conditions. This complex community may be a small part of the food chain in the open ocean. The shrimp are eaten by these predatory fishes and are in turn fed upon by larger game fish. Ultimately humans would prey upon these game fish. The shrimp are therefore an important source of energy for the fishes found in the *Sargassum* community. The results are discussed in relation to optimal foraging theory.

Species selection

L. tenuicornis survived significantly longer than *L. fucorum* from predation by *S. hispidus*. However, survival times of *L. tenuicornis* and *L. fucorum* did not differ significantly from predation by *H. histrio.* The selection of one prey species over another was also observed by Clements and Livingston (1984) where the fringed filefish chose one specific amphipod over two other amphipod species. They suggested the amphipod's pigmentation may have influenced the predator. The filefish chose the species of amphipod that had a barring pattern over the other two amphipod species which were a more solid color. A similar phenomenon may be occurring in my study as dot, stripe, and bar patterns of *L. fucorum* seem more distinctive than the dot patterns of *L. tenuicornis,* possibly making the latter species difficult for the fish to detect.

An alternate explanation for the selection of *L. fucorum* over *L. tenuicornis* by *S. hispidus* may be related to shrimp morphology. *L. tenuicornis* has a rostrum that is highly serrated both dorsally and laterally, which may be effective in partially deterring predation. Additionally, *S. hispidus* has a relatively small mouth and rostral serrations on shrimp may affect consumption by these fish. *L. fucorum* does not possess a rostrum with such anatomical modifications.

H. histrio may not have a preference for species because of its ambush predation strategy and relatively large mouth. According to Hughes (1980), ambush predators encounter prey at unpredictable rates and can procure a wide range of predators. Because *H. histrio* generally waits for prey to pass through its visual field, discriminating prey species may be less important in its foraging strategy.

Size selection

Several studies have shown that optimally-foraging predators are less selective when prey densities are low, but switch to selecting larger prey in high prey densities to maximize values with respect to time spent foraging (Werner and Hall,1974; Stein, 1976; Main, 1985; Mikheev and Wanzenböck, 1999). I predicted fish predators in my study would employ similar strategies and select larger shrimp when prey densities were highest. The results herein did not support this hypothesis.

For both fish predators smaller shrimp sizes were consumed faster than larger sizes. Furthermore, the overall consumption rate of shrimp was not affected by size of shrimp consumed. That is, fish that did eat larger shrimp continued to consume smaller shrimp in most of the trials. Thus, the data support the conclusion that these fish predators forage for smaller shrimp in these experimental trials.

One possible explanation for these fishes choosing smaller prey may be related to an active defense involving the shrimp's chelae. In a similar study with crayfish, Stein (1976) found that smallmouth bass consumed crayfish with the smallest chelae thus minimizing possible injury. Specific observations of *S. hispidus* showed that considerable effort was involved in capturing and eating larger shrimp of both species. Frequently, attacks on larger shrimps involved numerous attempts, many of which ended with the fish abandoning the initial target only to go after another, usually smaller shrimp. Specific attack behaviors involved the fish approaching the shrimp's body from the top, bottom, or side apparently avoiding the chelae which were usually fully displayed and snapping. Successful attacks by *S. hispidus* on large shrimp frequently involved the fish pulling off the chelae. Subsequently, fish would then be deterred very little and begin taking bites (with its relatively small mouth) from the shrimp's abdomen. Clearly, this increased amount of handling, and thus energy expenditure, to avoid the shrimp's chelae could be a significant factor in the fish's foraging strategy.

In the present study *H. histrio* attempted to capture smaller shrimp more often than larger ones. Smaller shrimp were much more active (i.e., motility) than larger individuals and may have been more easily detected by the fish. Larger shrimp would remain motionless most of the time unless disturbed by another shrimp. Chela size did not seem to play a role with *H. histrio*, as its relatively large mouth easily accommodated these shrimp prey.

Camouflage effectiveness

Camouflage is defined as an organism resembling in color pattern the mosaic of patches or spots of varying sizes, shapes, colors, and brightness levels of its habitat such that the predator does not perceive the prey against the background (Endler, 1978; Hacker and Madin, 1991). It was hypothesized that camouflage by the shrimp might be effective in deterring predation by *S. hispidus* and *H. histrio*. Furthermore, it was predicted the effectiveness of the shrimp's camouflage would vary if the habitat type varied and possibly be influenced by the predatory characteristics of the fish.

With the fish *S. hispidus*, there was no significant difference in survival times of either shrimp species (shrimp were the same size) in artificial red, artificial green or natural *Sargassum* habitats. However, in trials in which only *L. tenuicornis* was used, and the shrimp size was varied, the smallest shrimp survived longer in both artificial habitats compared to the natural habitat. Finally, the larger shrimp (20 and 30 mm) survived longer in natural *Sargassum* than did the 10 mm shrimp.

These results are difficult to interpret. It seems that when both shrimp species were present, and individuals were of the same size, *S. hispidus* consumed shrimp prey rather indiscriminately. Small shrimp, however, may have been better camouflaged in the artificial habitats used. This size trend was reversed when real seaweed was used as habitat cover, with larger shrimp realizing a greater survival advantage. The artificial habitats were used to vary the habitat background color, and could possibly mimic other types of floating matter that occasionally attract emigrating residents of the *Sargassum* community. The results showing survival of larger shrimp in real *Sargassum* are likely a more accurate representation of predation patterns *in situ.* Additionally, these latter results are consistent with my previous trials without habitat cover that showed larger shrimp survived longer. *S. hispidus* is an active pursuer, constantly looking for food and chasing prey once located. If small shrimp prey of either species are detected, the shrimp will likely be consumed. Larger shrimp may present some additional obstacles for this fish predator by using chelae as defense.

With the fish *H. histrio*, the sequence in which the predator and prey were introduced to the test arena had the greatest impact on the results. Specifically, when shrimp were added first, no significant trends in survival of shrimp species or size were observed. When *H. histrio* was allowed to acclimate for 10 minutes prior to the addition of both shrimp species, *L. tenuicornis* survived significantly longer than *L. fucorum* in the artificial green habitat. Additionally, *L. tenuicornis* survived significantly longer in both artificial habitats compared to the natural seaweed. These results suggest that the color patterns of *L. tenuicornis* may be unique enough to affect predation rates by this predator, even though the effect was associated with artificial habitats. Additionally, by altering the experimental protocol and allowing this ambush predator time to establish its position in the habitat, I was able to detect the differences in predation patterns discussed above.

Conclusions

The foraging activities observed by *S. hispidus* and *H. histrio* in these studies may give insight specifically into the structure and function of the complex *Sargassum* community, and more broadly illustrate factors affecting optimal foraging decisions. There are similarities and differences in optimal foraging strategies of two predominant fish predators. Additionally, both shrimp species ultimately receive some degree of protection from these predators by living in such complex habitats.

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